W. Abruel

ELECTRONICS LABORATORY

POST-ACCELERATION COLOR TUBE

VOLUME II

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ELECTRONICS LABORATORY POST-ACCELERATION COLOR TUBE

VOLUME I

Chapters I to III Inclusive

VOLUME II

Chapters IV to XVIII Inclusive

ELECTRONICS LABORATORY POST-ACCELERATION COLOR TUBE MANUAL

By

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of the
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PREFACE

This report covers the practical and theoretical considerations necessary to construct and operate the Post-Acceleration Color Tube. Its purpose is to give a working knowledge to those concerned with the development, manufacture, and application of this type tube.

The report has been organized to meet these objectives as lucidly as possible. Each chapter is self-contained and may be read separately without constant reference to other sections. The chapters contain a "flow chart" where necessary, description of the operations performed, and the design considerations, which were necessary to change an idea into an operable and demonstrable device.

Although the "flow chart" deals with the latest model developed, discussion has not been limited to the successful tube, but also includes results of unsuccessful experiments in an attempt to preclude a repetition of our mistakes by others.

The report represents the combined effort of the entire Tube Unit and, hence, covers many man-hours of work. Because the work covered is so extensive, complete detail may be lacking along certain lines. With the report, therefore, is an invitation for detailed discussions with members of our unit.

The various sections of the report were written by the members of our unit most intimately concerned with the particular phase discussed.

This has been a major development and represents the combined efforts of many people from within the Electronics Laboratory, from other departments such as Tube and RTV, and from the Knolls Research Laboratory. The advice and encouragement given to this program by L. T. DeVore, J. P. Jordan, and I. J. Kaar has been of inestimable value and in no small way has contributed to the success of this program.

C. G. Lob

12/10/54

TUBE NOMENCLATURE

1.	Name:	Electronics Laboratory Post-Acceleration Tube
2.	Screen:	Area on which phosphor is printed and the picture displayed.
3.	Grille:	An array of parallel wires placed between the screen and the gun which serve to mask or focus the electron beams into the proper direction for color selection.
4.	Plane of Deflection:	A plane passing through the yoke parallel to the grille and located along the tube axis by the point formed by the intersection of the straight electron paths before and after deflection by the yoke field.
5.	Plane of Static Convergence:	A plane passing through the static convergence elements parallel to the grille and located along the tube axis by the point formed by the intersection of the straight electron paths before and after deflection by the static convergence field.
6.	Plane of Dynamic Convergence:	A plane passing through the dynamic convergence elements parallel to the grille and located along the tube axis by the point formed by the intersection of the straight electron paths before and after deflection by the dynamic convergence field.
7.	Static Convergence Coils:	Coils positioned between the end of the gun and the plane of deflection providing a magnetic field which corrects static convergence of the three beams.
8.	C.P. Screws:	Four screws which form the contact points between the lava spacers and the phosphor plate. When adjusted, they determine the grille-phosphor plate distance.
9.	Bird:	A cross containing four pads in a plane, which contact the four C.P. screws, and four posts of definite length which contact the grille adjacent to the posts thus allowing the C.P.'s to be set in a plane at a predetermined distance from the grille.
10.	Color Center:	A point lying in the plane of deflection determined by the intersection of the undeflected electron beam with the plane of deflection. There are three such points, one for each beam.
11.	Color Base:	The distance between two adjacent color centers.

Potentials

12. V_s — Screen potential measured with respect to the cathode

13. V_m — Grille " " " " " " "

14. V_c — Cone " " " " " " "

15. ΔV — Suppressor voltage equals cone potential minus grille potential

16. ψ — Post-acceleration voltage ratio $= \frac{V_s}{V_c}$
This differs by about 2% from $\frac{V_s}{V_m}$

Distances

17. d — The distance between the grille and screen

18. D — " " " " " " plane of deflection

19. C1 — The distance between the plane of deflection and the plane of convergence

20. C2 — The distance between the plane of deflection and the plane of dynamic convergence

21. Dc — The distance between the grille and the light source in the lighthouse

$$\frac{D_c}{D} = \frac{\psi - 1}{2(\sqrt{\psi} - 1)}$$

22. S — The color base

23. δ — The distance between two adjacent electron beams in the plane of dynamic convergence

24. So — The distance between two adjacent gun axes in the plane of convergence

25. p — The grille pitch or the distance between adjacent wire centers

26. s — The distance between the centers of adjacent color stripes in the center of the screen

27. (1 + K) — The factor of enlargement from grille to screen where

$$K = \frac{d}{D} = \frac{s}{S}$$

28. M The color shift at the center of the screen, measured in units of color stripes, which a vertical magnetic field of .6 gauss produces on a 6.5 kilovolt electron beam. This is not the distance the magnetic field deflects the electron beam

CONTENTS

CHAPTER IV PHOSPHOR PLATE PREPARATION AND PROCEDURES

SECTION I FLOW CHART FOR PHOSPHOR PLATE PROCESSING

1. Inspect uncut glass as received for
   a. Scratches
   b. Bubbles, pits, and stones
   c. Flatness: if offset printing is to be used, wedge (difference in thickness across plate) must not exceed 0.002" in the direction of the offset roller travel. If printing is to be done by silk-screening, no flatness inspection is necessary.
2. Cut to drawing no. TSV-1184 R, Fig. IV - 1.
3. Inspect finished plates for
   a. Scratches
   b. Chips - must not extend into the phosphor area
   c. Dimensions within tolerances
4. Print phosphor plates.
   a. Inspect between impressions for smudges, dirt, blemishes, and color contamination: use ultra violet lamps (2537A and 3660A)
5. Inspect printed plates for
   a. Phosphor contamination under UV lamps
   b. Overlapping lines and line width
   c. Smudges
   d. Margin uniformity $\leq$ 1/32"
6. Air fire-approximately 1-1/2 hours at 425°C.
   See drawing no.TS-6050, Fig. IV-2, for furnace controller cam.
   Fire plates in covered trays - Fig. IV-3-4-5.
7. Spray Kasil on plates.
8. Inspect for contamination under UV lamps.
9. Film plates and dry.
10. Inspect film for holes, wrinkles, and tears.
11. Aluminize.
    For jig, see drawings Figs. IV-21 through 30.
12. Inspect for holes, smudges, oxidation.
13. Air fire - same as step #6.
14. Inspect finished plates for
    a. Blisters
    b. Smudges
    c. Holes
    d. Greyness

SECTION II DESCRIPTION OF PROCEDURES

Phosphor Printing (Flow Chart, Step #4)

We have used two processes for printing tricolor phosphor plates for the post-acceleration tube, both of which have yielded good results. These processes are dry-offset printing and silk-screen stenciling. A discussion of the merits of both processes is given at the conclusion of this section.

OFFSET PRINTING

Offset printing of our line pattern has been done in Building 6 on the equipment and with the techniques that were used several months previously for the RCA dot plates. Plates of acceptable quality were obtained almost at once, and no major changes were made in methods. It appears that the line pattern is somewhat less susceptible to color contamination during printing than the dot pattern. The line pattern is also easier to align on the printing press since translational motion of the plates in only one direction is needed between colors.

The principal improvement in offset printing was to introduce the use of a chrome-plated copper "dry plate" to replace the zinc masters. The dry plate has an indefinitely long life, and does not have to be "gummed down" or otherwise protected while not in use. In the past, frequent replacement of the short-lived zinc masters has entailed considerable lost time while each new master was mounted and aligned.

The dry-plates were made for us by the Buckbee-Mears Company. Line widths on the dry-plates are specified as $0.01085 {}^{+.0002}_{-.0004}$ inch, but we prefer to stay on the low side of this range, since overlapped lines are usually less desirable than gaps between lines.

SILK-SCREEN PRINTING

Two basic procedures are involved:

1) Preparation of the stencil;
2) Printing the phosphor plates.

An early form of silk-screen printing, first described by RCA in their Industry Service Bulletins at least as early as 1950, used a photographically-prepared gelatin stencil supported on a stainless-steel mesh, and a printing "ink" consisting of phosphor powder suspended in high-viscosity cellulose paste. A description of this process and other references are given in T.I.S. 52-E-228.

During the past two years, a modification of the above process has been developed in our Laboratory. This modification is "dry dusting" and was first described by C. E. Buchwald in a patent docket dated April 28, 1952. It consists of coating a glass plate with a pressure-sensitive adhesive, placing a stencil flat against the coated side, and dusting a single phosphor through the stencil. The excess phosphor is removed with a vacuum cleaner and the process is repeated for the other two colors. Dry dusting is much faster than paste printing and completely avoids the use of large quantities of toxic solvents that were necessary for cleaning the paste residue from the stencil between printings.

Preparation of the Stencil[1]

The starting point is the Kodalith printing master, the production of which is described in Chapter XII of this report. It is important that the printing master be thoroughly washed and the anti-halation backing completely removed according to good photographic practice.

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1 Some of the details are carried over from T.I.S. 52-E-228 while others are new; to preserve continuity, we will avoid further cross-references.

The emulsion side of the master is first waterproofed by coating it with Krylon lacquer[2]. This may be done by spraying or by painting with a brush; our best results have been obtained by brushing. The important considerations are complete coverage, uniform transparency, and freedom from dust and lint. The lacquer should be air dried for a minimum of four hours in a dust-free atmosphere.

The lacquered surface is then waxed and polished, using Simoniz paste wax. The purpose of the wax is to facilitate separating the master from the dried gelatin later in the process.

The gelatin-coated paper[3] as received is trimmed so that its length and width are about 1/2 inch less than the master, to allow for swelling when wet. The paper should be carefully inspected for flaws, creases, or breaks in the emulsion; none of these flaws can be tolerated, because they will inevitably lead to blemishes in the phosphor plate.

For the operations following, a darkroom should be used. After sensitizing, the gelatin responds primarily to blue and ultraviolet light, with very low sensitivity. We have used as a safelight a 100-watt yellow insect-repellent lamp at a distance of two feet. Exposure to fluorescent lighting, with its higher blue content, should be avoided.

The gelatin paper is sensitized by immersion in a 2% water solution of potassium dichromate for 3 minutes at 63° to 65° F. Use care to avoid wrinkles and scratches.

The gelatin paper is then transferred to the printing master, emulsion against emulsion, and the air bubbles and excess solution removed with a rubber squeegee. This should be done rapidly to avoid drying. The back of the master is then wiped clean and dry.

Exposure is carried out under five No. 4 Photofloods, mounted fifteen inches above the master. The lamps are arranged in a square nine inches on a side, with the fifth in the center, and surface-mounted on an aluminum plate 18" x 18". The lamps are rated 115-120 volts, but can be Variac-operated at 125 volts to increase the blue content of their spectrum. Under these conditions, exposure time is $3\frac{1}{2}$ to 4 minutes. In order to cool the gelatin paper during exposure, the "sandwich" is laid on an aluminum plate 3/8" x 18" x 22" which is pre-cooled by soaking it in cold water just prior to exposure. A better method would be to use a brass or copper plate with copper water tubing brazed to it. Some kind of cooling is absolutely necessary to prevent softening the gelatin during exposure: without cooling, the infra-red heat softens the gelatin and the paper backing absorbs some of it. The result is a thin washed-out stencil that has a short life, or a smeared pattern.

Immediately following the exposure, the printing master with the gelatin paper still adhering to it is transferred to a tray of warm water at about

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2 obtainable from Krylon, Inc., Philadelphia 32, Pa.

3 Type P-5 Chemco Pigment Paper, Chemco Photoproducts Co., Inc., 235 Fourth Avenue., New York, New York

110° F. A large tray is desirable: our tray is 27" x 31" x 3" stainless steel (see Fig. IV-6). The master is agitated in the warm water with the gelatin paper up. In two or three minutes the paper backing will loosen and float off, leaving the gelatin emulsion adhering to the master. Care should be exercised to prevent gouging or scraping the soft gelatin. Washing should be continued for a total time of about 10 minutes to dissolve all the soluble gelatin. One indication of completion is when tiny bubbles no longer form on the gelatin upon removing it from the water. Room lights may be turned on at this point.

The printing master (gelatin side up) is then transferred to a white photographic tray containing cold tap water for a period of about five minutes. Close examination against the white background will reveal any tears or other defects in the gelatin. If there are defects, the wet gelatin can be removed with a rubber blade, the master rewaxed, and the process repeated. If the gelatin appears thin and washed-out, or with tattered and peeling edges, the most probable cause is under-exposure.

Having obtained a good gelatin, the next step is to place it, while still wet, in contact with the side of the mesh that will be against the glass plate on which the phosphor is to be printed. The stainless-steel mesh[4] must be stretched as tightly as possible on its frame with all wrinkles and dents smoothed out. Printing blemishes will occur everywhere the gelatin is not absolutely flat against the phosphor plate, whatever the cause. The mesh must be degreased in benzene or acetone and completely freed of dust and lint. Our print table is so built and adjusted with shims that the frame will bring the stretched mesh into contact with the phosphor plate with a positive but not excessive pressure when the phosphor plate is properly mounted with the vacuum chuck. Since the Kodalith glass master and the phosphor plates are the same thickness (.250"), the master may simply be placed on the print table in the same position the phosphor plates will occupy with the wet gelatin up and reasonably well centered, and the frame and mesh lowered into place. After contact is made, there must be no further movement of the plate or mesh so as not to damage the soft gelatin.

Forced drying with a blower at room temperature will not harm the gelatin and will dry it completely in about one hour. The frame and mesh, with the printing master adhering, is then removed from the print table and placed master up on a flat surface. The master can then be separated from the gelatin by lifting one edge so that separation occurs in the direction of the line pattern. Considerable force is usually necessary to start the separation, and it is well to ground the metal frame to remove unpleasant static charges that are generated.

The mesh may be reused as long as it has no broken wires, dents, or wrinkles. It cannot, however, be removed from the frame and remounted successfully. The old gelatin can easily be removed from the mesh by soaking the entire frame and mesh in an enzyme[5] solution, followed by thorough rinsing.

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4 Stainless steel bolting cloth, 165 x 165 meshes per inch, .0019" wire diameter. Newark Wire Cloth Co., Newark, New Jersey.

5 Sold as Naz-Dar #925 Fotogel Remover, Naz-Dar Co., 469 Milwaukee Ave., Chicago 10, Ill.

Phosphor Printing

Drawings of the most important component parts of our printing table and frame are given in Fig's. IV-7 through 20. The finished table and a frame with stretched mesh are shown in photographs, Fig's. IV-21-22-23. The mesh is held in place in the grooves (Fig's. 11 and 12) by means of 3/32" brass rods encased in .020" wall-thickness polyethylene tubing.

The glass plates (Flow Chart, step #3) are first washed in hot Calgonite, thoroughly rinsed in hot tap water, and dried. They are then wiped with reagent methyl alcohol.

The adhesive spray solution is made as follows: 1 gram of polyisobutylene[6] per 16 ml reagent Xylene. The adhesive as supplied is extremely viscous and the mixture requires about 24 hours at room temperature to go into solution.

Application to the glass plates is done by spraying; we use a Paasche airbrush at 40 lbs. pressure. The principal criterion is to obtain a frosted opaque coating by adjusting the gun for a "dry" spray. If the adhesive is sprayed "wet", it will form a glossy coating that adheres strongly to the gelatin and prevents a clean removal of the stencil. A "frosted" coating is not as tacky and the stencil can be removed easily. Plates should be used within 24 hours after coating.

The coated plate is placed on the vacuum chuck of the print table, and the bed is adjusted so that the plate is centered with respect to the gelatin pattern. The dial indicator is then set to zero and the mesh is lowered into contact with the plate. To insure good contact between stencil and plate, it should be rolled with a rubber roller between impressions.

The phosphor powder is freely dusted over the mesh, then smoothed out and rubbed into the stencil with wadded cotton swabs. The excess phosphor is removed by successive use of the brushes attached to a G-E swivel-top vacuum cleaner. The "floor brush" is useful for vibrating the phosphor out of the wire mesh interstices, while the "upholstery nozzle", with a strip of 1/8" felt attached to the lip to serve as a scraper, is effective in removing the loose phosphor. Cleaning should be continued until no further removal of phosphor is effected.

The stencil is then lifted off the table, care being taken to prevent jarring any loose phosphor down on the plate. The stencil may be cleaned in a few seconds with the "dusting brush" and is then ready for printing the second color. Of course, the stencil and the plate must be moved relative to each other for the second and third printings. Our table is so constructed that the frame and mesh are in a fixed position and the plate bed is mounted on a universal cross-feed with a dial gage (.0001" minimum reading) to indicate position.

The chronological printing order is blue-green-red[7]. This order has

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6 Sold as Vistanex, IM type H, Enjay Co., Inc., 15 W. 51st St., New York 19, New York

7 G-E Cleveland phosphors: Blue 3-200, Red 3-250, Green 3-253.

been determined as the best to minimize phosphor line width variations and is a compromise governed by phosphor printing characteristics and desired color emphasis. The line width of the three printings becomes successively broader because the second and third phosphor deposits are printed with the stencil slightly above the plate, held there by the thickness of the first and second deposits respectively. The phosphor powder thus spreads out under the stencil, resulting in a line width increase of the order of 10% to 20%. Blue phosphor is free-flowing and is printed first. Green and red both tend to agglomerate and hence do not spread as freely. Red is printed last because, as the lowest in luminescent efficiency, it should be widest in line width. This is an empirical compromise: tube design at present tolerates this line width variation, but it should be minimized.

The spatial printing order is blue-red-green. Present tube design requires red in the center; the blue-green order is maintained for consistency. The spatial order, of course, is controlled by plate position during printing as set with the dial gage.

The most common causes of printing blemishes are dirt and mesh imperfections. If dirt is trapped between the gelatin and the mesh, it causes raised regions in the stencil, and these permit phosphor to flow under the stencil, resulting in areas of abnormally wide, heavy phosphor lines. The mesh, as received, frequently contains broken wires, interwoven dirt, and dents or creases. Only selected portions of the mesh are suitable for phosphor printing, since these defects usually cannot be retouched or erradicated. Creases or dents, particularly, cannot be removed without stretching the wire in the mesh beyond its elastic limit, and this is not practicable.

Discussion of Printing Methods

Our present experience favors silk-screening, because design changes may be made and plates printed more rapidly. In addition, there are no tight tolerances on glass flatness, and no laborious shimming necessary. It also appears that color contamination is easier to avoid with silk screening than with offset printing. On the other hand, stencil life is quite limited and line width varies from color to color and plate to plate, and must be closely watched to keep it within tolerable limits.

Offset printing produces phosphor lines that are sharp and well defined, and there is no change in line width from color to color, or from stencil wear, once the dry plate is properly set up. But color contamination from phosphor carry-over has been a problem, and glass rejects because of flatness variation have been of the order of 50%. Even the acceptable plates each have to be carefully shimmed or "packed".

Obviously, neither process has been optimized. The use of a metal stencil to replace the gelatin stencil seems perfectly feasible and should obviate most of the present silk-screen disadvantages. Methods of reducing color contamination in offset printing are conceivable, as are ways of automatically compensating for glass variations. All these possibilities should be included in any long-range evaluation of phosphor printing methods.

Air-Firing of Phosphor Plates - Flow Chart, Steps #6, 12.

Each plate is enclosed in an aluminum tray designed to exclude air currents and dirt. Internal supports made of marinite are provided to insulate the plates from the trays. Tray details are given in Fig's. IV-3-4-5.

The furnace cycle is controlled by a Brown program controller. The program cam is shown in drawing TS-6050. It is important not to remove the plates from the furnace until the temperature is below about 50° C. to avoid cracking.

Spray Kasil - Flow Chart Step #7.

This step waterproofs the plates for filming. Extreme care should be used in handling the plates at this stage, because firing (step 6) removed all adhesive, and the phosphor is now adhering to the plate very lightly. It can easily be blown or brushed off, causing cross-contamination of colors.

The solution to be sprayed is 2% potassium silicate[8]. Spraying is done with the Paasche airbrush at 20 lbs. pressure. The airbrush must be flushed with water immediately after each use, and every precaution must be taken to prevent spattering of large droplets which scatter the phosphor and cause "craters" or clear spots.

Approximately 5 ml of the above solution is used, depending on spraying efficiency. Too much Kasil causes blistering of the aluminum on the margin of the plates where it should be mirror-smooth. Too little Kasil results in some of the phosphor washing off when the plate is immersed in water prior to filming; this may cause color contamination.

The plates should air dry at room temperature for about 1/2 hour.

Film Plates - Flow Chart Step #9

The filming solution[9] is prepared as follows:

Stock solution - 1 ml #L6685[10] nitrocellulose lacquer 7%
1.85 ml reagent amyl acetate
Mix thoroughly and filter through 250 x 250 stainless steel mesh.

Working solution - Mix 0.20 ml B-400 plasticizer[11] with each 10 ml stock solution

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8 Kasil No. 1 (28%) from Philadelphia Quartz Co.
9 More complete details of preparation are in S.I. 13701H3C or its successor.
10 Monsanto or Raffi and Swanson.
11 Carbide and Carbon Chemicals Corp.

The working solution should be made up at least one hour in advance of use, and mixed thoroughly by shaking: do not use while bubbles are present, or after 48 hours. The amount of plasticizer may be varied to suit drying conditions: too much will cause permanent grey areas in the viewing side of the phosphor, while too little causes holes or blistering in the aluminum.

Our filming has been done in a photographic tray with cover and siphon. It is important that the room be temperature-controlled to plus or minus 2° F., and humidity controlled to avoid wide fluctuations.

Following are the operational steps:
a) Clean tray thoroughly, rinse, sponge dry.
b) Fill with demineralized water that has been allowed to reach room temperature by overnight storage.
c) Immerse plate in water, phosphor side up, on rubber feet on bottom of tray. The water surface should be about $\frac{1}{4}$" above the phosphor plate.
d) Clean surface of water thoroughly of all lint, bubbles, and floating phosphor by using water aspirator and pipette to skim surface.
e) Place plexiglass cover over tray.
f) Dispense about 2.0 ml amyl acetate on water surface through center hole in cover. Bring tip of pipette close to water surface to avoid splashing. Droplets of amyl acetate will disappear in a few minutes, leaving the water surface pre-saturated with amyl acetate.
g) When water is quiescent, dispense about 5.0 ml filming solution in the same manner as step (f). Do not allow drops to fall on the surface.
h) When interference colors cover the plate (from 10 to 45 minutes depending on air circulation and drying conditions) and blend together smoothly, remove cover, start siphon, and trim the film with a pipette or hypodermic filled with amyl acetate. Timing is important and can only be developed with experience.
i) When the water has drained off, lift plate at the edges and prop up vertically to dry.

If flaws are observed in the film before trimming, the film may be pulled off the water and a new one dispensed. If flaws are observed after drying, the plate may be refired, or the faulty film may be washed off with amyl acetate.

The tray should be cleaned immediately after filming. The pipette should be filled with amyl acetate, drained, wiped clean on the outside, refilled, drained, and dried with the aspirator.

Aluminized Plates - Flow Chart Step #11

For this step, the filmed plates are held vertically in a jig placed inside an eighteen-inch vacuum bell jar. Drawings of the most important component parts of the jig are given in Fig's. IV-21 through 28. The complete jig is pictured in Fig. IV-29. Aluminum is evaporated from two .040" parallel tungsten filaments, each with 16 loops. The loops are 1 inch apart on the filaments, center to center. The filaments are 7-3/4" apart and $6\frac{1}{2}$ inches from the phosphor plate.

The aluminum slugs are formed from #24 B & S gage wire: 0.020"O.D. x 19/32" long. The mass of each slug is 8.3 milligram. If we assume that aluminum is radiated uniformly in all directions from each slug, we can calculate from the above geometry the thickness of the aluminum film that will be deposited on various locations on the phosphor plate. The results are:

Center of plate -----------1630Å
Each corner ---------------1030Å
Center of long sides ------1300Å
Center of short sides -----1280Å

Note added in proof: The aluminum thickness given above has been satisfactory until recently, when several tubes exhibited sparking at the edges of the phosphor plates and consequent destruction of the aluminum film in those regions. An increase in aluminum thickness of about one-half has apparently corrected this trouble. It is not known why this suddenly occurred without making any intentional changes in aluminizing. However, the aluminum layer needs to be somewhat thicker than that used in monochrome tubes because of the necessity of withstanding electrostatic forces. Still further increases in thickness may be necessary to provide an adequate margin of safety.

The loops in the tungsten filaments are formed on a jig (see Fig. IV-30) with a gas-oxygen flame. Each new filament must be flashed to eliminate the oxides resulting from flame-forming. This is done by mounting the filament, pumping to 5×10^{-5} mm or better, and heating to about 2000° C., then cooling. This treatment also serves to stress-relieve the filament.

The operation procedure is as follows:

One aluminum slug is crimped to each of 14 loops on both of the two filaments, ignoring the end loops which are cooled by conduction to the clamps. An additional slug is crimped at the ends, making a total of 16 slugs on each filament. The phosphor plate is mounted, the appropriate edge masks adjusted in the two alignment areas and the bell jar pumped to 5×10^{-5} mm or better. When this is reached, bring up the filament temperature until the aluminum melts and forms droplets, then slowly increase the temperature so that the evaporating time after the aluminum melts is about 20 to 30 seconds. During this time, the pressure must not be allowed to rise, or the aluminum deposit will appear dirty and oxidized instead of bright.

All the aluminum is to be evaporated. One can see when this has occurred by using dark glasses; the filament brightness suddenly increases when each droplet evaporates.

The filament should be allowed to cool for 3 or 4 minutes before letting down to air, to prevent oxidation. The air inlet valve should be adjusted so that an elapsed time of 3 or 4 minutes is needed to reach atmospheric pressure, because a more rapid inrush of air may damage the aluminum.

The tungsten filaments should not be used for more than about six plates. Mechanically they will last longer, but a slow accumulation of oxides usually causes a deterioration in the quality of the evaporated aluminum film.

After aluminizing the plates are fired and inspected as listed in the Flow Chart, and are then ready to be used in sealed-off tubes. The finished plate is pictured in Fig. IV-31.

PLATE FOR 21" C TUBE	MATERIAL #3720 TELEGLASS - PITTSBURG PLATE GLASS CO.	TSV 1184R

TOLERANCES;
ON TEMPLATE - ±.005"
ON GLASS - $\pm \frac{1}{32}$ OVERALL

NOTE: OPPOSITE ENDS & SIDES ARE PARALLEL
ADJACENT ENDS & SIDES ARE PERPENDICULAR

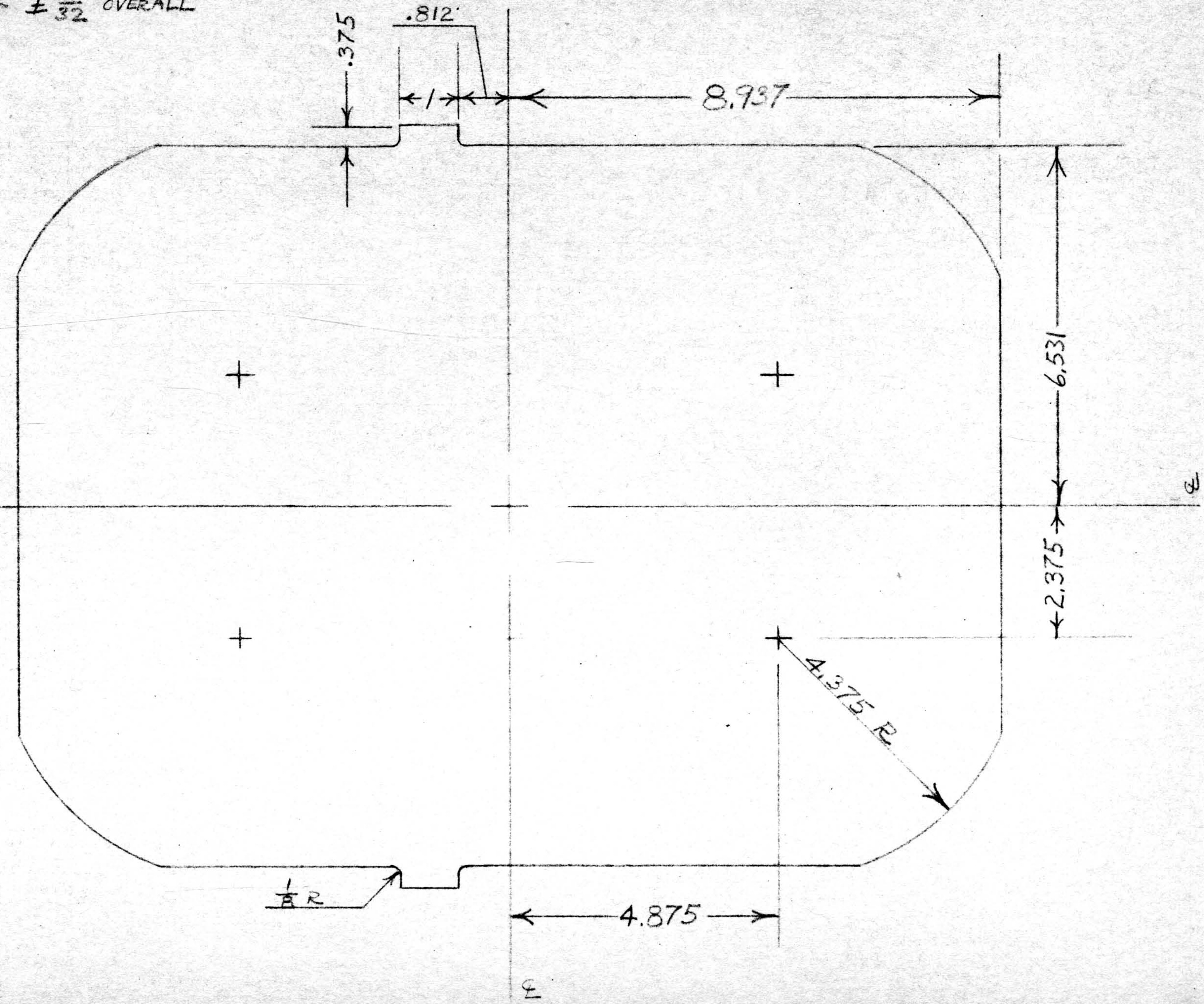
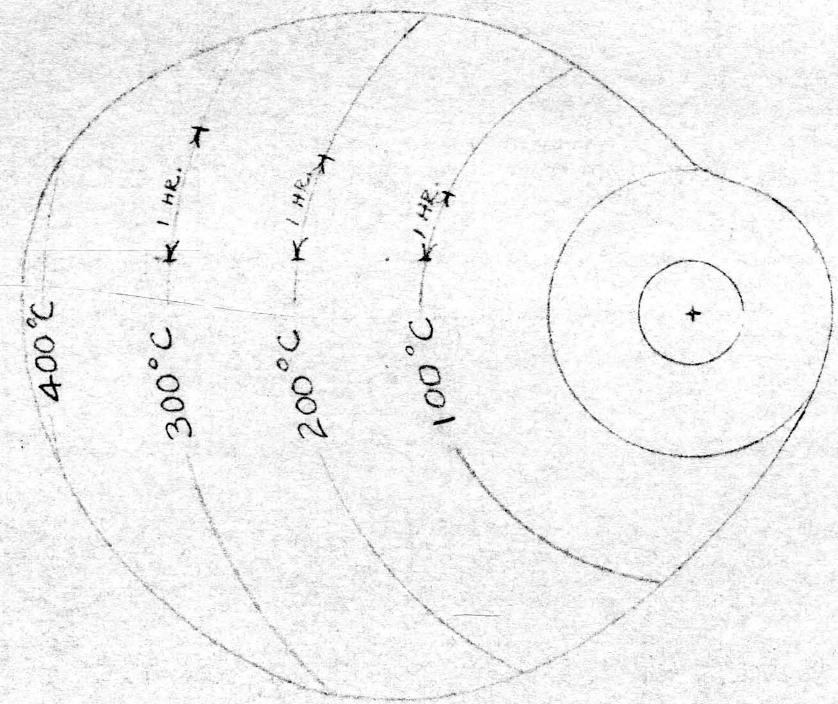


FIG. IV - I

CAM FOR FURNACE CONTROLLER	MATERIAL—PRECUT LUCITE BLANK	TS — 6050

SCALE - FULL SIZE



FOR BROWN PROGRAM CONTROLLER
CHART #14027 (0–700°C RANGE)
24 HOUR ROTATION

FIG. IV - 2

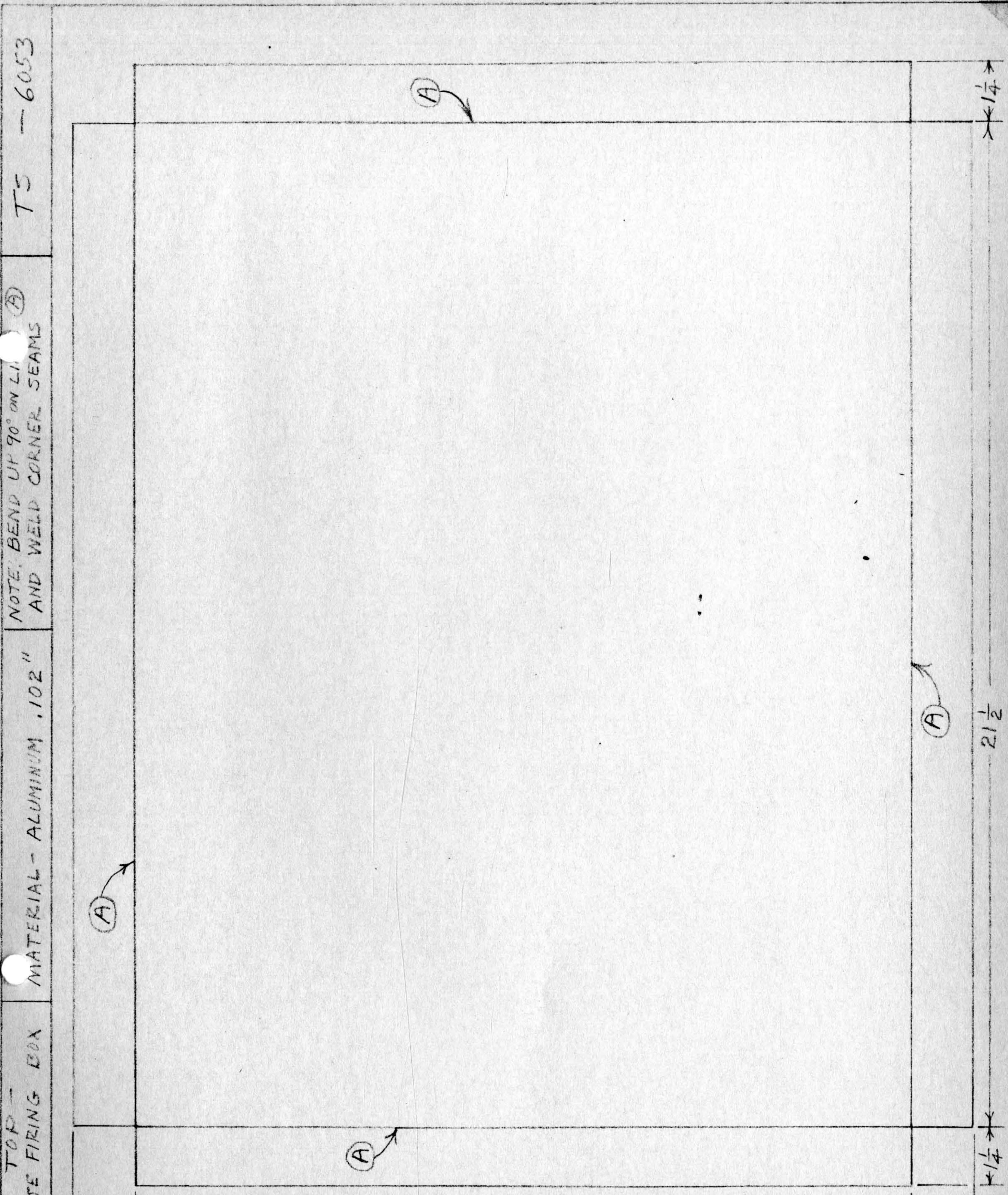

TOP - PLATE FIRING BOX
MATERIAL - ALUMINUM .102"
NOTE: BEND UP 90° ON LINE (A) AND WELD CORNER SEAMS
TS - 6053
A
1 1/4
21 1/2
16 5/8

FIG. IV - 3

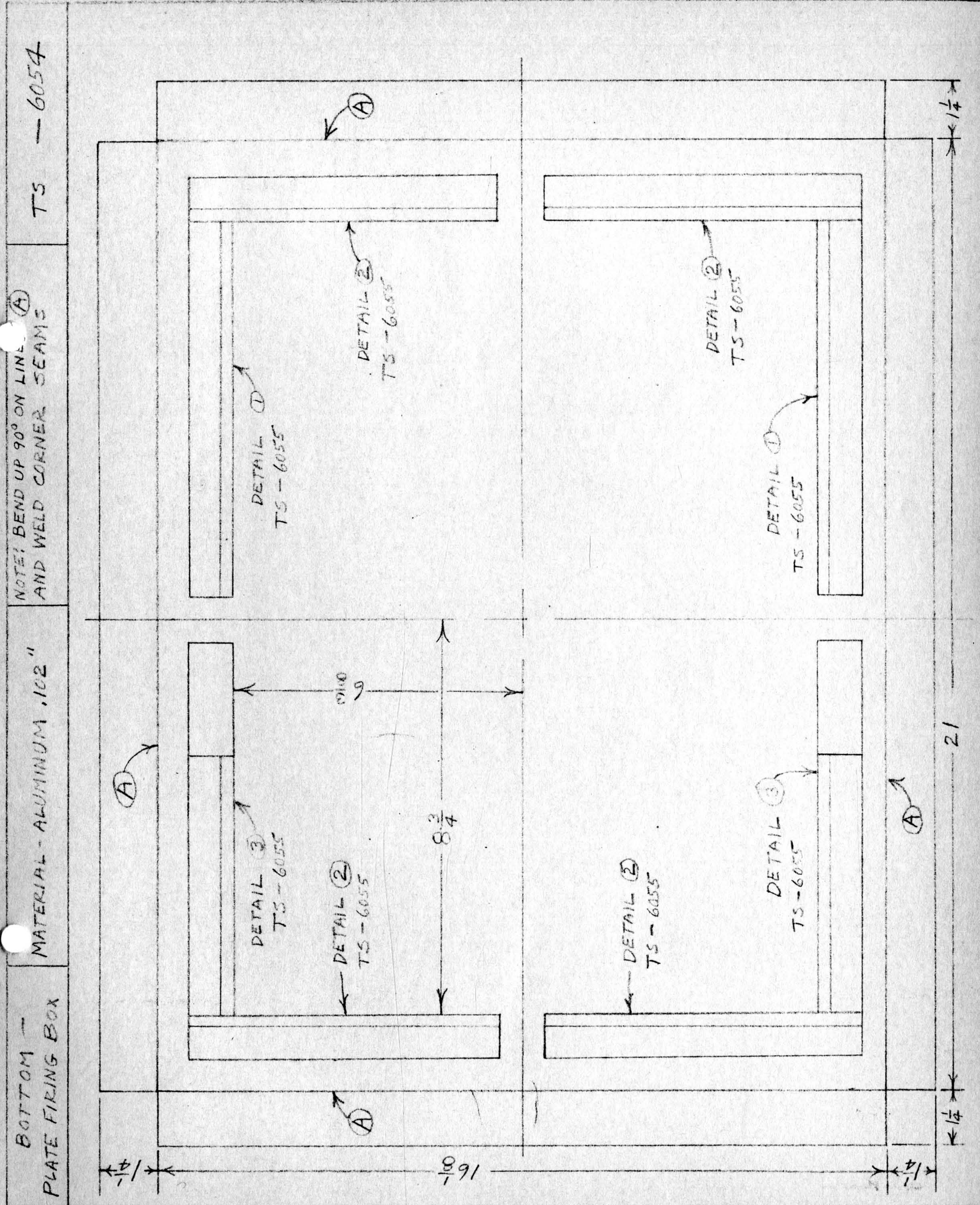

BOTTOM — PLATE FIRING BOX
MATERIAL - ALUMINUM .102"
NOTE: BEND UP 90° ON LINES (A) AND WELD CORNER SEAMS
TS — 6054
DETAIL (1) TS - 6055
DETAIL (2) TS - 6055
DETAIL (3) TS - 6055
(A)
8 3/4
21
16 1/8
1 1/4

FIG. IV - 4

PLATE SUPPORTS FOR TS -6054	MATERIAL- MARINITE		TS -6055

TAP 10-24 FOR RETAINING SCREWS - LOCATE CONVENIENTLY
DRILL MATCHING CLEARANCE HOLES IN TS-6054

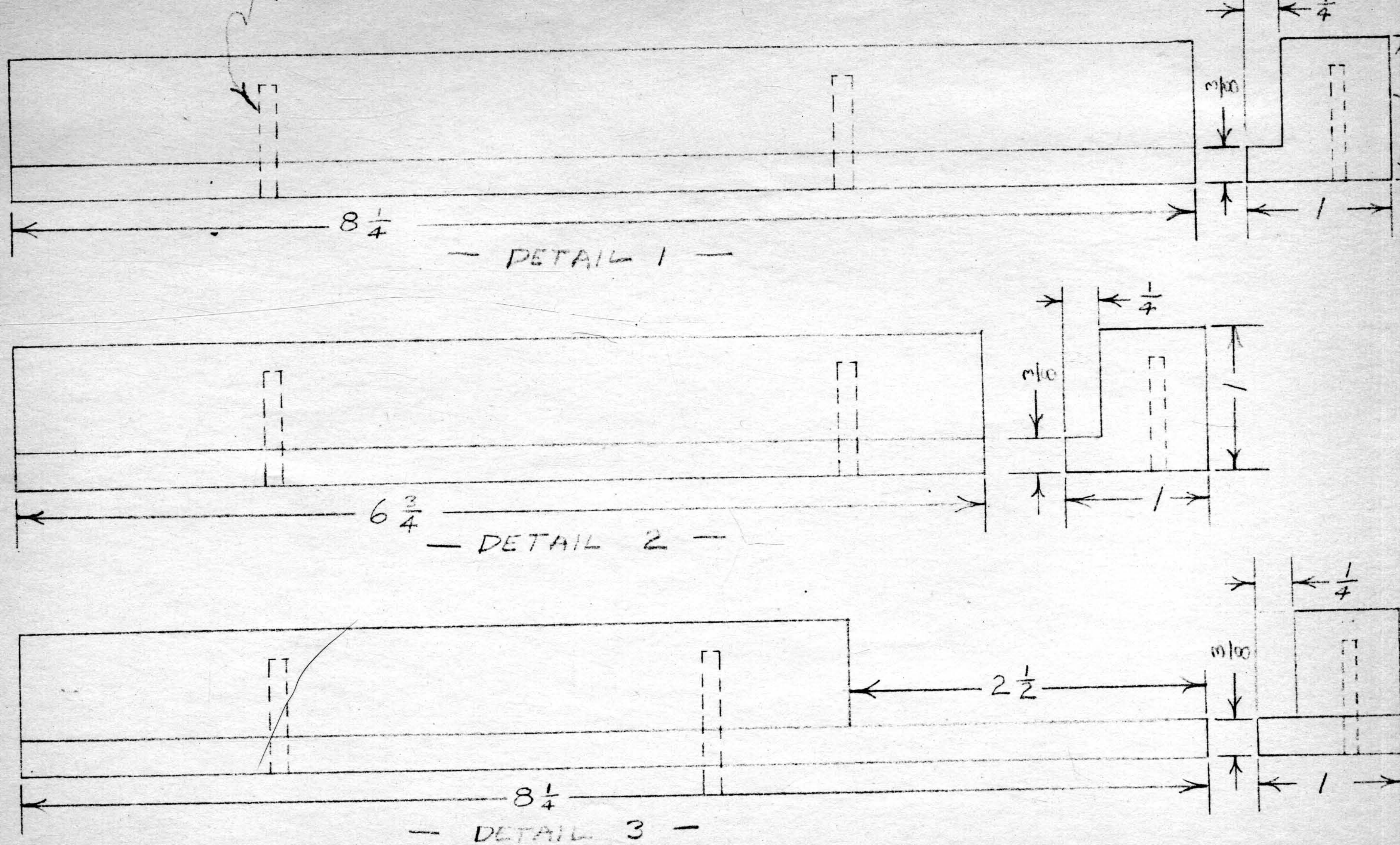
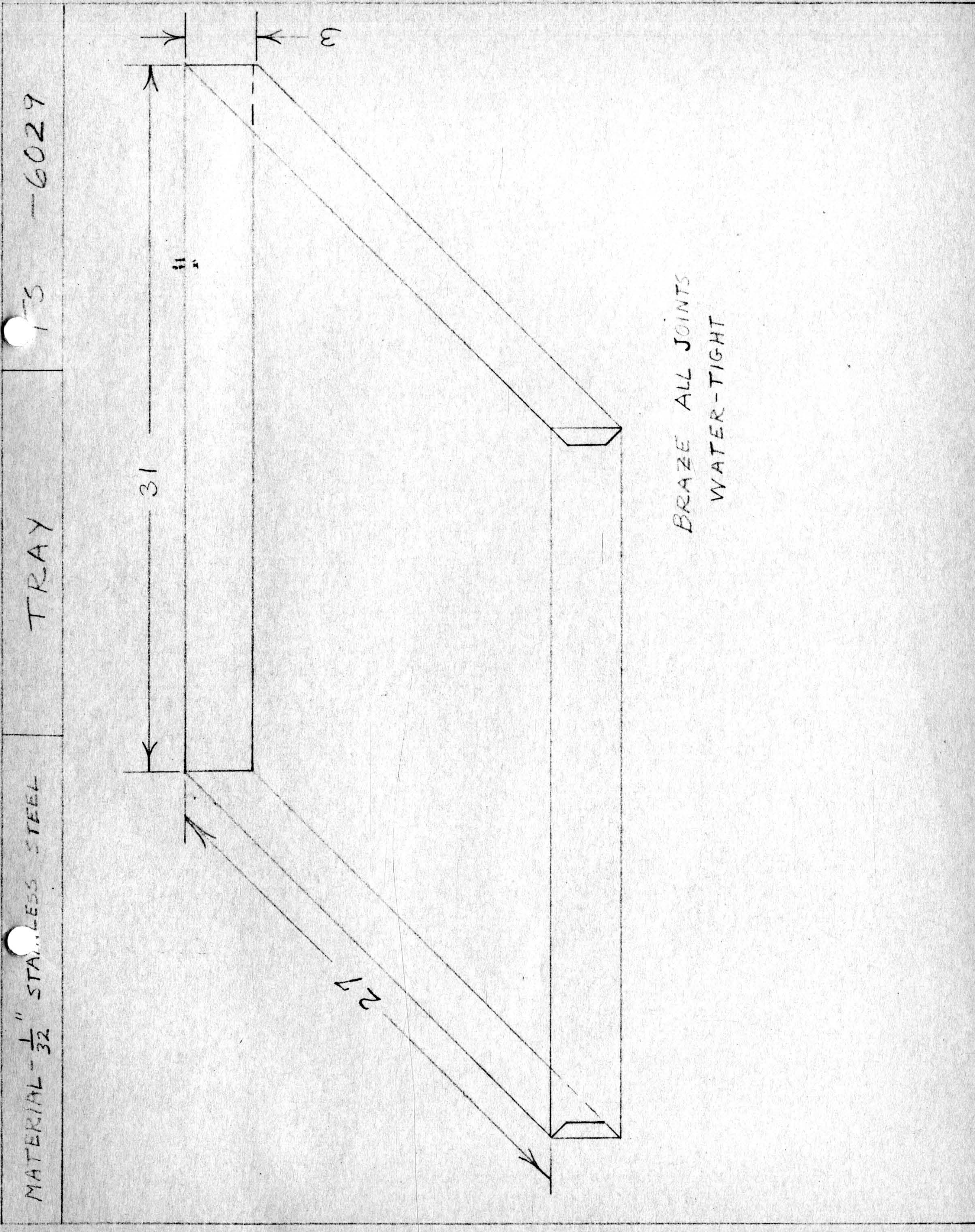


FIG. IV - 5



MATERIAL - 1/32" STAINLESS STEEL
TRAY
TS - 6029
3
31
27
BRAZE ALL JOINTS
WATER-TIGHT

FIG. IV - 6

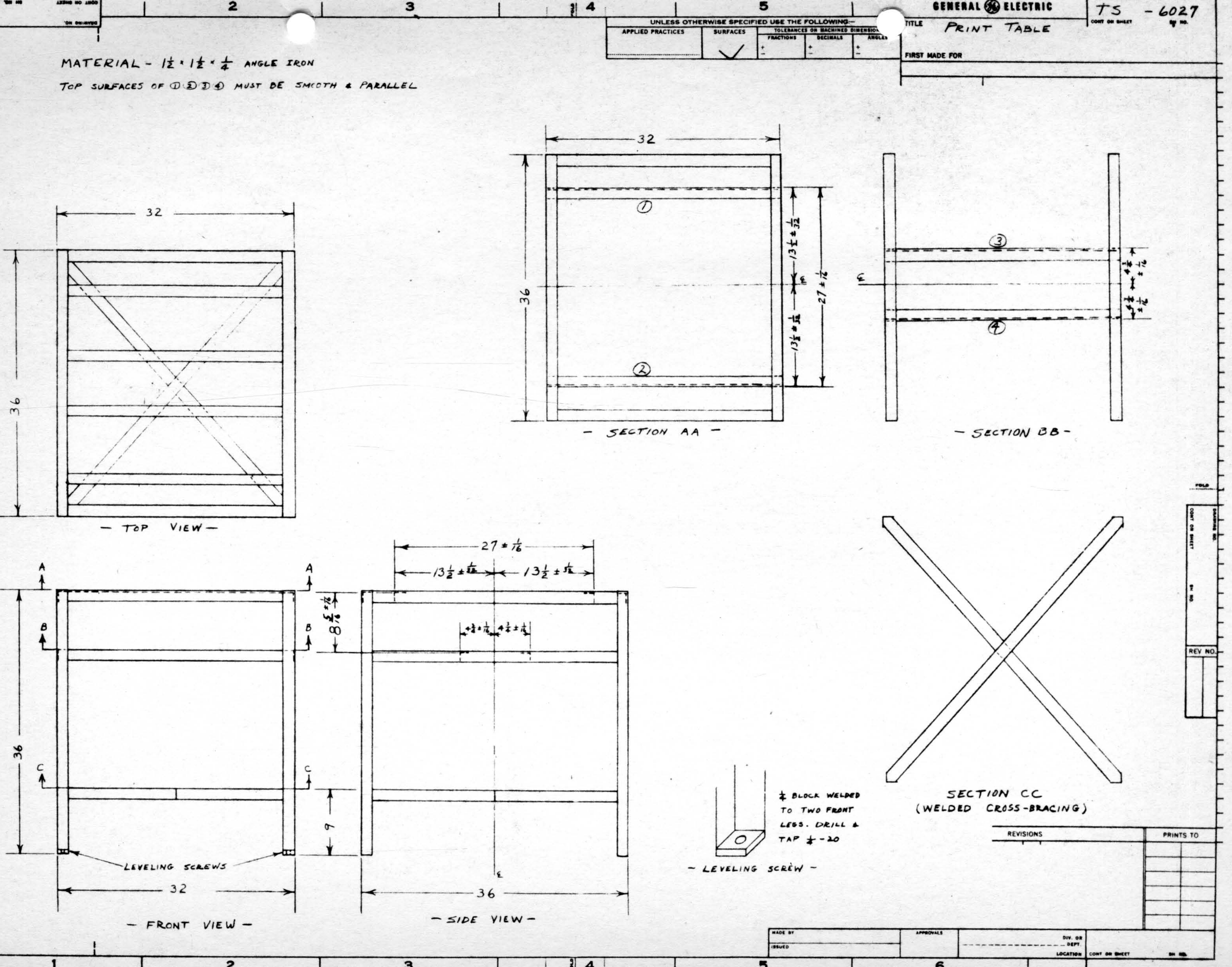

GENERAL ELECTRIC
TS - 6027
TITLE PRINT TABLE
FIRST MADE FOR
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING—
APPLIED PRACTICES
SURFACES
TOLERANCES ON MACHINED DIMENSIONS
FRACTIONS
DECIMALS
ANGLES
MATERIAL - 1½ × 1½ × ¼ ANGLE IRON
TOP SURFACES OF ①②③④ MUST BE SMOOTH & PARALLEL
- TOP VIEW -
- SECTION AA -
- SECTION BB -
- FRONT VIEW -
- SIDE VIEW -
LEVELING SCREWS
¼ BLOCK WELDED TO TWO FRONT LEGS. DRILL & TAP ¼-20
- LEVELING SCREW -
SECTION CC
(WELDED CROSS-BRACING)
REVISIONS
PRINTS TO
REV NO.
MADE BY
ISSUED
APPROVALS
DIV. OR DEPT.
LOCATION
CONT ON SHEET

FIG. IV-7

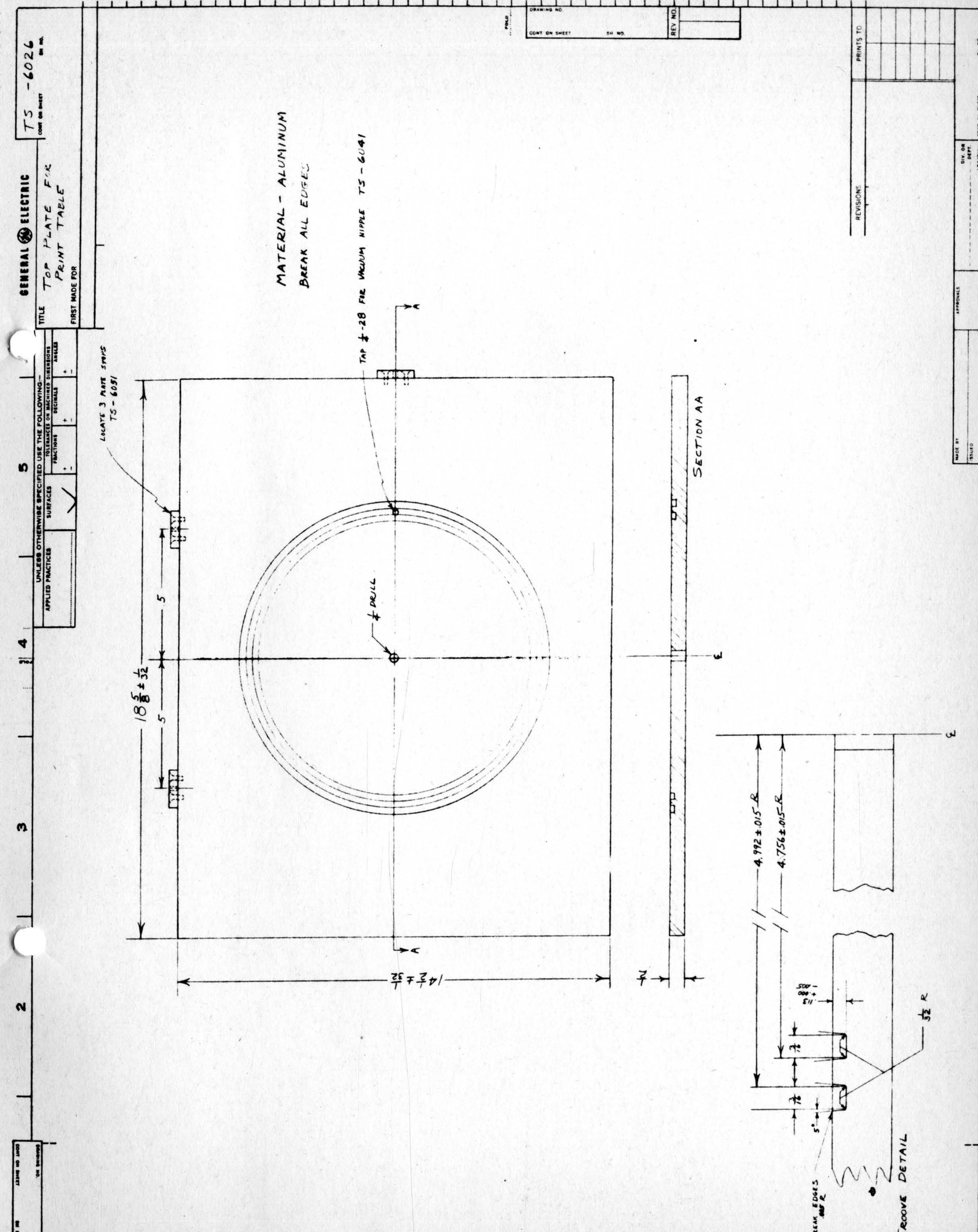
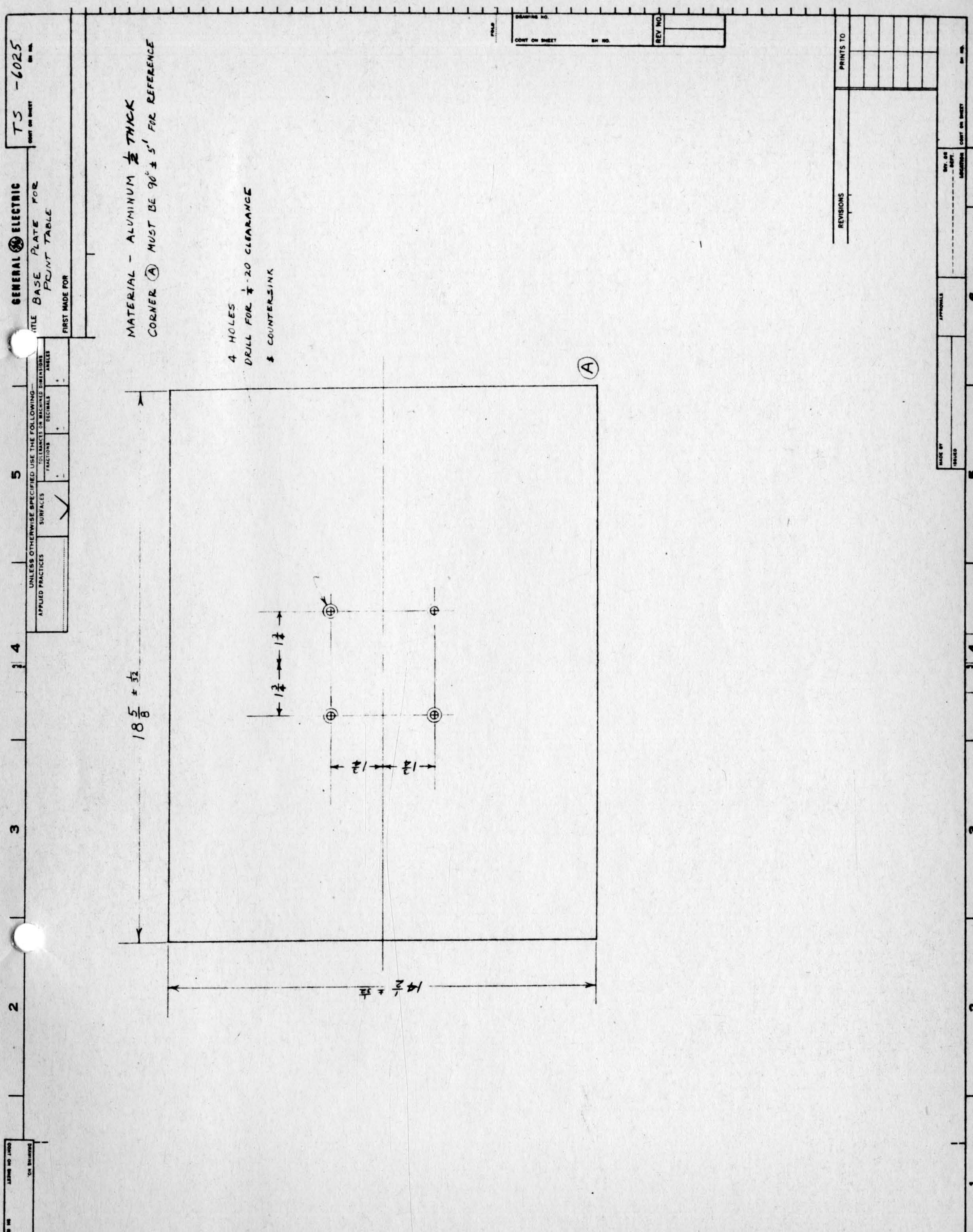

GENERAL ELECTRIC
TS -6026
TITLE TOP PLATE FOR PRINT TABLE
FIRST MADE FOR
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING—
APPLIED PRACTICES
SURFACES
TOLERANCES ON MACHINED DIMENSIONS
FRACTIONS
DECIMALS
ANGLES
DRAWING NO.
CONT ON SHEET
SH NO.
REV NO.
PRINTS TO
REVISIONS
MATERIAL - ALUMINUM
BREAK ALL EDGES
TAP ¼-28 FOR VACUUM NIPPLE TS - 6041
LOCATE 3 PLATE STOPS TS - 6051
¼ DRILL
18 5/8 ± 1/32
14 1/2 ± 1/32
SECTION AA
4.992 ± .015 R
4.756 ± .015 R
1/32 R
BREAK EDGES .005 R
GROOVE DETAIL
MADE BY
ISSUED
APPROVALS
DIV. OR DEPT.

FIG. IV-8



GENERAL ELECTRIC
TITLE BASE PLATE FOR PRINT TABLE
FIRST MADE FOR
TS -6025
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING—
APPLIED PRACTICES
SURFACES
FRACTIONS
DECIMALS
ANGLES
MATERIAL - ALUMINUM 1/2 THICK
CORNER (A) MUST BE 90° ± 5' FOR REFERENCE
4 HOLES
DRILL FOR 1/4-20 CLEARANCE
& COUNTERSINK
(A)
18 5/8 ± 1/32
14 1/2 ± 1/32
1 1/4
1 1/4
1 3/4
1 3/4
REVISIONS
PRINTS TO
DRAWING NO.
CONT ON SHEET
SH NO.
REV NO.
MADE BY
ISSUED
APPROVALS

FIG. IV-9

ELECTRONICS LAB TUBE SECTION	TS-6014R 21" FRAME		
MATERIAL: ALUMINUM	NO. REQ 1	SCALE 1"= 5"	DR BY gjcm 10-1-53
ALL DEMENSIONS ± 1/64			

NOTE: BREAK ALL EDGES

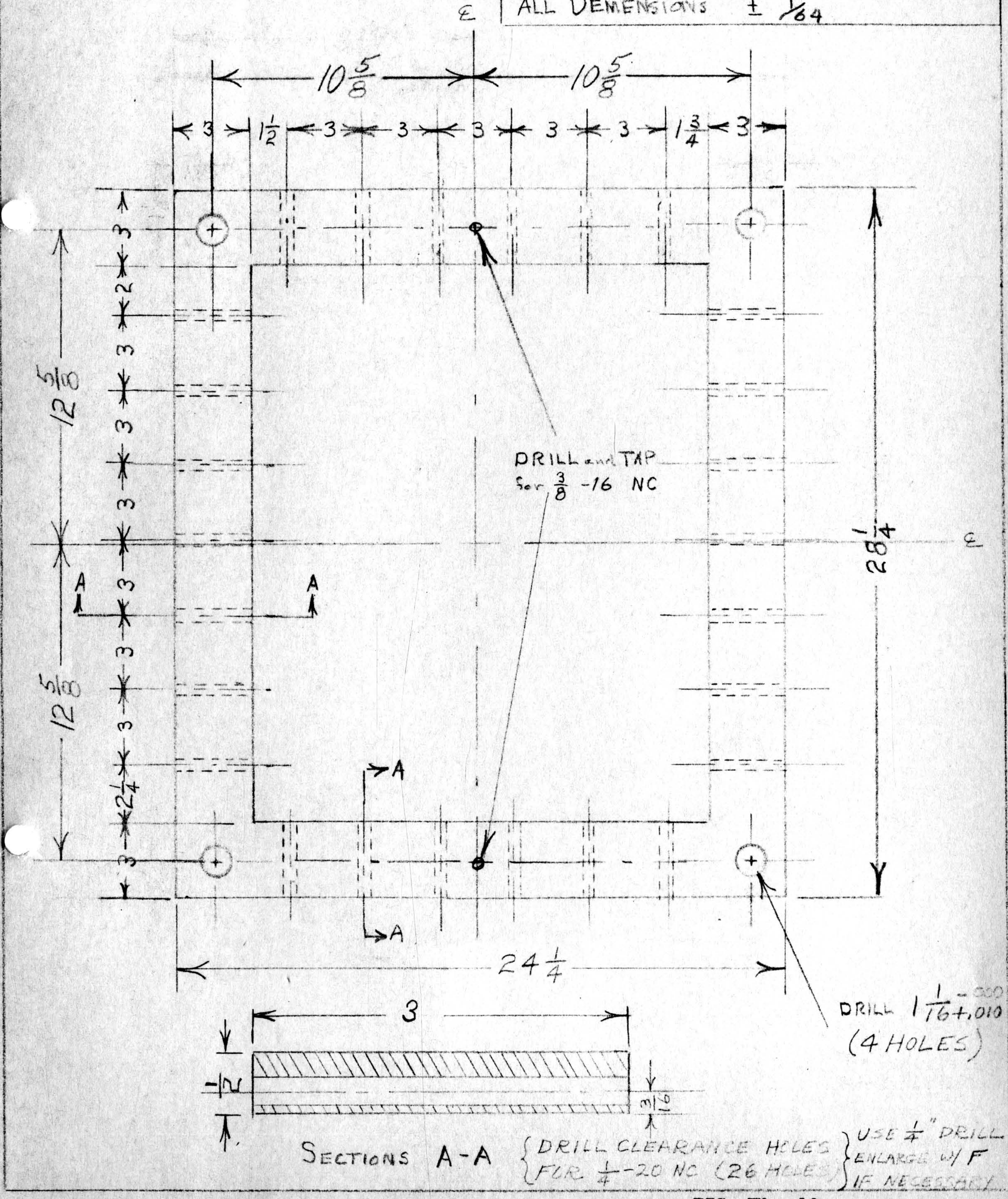


FIG. IV - 10

ELECTRONICS LAB	EDGE CLAMP	SCALE	MATERIAL	No REQ	DR BY
TUBE SECTION	TS-6016R		FREE TURNING BRASS	2	9-29-53

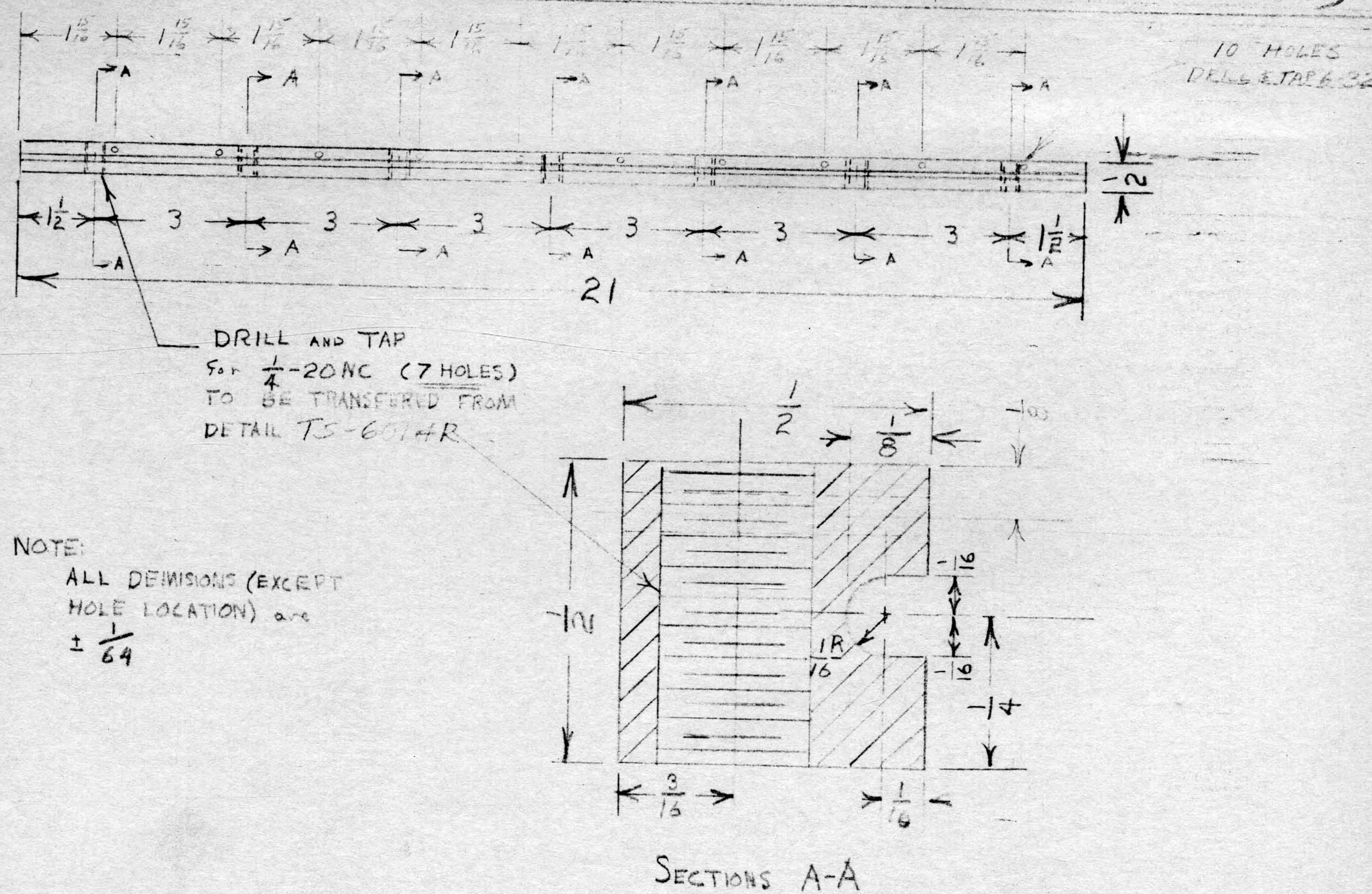


FIG. IV - 11

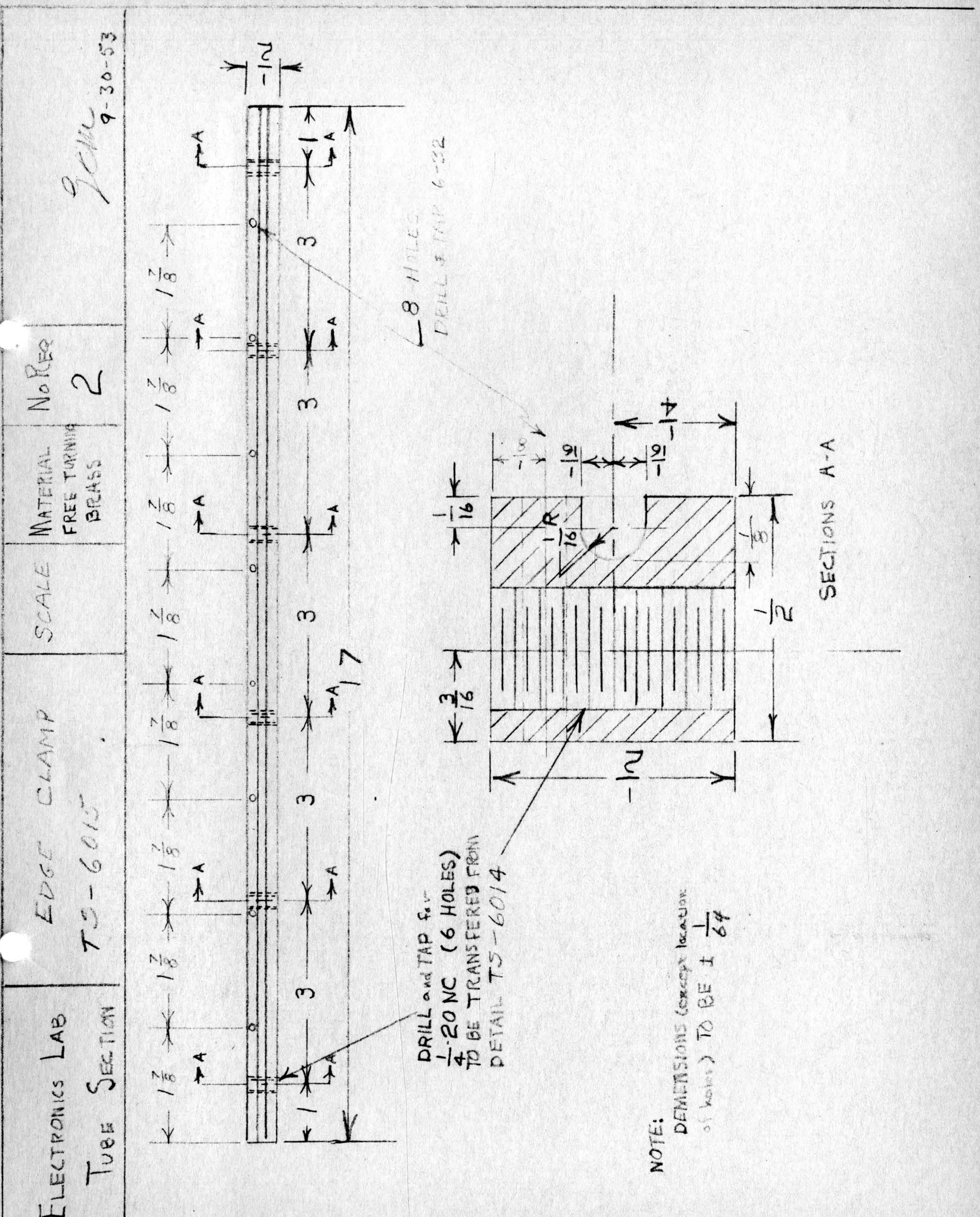

ELECTRONICS LAB
TUBE SECTION
EDGE CLAMP
TS-6015
SCALE
MATERIAL
FREE TURNING BRASS
NO REQ
2
9-30-53
DRILL and TAP for
1/4-20 NC (6 HOLES)
TO BE TRANSFERED FROM
DETAIL TS-6014
8 HOLES
DRILL & TAP 6-32
SECTIONS A-A
NOTE:
DEMENSIONS (except location of holes) TO BE ± 1/64

FIG. IV - 12

ELECTRONICS LAB TUBE SECTION	BUSHING TS-6017R	DR *	MATERIAL OILITE	NO REQ 4	SCALE 2"-1"	DR BY SCM 9-29-53

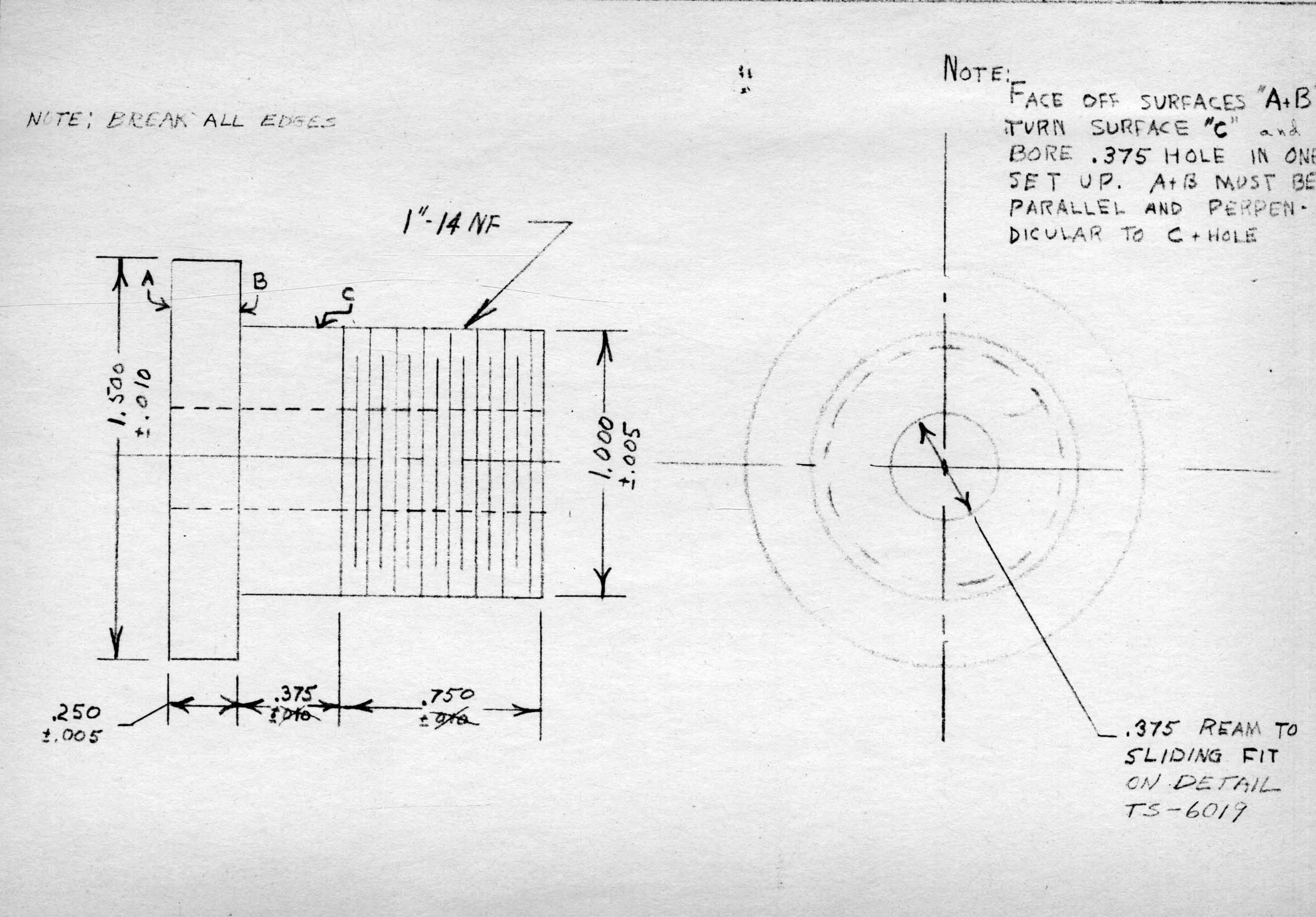


FIG. IV - 13

Electronic Lab Tube Section	Guide Rod TS-6019	Dr #	Material	No Req	Scale	Dr By
			18-8 SS	4	2" = 1"	9-29-55

NOTE: FACE OFF SURFACES "A+B" and TURN SURFACE "C" IN ONE SET UP. "A+B" MUST BE PARALLEL and MUST BE PERPENDICULAR TO "C"

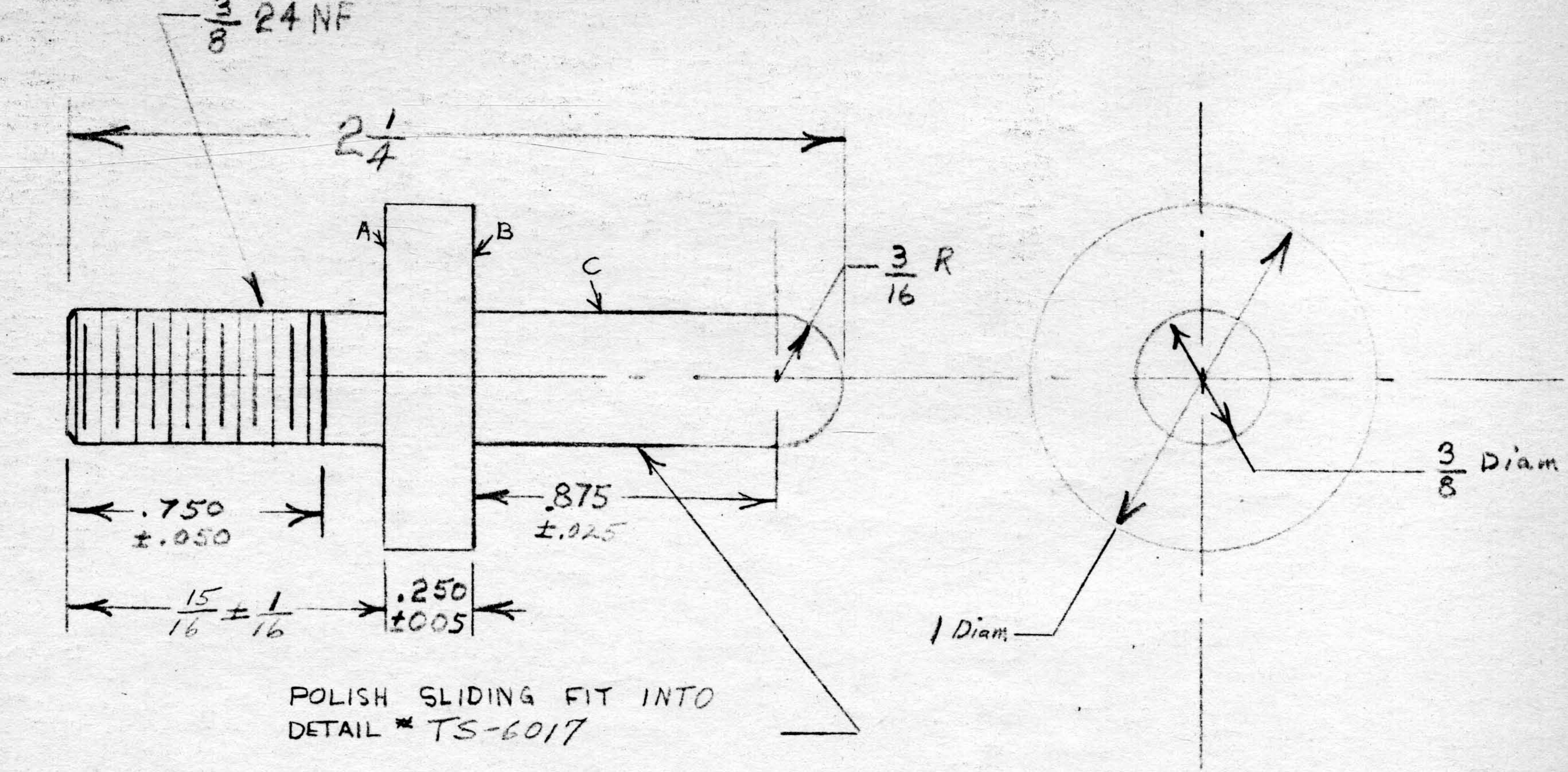
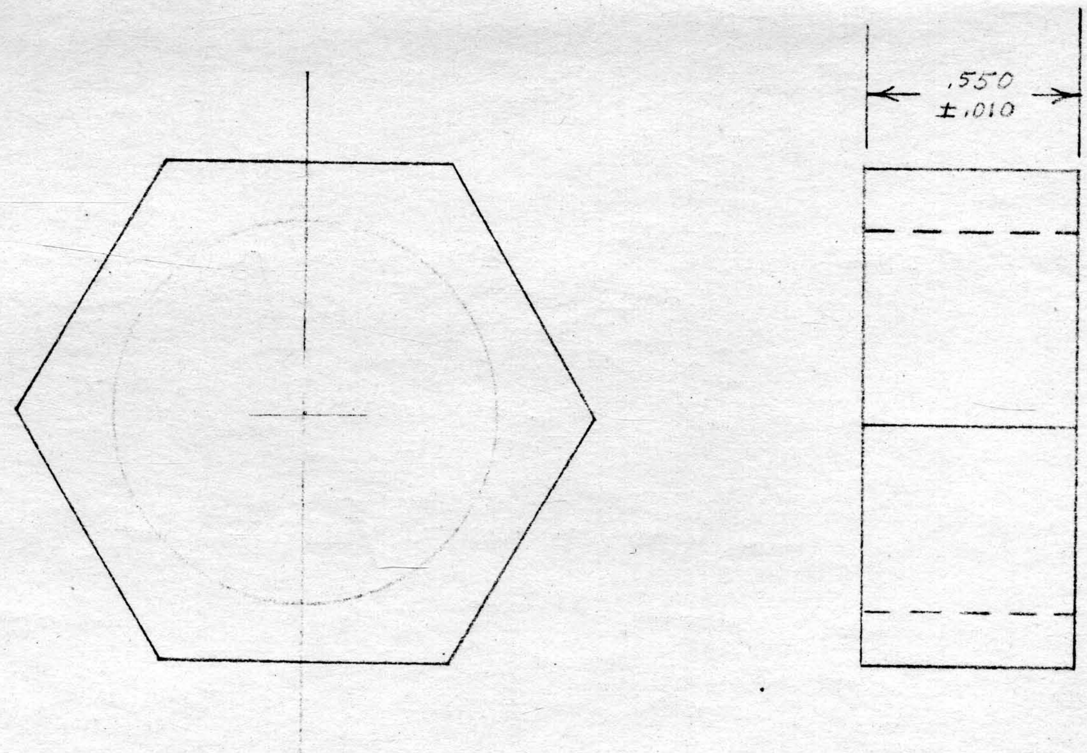


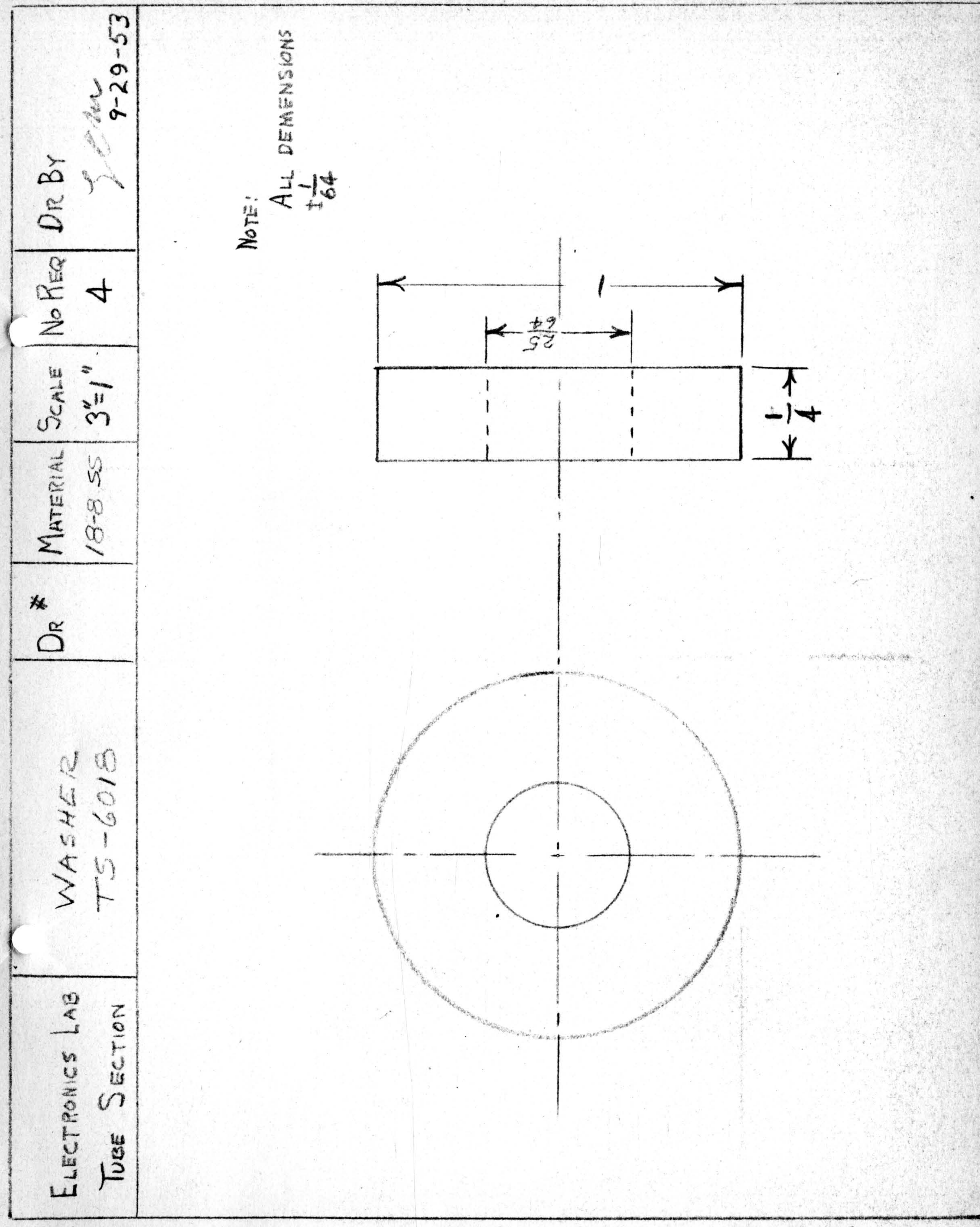
FIG. IV - 14

ELECTRONICS LAB TUBE SECTION	NUT TS-6020	MATERIAL BRASS	NO. REQ. 4	DR BY WEK



CUT DOWN STANDARD LIGHT HEX. NUT
1"-14 NF

FIG. IV - 15



ELECTRONICS LAB
TUBE SECTION
WASHER
TS-6018
DR #
MATERIAL
18-8 SS
SCALE
3"=1"
NO REQ
4
DR BY
9-29-53
NOTE!
ALL DEMENSIONS
±1/64
1
25/64
1/4

FIG. IV - 16

PLATE MARGIN ADJUSTER | MATERIAL - ALUMINUM | TS - 6051

3 NEEDED

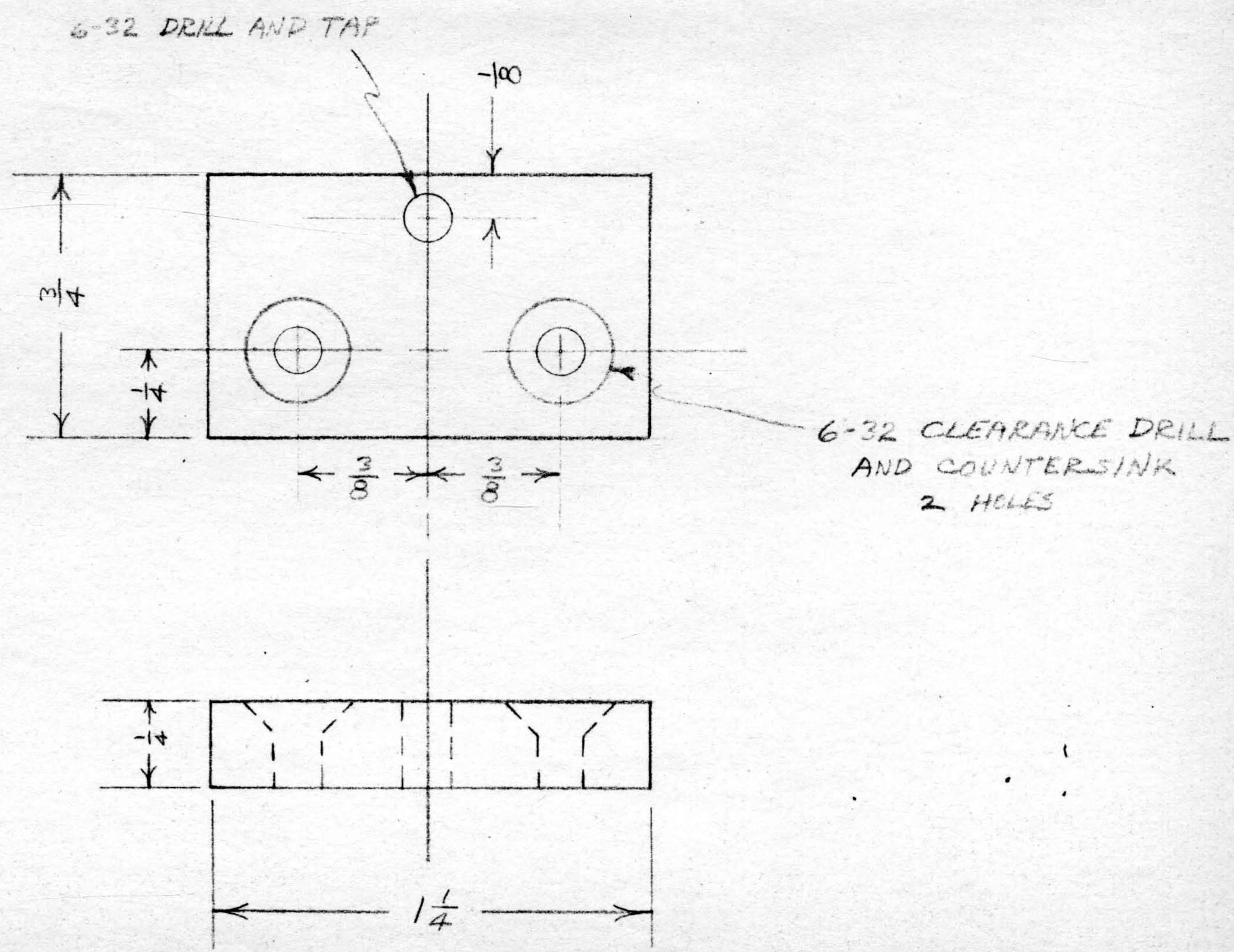


FIG. IV - 17

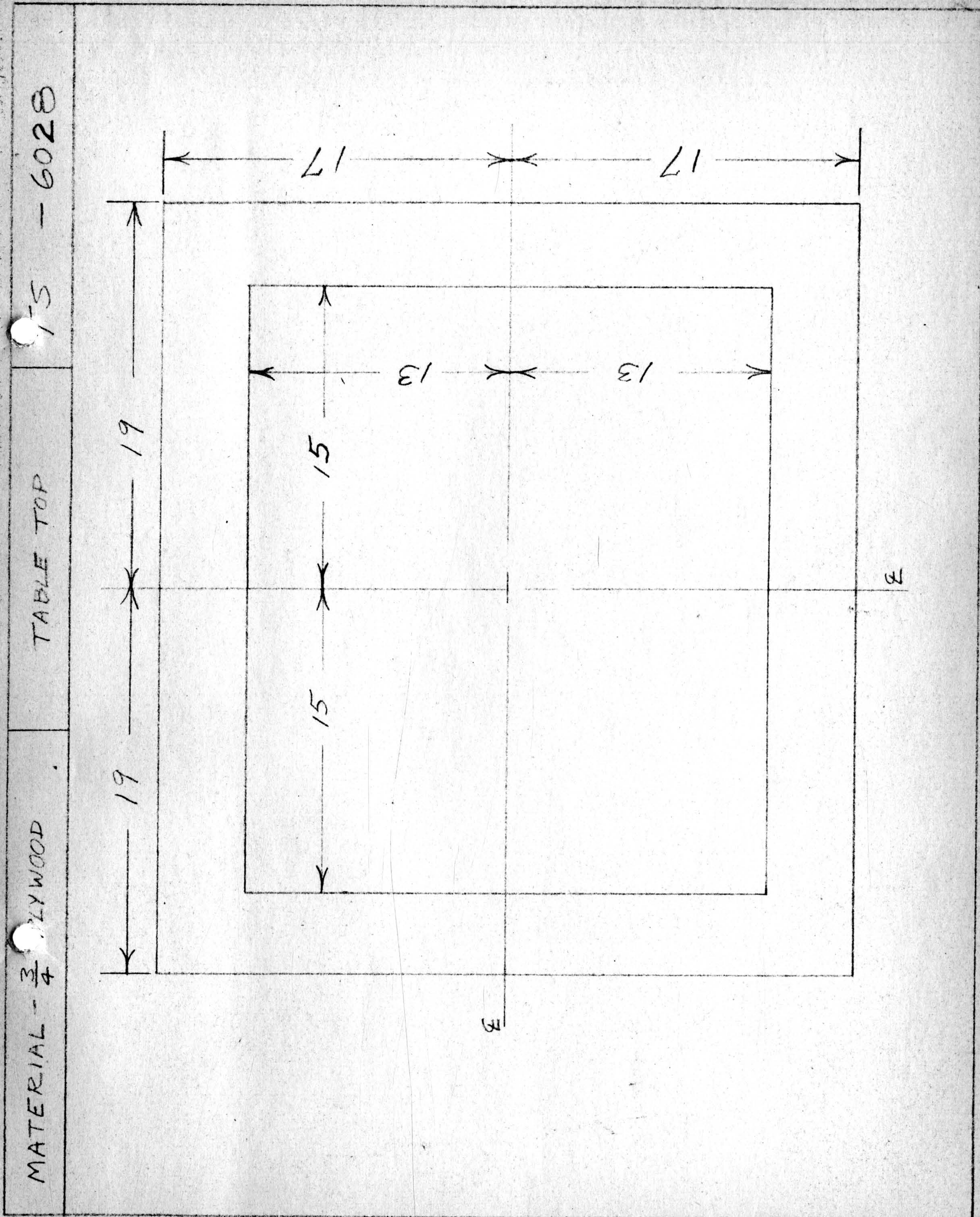


FIG. IV - 18

VACUUM NIPPLE	MATERIAL-ALUMINUM	TS - 6041

REF. TS-6026

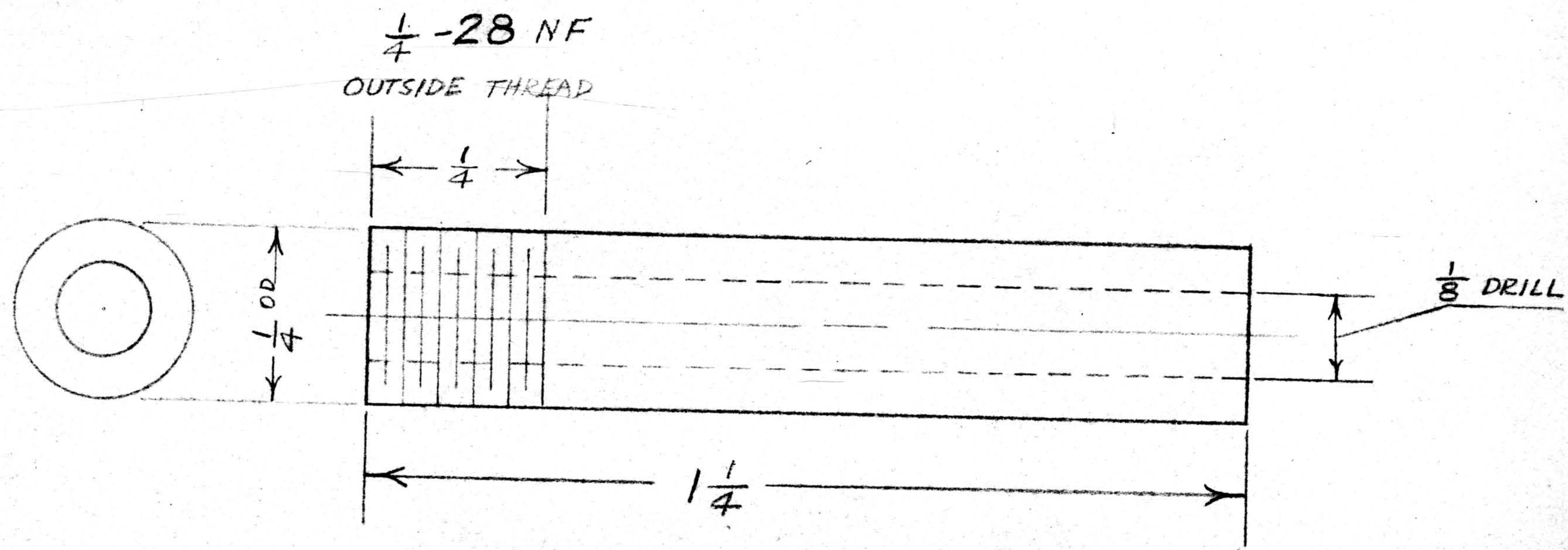


FIG. IV - 19

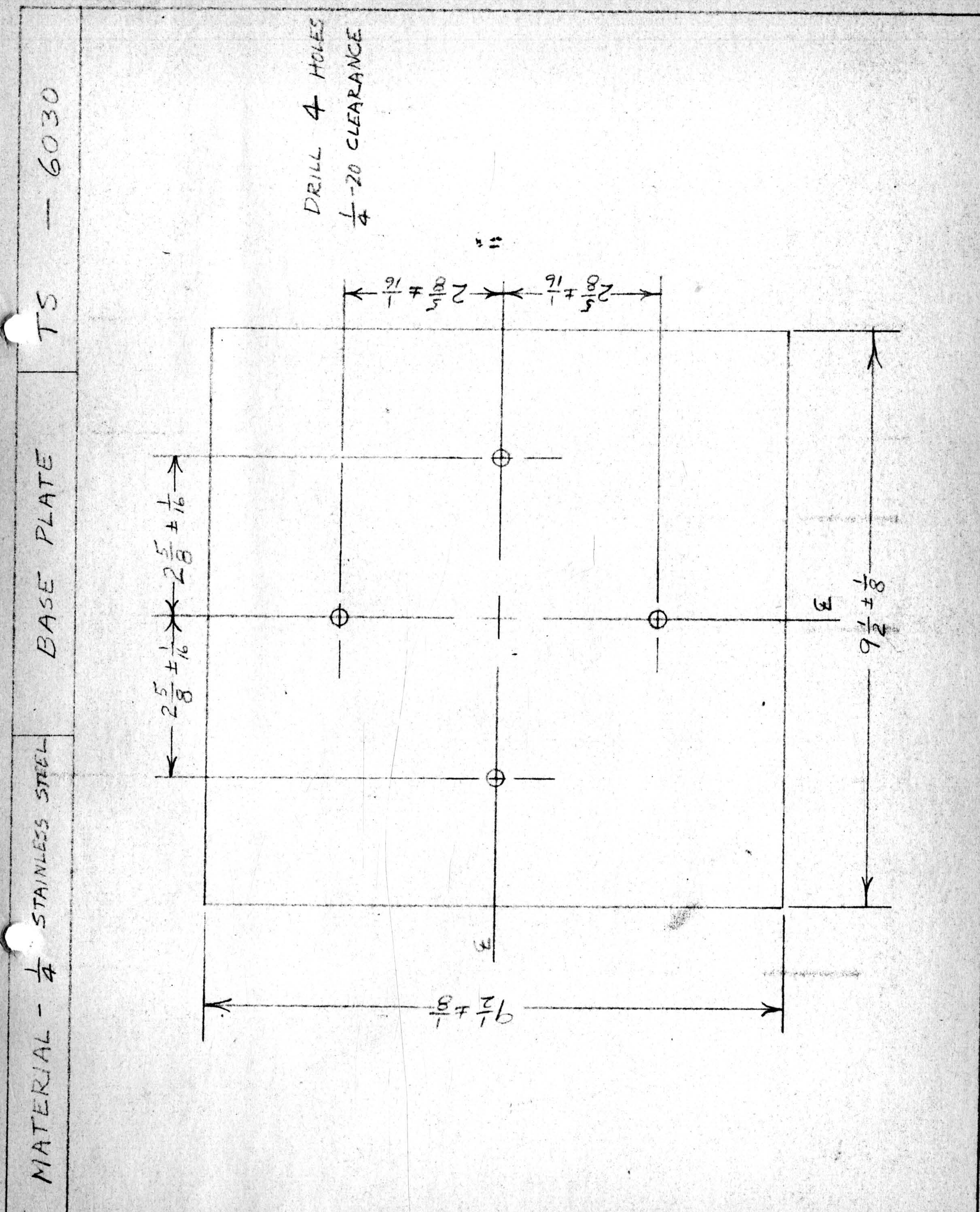
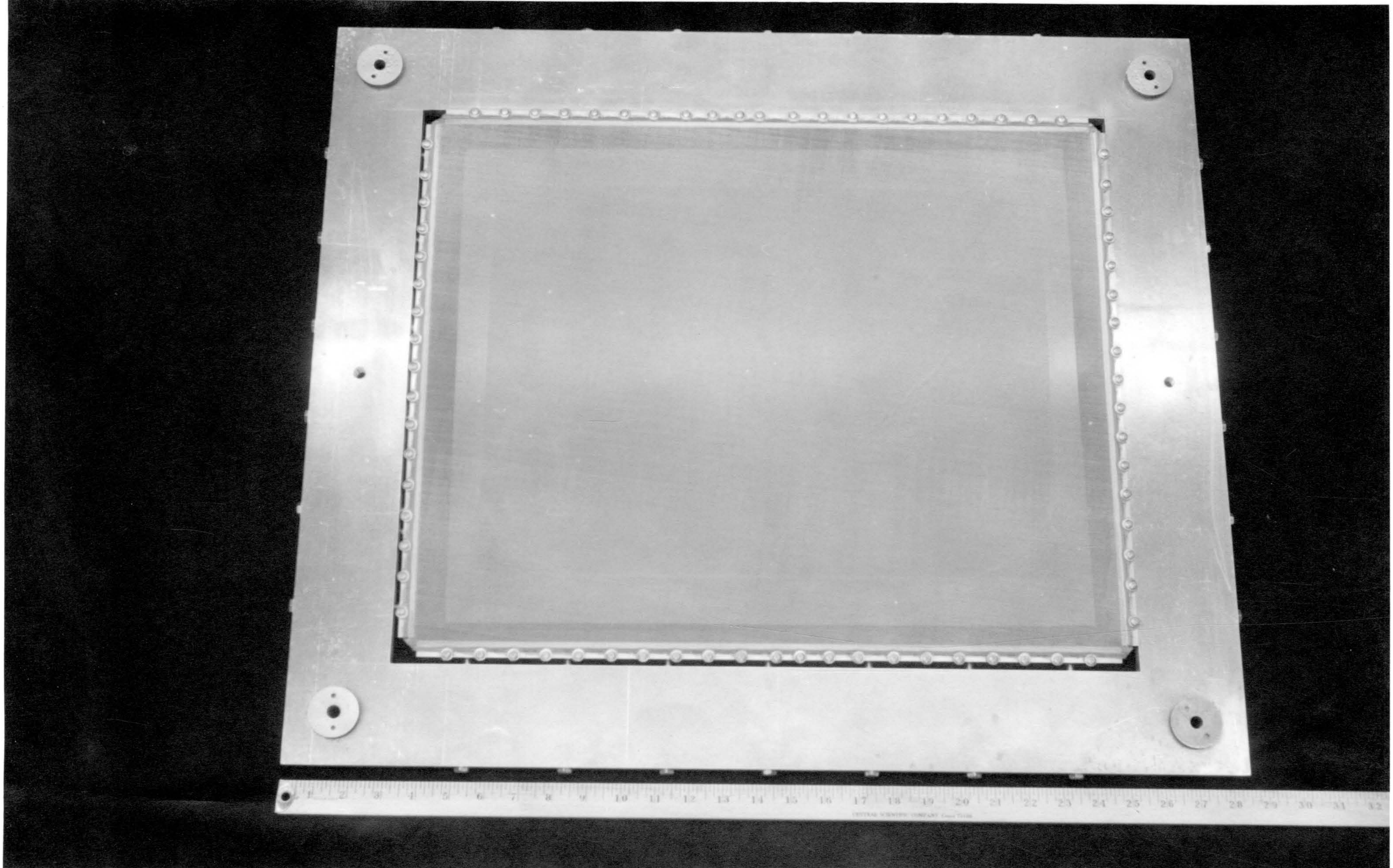
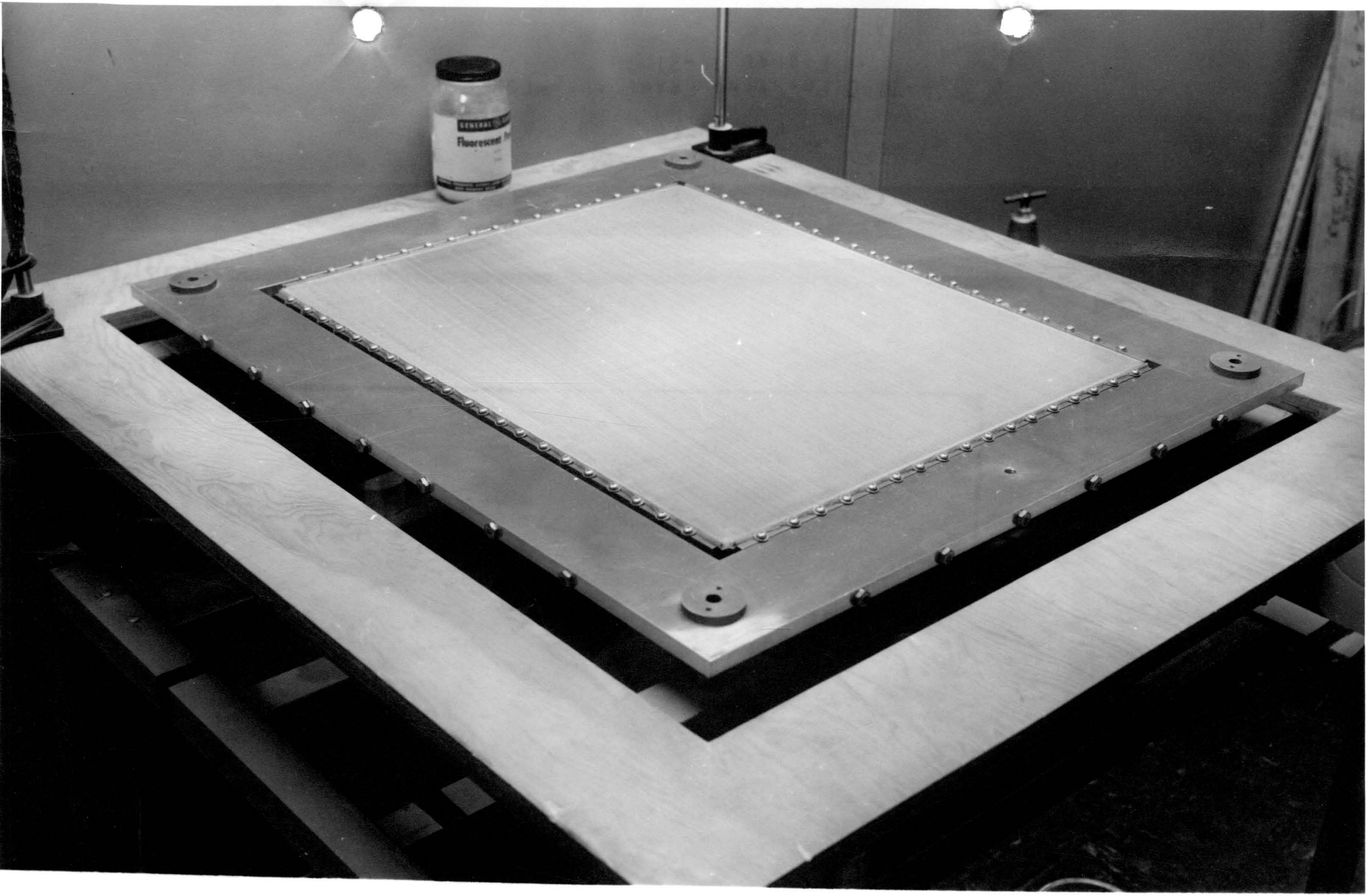

MATERIAL - 1/4 STAINLESS STEEL
BASE PLATE
TS - 6030
DRILL 4 HOLES
1/4-20 CLEARANCE
2 5/8 ± 1/16
2 5/8 ± 1/16
2 5/8 ± 1/16
2 5/8 ± 1/16
9 1/2 ± 1/8
9 1/2 ± 1/8
℄
℄

FIG. IV - 20

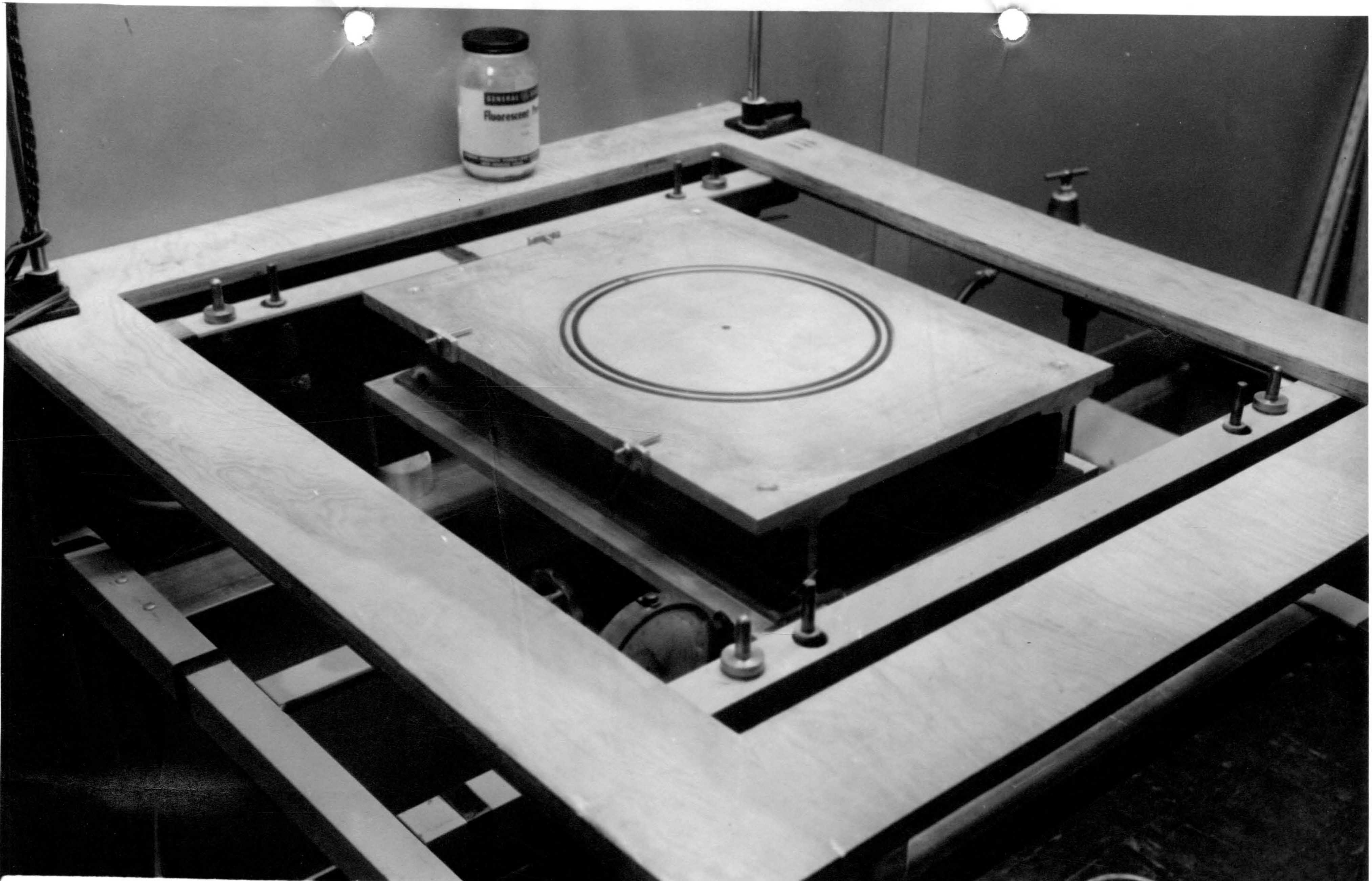


Electronics DIV.

4-7140 PRINTING FRAME AND MESH
FIGURE IV-21



GE Electronics DIV. 4-7138 PRINTING TABLE WITH FRAME AND MESH
FIGURE IV-22



GE Electronics DIV. 4-7137 PRINTING TABLE SHOWING ADJUSTABLE BED
FIGURE IV-23

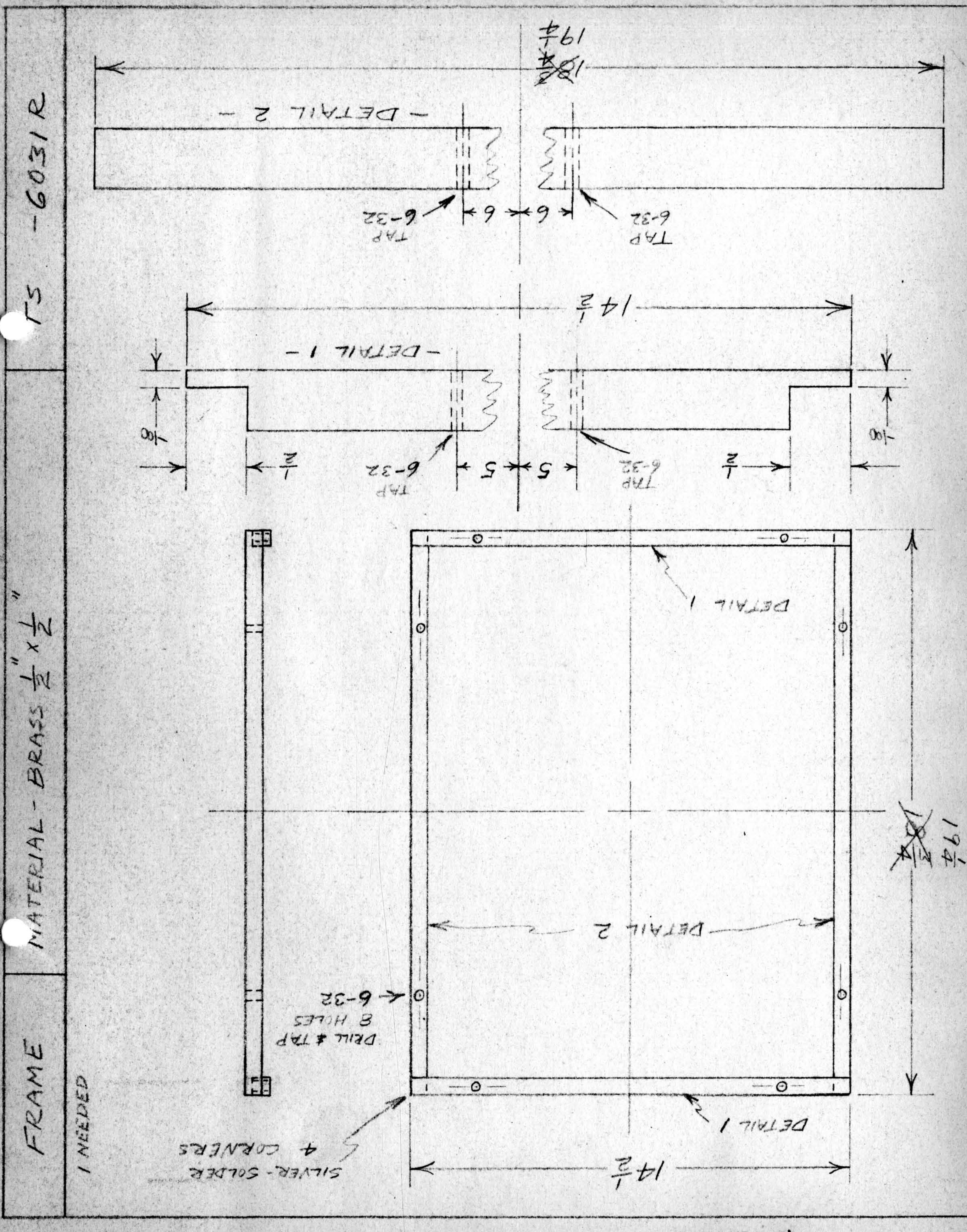

FRAME
MATERIAL - BRASS 1/2" x 1/2"
TS -6031 R
1 NEEDED
DETAIL 2
DETAIL 1
19 1/4
14 1/2
TAP 6-32
DRILL & TAP 8 HOLES 6-32
SILVER-SOLDER 4 CORNERS

FIG. IV - 24

PLATE SUPPORT	MATERIAL - $\frac{1}{32}$ BRASS	TS - 6033

2 NEEDED

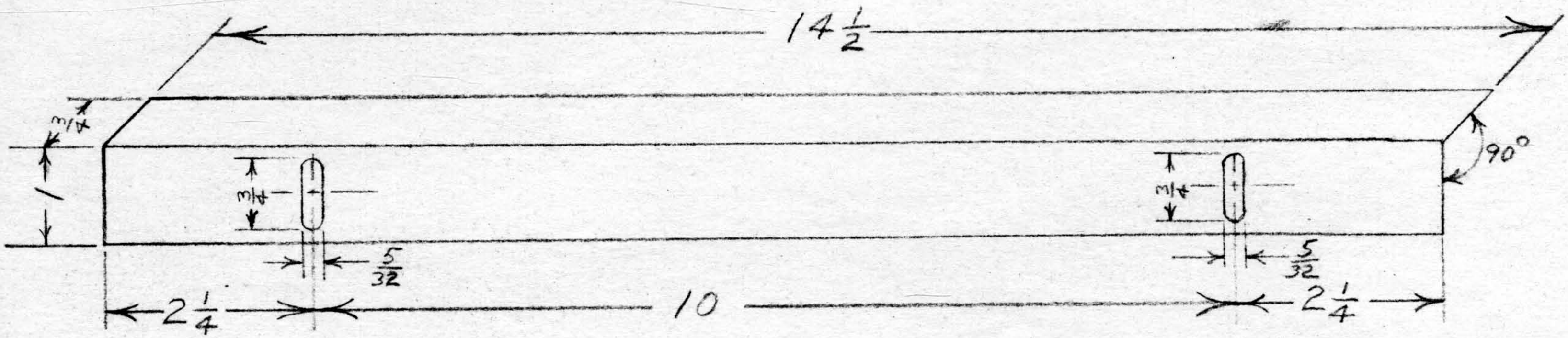


FIG. IV - 29

SIDE MASK	MATERIAL – $\frac{1}{32}$ BRASS	TS -6038

MAINTAIN FLATNESS
EDGES MUST BE SMOOTH
2 NEEDED

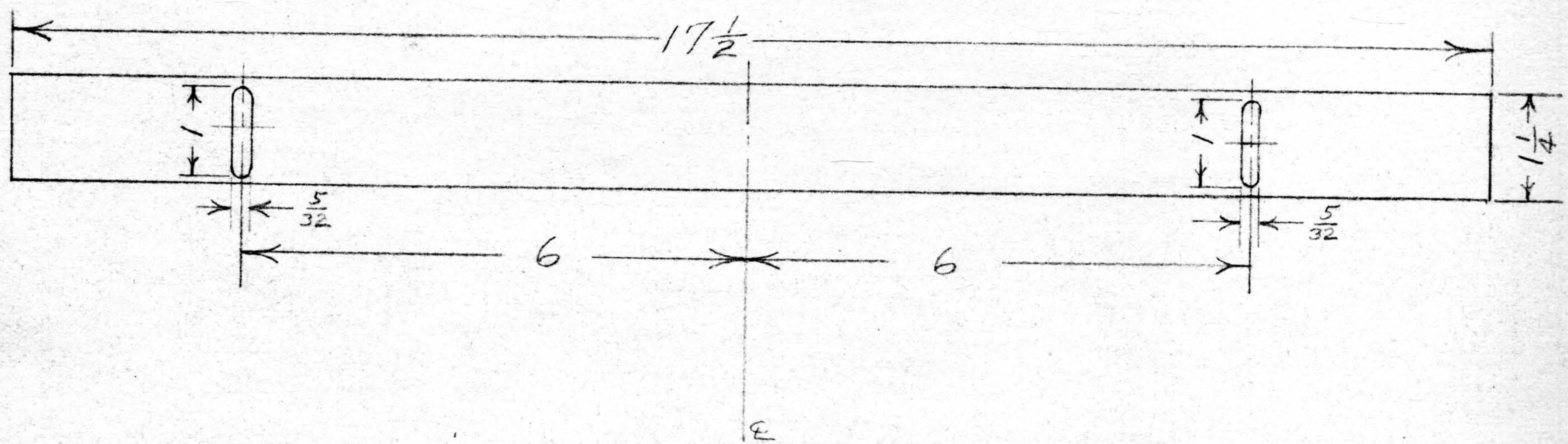


FIG. IV - 26

BOTTOM MASK	MATERIAL - $\frac{1}{32}$ BRASS	TS -6039

MAINTAIN FLATNESS
EDGES MUST BE SMOOTH
2 NEEDED

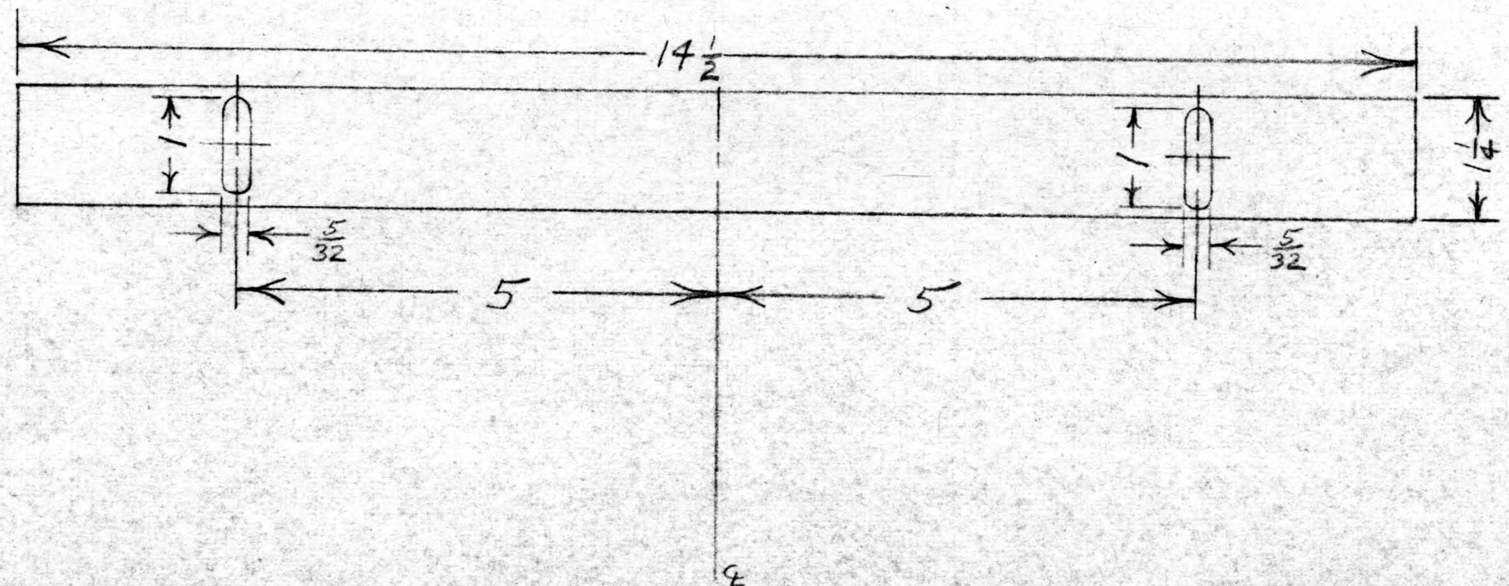


FIG. IV - 27

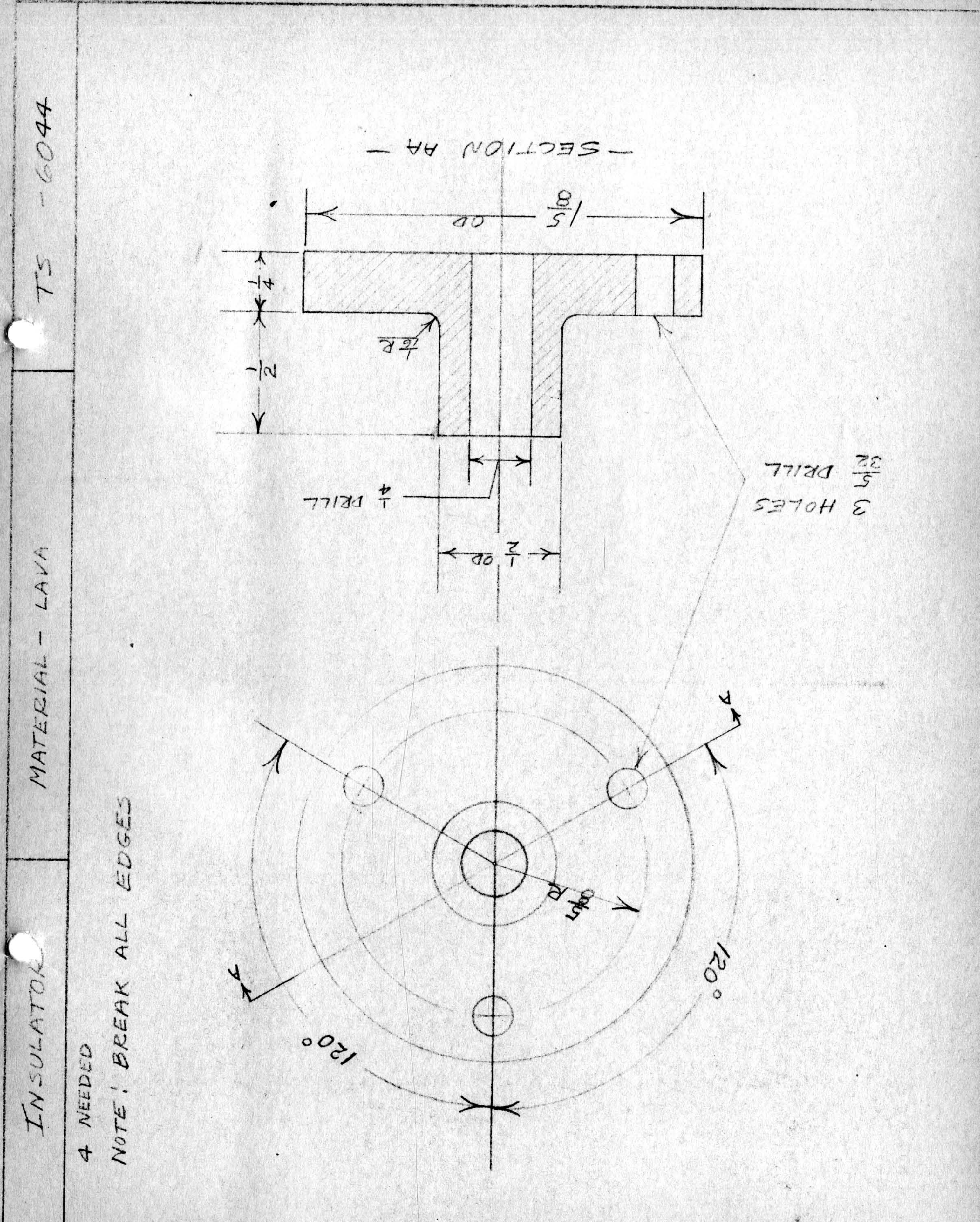

INSULATOR
TS - 6044
MATERIAL - LAVA
4 NEEDED
NOTE! BREAK ALL EDGES
SECTION AA
1 5/8 OD
1/4
1/2
1/16 R
1/4 DRILL
1/2 OD
3 HOLES 5/32 DRILL
120°
120°

FIG. IV - 28

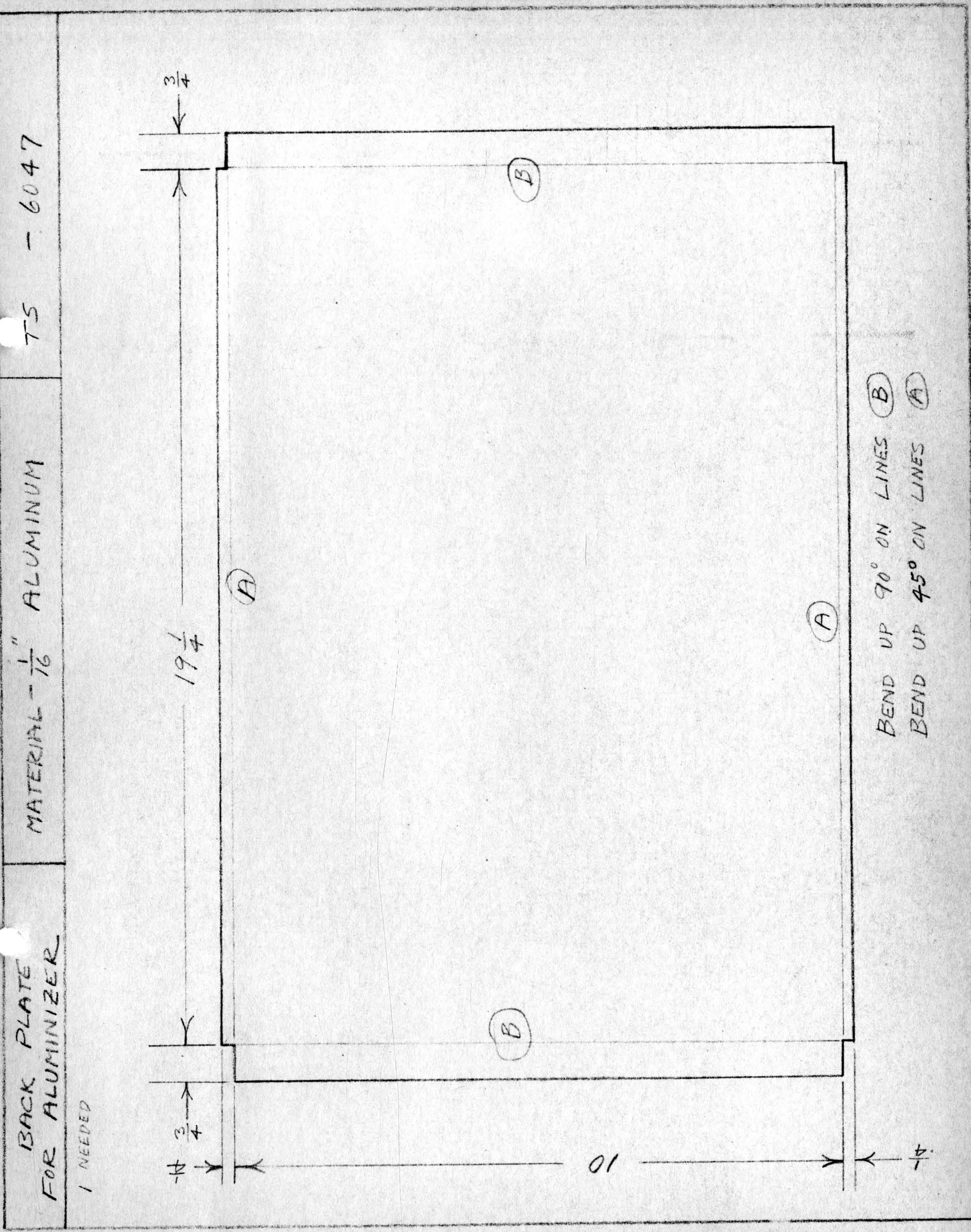

BACK PLATE
FOR ALUMINIZER
MATERIAL - 1/16" ALUMINUM
TS - 6047
1 NEEDED
3/4
19 1/4
3/4
1/4
10
1/4
A
A
B
B
BEND UP 90° ON LINES B
BEND UP 45° ON LINES A

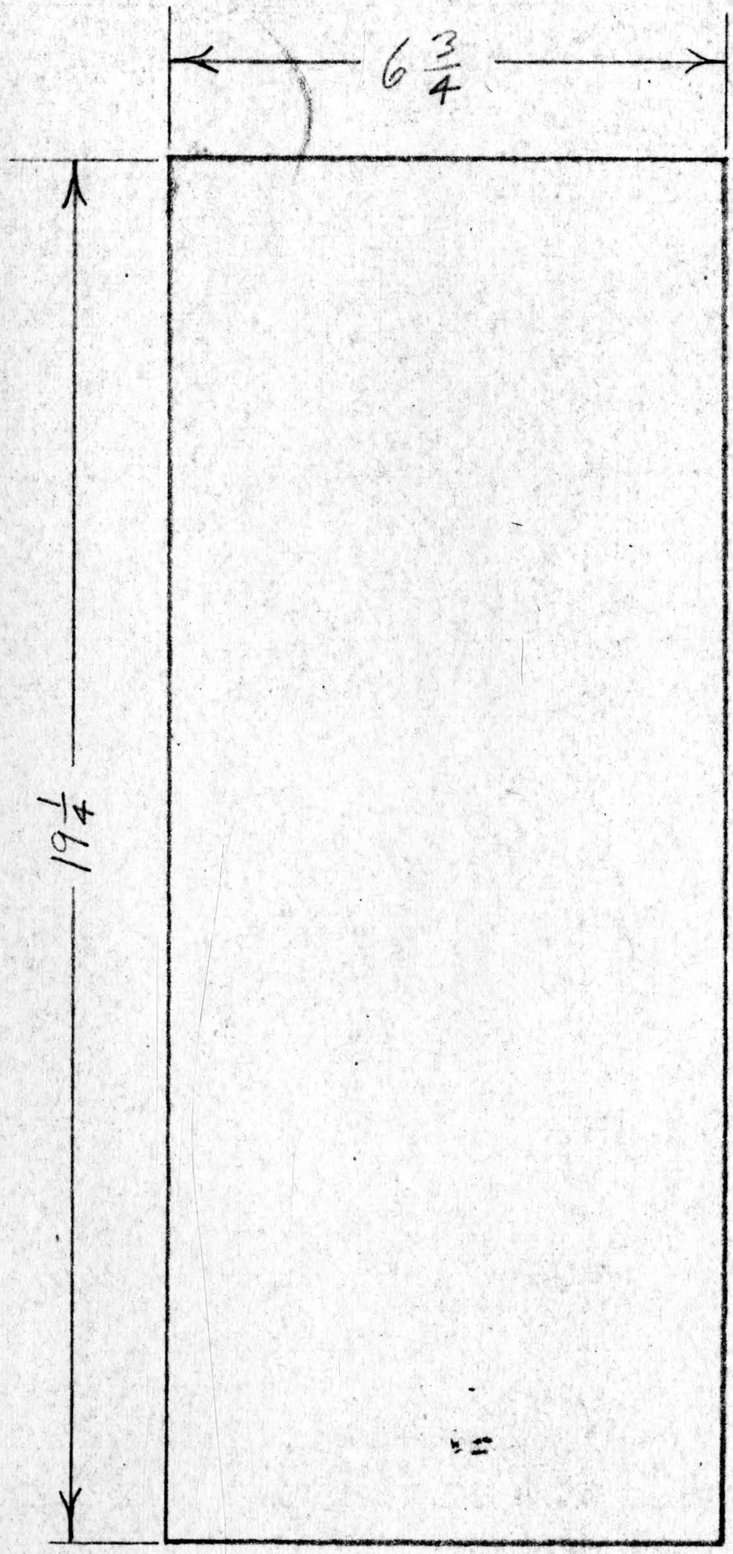
FIG. IV - 29

SIDE PANEL

2 NEEDED

MATERIAL - .020 ALUMINUM

TS - 6048



END PLATE FOR ALUMINIZER	MATERIAL - $\frac{1}{16}$ ALUMINUM	TS - 6052

2 NEEDED

NOTE: BEND UP 90° ALONG LINES (A)

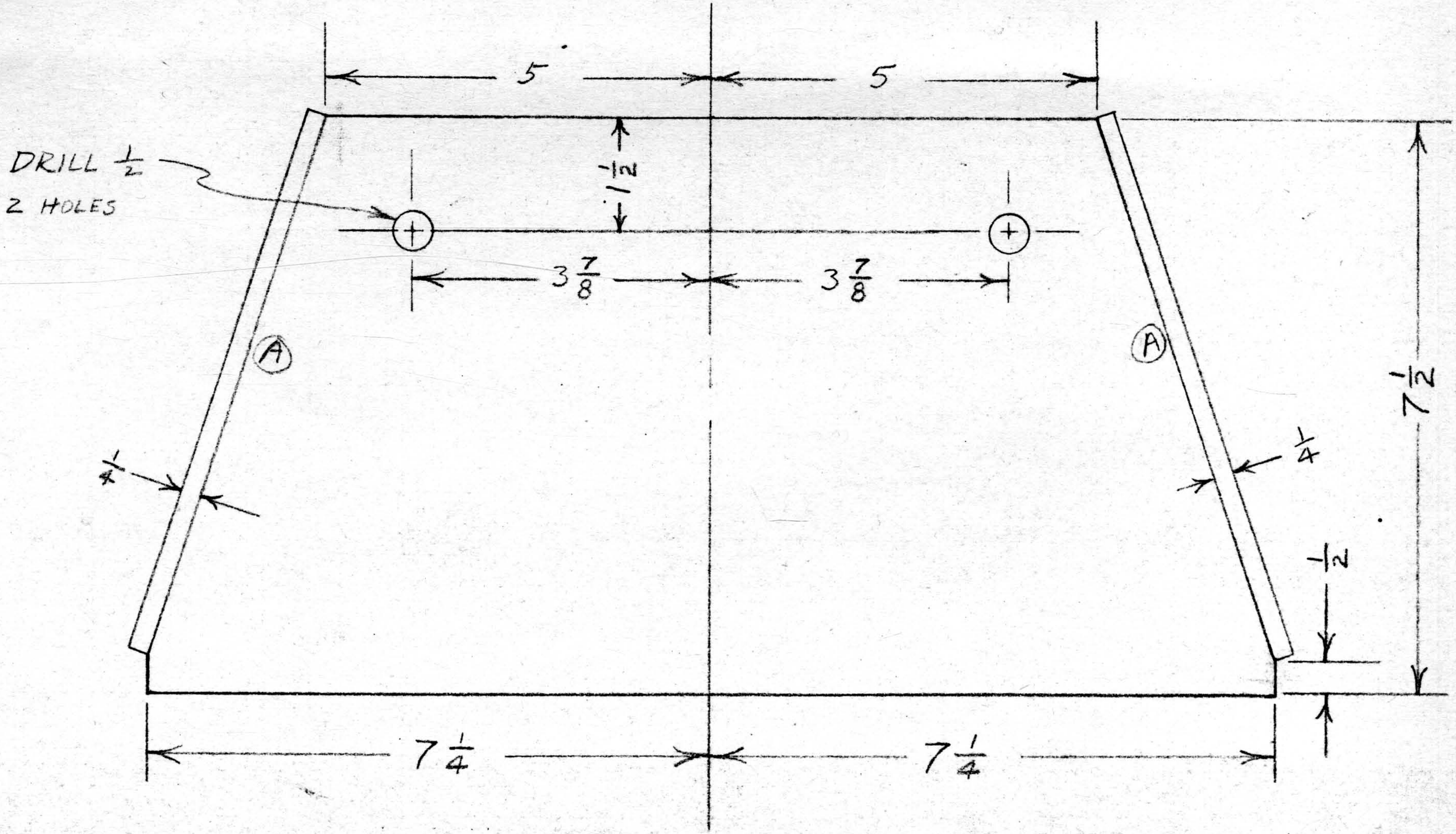
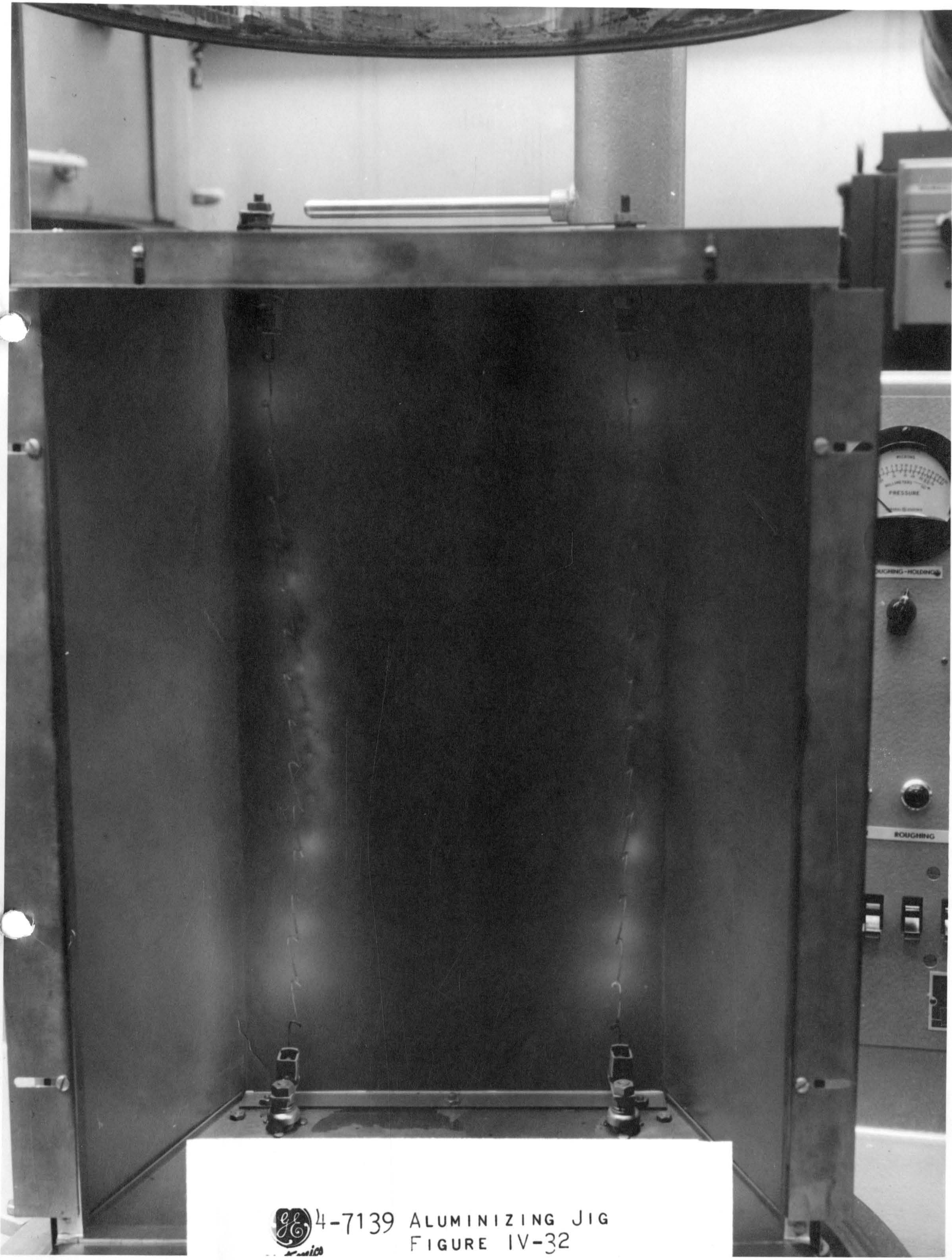
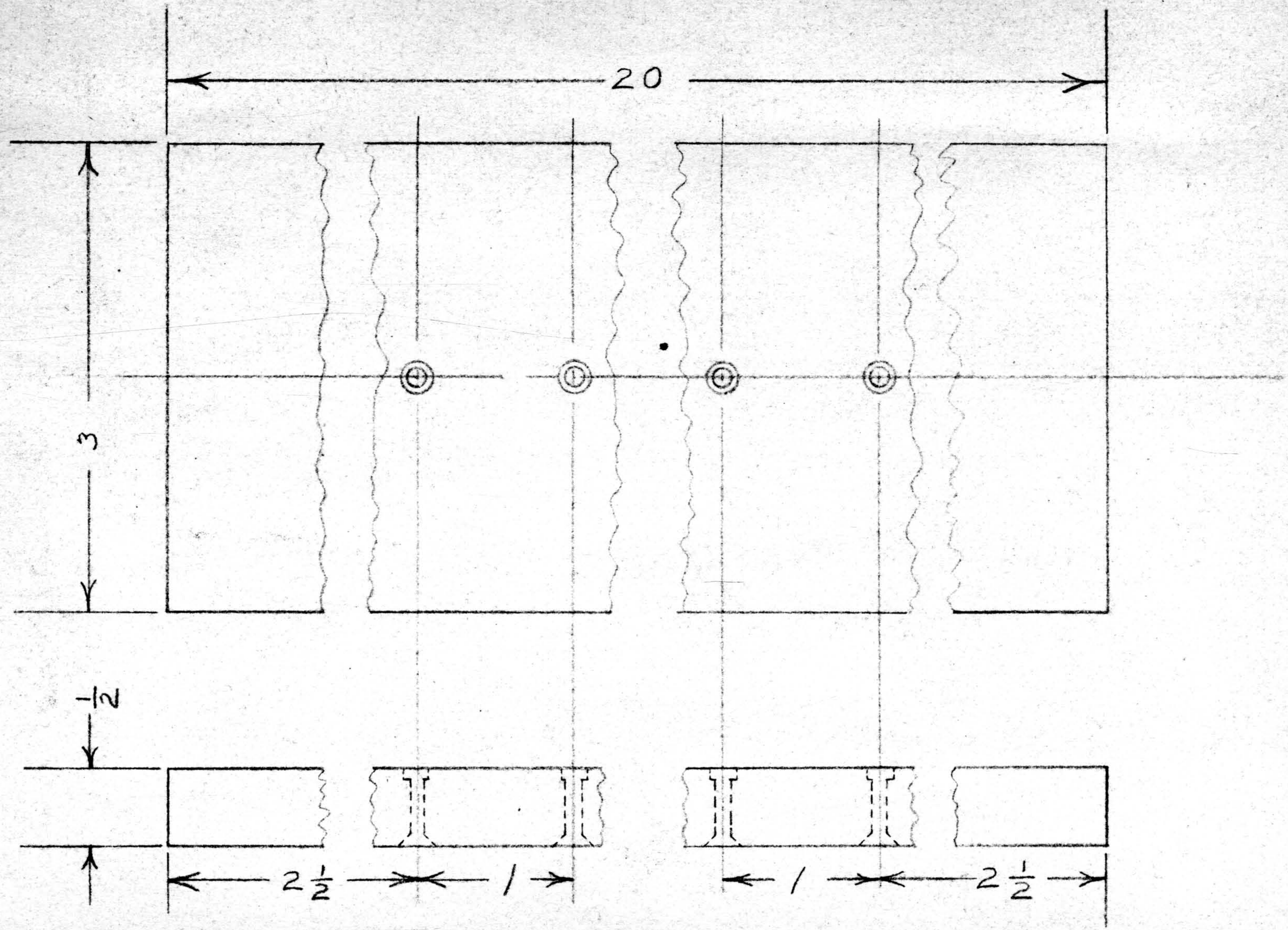


FIG. IV - 33



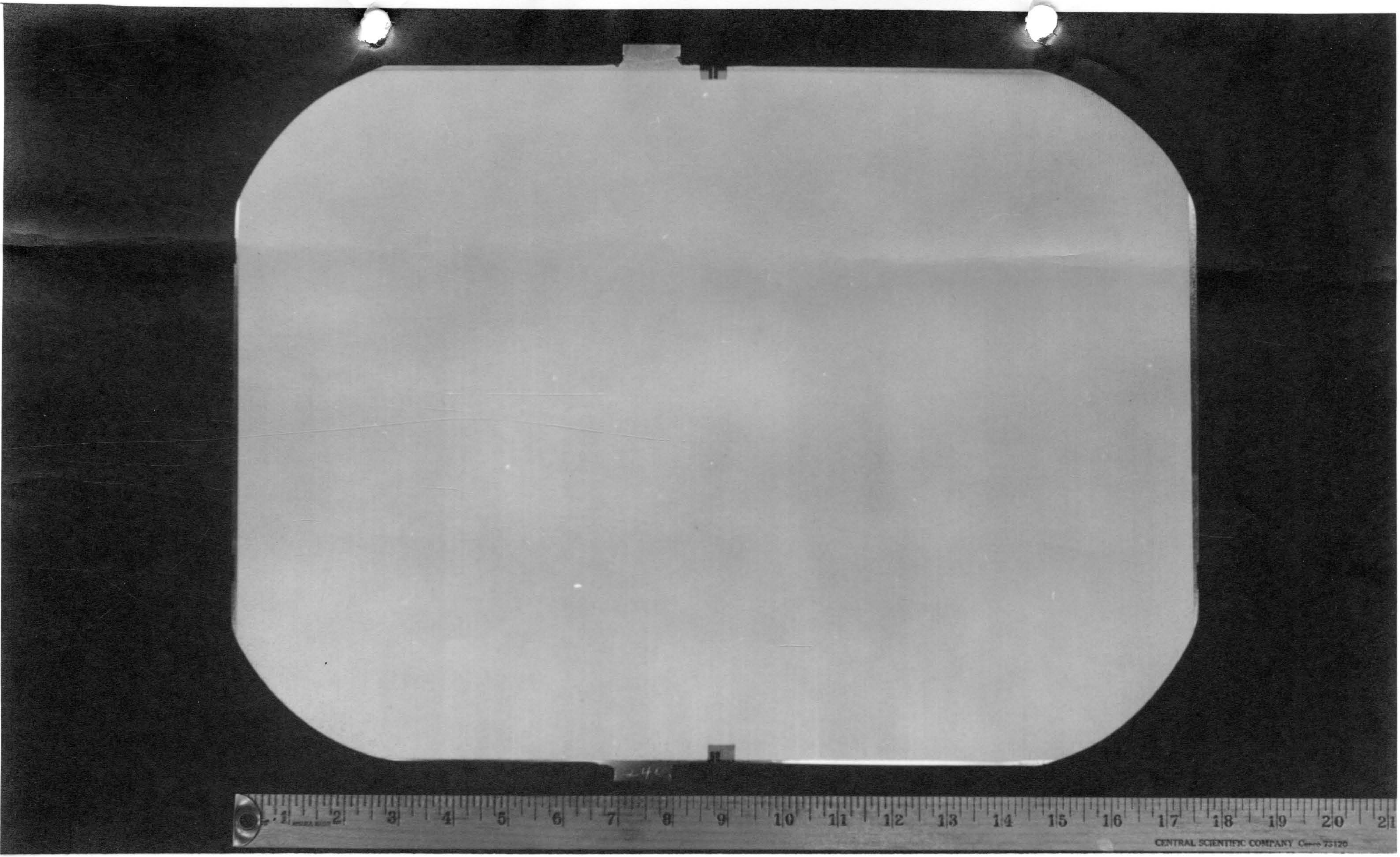
4-7139 ALUMINIZING JIG
FIGURE IV-32

FILAMENT JIG	MATERIAL - TRANSITE $\frac{1}{2}$"	TS - 6037



16 CLEARANCE HOLES FOR 5-40 FLAT-HEAD SCREWS
COUNTERSINK HEADS, COUNTERBORE CLEARANCE FOR 5-40 HEX NUTS

FIG. IV -330



Electronics DIV. 4-7141 Completed Phosphor Plate
Figure IV-34

CHAPTER V GRILLE FRAME DESIGN AND HISTORY

SECTION I GRILLE FRAME HISTORY

The first grilles used consisted of frames with small pins accurately spaced and wire strung on these pins. Later frames were wound on a lathe with the wires soldered and the excess layer of wire cut off. These grilles were not suitable for sealed-off tubes, but were used in the demountable vacuum station. It was found impossible to wind a uniformly spaced grille with the wire strung around pins. The springback in the wire is never zero for these strong wires, and it can not be compensated for because the tension and stiffness of the wire can not be held constant. Soft solder can not be used and the hard solders require the frames to be heated to the extent that they warp.

A successful method of fastening the wires consisted in cutting a slot along the edge of the top and bottom member of the frame, laying the frame under a loom of wires, pressing a rod down over the wires into the slot, and peening the rod in place. This unit was suitable for use in a sealed-off tube. However, the method did require a very precise cutting of the slot and it was discontinued when the sauereisening technique of wire cementing was developed.

The frames used for the first post-acceleration sealed-off tubes consisted of steel angle pieces for the top and bottom with compensated end pieces. The compensation of the end was required to reduce the effective coefficient of thermal expansion below that of tungsten wire. At that time, we felt that tungsten was the only wire strong enough to resist breaking, in the small sizes of .002 and .003 inches, during normal winding and handling procedures. Later, it was found that stainless steel wire #302 or #304 in the .003 inch diameter could be drawn in such a manner to give it a tensile strength of 300,000 p.s.i. Since the coefficient of thermal expansion of stainless steel is approximately one and one-half that of cold roll steel, it was no longer necessary to use compensated end bars, so they were replaced by cold roll steel.

No effort was made to produce maximum picture size in the first tubes. Ease of assembly and fabrication lead us to make a pure rectangular frame and phosphor plate. These frames had to be sent to Schenectady for proper annealing if they were made solid, since we did not have hydrogen furnaces large enough to braze and anneal the frames as one unit. The brazing, annealing, and material limitations, coupled with the pressure for rapid development, made it imperative that our designs for studying the various tube principles and characteristics permit the structures to be made here in Syracuse. These considerations led to frames made from pieces which would go into our furnaces and later be fastened together with screws.

Another factor effecting early frame design was the color purity problem which was worst on the corners where the tolerances were the smallest. This led to the decision to use four spacing supports between the phosphor plate and the grille frame. These spacers accurately determined the distance at each of the four corners with the inaccuracies due to non-flatness being forced into the screen center where the tolerances were larger.

With a rigid glass phosphor plate and a rigid frame connected at four points, alignment of the screen and grille was difficult because a translation on one side without a translation on the other forced one member of the assembly to rotate. This rotation feature also gave a great deal of trouble during bakeout and was a primary cause for misalignment after bakeout.

These considerations led to the flexible rectangular frame which would be indexed to the glass plate and spring loaded to maintain the index point against a fixed glass surface. These units were easy to aligh, since the top and bottom could move independently of each other without any rotation. They also held their alignment during bakeout since the springs pressed the assembly back into place after bakeout. These small rectangular units were used in the 15-inch round bulbs.

With the advent of the 21-inch rectangular bulb, the frame was redesigned to obtain a maximum picture size. This forced the purely rectangular frame to be replaced by one with rounded corners. The increased size, weight, flexibility, as well as the tighter tolerances caused by wider sweep angles, made it necessary to examine closely each design feature. The angle frame was replaced by one made from channel to maintain flatness when the frame carries the 200 lb. load imposed by the taut wires. The lavas on the corners were spaced to reduce picture interference to a minimum. A strap or stirrup was passed around the glass plate and attached by spring loading to the corner ceramic next to the end reference ceramic. This reduced the bending in the frame caused by the spring loading to a negligible amount. The flexible frame idea which had proved so successful was maintained, although the frame was no longer a pure rectangle. It was later found that the curved ends which force the end wires to be shorter than those in the middle greatly limits the usefulness of the flexible frame. A little consideration shows that a displacement of one side with respect to the other produces a larger angular shift on the shorter end wires than the angular shift produced on the center wires. This produces color impurity on the corners.

The increasing pressure to get the largest possible picture size from a given bulb not only forced the grid wire to be pushed to the very end of the bulb panel, but also caused the glass companies to develop a new bulb designed especially for color tubes. The large variation in wire lengths in the grille made a rigid frame very desirable. The change from a rectangular to an elliptical panel made it desirable to shift the lava supports from the corners to the middle of the ends and sides of the picture. This shift had the disadvantage that the corners are no longer accurately spaced between the grille and screen in these critical regions. The advantages, however, outweighed the disadvantages. Some of the advantages are:

(1) A rigid one-piece frame could now be made. This decreased the gas problem as well as decreasing the weight. (2) The lava fringe field was transferred to a less sensitive region. (3) The single point independent alignment of each side could be incorporated. (4) All forces tending to produce bending moments in the frame could be eliminated. (5) And most important, the insulated spacers could now be designed to withstand mechanical shock. Other desirable features, such as adjusting screws for determining the grille-screen spacing and the painting of the insulator surfaces with a semiconductor paint, could be retained.

The chief problem with the single-point support and alignment in the center of the top and bottom of the phosphor plate is the forming of a rigid reference point on the glass edge. This idea had seemed so attractive that it had been taken up with the glass companies a year earlier only to receive their condemnation that it would supply a source of shrinkage from cracked glass. Since no satisfactory method of sealing lugs to the glass without warping or cracking the glass was known, the idea lay dormant and the six-lava approach with the reference at the ends was pursued.

With the advent of the 22" "elliptical" bulb with ample room for center lavas, we again considered methods of fastening lugs to the edge of the phosphor plate to form rigid reference surfaces. Pieces of 446 and 430 chrome iron, as well as pieces of the glass from the phosphor plate stock, were sealed to the edge of the glass plates with various high-temperature cements. While many seals were successful there was some shrinkage from cracked plates so that production planning using this technique was considered unfeasible. It was then decided to cut the glass with the lugs as a part of the plate. Although this does not meet the approval of the glass specialists, it does work as of this date.

SECTION II DESIGN CONSIDERATIONS OF GRILLE-PHOSPHOR PLATE ASSEMBLY

Any assembly design requires that one examine carefully all the factors which go into the production of the unit. The final design must be a balance between these factors for some are contradictory. This discussion will cover twelve of the fundamental objectives of a good design. These objectives are:

1) To provide an assembly which permits single point independent alignment of the grille and phosphor plate at the top and bottom. (We assume vertical grille and phosphor lines.)

2) To provide an assembly which is shock resistant to mechanical shock.

3) To provide an assembly which allows for differential expansion during bakeout without losing alignment after bakeout.

4) To provide an assembly which compensates for small deviations from perfect components.

5) To provide an assembly which can be adjusted to take care of modification in design.

6) To provide an assembly which has no forces tending to put bending moment into the phosphor plate or grille frame.

7) To provide an assembly whose insulating supports between phosphor plate and grille frame are so positioned as to produce minimum interference with the picture area.

8) To provide an assembly which requires no accessory jigs or additional waiting time to make the alighment between grille and phosphor plate.

9) To provide an assembly all parts of which are so constructed that a rapid bakeout can be carried out.

10) To provide an assembly composed of such structures and materials that gas evolution will be a minimum during the life of the tube.

11) To provide an assembly whose structures and materials are economical to construct or obtain.

12) To provide an assembly which will permit 30,000 volts potential difference to exist between the phosphor plate and grille.

These objectives will now be discussed in detail.

1) For ease of alignment, it is quite important that each end of the center phosphor stripes can be moved completely independent of the opposite end. This requires microadjustments, accurate to .0005". This type of adjustment must be made against a spring loaded opposing force to avoid any backlash. It also requires that a screw be used to produce the displacements. Furthermore, it requires that the contact between the ball nose screw and the surface against which it presses be hard and smooth. The type of mount used in our assembly provides these features.

2) To provide a structure strong enough to withstand mechanical shock, such as the standard dropping test, requires special connecting elements. If these could be metal, it would be easy. However, the voltage isolation of 30,000 volts and the gas and refractory problems require that the elements connecting the grille frame and phosphor plate be made of an inorganic material such as ceramic. Since ceramics are weak under tension, the ceramics supports must have wide bases and large screw threads so that the ceramics may at no time have any portion under excessive tension.

One important point in decreasing danger from mechanical shock is to make the assembly light. Stiffness is the important requirement in both frame and glass plate. Since the stiffness varies as the cube of the thickness, it is important that the frame be made from a channel or angle stock. A frame composed of two angles placed adjacent to each other with the grille wire in between would give symmetrical loading and a frame of minimum weight. Since fringe fields and methods of wire fastening make this type of frame impractical, we chose the channel as the next best.

3) Some designers have tried to match the thermal expansion coefficients of the components and then rigidly clamp them together after alignment. We have rejected this thesis on the basis that one can not assure uniform temperature of the assembly during bakeout unless an excessively long bakeout is used. Our approach has been that adjustable stops should be set at the time of alignment and then made rigid. The glass phosphor plate will be held against the stops by spring loading so that differential expansion can take place with the plate always returning to the same position when cool. The same can be said for a displacement by a mechanical force from shock.

4) Although we try to have flat glass plates and plane grilles, we always have some small variation of a few thousandths of an inch from flatness. Since the most important requirement is the distance between the grille and phosphor plate and not the absolute flatness, we may use four points of support and produce distortions in the glass to counteract those already present in the glass or grille.

5) As long as design studies are going on which require variations in the grille-phosphor plate spacing, it is not advisable to use precision-ground spacers. It has been found more satisfactory to use screws which could be adjusted to give various spacings. After setting these screws are locked in place with a touch of ceramic cold-setting cement.

6) The wires produce a slight compression in the frame (about .035" at the center). This is compensated for by prestressing the frame. If the prestressing is correct, there will be no deformation of the frame when the load is shifted from the prestressing rods to the grille wires. However, when we speak of making a frame free from bending, we are referring to bends tending to destroy the flatness of the grille frame or phosphor plate. In the present design, there are no aligning forces other than pure compressional forces. Thus no bending moments are produced.

7) For strength and minimum weight on the glass bulb, it is imperative that the bulb have curved surfaces which are convex outward. This changes the contour at the picture plane from a rectangle to an outline approaching that of an ellipse. If we now use a rectangular raster, there will be a maximum spacing between the raster and the bulb wall at the center of the sides and ends of the raster. By placing our grille frame to phosphor plate spacers in these positions, we can avoid interference with the usable picture area.

8) If production quantities are to be high, it is important that the assembly use a minimum amount of jigs and fixtures for alignment. In the present design, precision aligning screws are incorporated into the supports by means of ordinary stock screws which are adjusted and locked.

9) For a rapid bakeout, the design should be such as to avoid strain on the glass and excessive tension in the wires. The wires need to have a tension of from 30,000 to 50,000 lbs. per square inch in order that no vibration of the wires show up during electrical voltage transients between the grille and phosphor plate. The wire used should be kink free, have a cold tensile strength of 200,000 or more lbs. per sq. inch to withstand mechanical shock during winding, a high hot tensile strength at bakeout temperature, and be of such material to meet fastening conditions. It is desirable that the tension in the wires be nearly released during the higher temperatures of bakeout. This removes any load from the grille frame which would tend to put a warp into it and destroy its flatness. If the wire used for the grille does not have hot strength, then it becomes absolutely necessary that the design be such as to remove the tension from the wire at the higher temperature. This is done by choosing a frame and wire whose differential thermal expansion permits the wire to become loose.

The formulas for determining the values to be used are given below. The strain e produced by a stress F is

$$e = \frac{F\ell}{y} \qquad (1)$$

where: e is elongation in inches
F is the force in lbs. per sq. in.
ℓ is the length of the wire in inches
y is Young's modulus in lbs. per sq. in.

For thermal expansion,

$$e = \alpha \ell \Delta T \qquad (2)$$

where: e is the elongation in inches
α is the thermal coefficient of linear expansion in inches per inch per degree C.
ℓ is the length in inches
ΔT is the change in temperature in degree Centigrade.

If we equate Equations (1) and (2) and rearrange, we have

$$\Delta T = \frac{F}{\alpha y}$$

There are two cases to consider: One is the rise of the exhaust cycle; and the other is the fall. On the rise, the grille wire temperature will be equal to or greater than that of the frame; on the decline, the temperature of the grille wires will be equal to or below that of the frame. In general, the rise time will not give trouble if the coefficient of thermal expansion of the wires is greater than that of the frame. For the slow rise case where thermal equilibrium prevails one can calculate the temperature at which the wires lose their tension. In this case, is the differential coefficient of expansion between the grille wire and the frame. For cold roll steel frames and 18-8 stainless steel wire under an initial tension of 50,000 lbs. per sq., in.,

$$\Delta T = \frac{50{,}000}{6 \times 10^{-6} \times 30 \times 10^{6}} = 278^{\circ}C.$$

If the starting temperature is 22° C., we would expect the wires to lose all of their tension at 300° C. Actually, this is not the whole story because the frame relaxes and expands in the center as the wires relax. We prestrain our frame by .035". If the frame is correctly prestrained, there will be no shape change when the wires are added and the stressing rods removed. Each prestrain should be set empirically for each frame design and wire tension.

Otherwise, frame distortions will take place which give a non-uniform pitch to the grille.

On the down phase of the exhaust cycle, the wires will lead the frame unless a cap is placed over the bulb panel. If the grille wires lead the frame, then one must use the full coefficient of expansion of the wires. If we take the end wires where the effect of the frame bending is much less, then we can say that above 300°C. the wires are loose. If the wire temperature is as much as 100° C. below the frame temperature when the frame temperature is at 300° C., then the wires will be under a tension of

$$F = \alpha Y \Delta T = 18 \times 10^{-6} \times 30 \times 10^{6} \times 100 = 54{,}000 \text{ lbs./in.}^2$$

The wire seems to be able to take this tension at this temperature, and it is doubtful if such a large temperature differential exists.

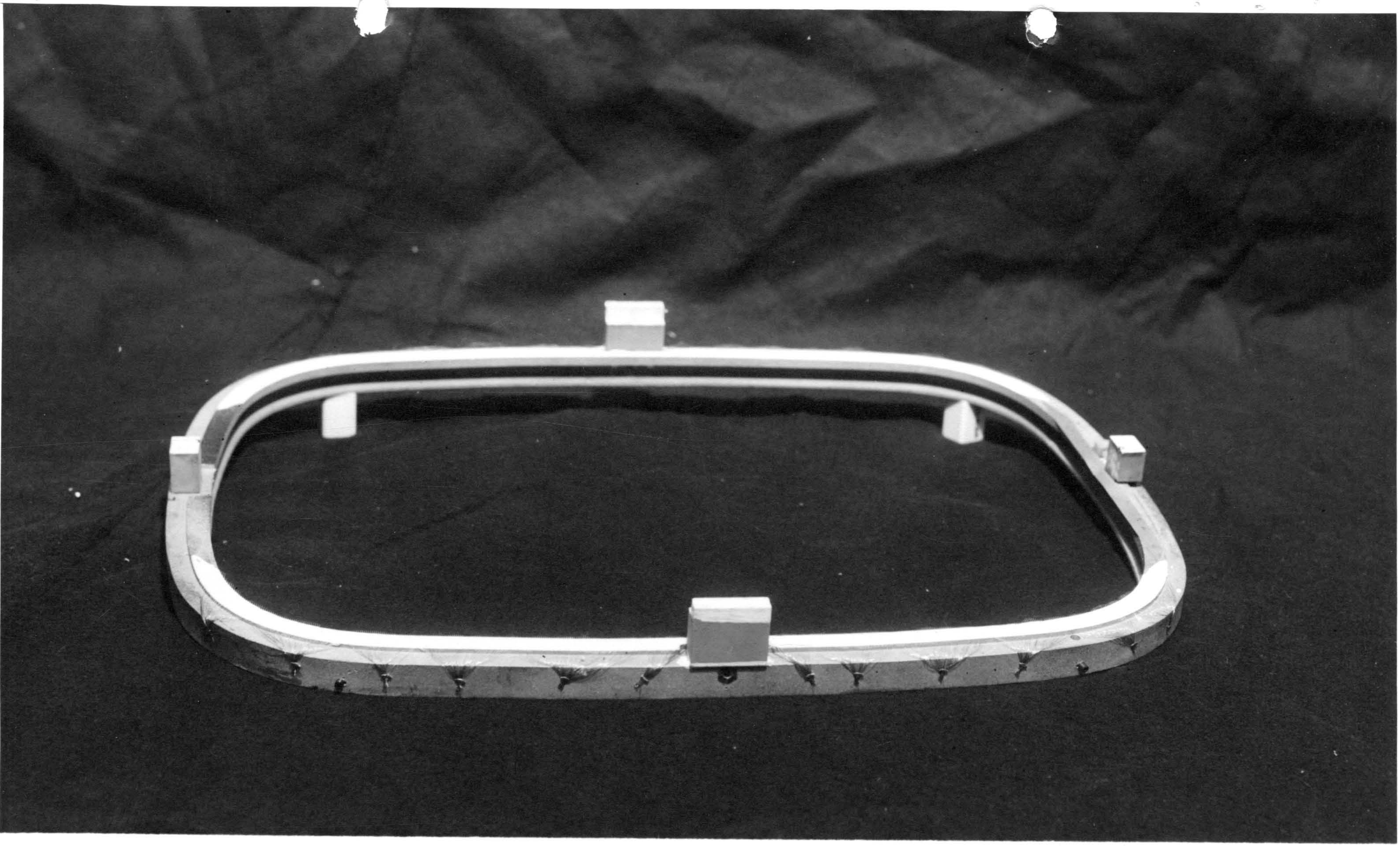
10) One of the serious problems that must be faced in color picture tubes is the evolution of gas from the assembly. Our one-piece welded frame with no dead end holes is a good structure. It should be thoroughly washed, fired, and then handled with care to avoid contamination or oxidation. The lavas should be either porous or vitreous; not a material that gives occluded gas pockets. The phosphor plate and all accessories should be thoroughly baked before exhaust.

11) The present assembly is composed of inexpensive parts. The biggest saving can be made in the processing and in the elimination of some parts such as fringe field correctors.

12) Great care must be taken in the elimination of sharp points from the grille frame if sparking is to be avoided. The screw lengths in the ceramic supports must not be too long or sparking below the lower end and the frame may occur. Scrupulous care must be exercised to remove all lint and aluminum film particles from the grille. Otherwise, there will be continuous discharges which produce white glowing dots on the screen. Lint is especially bad because it carbonizes during exhaust and becomes a good electrical conductor.

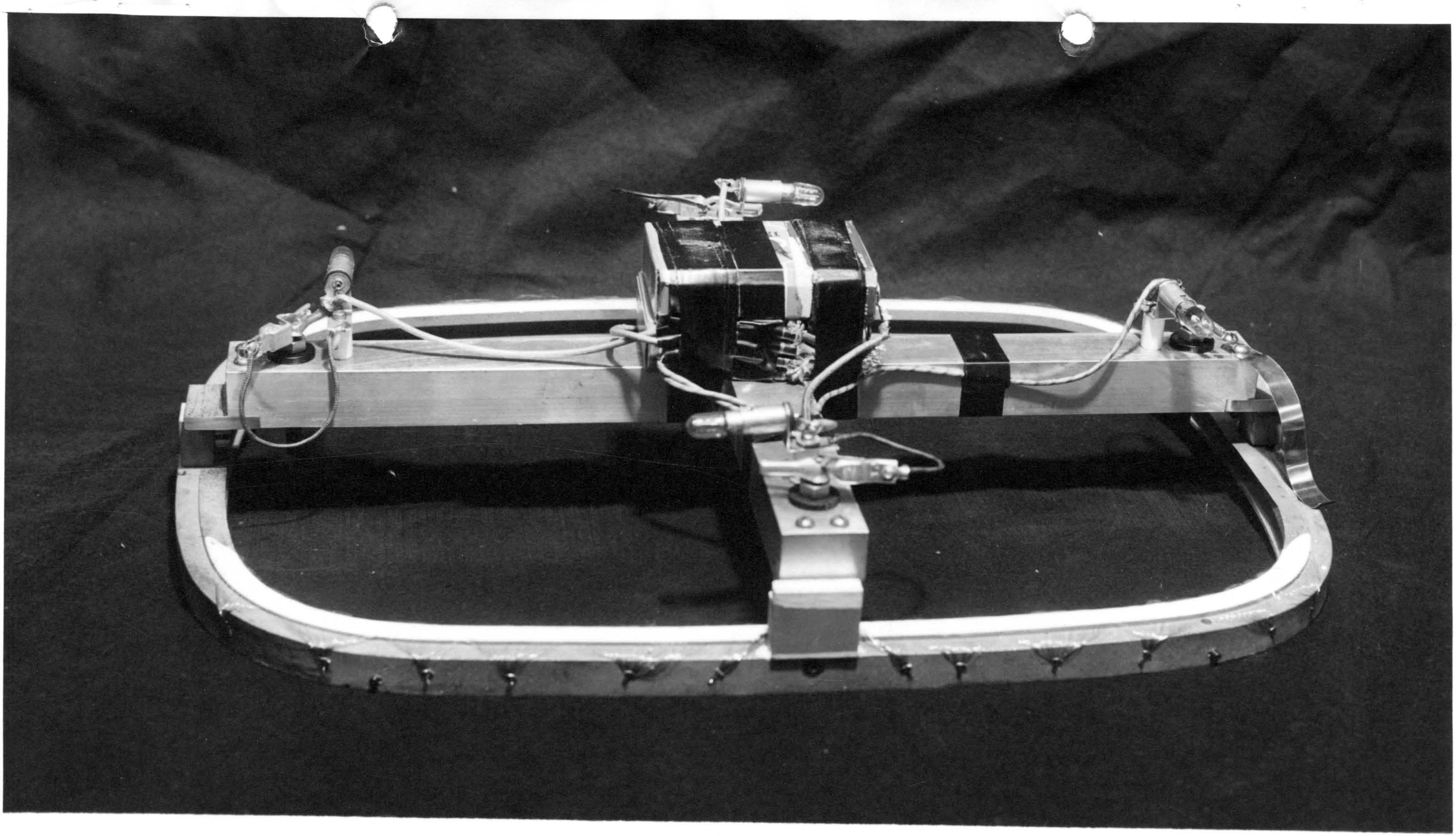
SECTION III FLOW CHART FOR GRILLE FRAME

1. Obtain cold roll steel bars 3/4" x 3/4" x 62"
2. Mill channel and offset on bar
3. Anneal channels
4. Bend channels around the demountable jig and weld
5. Remove jig from frame
6. Anneal frame
7. Sandblast frame to remove scale
8. Check frame for flatness, straighten and rough grind.
9. Jig bore, drill and tap holes
10. Mill flats for lavas
11. Add tension bars and compress frame
12. Finish grind frame to .001" flatness
13. Light sandblast rib for sauereisining.
14. Degrease in hot blacosolv vapor
15. Do not touch with hands and store in dessicator



Electronics DIV. 4-6770 GRILLE FRAME WITH CERAMICS AND WIRE ATTACHED

FIGURE V-1



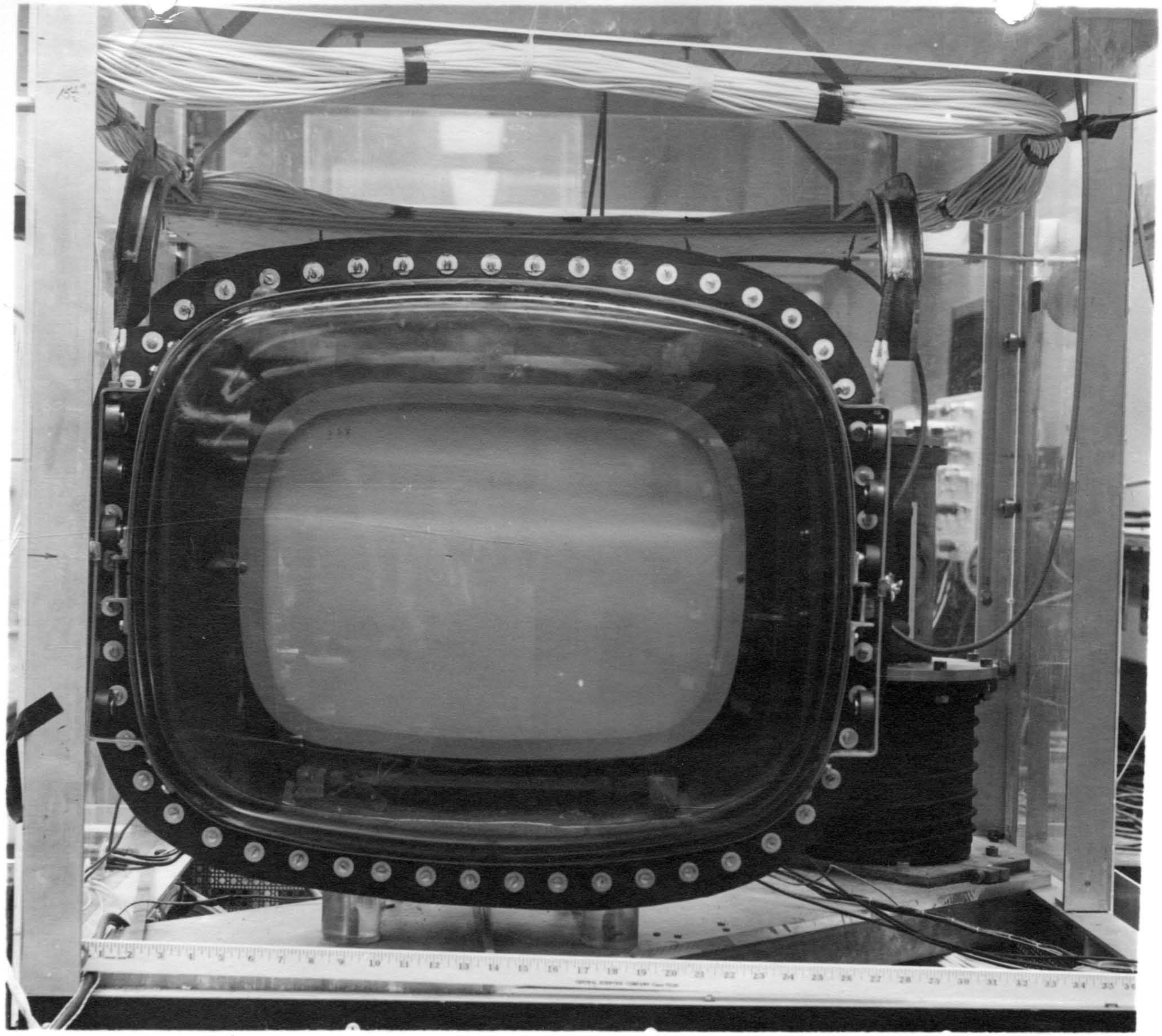
GE Electronics DIV. 4-6772 GRILLE FRAME WITH BIRD IN PLACE

FIGURE V-2

GE Electronics DIV. 4-6771 SANDWICH ASSEMBLY

FIGURE V-3

GE Electronics DIV. 4-6775 EXPLODED VIEW OF TUBE
FIGURE V-4



GE Electronics DIV.

4-6768 DEMOUNTABLE EXHAUST STATION
FIGURE V-5

GENERAL ELECTRIC

K-69982-16A41

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TITLE SCREEN LEAD SHIELD

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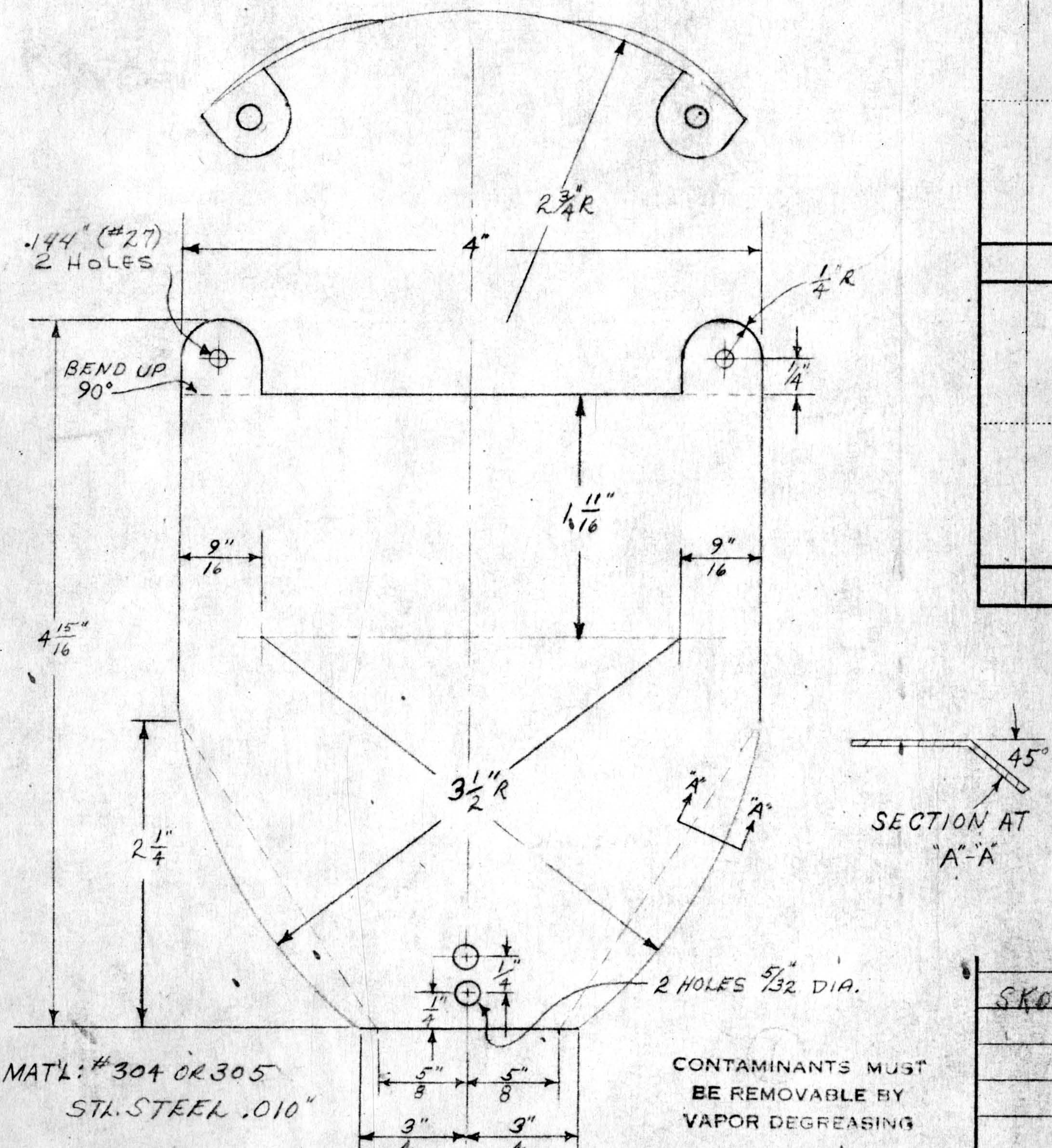

MAT'L: #304 OR 305
STL. STEEL .010"

CONTAMINANTS MUST BE REMOVABLE BY VAPOR DEGREASING

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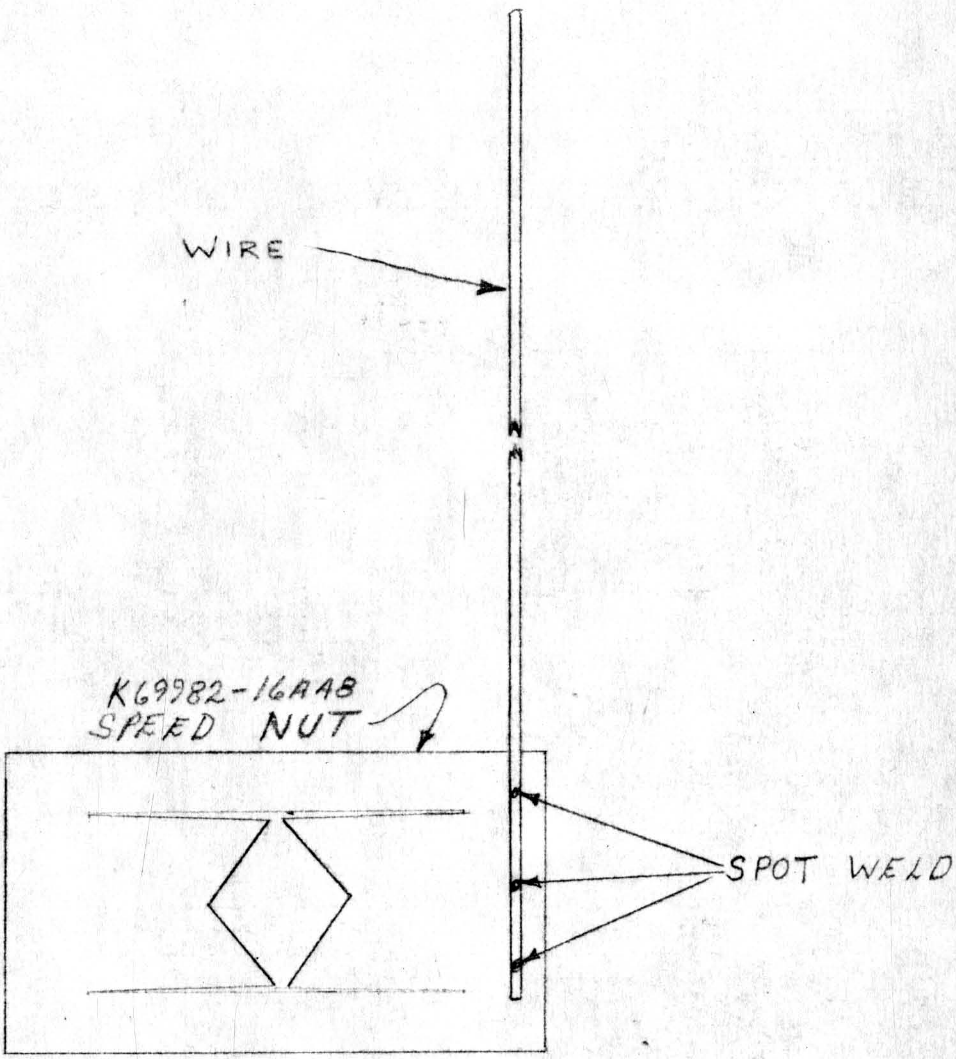

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TITLE POSITIONING SCREW (XY,Z)

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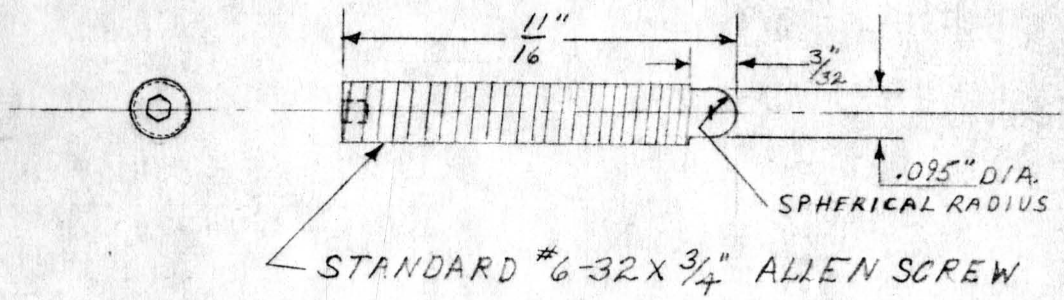

SKD

CONTAMINANTS MUST BE REMOVABLE BY VAPOR DEGREASING

VARIATIONS ON FRACTIONAL DIMENSIONS UNLESS OTHERWISE MARKED
1/4" OR LESS ±.008" OVER 1/4" ±.015

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GENERAL ELECTRIC

K-69982-16A56

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TITLE LAVA BLOCK (RIGHT & LEFT)

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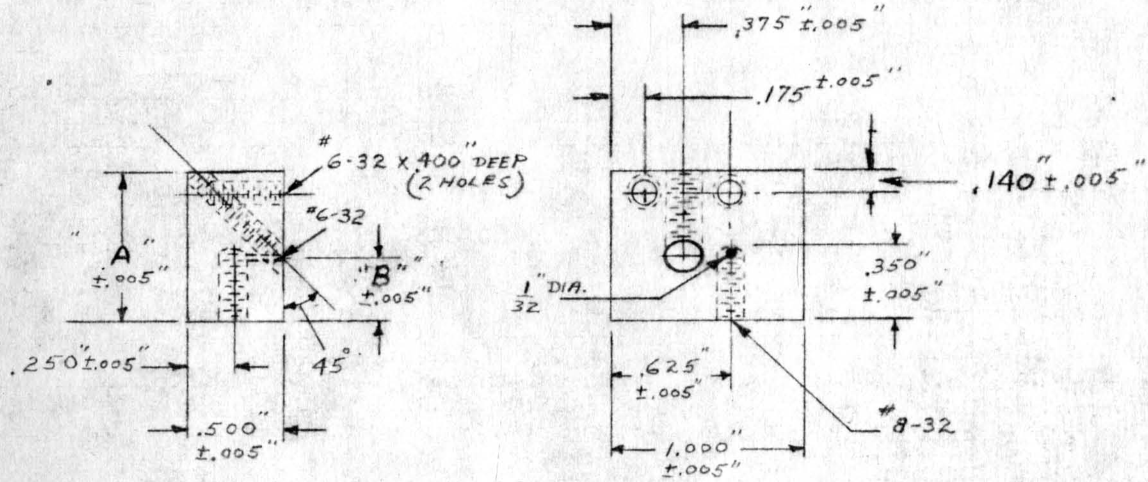

MAT'L- AFRICAN LAVA

PT	A	B
1	.790"	.325"
2	.710"	.245"

VARIATIONS ON FRACTIONAL DIMENSIONS UNLESS OTHERWISE MARKED
¼" OR LESS ±.008" OVER ¼" ±.015

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K-69982-16A57

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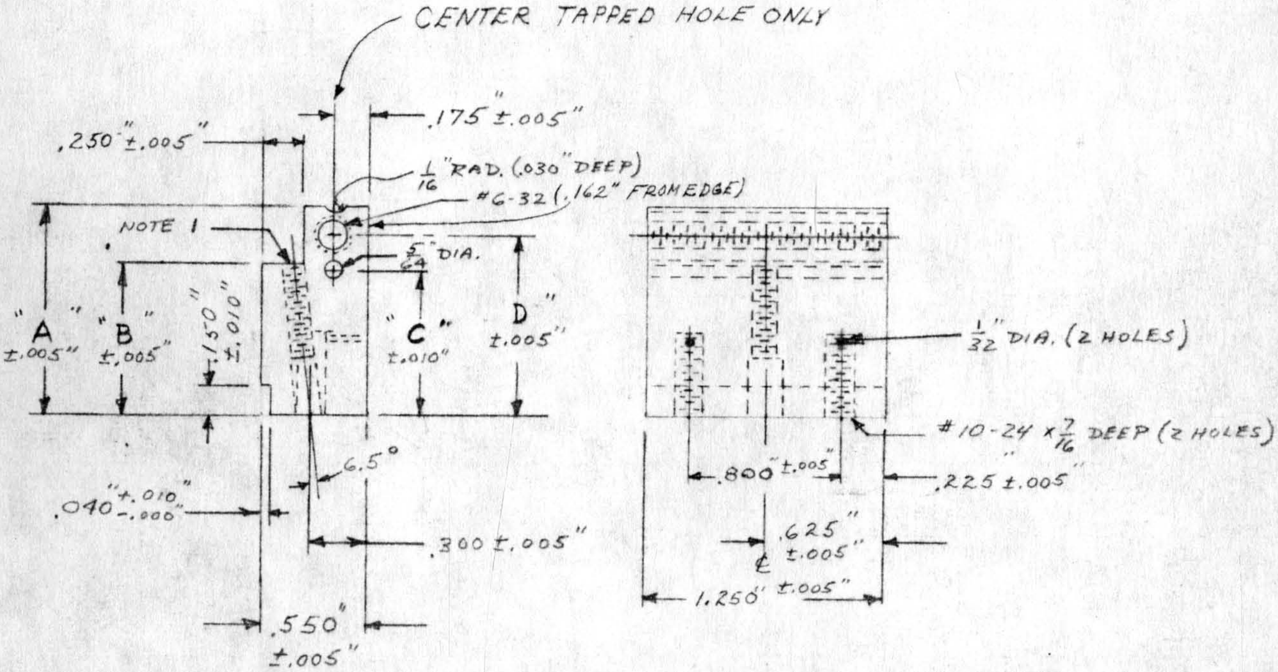
LAVA BLOCK (TOP & BOTTOM)

CONT ON SHEET | SH NO. | FIRST MADE FOR PAGE 21

REVISIONS

PT	A	B	C	D
1	1.096"	.790"	.765"	.940"
2	1.016"	.710"	.685"	.860"



NOTE-1. TAP FOR #6-32. DISTANCE OF 1/2". REMAINDER OF HOLE TO HAVE CLEARANCE FOR #6-32.

MAT'L.- AFRICAN LAVA

VARIATIONS ON FRACTIONAL DIMENSIONS UNLESS OTHERWISE MARKED
1/4" OR LESS ±.008" OVER 1/4" ±.015

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	ALIGNMENT SPRING
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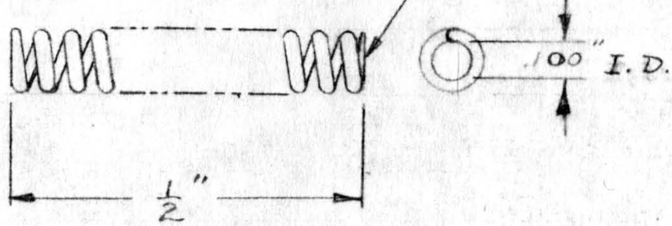
1 R. Cole SKC-23 12-1-54



24 TURNS / INCH

MAT'L:- INCONEL-X FULL ANNEALED
.025" DIA.

NOTE- AIR FIRE 1350°F FOR 16 HOURS AFTER FORMING.
AIR COOL.

VARIATIONS ON FRACTIONAL DIMENSIONS
UNLESS OTHERWISE MARKED
¼" OR LESS ±.008" OVER ¼" ±.015

SKO

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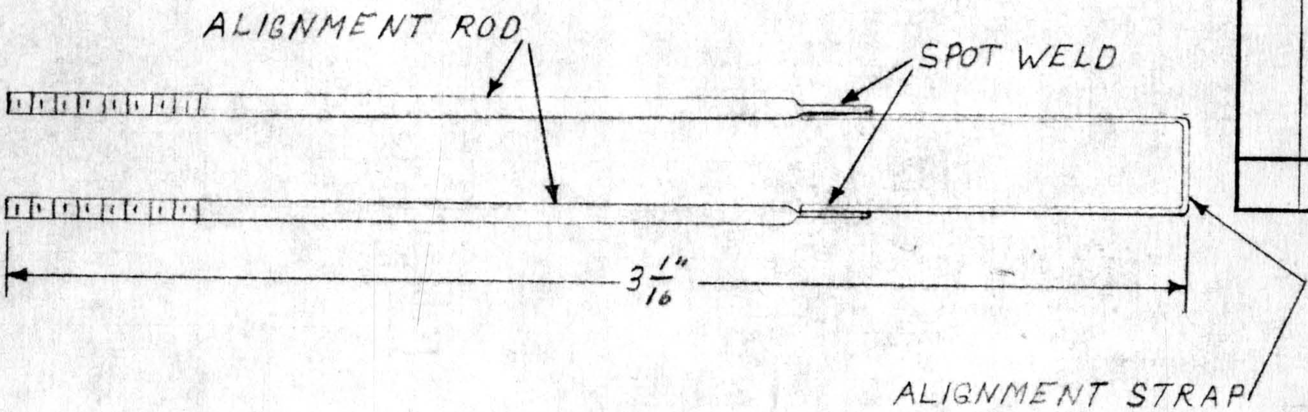

5K03

VARIATIONS ON FRACTIONAL DIMENSIONS UNLESS OTHERWISE MARKED
¼" OR LESS ±.008" OVER ¼" ±.015

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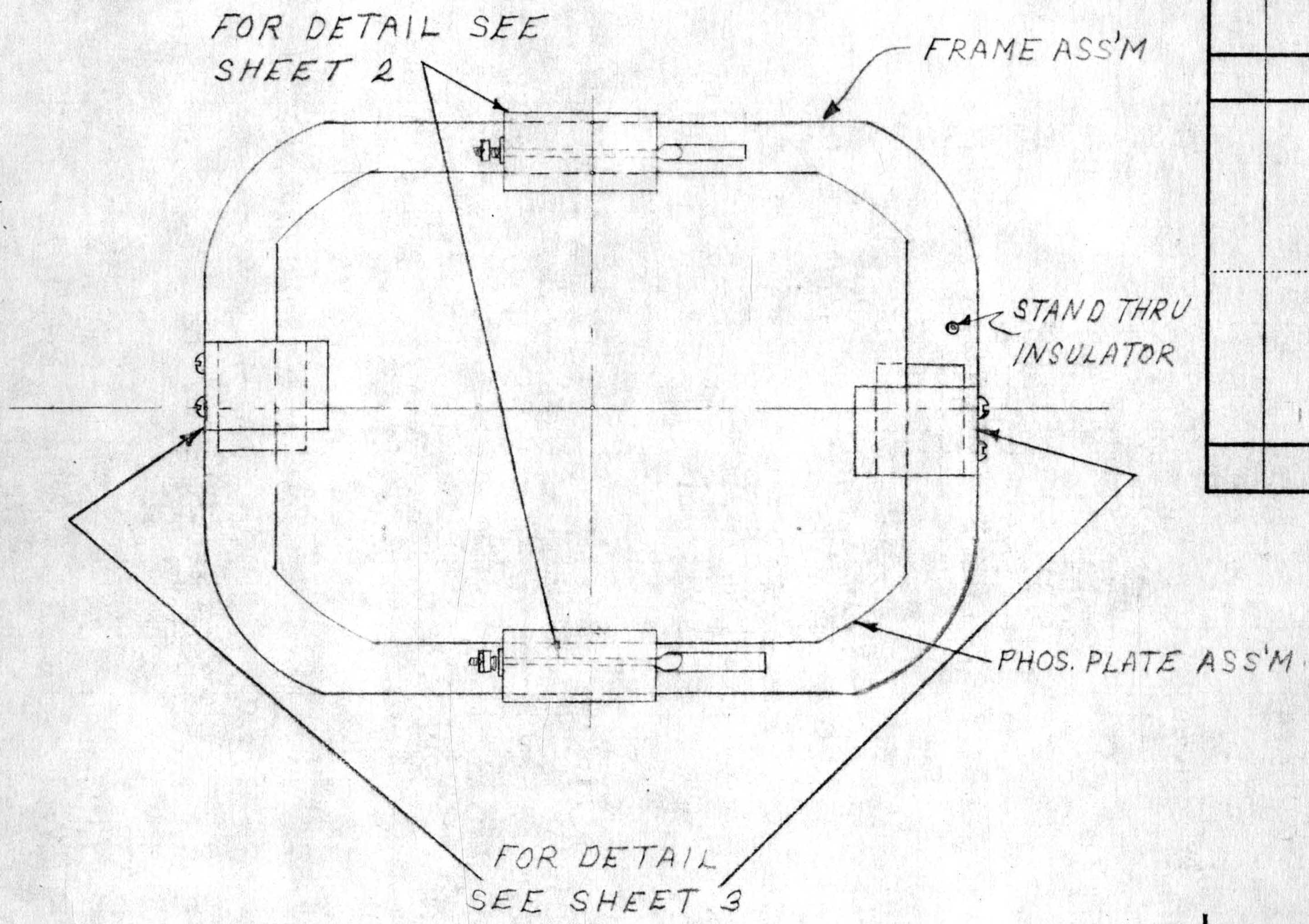

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TITLE SCREEN ASM.

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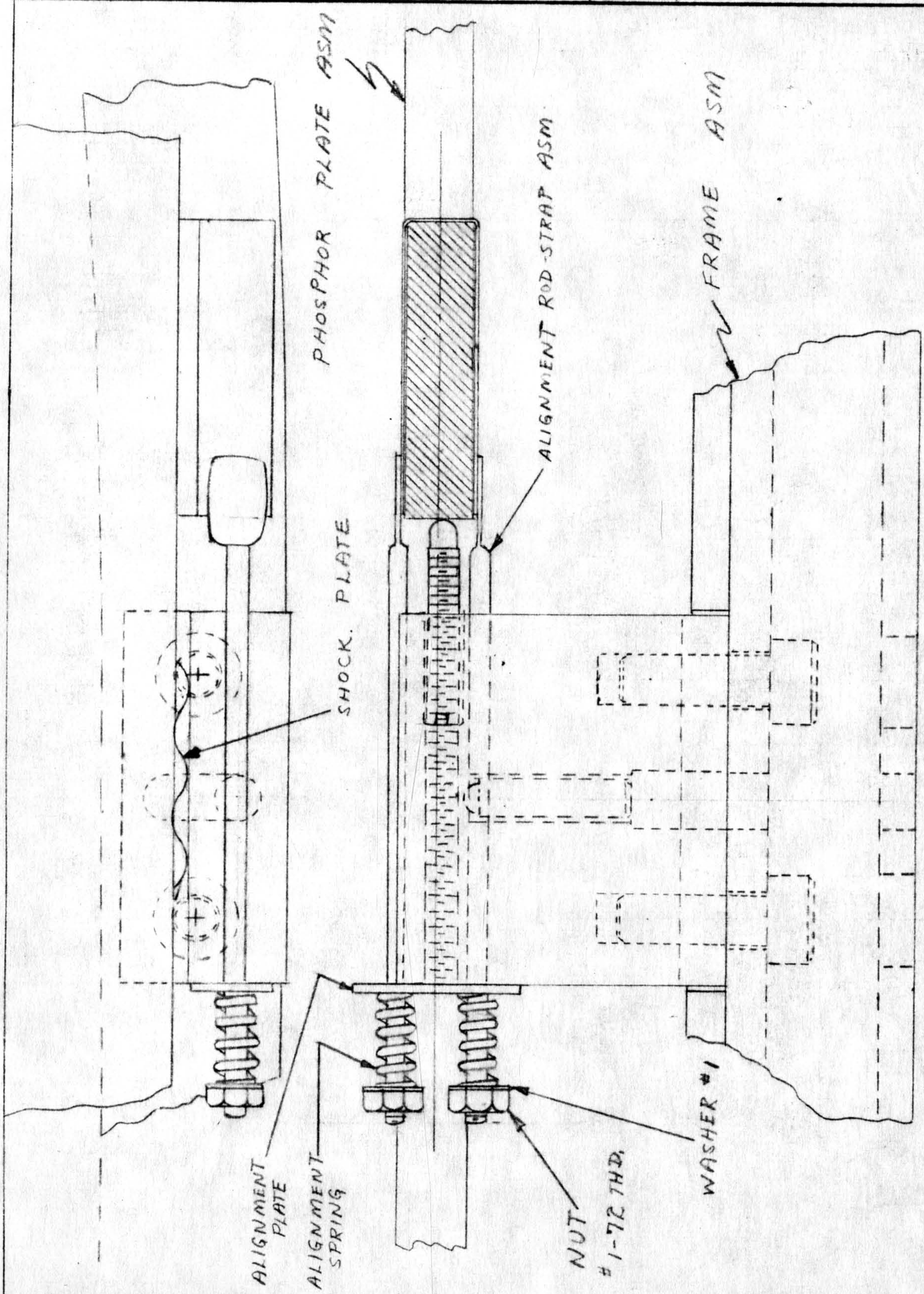

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TITLE SCREEN ASM.

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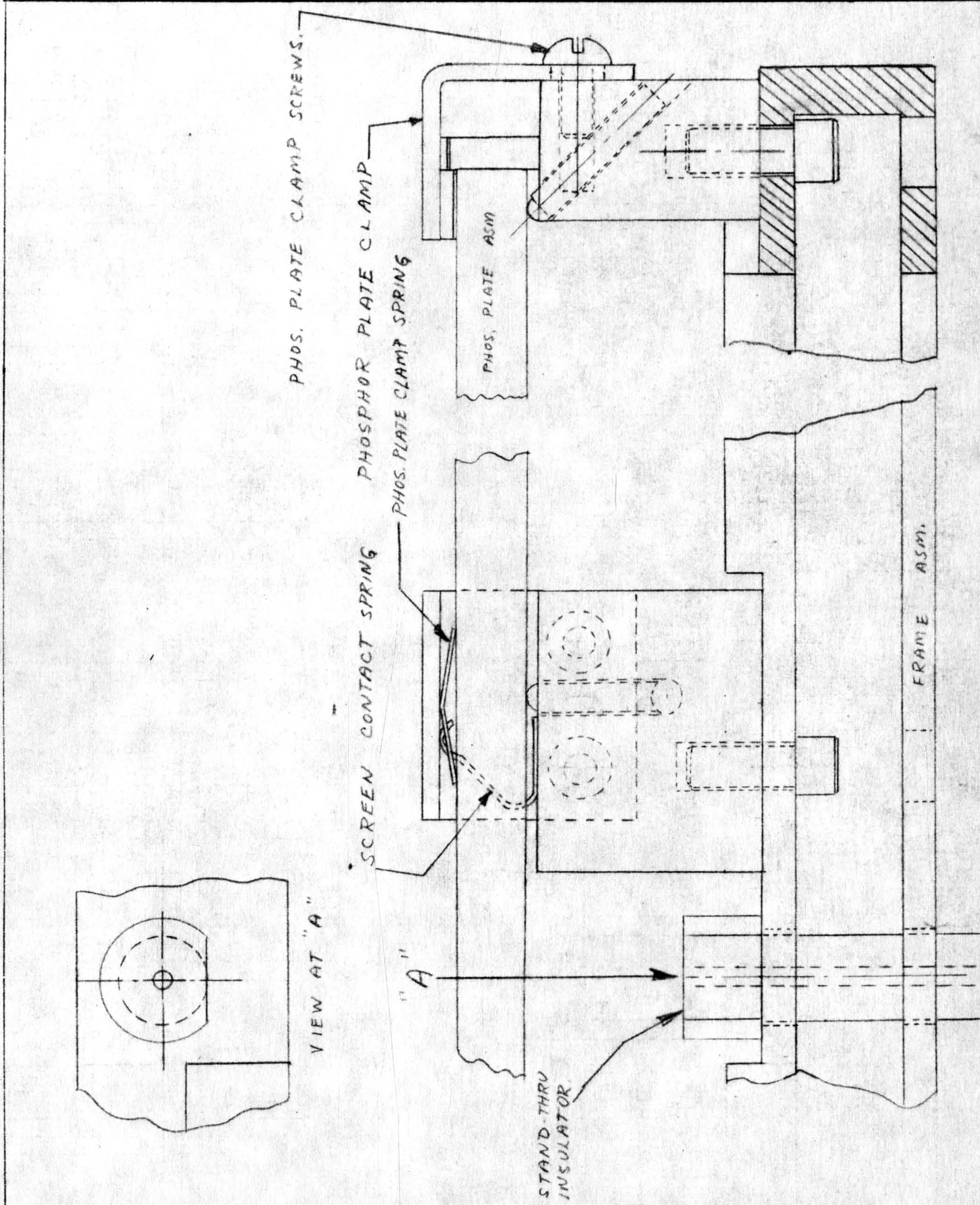

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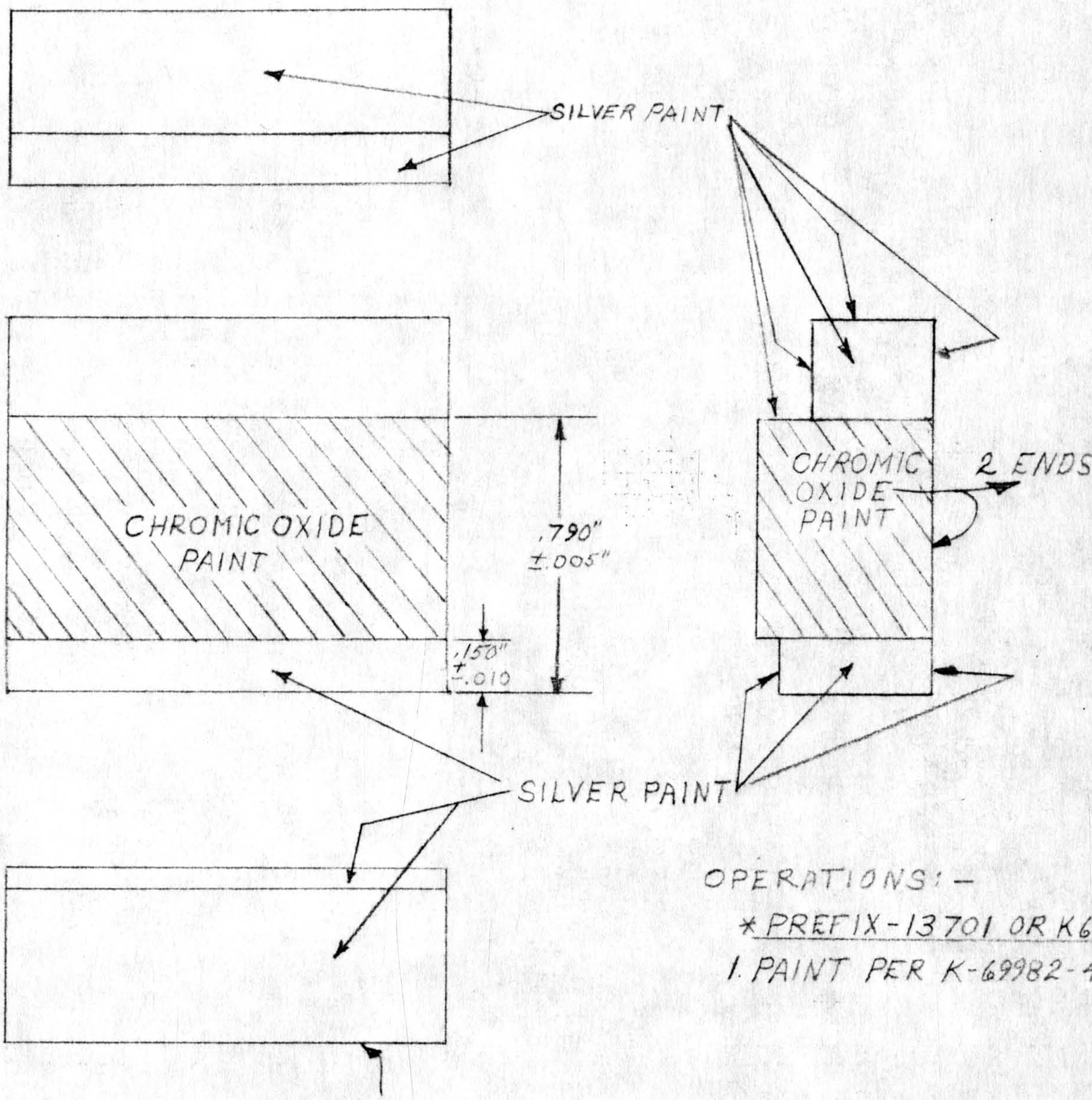
1 AGC SK-255 11-10-54



OPERATIONS: -

* PREFIX-13701 OR K69982-42A

1. PAINT PER K-69982-42A 43

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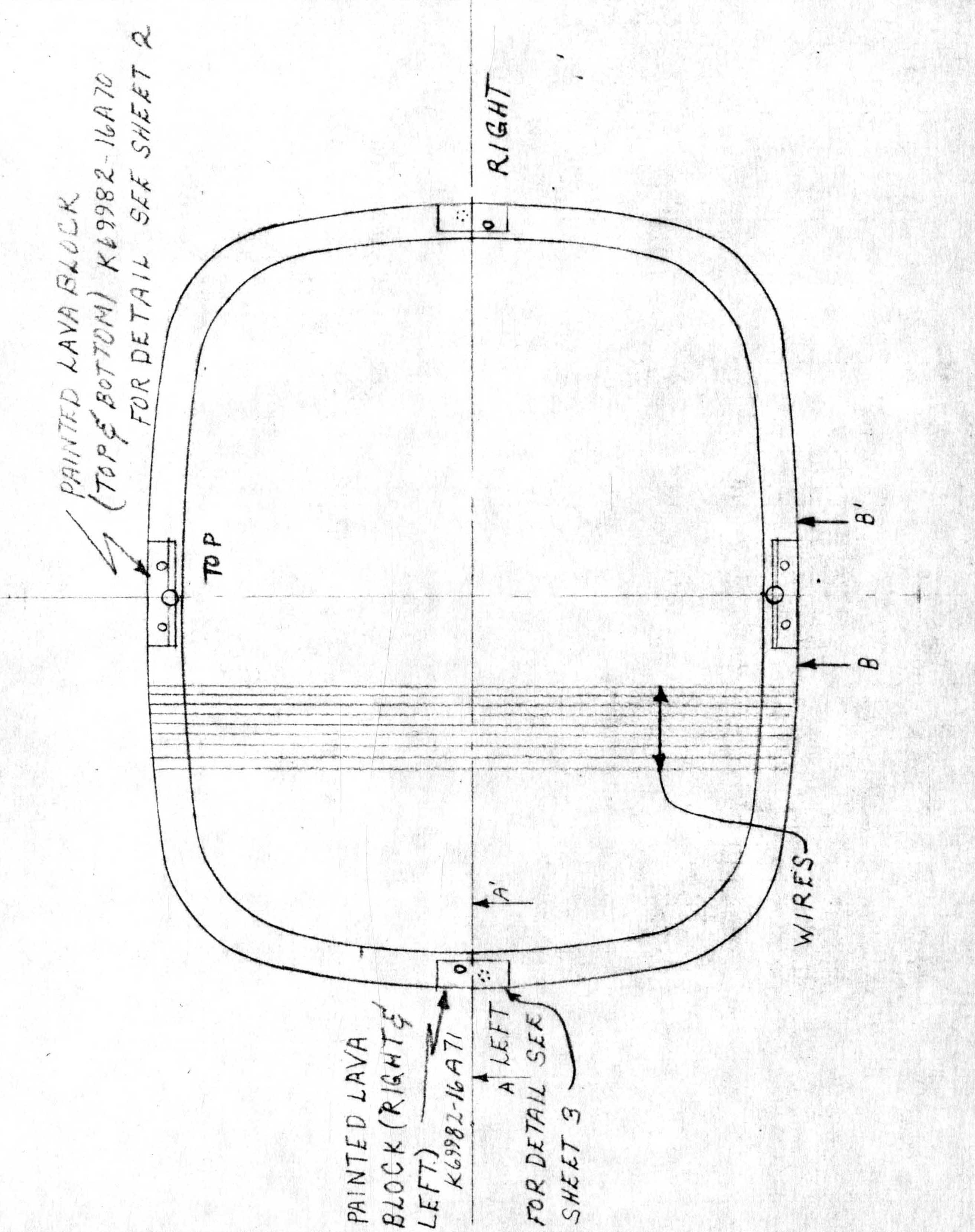

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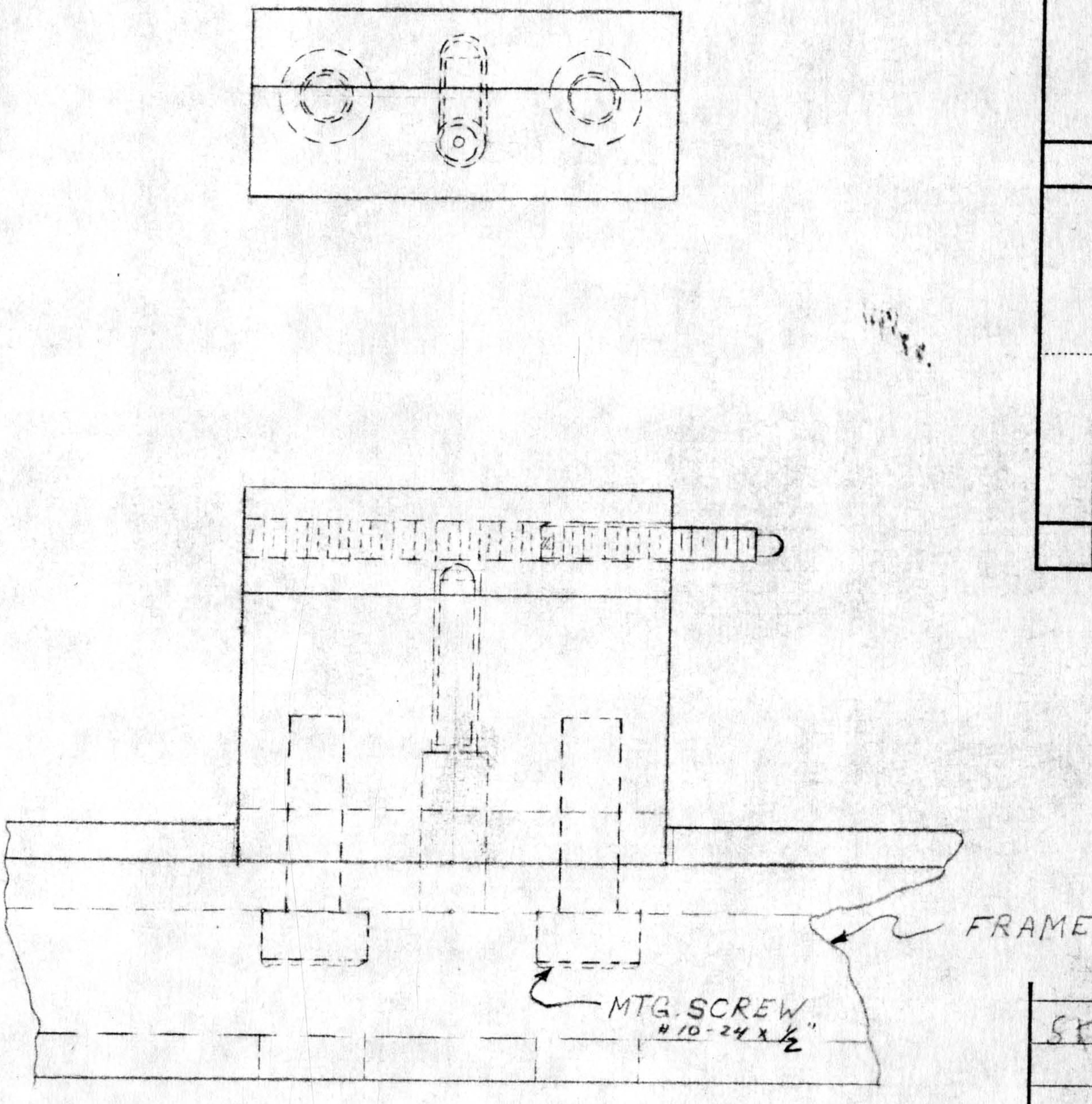

VIEW AT B - B'

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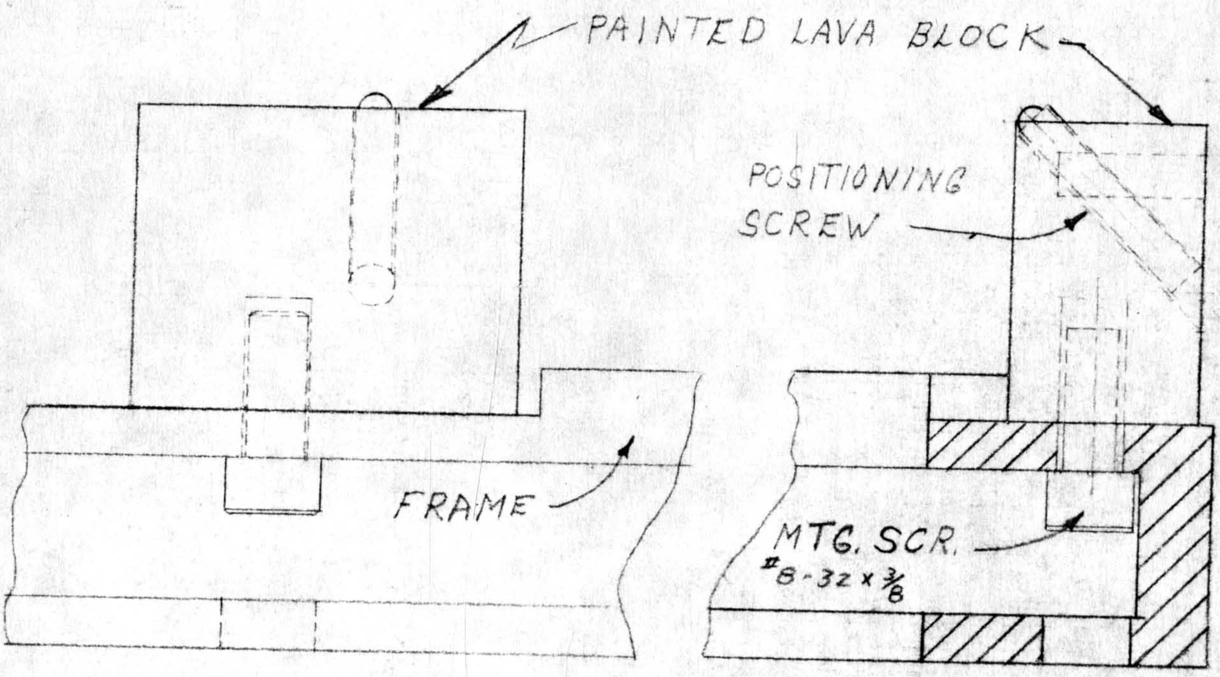

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	PHOSPHOR PLATE ASSEMBLY		
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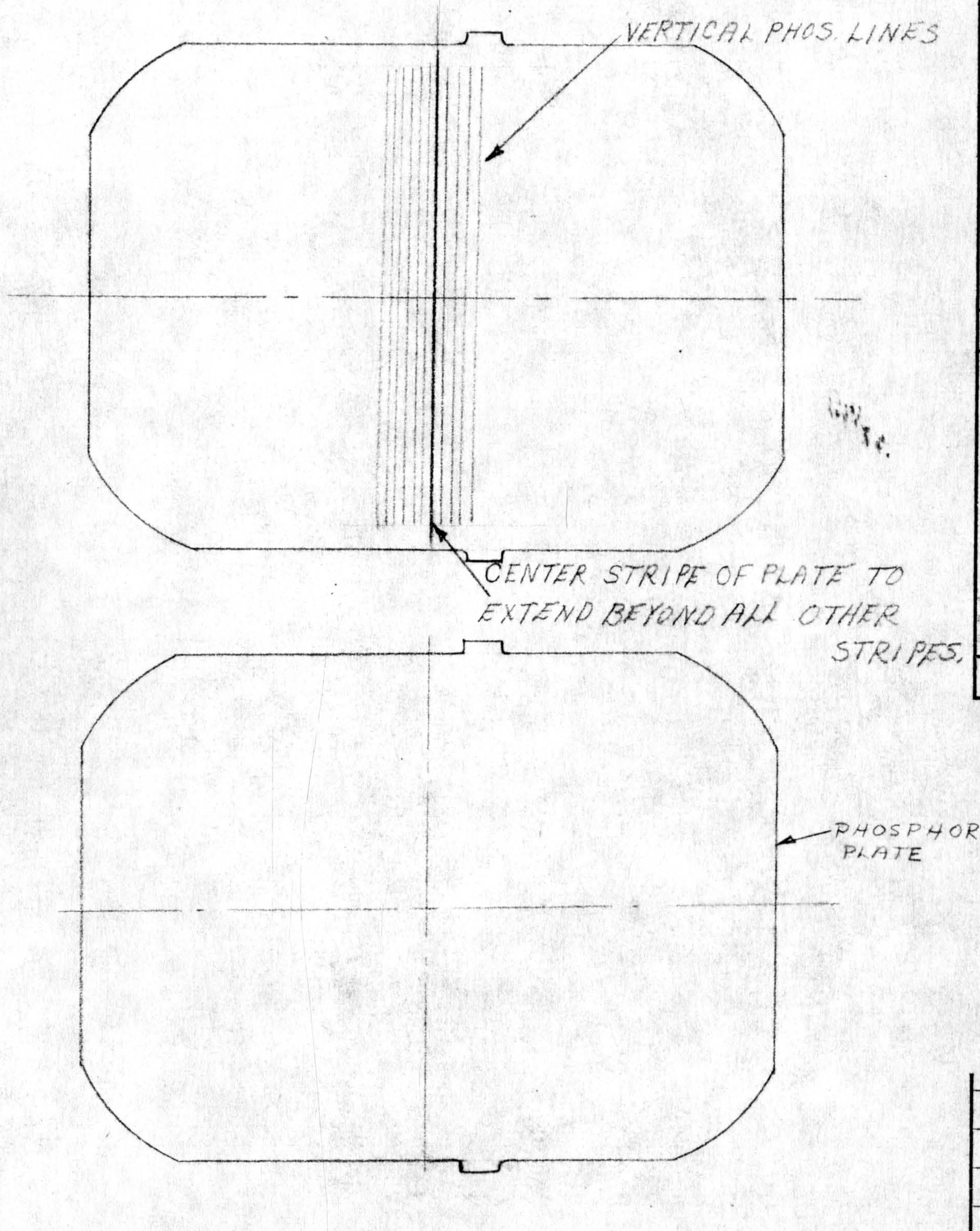

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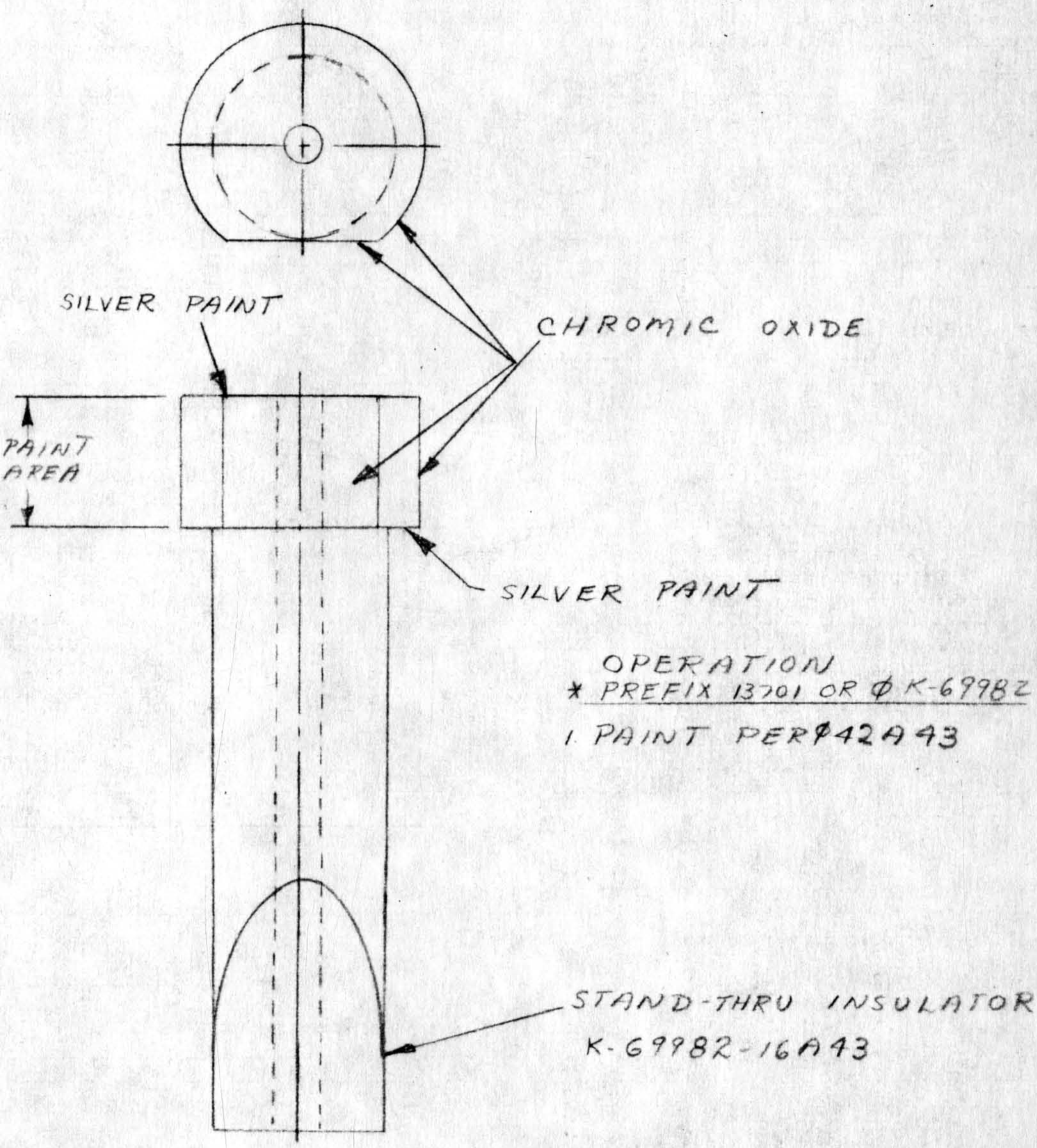

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CHAPTER VI WIRE GRILLE ATTACHMENT AND DAMPER INSERTION

1. Inspection of the Frame

This inspection checks flatness of the frame by placing it on a ground surface and measuring the height of the frame ledge all around.

To meet the accuracy requirements explained in other chapters, it is necessary to start off with a completely released and plane frame in order to make sure that no inaccuracies go into the tube with the frame. Although the accuracy of the wires themselves is taken care of by the combs as shown below, it is still necessary to have the frame flat within ± 0.0015".

2. Degreasing and Cleaning

The frame should be dipped into a degreasing solution, or, for example, degreased in a solvent vapor degreaser.

It is evident that only a completely degreased frame may go into a tube if poisoning of the cathodes is to be prevented. Some trichlorethylene or the commercial solvent called Permaclor may be used in a commercial vapor degreaser set-up. All other impurities not removed by the degreaser, for example, impurities from sandblasting which have been driven into holes, have to be cleaned off in a separate cleaning step using brushes and clean liquids.

3. Demagnetizing

Being careful to avoid touching with bare hands, the frame should be demagnetized in an a-c field strong enough to take out all internal magnetic forces.

The color purity of our tube can easily be influenced by weak magnetic fields as explained in the chapters dealing with magnetic shielding and magnetic corrections. Therefore, the frame, which is cold rolled steel, has to be demagnetized carefully to avoid magnetic fields inside the tube which could distort the colors.

4. Setting on Jig on Loom

After being cooled down from heat induced by the degreasing and demagnetizing processes, the frame is set into a jig. Three dowel pins on the jig fit into holes in the frame. Adjustable combs bring the wires of the loom into proper location with respect to the frame.

The wires for the mask grid are supplied from a loom. For the purpose of a laboratory set-up, the method of using a loom seemed to be the most reasonable and cheapest. This almost classical way proved to be also the best. Loom requirements are: about 550 clean wires of 0.003" diameter, the wire material being stainless steel (302 or 304, hard)* strung under a tension of 150 g per wire with a spacing distance of 32 wires per inch. Good accessibility to the wires is required.

---

* Wilbur, B. Driver Co., Newark, N. J.

The set-up is sketched in Fig. VI-1. This figure shows a table (1) to which a scale (2) is fastened to read the total tension of the wires. Rod (3) serves as an anchor bar to which the wires are cemented. The wires are held in position by precision grooves cut in bar (5). Each pair of wires passes over pulleys (6) and are held in tension by 300 g weights. By this set-up, friction is reduced to a minimum and the tension of all wires is equalized in a high degree. Wrench (11) at the one end of the loom permits the whole loom to be let down or pulled up. Picture VI-2 shows the part of the loom carrying the weights.

For mass production, the loom can have the wires fed from individual spools. Well-known techniques exist for holding constant tension on wires fed from spools. An easier method than controlling hundreds of single spools is to use a large single spool of about 2' diameter provided with numerous sections and having these sections layer-wound simultaneously in order to pull the whole amount of wire at one time from one spool. A set of weights equalizes possible differences of tension, as well as of length of wire. Single spools, as described here, can be used for wire fastening to frames as well as for tube designs which do not incorporate a frame.

For the present sandwich type tube, the grille can also be wound without any loom on tools similar to a lathe or grid winding machines as used in receiver tube production.

The procedure of attaching the wires to the frame uses a jig which holds the frame in proper location with respect to the wires for the cementing process. After having cooled down from the preceding processes, the frame is set into the jig which is sketched in Fig. VI-3. A relatively heavy flat ground base (1) is provided with two fixed (2) and one movable dowel pin (3), which fit in holes on the lower side of the frame (4). Two pairs of combs having a pitch of 32/inch, an inner one (5) and an outer one (6), are attached adjustably to the base plate. The inner pair of combs is a high precision comb cut on a precision lathe. Combs (5) supply all the accuracies of the whole set-up, and the final grid. The teeth of the combs (5) and (6) are V-shaped, as shown in the figure, having an angle of about 60°. They control the spacing of the wires as well as the planarity of the wire set. The procedure of adjustment consists of locating the wires (7) by adjusting the height of the combs (5) in order to just clear the ledge of the frame to which they are to be cemented. The distance between the frame and the wires is preferably about 0.001" all around the frame. By means of a light incident at an angle of about 45° when looking at the shadows and wires from the other side, this distance can be estimated easily with bare eyes. Frame flatness variations can be overridden so that the said distance of 0.001" will vary with the tolerances of the frame.

The outer pair of combs do not need high accuracy. These combs serve only to set the wires run into the precision comb under pressure in order that the wires will be pressed into the V-shaped grooves thus securing a correct spacing. A view of the frame set in the jig is shown in picture VI-4.

5. Cementing and Curing

Almost all of the grid masks produced in our laboratory were cemented with Sauereisen #1 and thinner #14 mixed to a viscosity which allows brushing.

Parallel to this, developments were carried on which ended in very good results using cements containing either basically about the same ingredients as the Sauereisen and thinner, but with additional ingredients like carbon or silver powder added to get electrical conductivity. Conductive cements on the phosphate basis set faster than the silicate cements. These cements shorten the time for the wire attachment from 440 minutes to 145 minutes, and reduce shrinkage.

The cement is brushed on the ledge of the frame so that it covers the wires completely. The thickness of the layer is more or less controlled by the viscosity of the cement because excess quantities run down the sides of the frame. A hair bristle brush is used. A weak heat source like a heat lamp at a distance of about 3 feet may help to speed up the drying time somewhat but an excess of heat favors the setting up of a skin which slows down the curing process rather than accelerating it. Heating up the frame itself, on the other hand, means a thermal expansion and a loss of accuracy in the spacing. So, in case of sodium silicate cements, it seems best to be patient and wait until the cement hardens. A hardness sufficient to hold the 550 wires at 1/3 pound per wire is reached - to be on the safe side - in about 2-3 hours. Additions of very finely ground glass powder to the Sauereisen cement to speed up curing time failed.

Shortening the setting time and obtaining sufficient electrical conductivity of the fastening cement was the main goal of parallel cement developments. Cements basically different from the sodium silicate types (i.e., Sauereisen) such as metal-oxy-phosphates like the dental cements show a very short setting time of some minutes. Their strength does not quite reach that of the silicates, but is still more than sufficient. They stand bake-out processes of 430° C as well as the silicates and show even an increase of strength after being heated up.

Additions of carbon or silver take care of the electrical conductivity of the cement. These ingredients may be added to the silicate cements as well as to the faster setting ones. A resistance of 4 megohms or less across one side of the frame is acceptable. Some cements containing a relatively high amount of silver powder show a resistance of a couple of ohms without any loss of strength. A conductive cement helps two ways: first, a later step of collecting all wires to define the potential becomes unnecessary and, second, possible effects of charging up of the cement surface becomes impossible.

Of course, there are many other possibilities of fastening the wires to the frame, some of them are more suitable for production than this laboratory set-up.

Things tried in this field were different welding procedures for attaching the wire to the frame, for example, the use of rollers across the wires. The wires also were covered with metal strips and then the welding procedure carried out. Other tests dealt with metalizing procedures using small diameter molybdenum wires or low carbon iron wires. But all these tests ended in the knowledge that the best way to obtain the accuracies required require cold fastening methods. There are also tests going on to plate the wires onto the frame as done at RCA, but the way it is done now still seems to be the best.

Things in this field which were just suggested but not tested, due to lack of time or tooling, are peening the wires in pre-cut grooves as the grille wires are held in receiver tubes or to use a stencil and press grooves into a ledge of the frame and then hold them on a suitable spot by different means.

6. Cutting Off from Loom

After blocking the loom on the side where the weights are located, either by means of another frame or some gadget to hold the wires, the tension on the other side of the loom can be released - for example, by turning back the pulling device, shown in Fig. VI-1. The wires are then cut off and the grille is removed from the loom. The holding device is then again attached to the pulling wench and unlocked so that the pulling wench again takes over the load.

7. First Bake-Out

The grille is now subject to a curing or bake-out procedure which consists in heating it to 120° C in air at a heating and cooling rate of about 2° C per minute.

This process is important practically only when silicate cements are used because of their long setting and curing time. When other cements are to be used, this bake-out process probably should be omitted completely.

8. First Inspection

A helpful set-up for an immediate accuracy check of the grille is to investigate the interference pattern between the wires of the grille and a standard lined master. A photographic plate which is a copy of a ruled master is placed over a distributed light source. The grille is laid upside down in such a way that the wires of the grille and the lines of the master are not exactly parallel. The crossing points of the wires and the photographic lines produce interference lines which magnify all errors of the grille. Errors in the spacing of these lines can be checked by observing the pattern perpendicularly to the grille. Errors in planarity of the wire set may be obtained by observing the pattern under an angle of about 45°. A simple calculation even gives the numerical amount of the shown errors.

All other kinds of measurements, i.e., on comparators or similar instruments can be omitted.

9. Pigtailing and Grinding

After removal from the loom, the grilles still have excess wire ends sticking out on both sides. How to take care of them depends on whether the cement is conductive or not.

A. Nonconductive Cement. Owing to the small clearance between the frame and the wires at the time of cementing, there is no electrical contact between the wires and the frame in case of a non-conductive cement. So the wire ends have to be connected in a separate procedure to the frame. This is done by collecting them in bunches and pulling these bunches through small conical eyelets, squeezing these eyelets and welding them to the frame. Excess wire ends still sticking out from the eyelets are cut off.

B. Conductive Cements. In this case, the procedure is much simpler because by means of a grinder the ends of the wire can be ground off all around the cemented area.

10. Removing Retensioning Rod

To be done at this stage of production.

11. Damper Fiber Insertion

Put the grid on a comb which lifts only every other wire. Into the gap formed by this comb, a rod can be inserted which keeps the wires separated. A second rod pushed in can be used to attach to a glass fiber and pull the fiber in while removing the rod. Then the first rod can be pulled out, leaving the glass fiber woven into the grille.

This procedure is a very delicate one because the glass fiber should have a diameter of about 0.001". The fibers are pulled from Nonex glass rods. Their purpose is to dampen any vibrations of the grille wires which might easily be initiated by shock or the sweep frequency and cause color impurity. Vibrations can also be suppressed by high tension of the grille wires and provide frequencies which are off multiples of 60. But to do this is difficult because higher tensions of the wires mean heavier frame design, more delicate bake-out processes so it is much more reasonable in order to reduce shrinkage to allow lower tensions and also uneven ones and to dampen vibrations by means of fibers.

A method of measuring the resonance frequencies is to put the grille on an insulated metallic surface and to apply an a-c voltage to this system. Small particles of insulation like puffed mica are distributed over the grille and an a-c voltage of 1 KV or so is varied in frequency. Wire vibrations are indicated by the jumping of the particles and the frequency can be read on a calibrated dial. These measurements give information about uniformity and absolute value of tensions throughout the grille.

The damping fiber must meet three requirements:

1) It must reduce wire vibrations to an invisible amount;

2) It must not distort the electrical field around the fiber; and

3) It must not give off gas under electrical bombardment or decompose during bake-out.

The first and third requirements led to a small inorganic fiber interwoven between the wires. The second requirement requires that the fiber be an insulator with a sticking potential near the value of the grille potential. Nonex glass fibers meet these requirements reasonably well for grilles operated near 5 kilovolts. If the tube is operated at higher potentials, it probably will be necessary to treat the fiber surface to raise the sticking potential. Metallic surfaces evaporated onto the fibers and then oxidized is one approach.

12. Softening the Damping Fiber

This procedure consists in putting the grille on a pair of combs which are warmed slightly. A straight 0.020" nichrome resistance wire is then located at a distance of 0.020" away from and parallel to the glass fiber. For 3-4 minutes, the wire is heated with about 20-22 amperes a-c, then the grille is removed slowly, the current reduced and finally switched off.

The damping fiber, as woven into the wire grille, gives very good damping but mislocates the grille wires at the same time by pulling them out of plane. Therefore, the fiber must be locally heated in order that it match the grille structure instead of making the grille match the fiber.

The device used is sketched in Fig. VI-5.

(1) of this figure shows the grille frame carrying the grille wires (2). (3) is the interwoven glass fiber. The grille rests on two combs (4) which maintain accurate spacing and location of the wires. Parallel and close to the fiber (3), we arranged a resistance wire (5) which is kept straight by a weight (6) and a pulley (7). Either the resistance wires, which are heated electrically by a power supply (8) or the combs (4) carrying the grille are provided with means for adjusting the proper (small) distance between the heater wire and the glass fiber to be softened. In the figure, the heater wire system can be adjusted as indicated by arrows.

Picture VI-6 shows parts of this set-up.

It is important to remove the grille slowly from the heating set-up at least to a distance of about 1/2", before reducing the current, because the cooling resistance wire rises on cooling and may touch the grille and spoil it. There is also a reason for reducing the current instead of interrupting it right away because it is possible to magnetize wire set and frame.

13. <u>Second Bake-Out</u>

The grilles are now put through a bake-out process going up to 420° C. in a protective atmosphere, for example forming gas. They are put in a stainless steel container having an inlet for a preheated protection gas.

14. <u>Second Demagnetizing</u>

This has to be done more carefully than the first demagnetizing procedure, where only the frame minus wires and fiber dampers was demagnetized. The reason for this procedure is to take out magnetic forces which might have been brought in by welding operations, location near magnets, magnetic tools, and the current in the damper softening wire.

15. <u>Final Inspection</u>

As in the first inspection, the grille is put on the photographic master and the interference lines are observed. The softening procedure can be checked by observing the deviations from the plane by a 45 or more degree observation of the pattern.

By means of small tools, it is now possible to straighten out small errors during observation of the pattern.

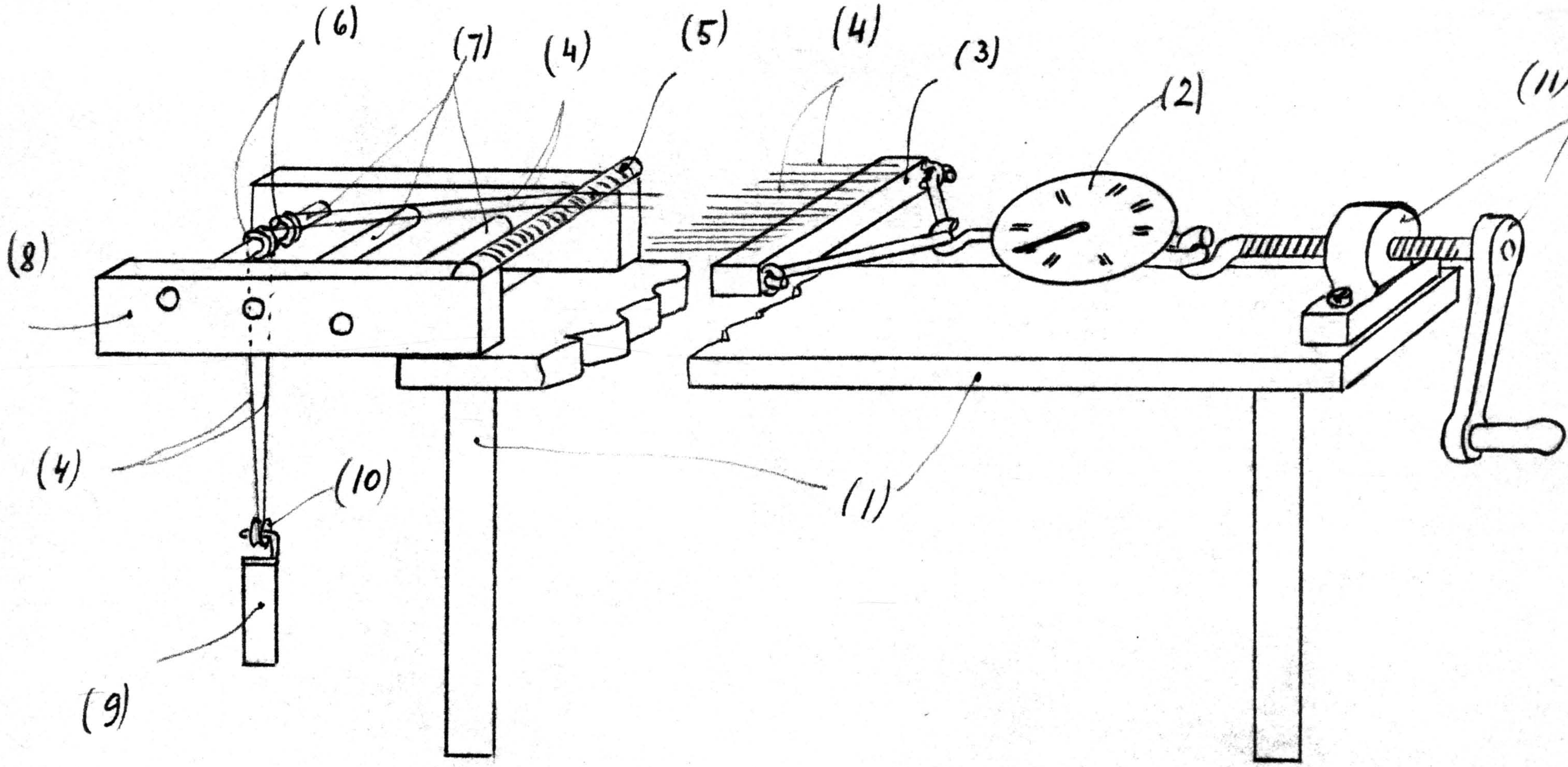
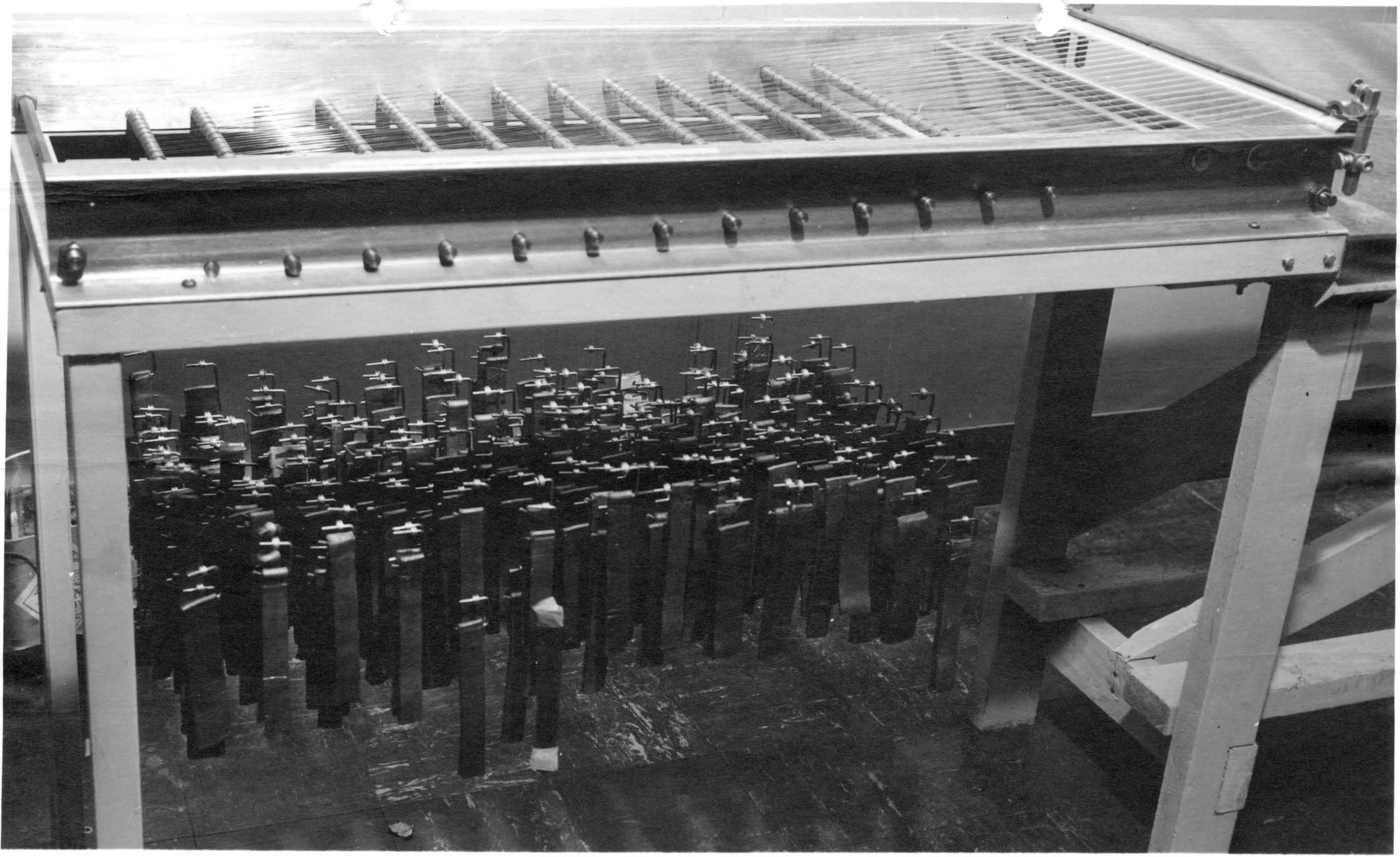


FIG VI-1 LOOM



Electronics DIV

4-6783 TENSION WEIGHTS ON LOOM
FIGURE VI-2

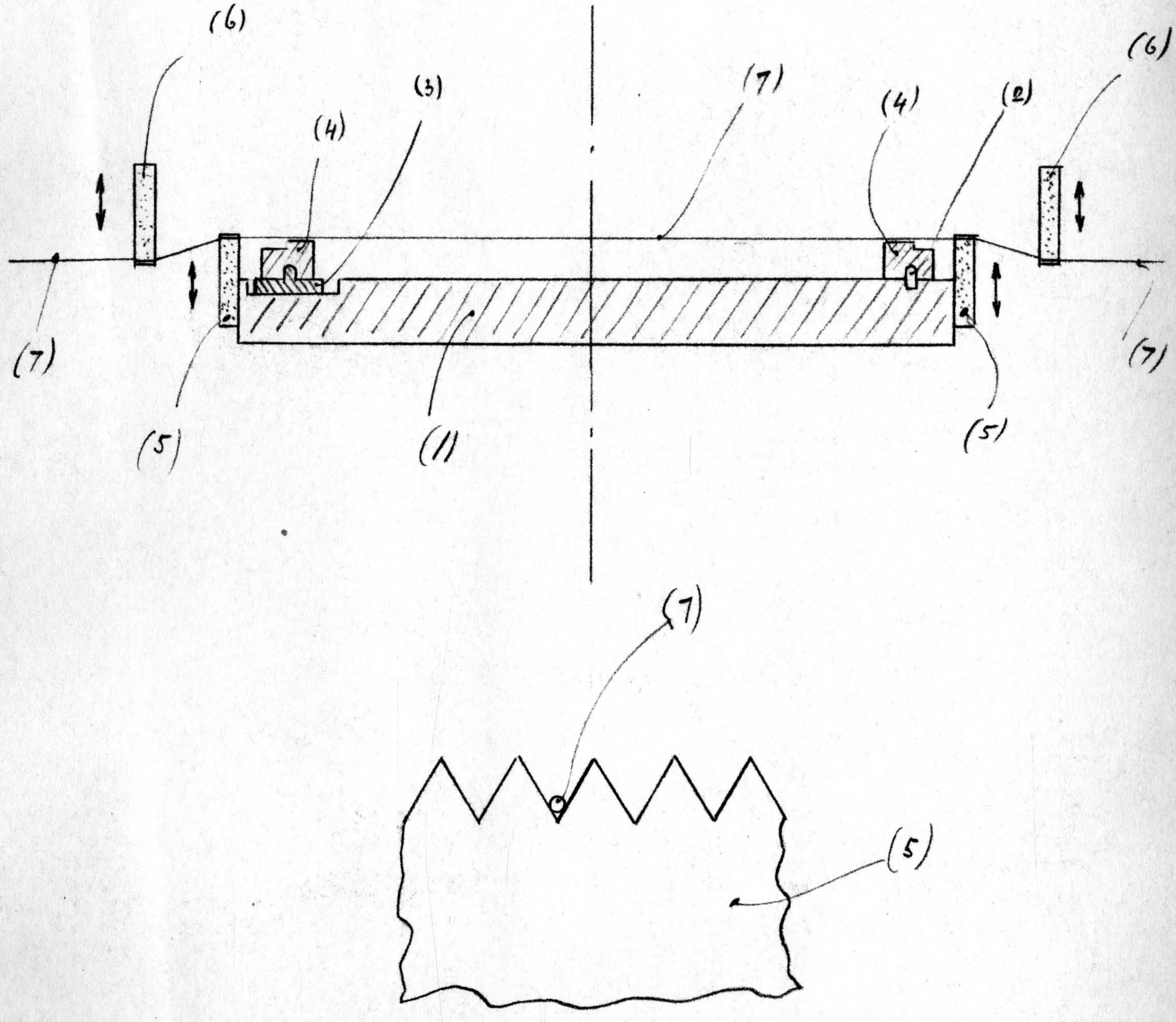
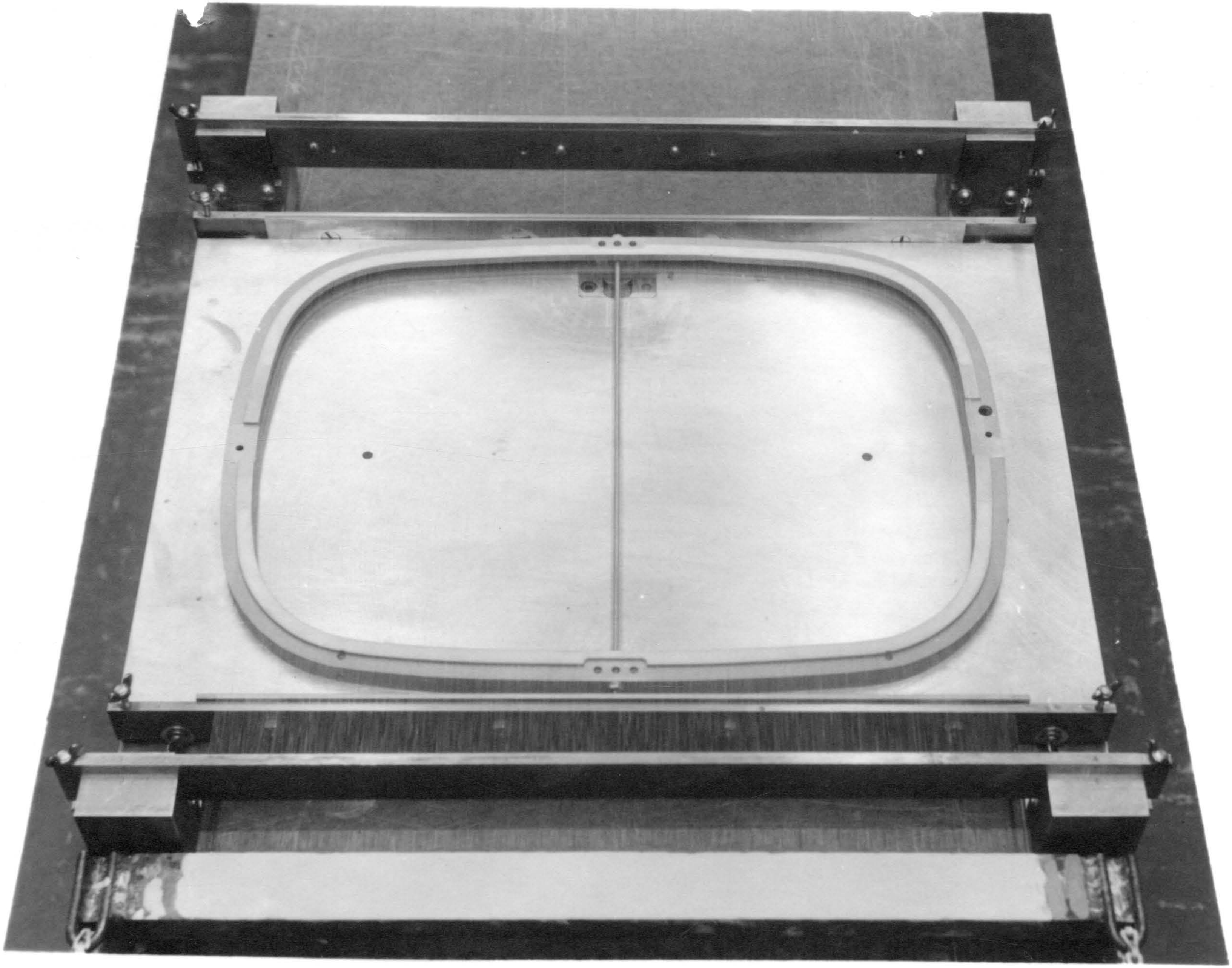


FIG. VI-3 GRILLE TO FRAME FASTENING JIG.



4-6790 GRILLE FRAME ON LOOM
FIGURE VI-4

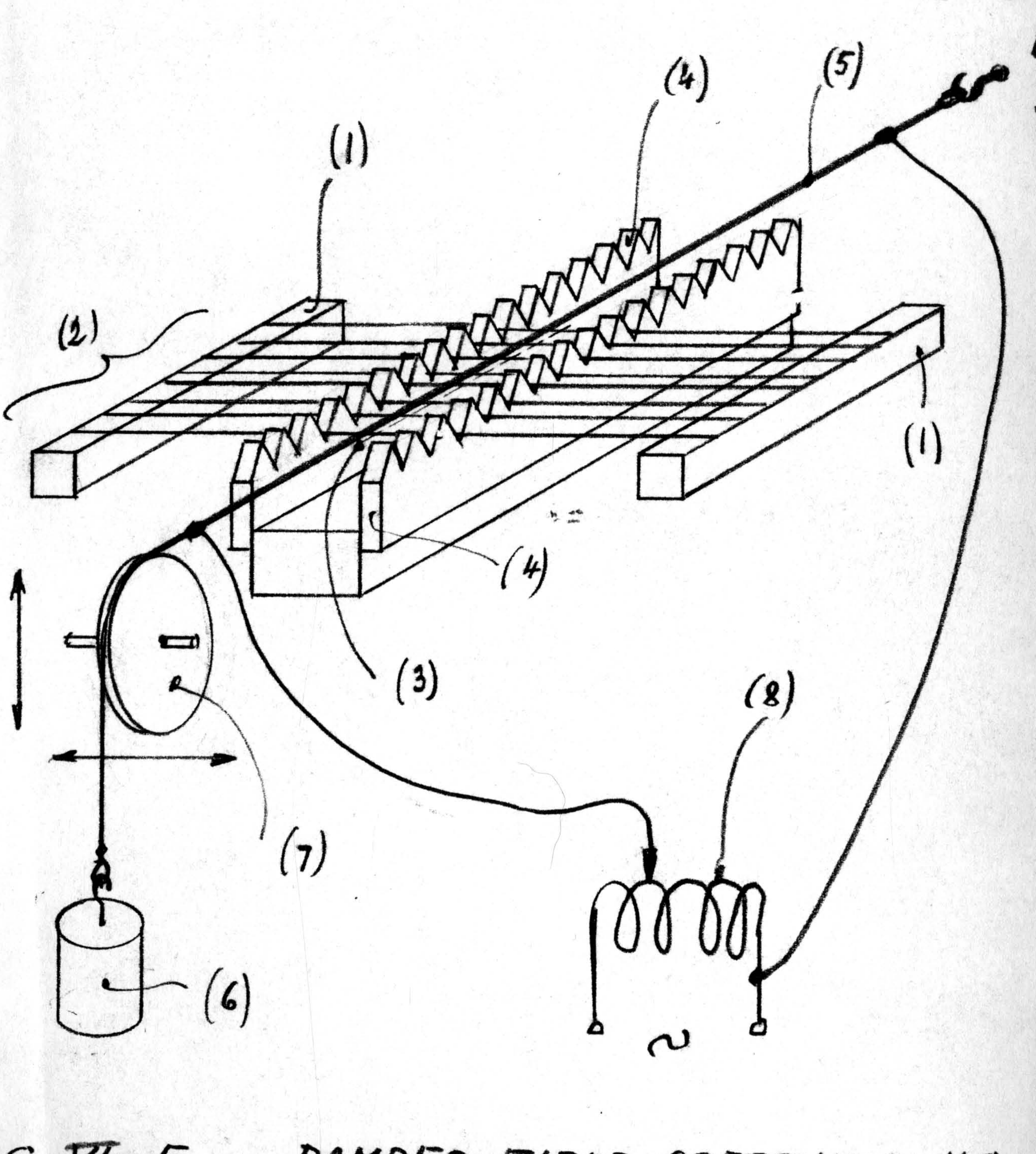
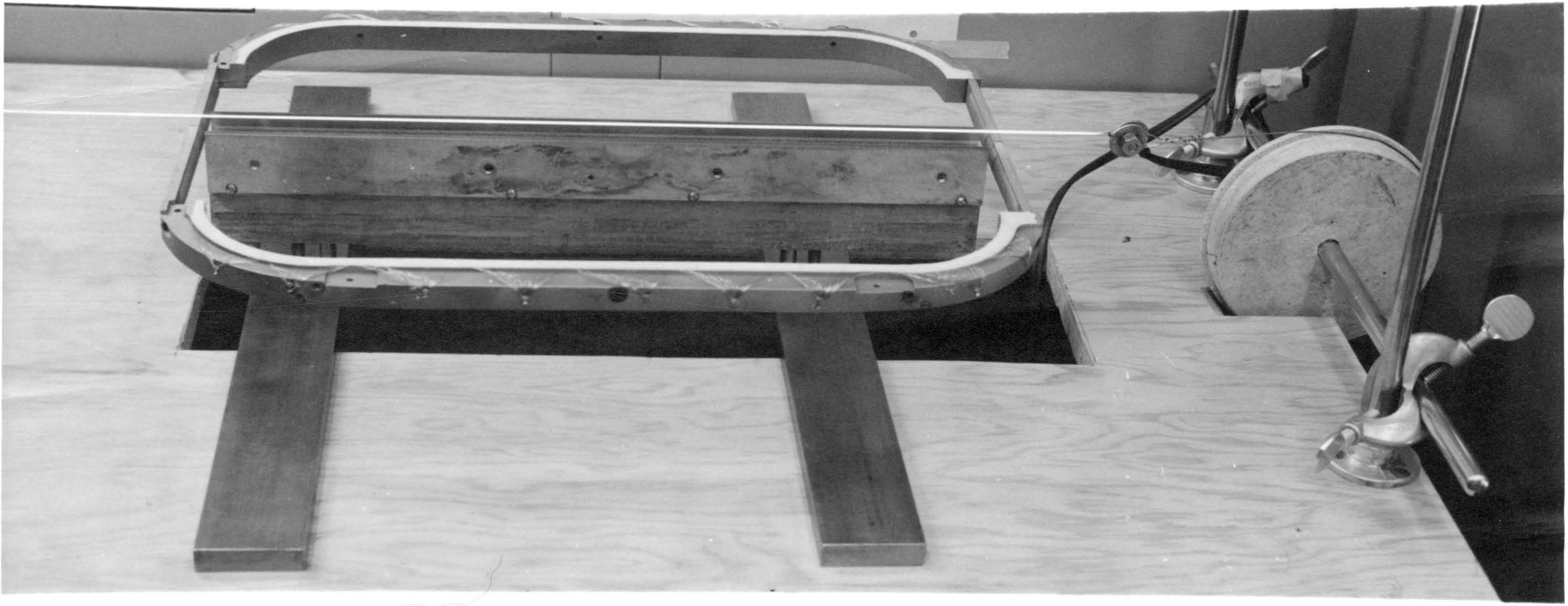


FIG VI - 5 DAMPER FIBER SOFTENING JIG.



GE Electronics DIV. 4-6784 DAMPER FIBER SOFTENING
FIGURE VI-6

CHAPTER VII SANDWICH ASSEMBLY AND ITS INSERTION IN TUBE

1) Take grille from dessicator, place on bench and with pencil mark center wire (approx.) for future alignment purposes. Mark same wire on both ends.

2) Pick up lava blocks that have been silvered and chrome oxide painted. Insert "CP's" and assemble blocks to grille (2 side blocks and 2 end blocks).

3) Place "CP" adjustment device (bird) on lava blocks and adjust height of "CP's".

4) Lock "CP's" in place with Sauereisen cement; do not get cement on top of "CP".

5) Place Phosphor Plate on lavas and install stirrup assembly with springs and set screws.

6) Install fringe field correctors and twist end leads making contact with stirrup assembly.

7) Assemble end clamps on end lavas. Do not tighten.

8) Place assembly on lighthouse.

9) With side (25 watt) light illuminating pencil lines indicating center wire, rough align plate so as to have the same phosphor sequence over the same wire at both sides of plate.

10) Using alignment light, fine align phosphor plate so wire shadows fall between color sequences.

11) Tighten end clamps - recheck alignment - install over-lay.

INSERTION IN TUBE

1) Install high voltage shield in cone.

2) Degrease retaining studs, electron shield, and corrugated ring.

3) Install components mentioned in (2) above.

4) Remove any paper that may be in tube neck.

5) Place sandwich assembly on retaining studs and insert in place.

6) Install set screws, attach high voltage lead to screw on end clamp.

7) Clean phosphor plate and tube cap with alcohol.

8) Place cap on tube assembly.

CHAPTER VIII BULB WELDING

SECTION I TECHNICAL DISCUSSION

The panel and funnel are each sealed to chrome-iron rings which must be welded together as the last operation prior to exhaust.

In order to obtain a satisfactory one-pass weld by machine (as opposed to hand welding), it is important that the mating flanges fulfill the following requirements:

1) Reasonably clean and free from large burrs.
2) No gaps greater than .005" when tube is clamped in welder.
3) No overlaps greater than 1/32" when tube is clamped in welder.

If gaps occur outside the above limits, the flanges should be bent the proper amount. The cap and funnel should be separated to do this properly - a pair of linesman pliers is all that is needed. Generally speaking, if the manufacturer's pairing of panel and funnel is adhered to, the amount of overlap will be negligible. Occasionally, either because panel and funnels have been interchanged, or because the position of the panel is severely limited by the frame, it may be necessary to trim the flanges in order to minimize overlap. Because the trimming operation involves considerable vibration, with the consequent possibility of affecting sandwich alignment, it is wise to do the trimming with the front end assembly removed. If there is a tight fit between panel and frame, a dummy frame should be installed prior to this operation.

The welding-trimming machine is essentially a rotating oblong ring shaped to receive the tube panel face down. An upper brass ring and five rolling clamps hold the funnel flange tightly to the cap flange as the tube rotates. The lower and upper rings match the shape of the O.D. of the flange except for a difference of about 1/4" in radius. The lower ring is used as a cam controller, as will be described below.

The motive power for the machine is a d-c motor with a "Thymatrol" speed control. In the actual welding, it is convenient to weld at a constant linear speed. In order to achieve this a part of the resistance which controls the motor speed is operated automatically by means of a push rod working off the lower cam ring. The variation of this resistance is such that the linear speed of the flange is independent of radius.

The lower cam ring also serves to vary the position of a sliding carriage which holds both an end-mill for trimming and a torch for the welding. A hand wheel for manual control of the end-mill and torch position is also available.

Preparatory to welding, the tube is inserted in the machine and only roughly centered. Slow variations in the work-electrode spacing can be taken care of by operation of the hand wheel as the work rotates.

An argon fed Linde Air Products Hand Welding Torch HW-9 with a #5 ceramic tip and a 40 mil thoriated tungsten rod is used. It is found convenient to ignite the torch with a low frequency discharge coil rather than with the usual "match". If the condition of the work is as specified previously, a good weld will be obtained with the following parameters: Gas flow, 16-20 ft.^{3}/min.; arc current, 25-30 amperes; arc voltage, 9-11 volts; nominal work-electrode spacing, 50 mils; linear welding speed, 12-16 in./min. A wide range in spacing can be tolerated depending on the work condition.

Careful attention to work conditions is extremely valuable. A bad weld can only be repaired by laborious and time-consuming effort on the part of the operator.

A useful feature which our welding machine lacks, but which might be very useful on a production instrument, is a device which automatically takes care of local gaps. This could take the form of a pair of small pressure rollers, located at the position of the torch. These rollers would close any small gaps, thus allowing a good weld.

SECTION II WELDING FLOW CHART

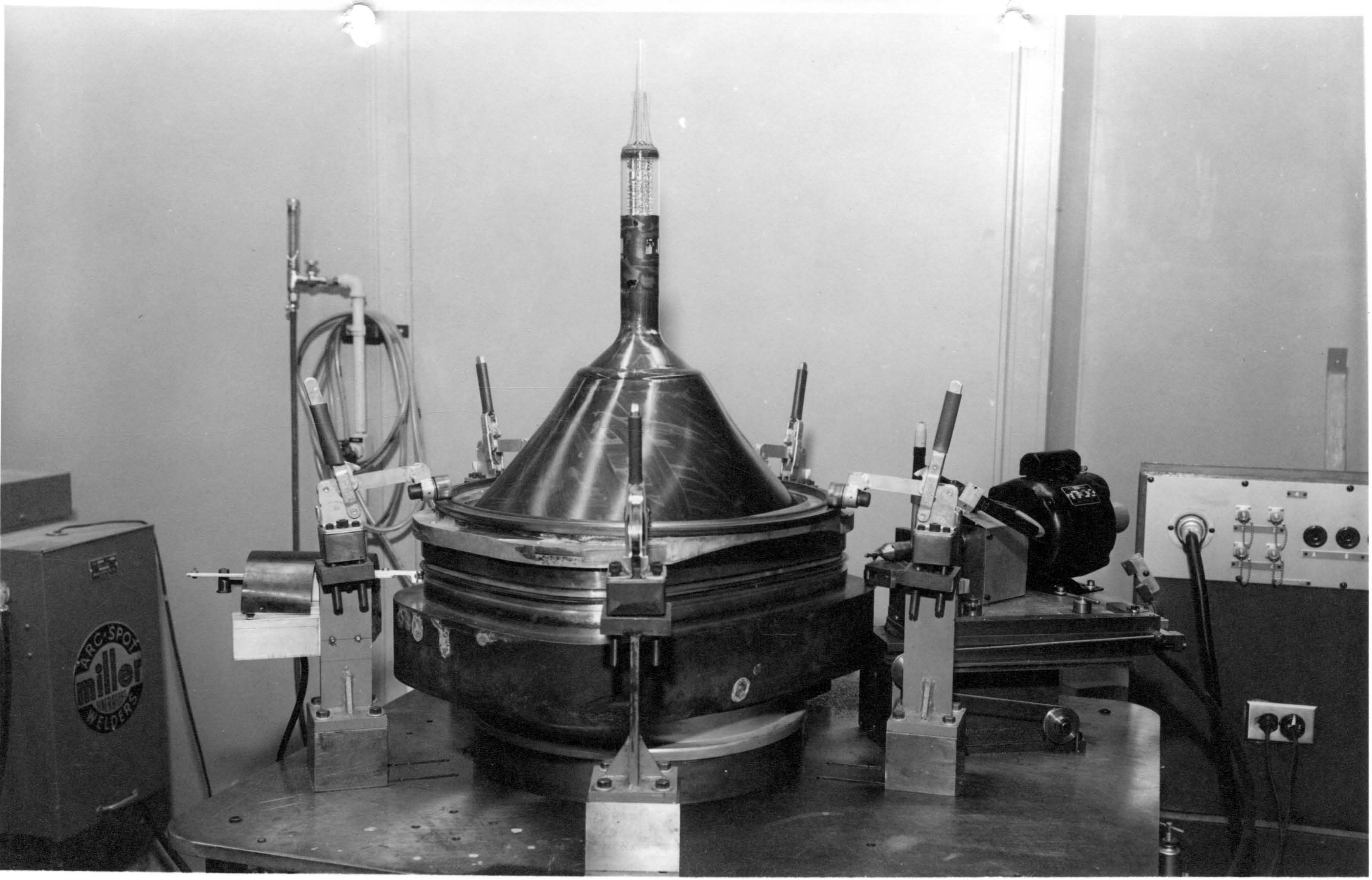
1) Gaps and overlaps of flanges should be checked (these should have been corrected as last step of bulb preparation). Any necessary trimming should be done with sandwich removed.

2) Tube inserted in welding machine and centered in clamping rings. Tube welded.

3) Flange inspected and tube rewelded if needed.

4) Final inspection for pinholes.

5) Gun checked for heater continuity and shorts.



4-6769 WELDING MACHINE WITH BULB IN PLACE
FIGURE VIII-1

Electronics DIV.

CHAPTER IX TUBE BAKEOUT AND EXHAUST

SECTION I TECHNICAL DISCUSSION

The pumping schedule for the color tube is deliberately grossly conservative. The point of view has been simply to get a good tube as well as a whole tube (i.e., no implosions or cracked phosphor plates).

Most of the tubes manufactured in this laboratory have been pumped without the aid of a liquid nitrogen trap. Almost all the tubes so processed have had poor cathode images. The installation of a trap resulted in an immediate vast improvement in emission characteristics. It is, of course, possible that a shorter pumping cycle, with the attendant shorter exposure to oil vapors, might have a similar effect.

All tubes have been pumped in a large bell-type oven with forced air convection. The thermocouple, somewhat illogically, is located on an inside false wall of the oven. Because of this, the tube is always about 10°-15° hotter than the indication of the thermocouple. Tube tip-off is done with a radiant heater because of the practical difficulty of obtaining access to the tube with a torch. The actual baking schedule has been adequately described in the flow-chart. Here, only a few pertinent remarks are included.

The 4°/min. rise is probably not too far from maximum with the present cap design. We have had three implosions out of some 60 tubes on the going-up portion of the cycle. These occurred in the region from 280-370° C. It might be possible to increase the temperature rise rate at the lower temperatures, while maintaining a low rate above 300° C., and thus achieve a time-saving without increasing implosion probability.

With the color tubes with simple (lugless) phosphor plates, it was the practice to allow the oven to cool naturally (no air circulation) as soon as the hold period of baking was over. This corresponded to a rate of about 2.5°/min. cooling. There have been three implosions with this cooling rate in the temperature range 270-200° C.

When the lugged phosphor plates were introduced, it was decided to become extremely conservative for fear that the lugs would be the source for strain cracks. For this reason, it was also decided to place a metal shield over the tube panel in the hope that it would slow down and even out radiation cooling. No phosphor plates have cracked with this schedule, but, on the other hand, there is little evidence that it is even necessary. It has been found, however, that phosphor plates with cemented lugs (Sauereisen or glass frit) invariably cracked during exhaust for schedules only a little faster than the one described in the flow chart.

Most tubes were tipped off at a pressure of about 1.5 - 2.0 x 10^{-6} mm. at a tube temperature of 100-150° C. In a few consecutive cases, an air leak in the system forced us to tip off at a pressure higher by a factor of approximately ten. No appreciable difference in emission or in tube performance was noted. Lifetime may, of course, be affected.

All tubes to date have been responsible for a yellowish tar-like deposit on the inner stem wall in the immediate vicinity of the water-cooled compression rubber. The origin of this deposit is at present unknown. It definitely comes from the tube itself rather than from some part of the pumping system.

SECTION II FLOW CHART

The following schedule is intended for 21" tubes which have phosphor plates with built-in lugs. The pumping system employs a liquid nitrogen trap.

1) Stainless steel reflector placed over tube panel. Tube sealed on system after placement of gun r.f. coil and radiant heater tip-off.

2) After system reaches 25 microns or less with mechanical pump, the diffusion pump is turned on.

3) After diffusion pump has been on for ten minutes, the air circulation and the oven are turned on.

4) Temperature is cam-controlled as follows (at 150° C. liquid nitrogen trap is filled):

a) Room temperature to 380° C. at 4°/min.
b) Hold at 380° C. for 15 min.
c) 380° C. to 280° C. at 0.67°/min.

5) Oven and air is turned off and tube sits for one hour. At end of this time, oven (and tube nearly) is at about 220° C. Oven is raised just enough to permit subsequent operations. Pressure is about $3 - 5 \times 10^{-6}$ mm.

6) Getters outgassed at about 800° C. until initial pressure is obtained.

7) Gun r.f.'d for about 10 min. at dull red (about 650-700° C.)

8) Cathode converted and activated as follows:

a) Heater at 3 volts for 2 min.
b) " " 7 " " 2 "
c) Heater at 9 volts for as long as necessary for pressure to return to nearly original value (about 5 minutes).
d) Heater then raised to 11.5 volts and 5 volts on first grid applied until emission shows little or no signs of increasing (emission per gun will generally be in range of 5-8 ma.).

9) Cathodes turned off and getters flashed.

10) Tube is tipped off. Pressure is in range of 1 - 2 x 10^{-6} mm. and oven temperature approximately 150 - 180° C.

SECTION III AGING

11.5 volts on heater, 3 volts on first grid for about 3 minutes then 8.5 volts on heater, 3 volts on first grid for about 40 minutes.

Aging may be conveniently done immediately after tip-off and before basing. Cracked stems have a greater possibility of occurring if aging is done while tube is cool and after basing.

4-6788 EXHAUST FACILITY SHOWING
BELL-TYPE OVEN
FIGURE IX-1

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CHAPTER X TUBE TESTING PROCEDURES

Test:

1) With no heater voltage, and the grille grounded, apply the screen voltage through a 50-meg resistor which may be made with a string of 5-meg resistors. Gradually raise this voltage from zero to 20 KV. Watch for leakage and cold emission between the grille and screen. Turn off the voltage and disconnect the resistor after about 10 min.

2) Gradually raise heater voltage to 8 volts. Apply about -150 V control grid bias. Observe the grid current of all three guns to check for grid-to-cathode shorts and leakages. Use the spark coil to burn out the shorts, if necessary.

3) Turn on the sweep circuit. Apply 5 KV to the screen, and then 3 KV to the anode and focus electrodes. (For tetrode guns, apply 700 volts to the screen grid.) Adjust the control grid bias of individual guns to get about 200 μa cathode current from each gun. Wait for 15 min. in order to further age the center portion of the cathode.

Note: Always apply screen potential before the anode potential and keep the screen at higher potential to avoid excessive grille current and possible damage to the grille wires.

4) Bias all guns to beyond cut-off. Reduce the heater voltage to 6.3 volts. Then momentarily turn off the sweep and gradually reduce the bias of individual guns. Notice that the focus electrode is at the same potential as the anode - i.e., there is no focusing action. A magnified picture of the cathode emitting area should now appear in the screen. By varying the bias, the relative position of the cathode emitting area and the limiting aperture of the anode can be observed. Any poor emitting area of cathode also shows up as dark spots in the picture. Thus, the alignment of the gun and the condition of the cathode can be checked.

Note: Beware of grid-to-cathode shorts and leakages whenever the sweep is turned off. If the cathode image of any gun is not affected by the control grid bias, the gun most likely has grid-to-cathode leakage.

For the above observation of the cathode, it is sometimes more convenient to pulse the control grid at a negative bias near cut-off in order to reduce the brightness of the image.

5) Adjust the screen potential to 12 KV, and the anode potential to 7 KV. Then set the focus potential to about 3 KV and adjust it to give the sharpest focus. With correct focus, the line structure of the raster should be clearly seen.

Check the color interference pattern of the picture raster using any one gun. All the color strips should be vertical. If not, the alignment of the grille wires to the phosphor strips is off and requires correction by an axial magnetic field with the axial field coil.

6) Now, with the tube biased beyond cut-off, turn off the sweep temporarily and slowly adjust the bias to get three dim spots from the guns. Be careful not to burn the phosphor. The spots of the two side guns should be close to 0.100" horizontally on each side of the center gun spot.

7) Turn on the sweep and raise the screen potential gradually to about 26 KV and adjust for a pure red color for the center gun only, with the side guns biased beyond cut-off.

Occasionally, there may be slight misalignment of the relative positions of the guns, the grille wires and the phosphor strips. With a misalignment of the grille wires and the phosphor strips, as mentioned in (5), the color would no longer be uniform vertically. A typical indication is a greenish color at top and/or a bluish color at bottom, or vice versa. The axial magnetic field of the axial field coil can be used to correct this misalignment. On the other hand, there may be a uniform misregistration between the grille wires and the phosphors, causing different colors to appear on the screen - e.g., left-hand half of the picture raster becomes green. The color purity coil can be used to shift the beams horizontally and thus corrects for the uniform misregistration.

It should be remembered that the post-acceleration voltage ratio has to be maintained at the correct value of about 3.8 to get the color purity. Thus the screen potential may need slight readjustment after each adjustment of the color purity coil. The usual procedure is to adjust the color purity coil such that impurity of color appears to be symmetrical on the screen. Then adjust the screen potential to achieve a pure color. The reasoning is that with improper voltage ratio the electron beam would hit the wrong phosphor strips near the sides and show up as symmetrical green and blue areas on a raster of red color from the center gun.

With the above adjustments, the color should be pure for the center gun as well as the side guns provided the convergence is correct. Further impurity of color may be caused by improper handling. For example, the ceramic spacer may charge up and the fringe field corrector may not be made properly.

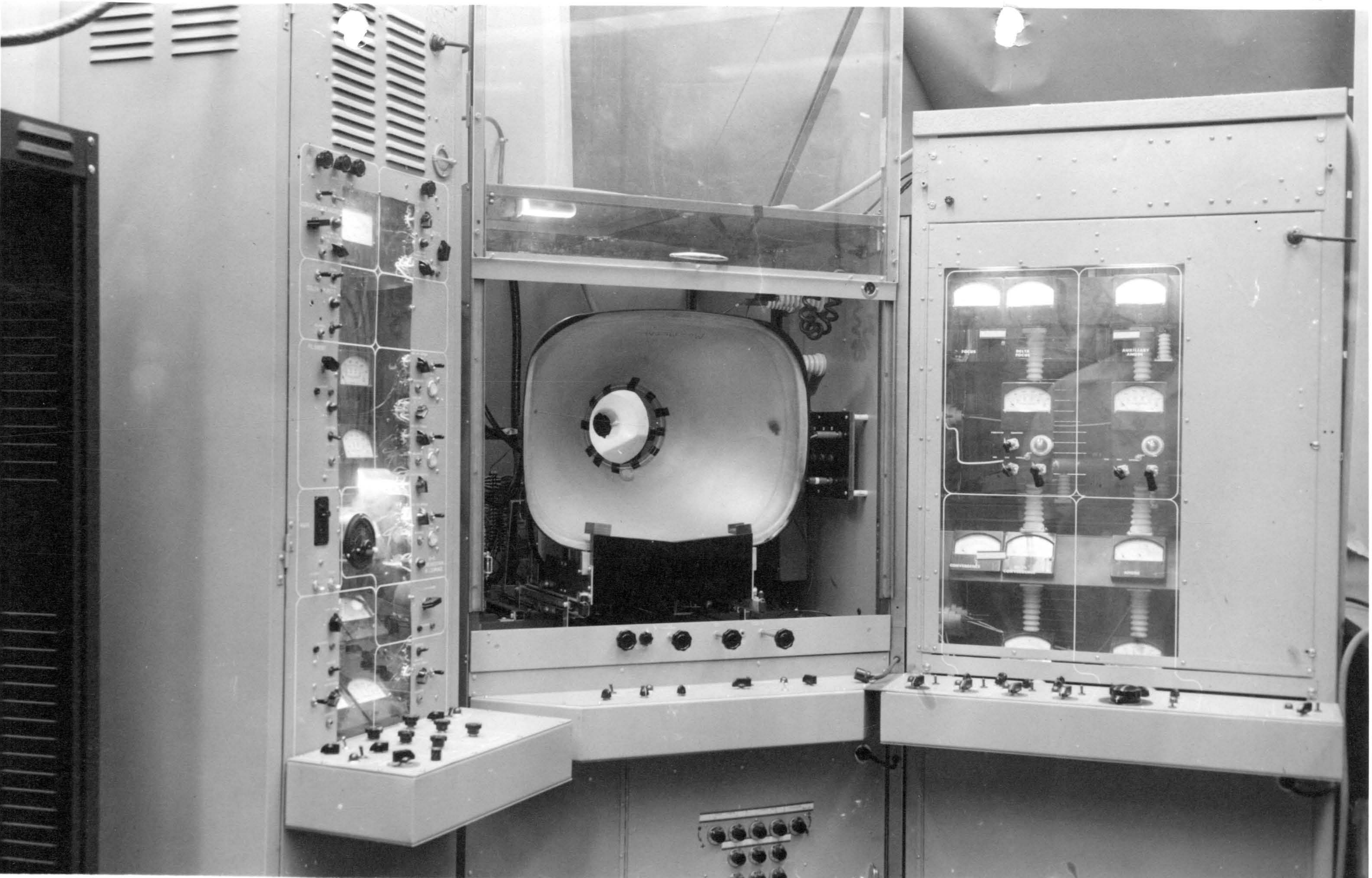
8) The color purity is also affected by the suppressor voltage between the grille and cone. To achieve best color purity, the suppressor voltage is usually adjusted such that it is just large enough to eliminate the screen illumination by the secondary electrons.

9) The characteristics of the guns can be measured according to the requirements of the circuit group. Normally the characteristics of the guns are

very uniform as long as all their constructions are held within tolerance. The present practice in the Laboratory is to record and compare the following quantities of different guns as a means of checking the quality and uniformity of the guns. We measure:

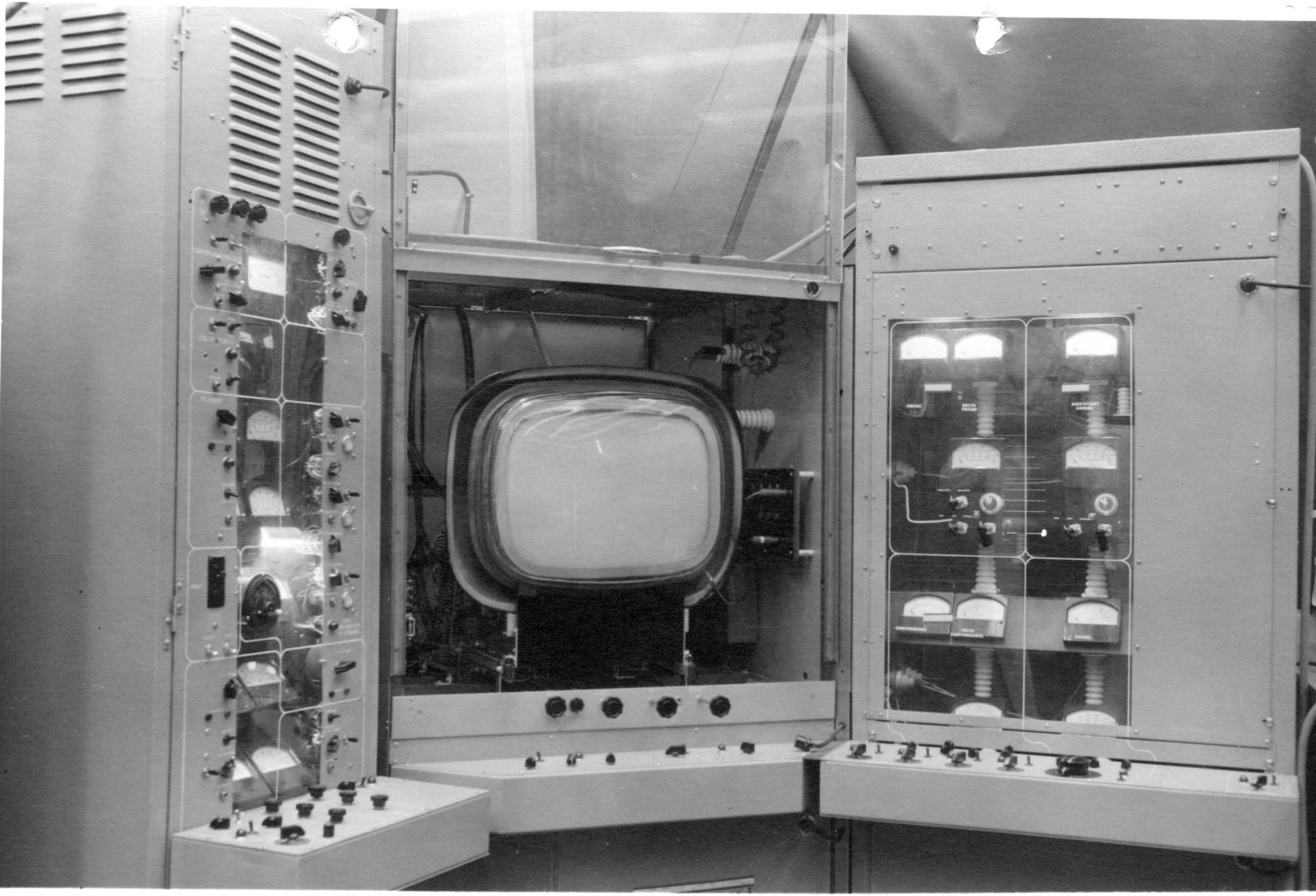
a) Cut-off bias.
b) Driving voltage or bias at 200 μa of screen current.
c) The anode limiting aperture current at 200 μa of screen current.

A departure of the cut-off bias from its normal value used to be an indication of the variation of the control grid-to-cathode spacing. The sparking equipment is found to be very useful in controlling this spacing. The ratio of the screen current to the limiting aperture current, if too low, used to indicate poor emission and/or misalignment of the gun. Knowing the driving voltage, the total cathode current at any other grid voltages can be estimated by making use of the 5/2-power law.



4-6777 Test Station with Magnetic Shield Exposed

Figure X-1



4-6779 TEST STATION WITH TUBE IN PLACE
FIGURE X-2

CHAPTER XI QUALITY CONTROL DEVICE FOR COLOR TUBE GRILLES

1. Introduction

The grille of the post-acceleration tube is a component which requires highest accuracy in the maintenance of the proper location of the wires. More than 500 wires are fastened to a frame of more than 200 square inches of area and any dislocation of any one wire, or group of wires, should not exceed 1 or 2 mils (1 mil = .001") in order to secure color purity and maintenance of the proper electrical data in the final color tube.

Each manufactured grille assembly should, therefore, be properly tested in regard to any dislocation of wires in vertical and in horizontal direction. A device which measures only one spacing at a time (e.g., a microscope) would be much too slow for an application in the factory. It is therefore suggested that the grille assemblies be tested by comparison with a photographic picture of an "ideal" grille or a ruled master. This optical comparison device allows one to see at a glance dislocations of single wires or whole groups of wires, and it is sensitive enough to measure dislocations in vertical or horizontal direction which are as small as one mil. It should, therefore, be applicable to the mass production of grilles as a piece of test equipment.

2. The Method

The method of testing grilles as to the proper location of the wires consists of a comparison of the grille with a master. The latter is a glass plate with transparent lines on the otherwise blackened surface. The pitch should be the same for master and grille; the line width on the master can range between 3 and 9 mils.

The comparison is done by placing the grille assembly on top of the master plate so that the surface of the master containing the line pattern faces the grille plane, and the surface and the grille plane are parallel to each other. The distance between these two planes should be as small as the construction of the grille assembly allows (preferably a few mils only). The wires of the grille and the lines of the master should form a small angle in order to let the wires cross the transparent lines of the master. If the whole setup is illuminated from underneath, one can see the light coming through the transparent lines except at places where it is blocked by a crossing wire of the grille. The totality of these cross-over regions we will call "interference lines"*. Looking perpendicular to the grille plane at the interference lines, the latter are straight and parallel to each other provided the grille is perfect. Any deviation of the perfect location of wires would show up as a deviation from the straightness of the interference line. The smaller the angle between the wires and the master lines, the more sensitive is the method.

Dislocations in horizontal direction can be seen by looking along an interference line under an angle of about 450° between the plane of the grille and line from the eye to grille assembly. For both cases - vertical

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* It should be noted that this phenomenon is not an interference in the sense which is usually considered in interference optics.

and horizontal dislocation - it is necessary that the viewer maintains a certain distance from the assembly, which depends on the distance between the plane of the grille and the surface of the master.

Some special grille errors and dislocations of wires will be discussed in detail in Section 4.

3. The Experimental Setup

a) The Master. The most accurate way of making a master is to have the lines ruled into the black coating of the surface of a plain glass plate by means of a ruling machine. This has been done by the Levy Bros. Co., Philadelphia, Pa. The location of the lines is correct within a few tenths of a mil and accurate enough for this purpose. As those ruled masters are fairly expensive, we use a positive photographic copy of the ruled master for the above described setup. Kodalith photographic plates, not less than 1/4" thick, were found to be satisfactory for making contact prints of the ruled master.

b) The Light Source. An extended light source which illuminates the whole master fairly equally is needed for the setup. A wooden light box with several 15-watt fluorescent "cool white" lamps, spaced 2 to 3 inches apart, is a simple and effective light source. The lamps should be covered by an opal glass plate on top of which the master is placed.

c) The Mounting of the Grille Assembly. The grille assembly should be set on top of the master so that the plane of the grille and the master surface are parallel to each other and the distance between them is only a few mils. The latter might not be possible in some cases due to the construction of the grille frame - e.g., when the wires are lying in grooves in the frame or when the wires are covered with Sauereisen cement to fasten them to the frame. But, in any case, the distance between the two planes should be held as small as possible. It is suggested to place the grille assembly on spacers which are ground to the proper distance and which are glued to the master in order to be held in the right position (Figure 1). These spacers may support the grille frame on its ground surfaces on which later on the posts will be mounted. For a master-grille spacing of 15 mils, the viewing distance should be not less than 3'-4'. The parallelism between the two planes should be held within 3 mils.

d) Measuring Equipment. In order to be able to decide which dislocations of wires are tolerable and which are intolerable, a plexiglass template may be set over the whole assembly (Figure 2). The template should contain some parallel lines A_1, A_2 and B_1 B_2. The grille, master, and template should be adjusted so that two interference lines coincide with the lines A_1 and A_2 of the template if the viewer looks at the assembly from above. Grilles with dislocated wires which show up in the interference line and extend over the lines B_1 and B_2 are rejects. The distances between A_1 and B_1, resp. A_2 and B_2 should be chosen according to the specifications. E.g., if dislocations up to 1/15 of the pitch are tolerable, A_1 - B_1 should be 1/15 of A_1 - A_2. The distance A_1 - A_2 must be chosen so large that the interference pattern is sensitive enough to show up dislocations in the order of the required tolerance.

4. Analysis of Errors

a) One Mislocated Wire. If two systems of parallel lines with equal pitch are crossing each other under an angle α, the cross-over points lie on a straight line forming an angle, $\alpha/2$, with each of the perpendiculars of the two systems (Figure 3). The distance between two adjacent lines (pitch) is p. If a wire is dislocated by Δ p, one can easily deduce from Figure 3.

$$\frac{\Delta p}{p} = \frac{\Delta P}{P} \qquad (1)$$

and

$$P = \frac{p}{2 \sin \frac{\alpha}{2}} \qquad (2)$$

The first equation means that the ratio of the deviation from the interference line Δ p to the difference between two interference lines P indicates the amount of deviation Δ p from the pitch p. The second equation states that the distance between interference lines increases with decreasing angle between the two systems, thus increasing the sensitivity of the method. For small angles, the factor P/p becomes $1/\alpha$ (in radians).

b) Periodic Errors. Periodic dislocations appear easily if the wires are laid down by a machine whose gears do not run quite true. The result is a periodically increasing and decreasing pitch. E.g., a periodicity of 8 means that 4 successive wires have an increase of pitch, whereas the next four wires decrease, etc. This periodic error can be detected as a sine-shaped interference line. The amplitude of this sine is again a true reproduction of the amplitude of the pitch error, except enlarged by the factor $1/\alpha$.

c) Difference in Pitch. A different pitch between the two systems would still give an interference pattern of straight parallel lines, but they would form an angle different from $\alpha/2$ with the perpendiculars of the line systems. Small deviations in pitch would not be easily noticeable, and some accurate measurements would be required. But once the agreement in pitch is secured, no further tests of mass-produced grilles as to an agreement in pitch has to be undertaken. (If present, this effect would not affect color purity, but only the setting of the voltage ratio or the yoke position).

Non-parallelism of interference lines would indicate a steadily increasing or decreasing pitch, an effect which would hardly ever occur in practice.

d) Parallelogram Effect. If the grille frame is not rigid enough to withstand small dislocations in itself, the most probable effect is a shift of one frame side against the opposite one to form a parallelogram. This would only result in a uniform decrease of pitch if all wires had the same length. But in a case of variation of the wire length (e.g., because of rounded off corners), one can easily see that a parallelogram shift of the frame would have the effect that the long and short wires are not any more parallel to each other, thus causing a serious deviation from a perfect grille. This effect is easily detectable with the control device and would show up in a curvature of the interference lines in regions where the length of the lines changes.

e) <u>Mislocations in Height</u>. The view along the interference pattern from the side, as described in (1), permits the observation of dislocations in a vertical direction. If the angle between the plane of the grille and the line from the dislocated wire to the eye of the observer is 450°, equation (1) in Section 4a is still valid

$$\frac{\Delta p}{p} = \frac{\Delta P}{P}$$

except that now P/P represents the grille irregularities as projected into a plane perpendicular to the line of observation.

In Figure XI-4 is shown a photograph of the interference pattern of one corner of a grille which has almost all the above described errors. The curvature of the lines in the corner indicates a strong parallelogram shift of the frame. A couple of wires are drastically dislocated. All interference lines are slightly sine-shaped as a result of a periodic error in the spacing of the wires.

FIGURE ~~XI-4~~ XI-1

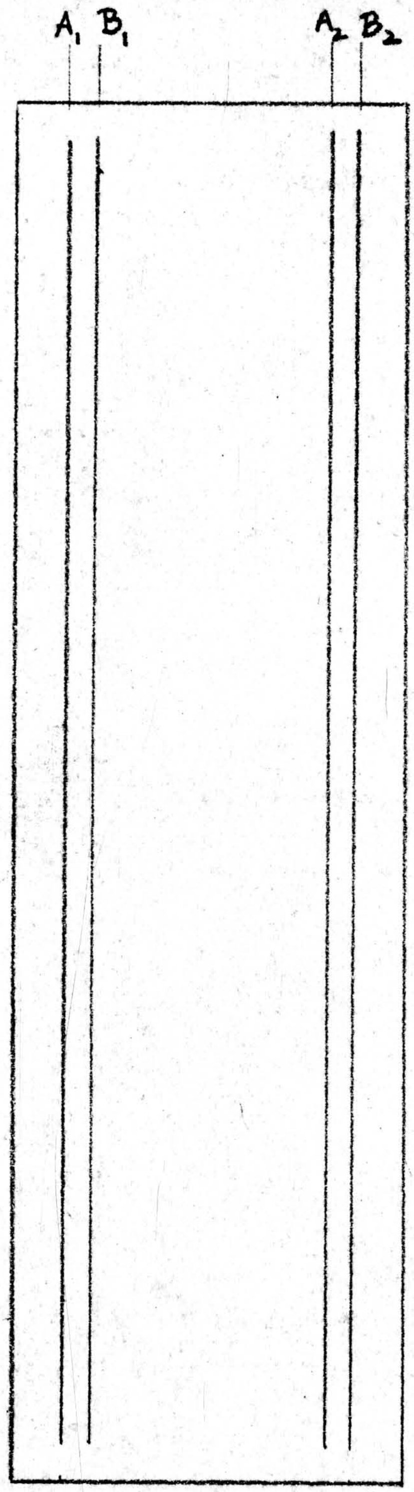

Fig. 2

Plexiglass Template

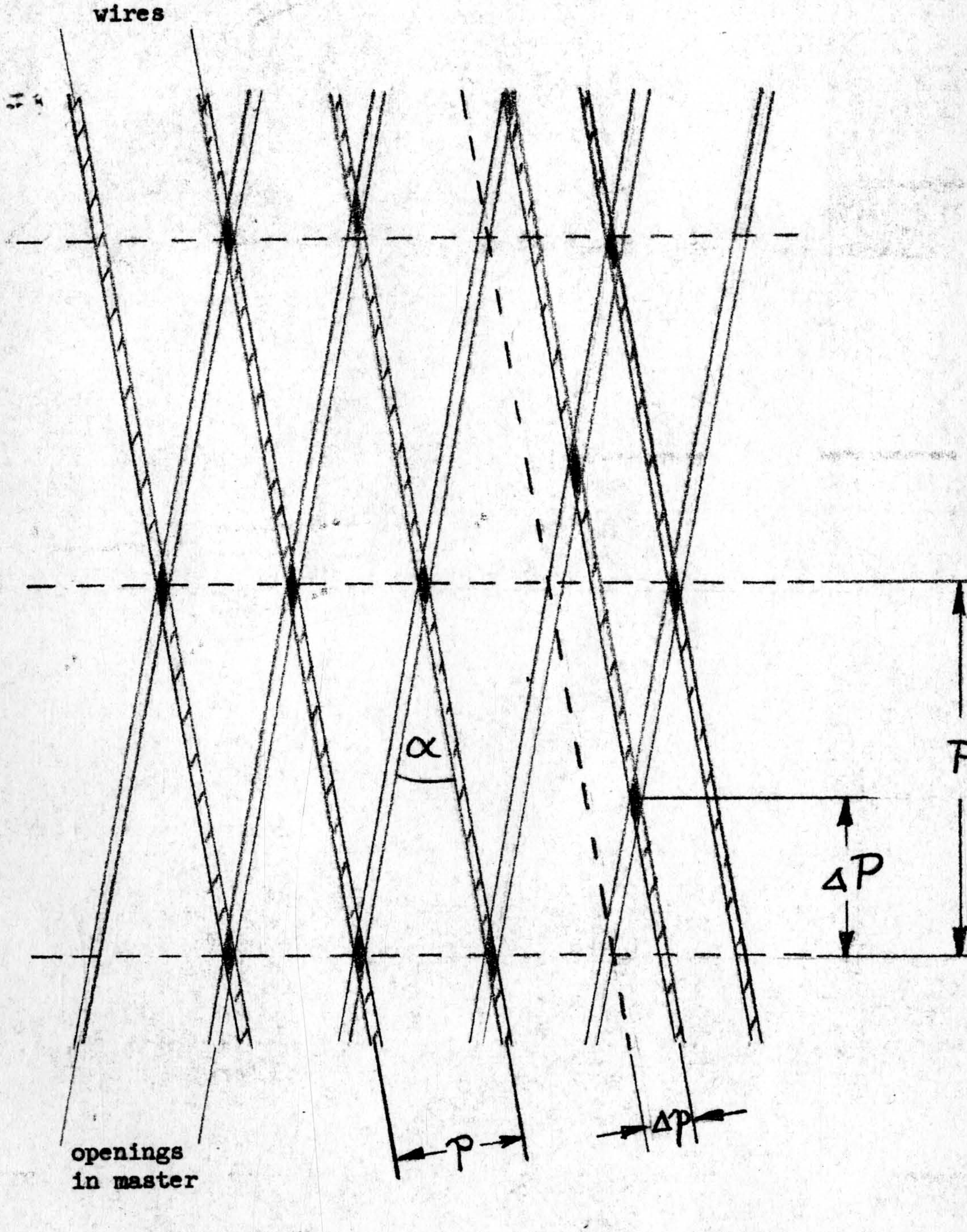

Fig. 3

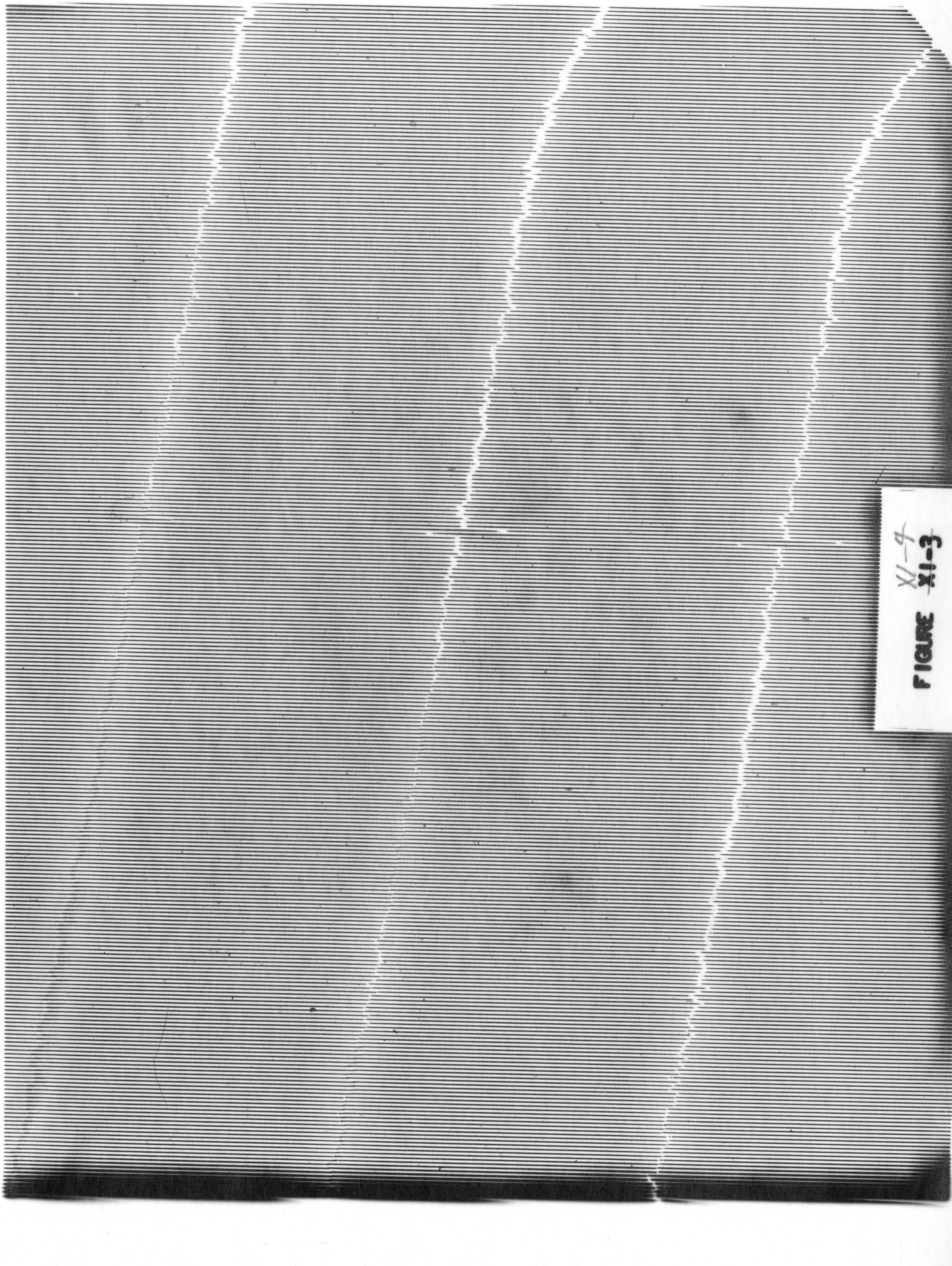

FIGURE XI-4 ~~XI-3~~

CHAPTER XII MASTER MAKING

INTRODUCTION

For the printing of the phosphor stripes on the screen in the post-acceleration color tube, it is necessary to make a master containing the required line pattern with the suitable line width for each line. The line pattern of the master has to be in agreement with the pattern which is written by the electron beam on the screen of the post-acceleration tube. The making of a master has been approached in two different ways: One is an optical one; the other an electron exposure master. The first is made in a lighthouse in which the conditions of the electron beam of the color tube are substituted by a light. The calculations for the setting of the lighthouse for this substitution are given in T.I.S. 52E-205-1.

In the case of the electron exposure master, the line pattern is directly written by electrons on the photographic plate which is used as a screen in a color-tube-like setup in the demountable station. Each method requires a different experimental technique which will be discussed below in detail.

SECTION I OPTICAL MASTERS

a) The Lighthouse

The required line pattern on the optical master can be obtained by taking a photograph of a uniformly spaced master grille or a ruled master. The light source is an equally illuminated rectangle with the longer side parallel to the lines of the master. As has been shown, a mere adjustment of the distances between light source and grille, and grille and photographic plate, respectively, would not fulfill the requirements of the post-acceleration pattern. A special ground glass lens between the light source and the master grille will take into account the post-acceleration distortion if adjusted in the proper position.

In Figure XII-1 is shown a lighthouse for the making of optical masters which has all facilities for adjusting the distances according to the calculations. The light source and lens assemblies are mounted on a 3" steel tubing which has a long thread (8 per inch) on the outside. It is held in position by a brass nut mounted into a 3-leg spider. The 3 legs rest in a 15" cast-iron tubing - the frame of the lighthouse - and can be adjusted by 3 screws in order to secure centering of the light source. The 3" tubing contains a photographic opal glass lamp (75 watt) inside and is closed on the top by a cap with a slit opening 1/8" x 1". Two razor blades serve as slit jaws. The required distance from the slit to the grille can be adjusted by turning the threaded 3" tubing to the proper height. The lens holder is mounted to the 3" tubing by a threaded disk and the proper slit to lens distance can be adjusted separately from the slit to grille distance. A holder for the variable density filter is also fastened to the disk.

The top of the lighthouse consists of a 3/4" steel plate with a rectangular opening in it of such size that it acts as a limiting aperture for the required picture size. The walls of the opening are recessed under an angle of 45° to prevent light reflections. A 30 mil wide slit has been cut into each wall in the center of the two longer sides of the opening. These slits allow the extension of one line over the picture size of the pattern in order to mark the center of distortion of the pattern for later assembly of the printed phosphor plate with respect to the grille.

Either a ruled master or a master grille is placed on top of the steel plate. Two dowel pins are provided on the steel plate to keep the frame of the master grille in position. These dowel pins also serve as a reference for the alignment of the lighthouse. The ruled master or the master grille, the spacer bars for the proper grille to photographic plate distance and photographic plate, are clamped together as shown in Figure XII-1.

The construction of the master grille frame is shown in Figure XII-2. The wires are held in position by combs and fastened to the frame by Sauereisen cement. One side of the frame can be adjusted by 5 screws in order to secure the necessary tension of the wires. We used 9 mil music wire or 9 mil nylon thread for the master grille.

The ruled master is a 1/4" glass plate coated on one surface with black paint, into which the lines ($\sim$6 mils wide) are scratched by a ruling machine.

The alignment of the lighthouse is done with the help of a mandrel which is held in the proper position by the two dowel pins on top of the steel plate. The construction of the mandrel can be seen in Figure XII-3. For the alignment, the slit of the light source has to be replaced by a small opening. This point source, a small ink dot in the geometrical center of the lens, and bottom and top opening of the mandrel have to be aligned visually so that they form a straight line. The alignment of the lighthouse should be made after the required slit-to-lens and slit-to-grille distances have been set.

b) <u>The Photographic Material</u>

As photographic plates for making printing masters, we used exclusively Kodalith plates. We found that the thickness of the glass plate should be not less than 1/4" for plate size 16" x 20". Smaller glass plates tend to curl if not stored in the proper humidity and would, therefore, not meet the requirements for parallelism (distance grille-photographic plate ± 2 mils in the center of the plate, ± 1 mil near the sides) between the plane of the grille and the photographic plate. We developed the plates in Kodalith developer, 1 part solution A and 1 part solution B. The developing time was usually 2-1/4 minutes. In cases where the proper developing time was critical, we thinned the developer by adding two parts of water and had developing times between 3 and 4 minutes. The plates were immersed in a normal Kodalith Stop Bath after the developing. The fixing time was 3-5 minutes in Kodalith fixer and all plates were rinsed for 15 minutes in running water. All temperatures of the different processing baths were kept between 19 and 20° C.

As the line width depends on the exposure and developing time, we made test exposures with different exposure times and developed them for 2-1/4 minutes. A plot of line width versus exposure time, then, yields the proper data. However, we sometimes had to allow a slightly longer exposure or developing time if the developer solution aged after several test exposures.

c) The Line Width

The line width of the line structure depends on the geometry of the arrangement, the brightness of the light source, the exposure, and developing time. As the distances light source to grille, and grille to photographic plate are 20" and 3/4", respectively, and the light source is extended (1/8 wide), we get umbras and penumbras on the photographic plate which are superposed by diffraction from the wires of the master grille respectively from the line openings of the ruled master. The Kodalith emulsion has a very steep blackening curve and, as a result, we get pictures of extreme contrast. All exposed areas which were hit by more light than a certain minimum amount are completely blackened, the others remain transparent. By changing the exposure and developing time, as well as the intensity of the light source, one can develop a more or less amount of the half shadow regions and by that means control the line width.

In the lighthouse, the light intensity decreases from the center of the plate toward the corners because of the geometry of the whole setup, thus changing the width of the line pattern between the center and the corners. We therefore used variable density filters to reduce the light intensity in the center of the photographic plate. For detailed information about using those filters, see the report, "Producing Kodalith Master Plates for Post-Acceleration Tubes with Uniform Line Width", by Sherwood Parker, August 14, 1953. In some cases, this method is not applicable because the scattered light from the filter might blacken the whole photographic plate. We overcame this difficulty by pre-exposing the photographic plate through the filter without the grille for such a length of time that the regions which are not reached by any light in the subsequent exposure with the grille remain transparent. This method has the advantage also that the lighthouse settings do not have to be corrected for the finite thickness of the filter plate.

d) Photographic Techniques

The different printing methods - silk screen printing and offset printing - which were used in the manufacture of our tube so far, require a different line width distribution over the master. Furthermore, for S-printing*, the distribution of line width over the master plate area has to be different from the requirement for s-printing. Also, the photographic technique by the use of a ruled master is different from the technique by using a master grille. The making of a master under all these different cases will be discussed in detail, and the exposure and developing time data

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* Chapter XIV.

for some typical exposures will be given.

A) Master for Silk Screen Printing

The line width of the master for the silk screen printing technique has to be about 20% less than the theoretically calculated line width on the screen. The reason is an increase of line width during the printing process from the printing of the first to the third color. For details, see the report on silk screen printing, Chapter IV.

B) Master for Offset Printing

The offset printing technique requires exactly the same line width on the master as for the printed phosphor lines on the screen. From our optical master, either a zinc master or a dry plate has to be made for application in an offset printing press. The Buckbee Mears Co., in St. Paul, Minnesota, has made for us zinc and dry plates of high quality. Zinc masters from other companies sometimes showed distortions of the line pattern due to shrinkage of photographic material during the process of manufacturing the zinc.

C) Masters for s-Printing

The difference between s- and S-printing has been explained in detail in Chapter XIV. In s-printing, the side color stripes are shifted by one line width with respect to the center color stripe pattern.

In this case, a line pattern of equal line width over the whole master plate is required.

1) With Master Grille

The exposure through the master grille gives a master negative as the line pattern is a transparent one on the otherwise blackened photographic plate. To achieve equal line width over the whole plate, the use of a positive variable density filter is required. (A positive filter reduces the light intensity in the center of the plate). To prevent blackening of the whole plate by scattered light from the filter, a pre-exposure through the filter (without grille) has to be made. Then the following exposure with grille is made without filter.

A typical set of data for making a master for offset printing is:

Voltage for 75 watt photographic lamp	V = 70 volts
Slit 1" x 1/8" covered with 1 sheet of white paper	
Lighthouse distance (slit-grille)	19.91"
Grille-photographic plate distance	.831"
Slit-lens distance	8.96"
Exposure time (with grille)	135 sec.
Developer time (with agitation)	2-1/4 min.
Temperature of developer	20.2° C.
Pre-exposure through filter:	
Voltage	V = 100 volts
Distance slit-filter	6"
Exposure time (without grille)	44 sec.

From the negative master, a positive copy has to be made. This has also been done in the lighthouse by putting the photographic plate in contact with the negative and exposing with the same light source with the following data:

Voltage	V = 110 volts
Exposure time	90 sec.
Developer time (with agitation)	2-1/4 min.
Temperature	20.2° C.
No filter	

The resulting line width is 10.7 ± .7 mils.

The data for making a variable density filter are:

Photographic material: separation negative plates 5" x 7"
Developer DK50 1:1 diluted

Voltage	V = 30 volts
Slit: 1/8" x 1" covered with 4 sheets of white paper	
Distance slit-filter	1"
Exposure time	8 sec.
Developer time (with agitation)	5 min.
Temperature	19.8° C.

2) With Ruled Master

The exposure of a photographic plate through a ruled master is the simplest and most accurate way to make an optical master, as only one photographic step is required. For the achievement of equal line width, it is not necessary to use a variable density filter. The reason is an increase of line width from the center to the corners due to diffraction of the light beams which are limited by the openings of the ruled master. This line broadening compensates for the decrease of light intensity from the center to the corners. The original ruled master can not be replaced by a photographic copy as the scattered light from the photographic emulsion has the result of uneven line width.

Typical data are:

Voltage for 75 W photographic lamp	V = 110 volts
Slit: 1" x 1/8" covered with 1 sheet of white paper	
Slit-bottom of ruled master	18.86"
Slit-lens	7.28"
Exposure time (a) for silk screen printing)	1-1/2 min.
Exposure time (b) for offset printing)	3 min.
Developer time a)) with agitation	2-1/4 min.
Developer time b)) with agitation	2-3/4 min.
Temperature	19.5° C.
Line width a)	8.4 ± .5 mils
Line width b)	10.9 ± .5 mils

D) Masters for S-printing

The shift in printing the side colors in S-printing is a value which is close to the distance between 2 beams in the plane of deflection (color base) which is about 23 times the line width in our tube. As has been pointed out in Chapter XIV, S-printing requires a line width decrease of about 20% from the center of the plate to the corners.

1) With Master Grille

The photographic technique is the same as in C-1). The line width at the corners can be reduced by decreasing the distance from the slit to the filter to 4-3/8". All the other data are the same. The result is a line distribution as follows:

Center of the plate - 10.7 mils
Corners - 8.6, 8.4, 7.9, 8.1 mils

2) With a Ruled Master

The line width of the corners has to be decreased by some 20% by decreasing the light intensity from the center to the corners. A negative filter (copy of positive filter) has to be used. The photographic exposure through the filter and the ruled master can be made in one step. Pre-exposure through the filter alone is not necessary. In this case, the exposure time has to be increased by 50% to achieve the same line width in the center as in C 2).

SECTION II ELECTRON EXPOSURE MASTER

In the case of making a master by electron exposure, the line pattern is written on the photographic plate by the electrons themselves. A sandwich has to be assembled substituting the phosphor screen by a photographic plate which is made electrically conductive. This sandwich then is exposed in the demountable station by scanning an electron beam over the whole plate area for a certain exposure time at a given screen current. After the developing, the electron exposure can be used directly as a printing master or a positive copy of it may be made for this purpose.

The advantage of the electron exposure is the fact that the proper line pattern is written by the electrons themselves without calculations and substitution by light. It is necessary, however, that the grille assembly is perfect and the electrical and geometrical conditions in the demountable station are identical with the ones in the final tube; and, furthermore, that the grille assembly for the electron exposure and all grilles for final color tubes are identical. If these conditions are not fulfilled, one would not expect any better color purity with an electron exposure master than with an optical master.

1) The Photographic Material

Kodalith plates were found to be satisfactory for the purpose of the electron exposure. The 8 microns thick emulsion is quite sensitive to electrons in the required 10 - 25 KV range. Distinct and sharp lines are obtained with those plates. Kodalith developer, a stop bath, and Kodalith fixer were used for the processing of the plates. We also tried a special emulsion from Kodak, which is used in nuclear physics. However, the lines were not as sharp as in the case of Kodalith plates.

For making the plates electrically conductive, two different methods were applied:

a) The glass plates were coated with tin oxide by blowing $SnCl_4$ over the heated plate (about 500° C.). A conductivity of .1 to 1 MΩ from the center of the plate to the corners is sufficient for this purpose. Over the conductive layer, the Kodalith emulsion then is coated on the plate. This has been done by the Eastman Kodak Co. in Rochester.

b) A suspension of graphite in water is sprayed on the wet Kodalith emulsion. After drying, the graphite is wiped over the whole plate with cotton wool. A conductivity of 1000-100,000 Ω is easily obtained. After the electron exposure, before the developing, the graphite should be completely removed with water and soap.

According to our experience, the tin oxide method gives a cleaner picture with more distinct lines, of more even line width, than the graphite coating method.

2) The Electron Exposure

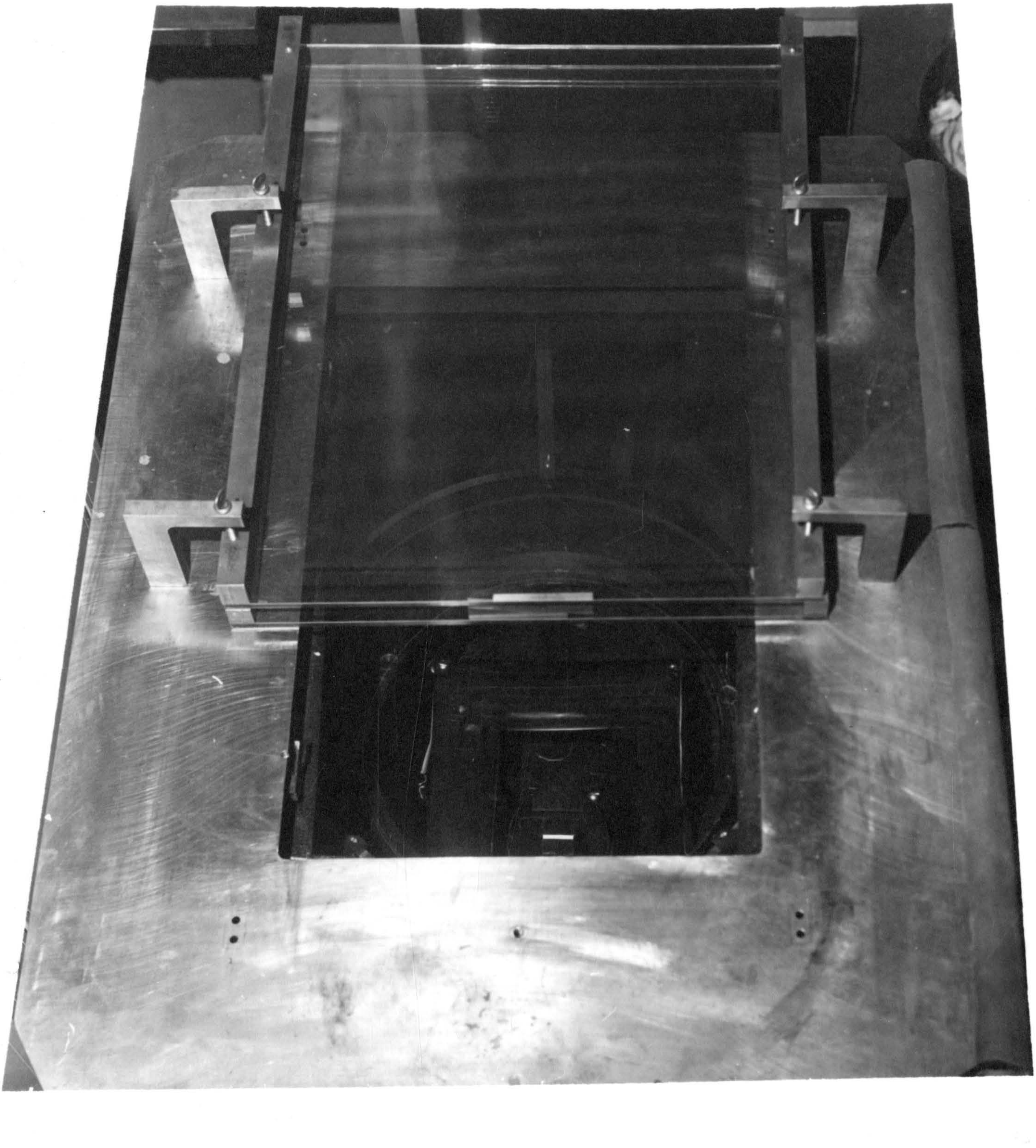
The whole experiment from the assembly of the sandwich to the developing of the plate has to be undertaken under dimmed red lights. Some special precautions have to be taken in order to prevent blackening of the plates from light, either from the cathode or from sparks. A diaphragm in front of the gun assembly leaving only a small hole open for the electrons, shielded most of the light from the heater and cathode from reaching the photographic plate.

Before trying an electron exposure, the demountable station should be pumped down for at least one hour using liquid air in the trap. This prevents sparks when the voltages are applied. The exposure time and the proper screen current may be controlled either by the heater voltage or the G_1 voltage on the gun. The screen current was measured by a galvanometer.

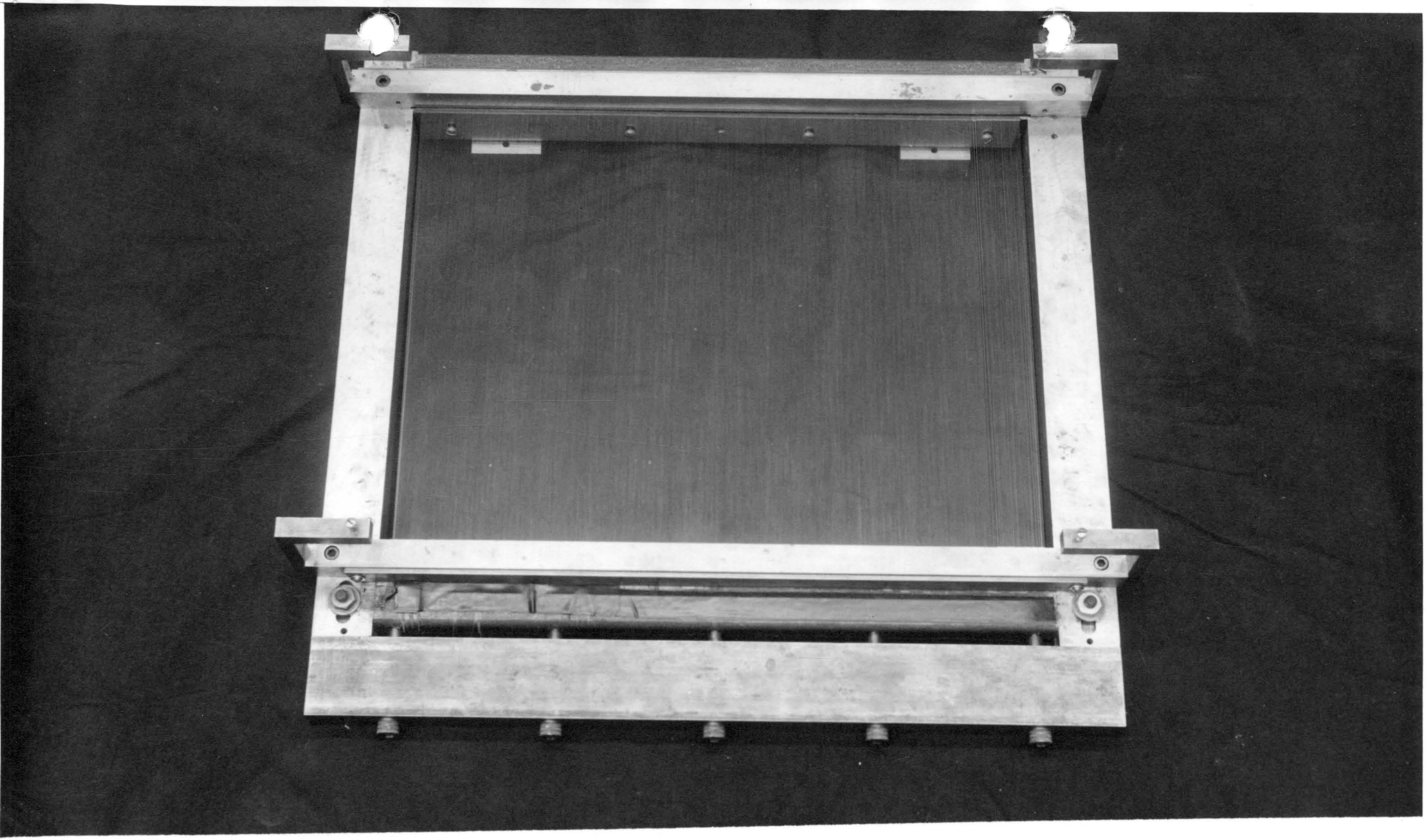
In order to obtain the proper line width, it was necessary to defocus the electron beam by applying a higher G_4 voltage on the gun. The evenness of the line width over the whole plate depends very much on the linearity of the sweep. The sweep we used so far did not allow us to achieve better tolerances in line width than ± 2 mils, which is a definite disadvantage compared with the tolerance of an optical master of ± .5 mils or better.

A typical set of data for an electron exposure is given below:

Screen voltage V_s =	15.7 KV
Mask voltage V_g =	4.12 KV
Focus voltage V_{G_4} =	2.5 KV
Suppressor voltage ΔV =	110 volts
Earth magnetic field compensated to about zero gauss	
Plane of deflection to mask D =	13.5"
Screen current I_s =	.8 μ A
Exposure time t =	5 sec.
Developing time =	2 min.
Temperature of developer =	20° C.



4-6789 LIGHTHOUSE
FIGURE XII-1



Electronics DIV. 4-7136 MASTER GRILLE
FIGURE XII-2

4-7135 LIGHTHOUSE MANDREL
FIGURE XII-3

Electronics DIV.

CHAPTER XIII YOKE AND PLANE OF DEFLECTION CONSIDERATIONS

In most sections of this report the "deflection plane" is considered as a fixed plane in space, perpendicular to the tube axis. The electron beam enters the plane from the gun, is instantaneously deflected, and then enters the grille-phosphor plate region.

This concept is quite useful in understanding the tube operation and also important in tube design. If all geometry is fixed, the position of the deflection plane determines the point at which the electron beam strikes the phosphor screen after having passed a particular point on the grille. The deflection plane is found at the intersection of the various loci of the central electron ray in the field free region on both sides of the yoke projected into the yoke region.

The idealized yoke analysis to follow shows that the deflection plane is not static but varies in position as a function of deflection angle. This variation must be taken into consideration when designing the optical correcting lens, or appreciable errors result on the final phosphor print.

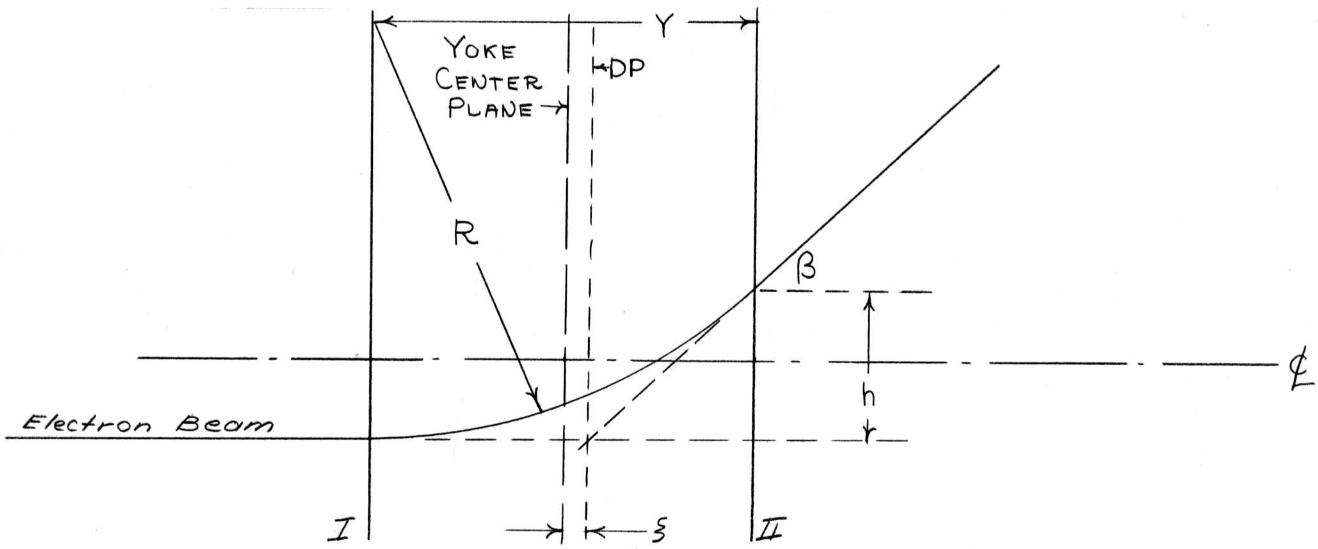


Fig. XIII-1

Figure XIII-1 shows the idealized yoke geometry considered and defines most of the symbols to be used. It is assumed that the magnetic deflecting field starts abruptly at plane I, is constant between planes I and II and then stops abruptly at plane II. The electron beam enters the yoke at I, travels in a circular path to plane II, and leaves plane II at an angle β (deflection half angle) to the tube axis. The deflection plane, DP, is ξ units in front of the yoke center plane. The magnetic field is obviously perpendicular to the plane of the paper.

If R is the circular path radius, and Y the yoke length, the:

$$R = \frac{Y}{\sin \beta} \tag{1}$$

From the geometry,

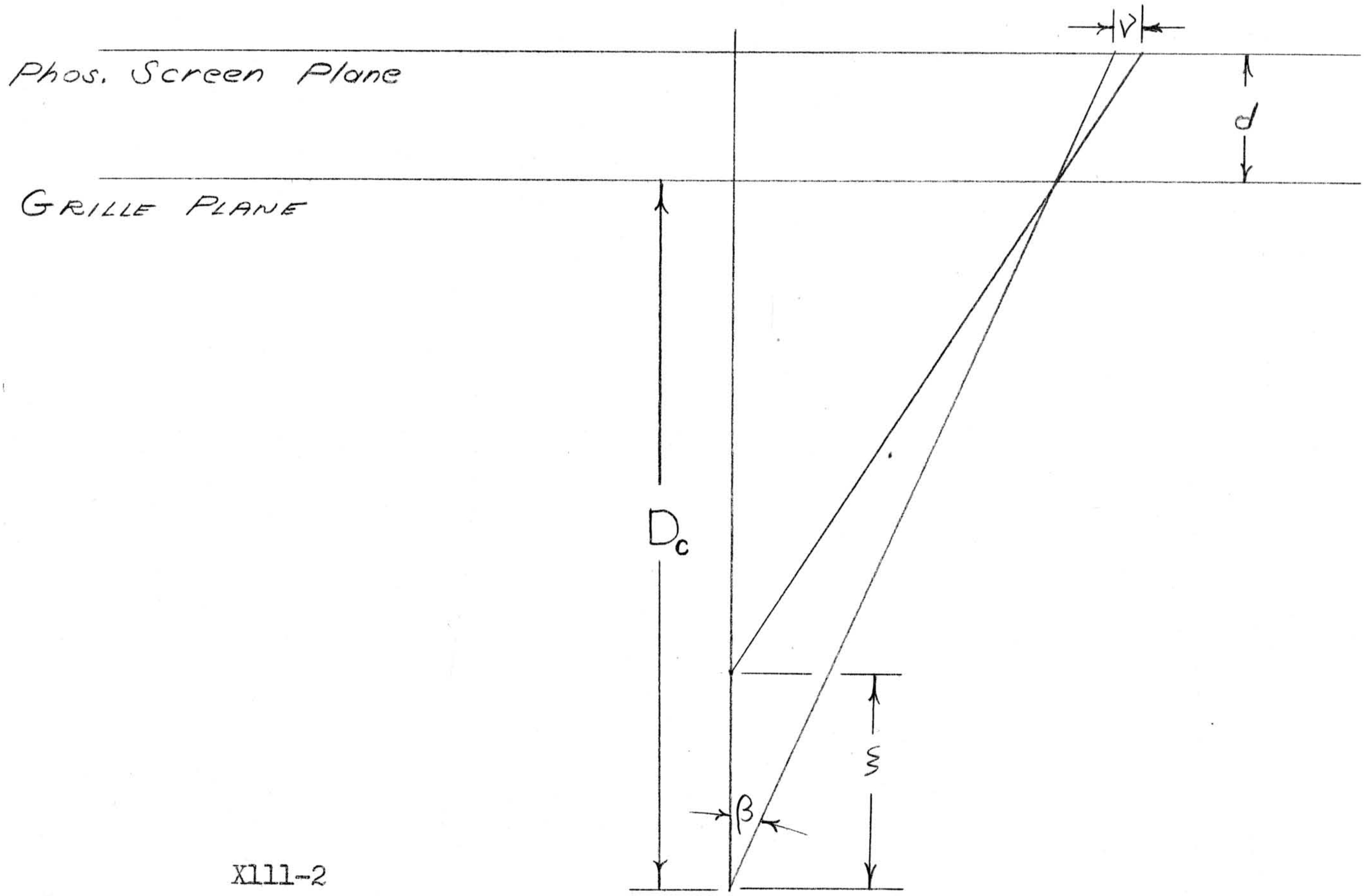
$$h = R(1-\cos\beta) \qquad (2)$$

and

$$\xi = \frac{Y}{2} - \frac{h}{\tan\beta} \qquad (3)$$

Substituting (1) and (2) into (3) we find ξ as a function of β

$$\xi = \frac{Y}{2} \frac{(1-\cos\beta)^2}{(\sin\beta)^2} \qquad (4)$$



X111-2

To transfer this deflection plane shift to a movement of the electron landing area on the phosphor screen, refer to Fig. XIII-2. In this figure the corrected distance D_c must be used as the electrons appear to emerge from D_c rather than the actual distance D (not shown). From the geometry of Fig. XIII-2 and assuming $\frac{\xi}{D_c} \ll 1$

$$\nu = \xi \frac{d}{D_c} \tan\beta \qquad (5)$$

Substituting (4) into (5) and simplyfing,

$$\mu = 4Y \left(\frac{d}{D_c}\right) \frac{\sin^4 \beta/2}{\sin 2\beta} \qquad (6)$$

Figure XIII-3 is a dimensionless plot of the deflection plane shift versus deflection half angle. Figure XIII-4 shows a plot of eq. (7) in terms of the dimensionless variable

$$\left(\frac{\mu}{Y}\right) \left(\frac{D_c}{4\,d}\right) = \psi = \frac{\sin^4 \beta/2}{\sin 2\beta} \qquad (7)$$

Figure XIII-5 shows a plot of this equation for an actual case in which

$$Y = 2''$$

$$d = .830''$$

$$D_c = 20''$$

The displacement, μ, is in mills.

FIG XIII-3

Forward displacement of deflection plane vs deflection half angle expressed in units of yoke length, Y.

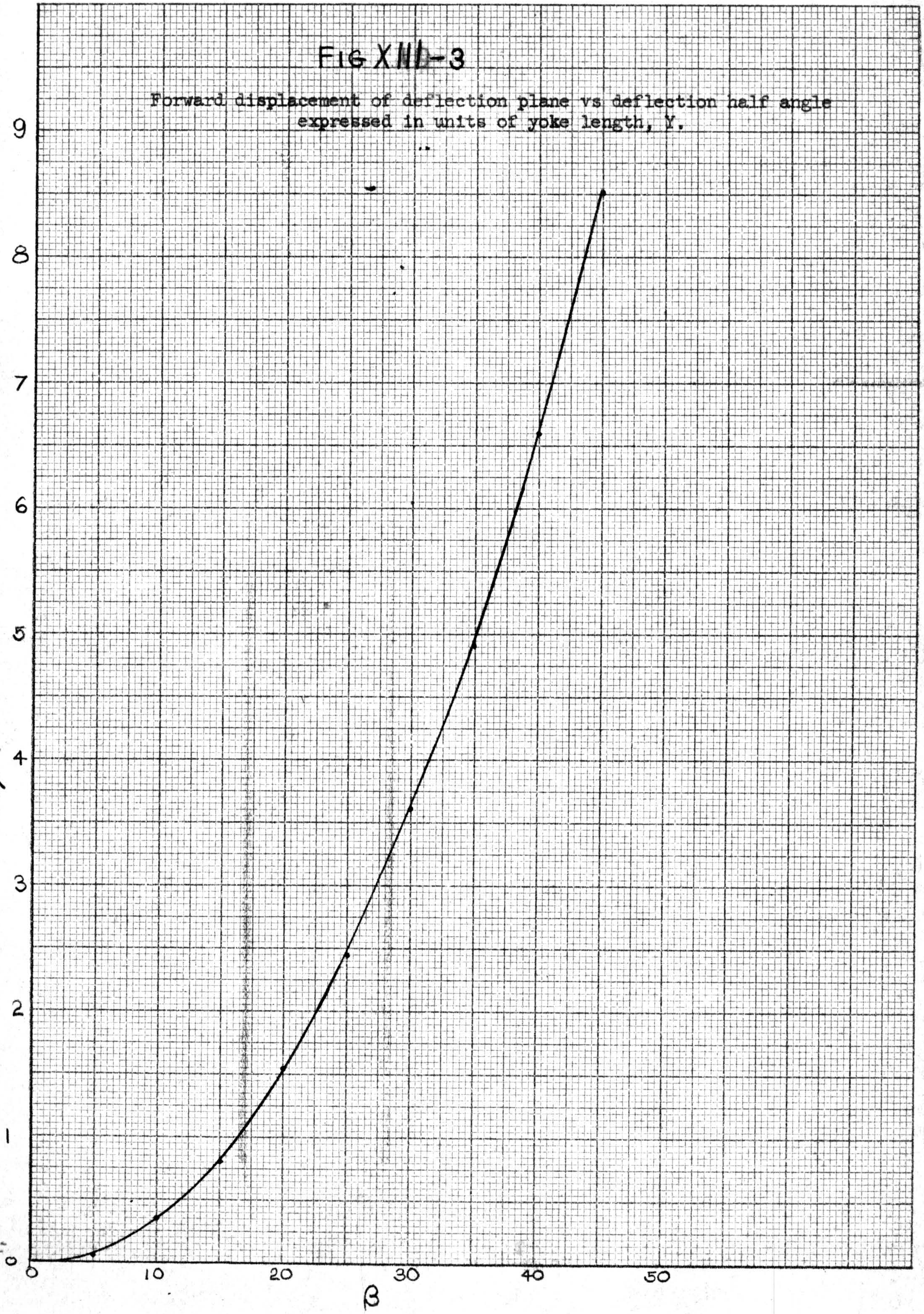
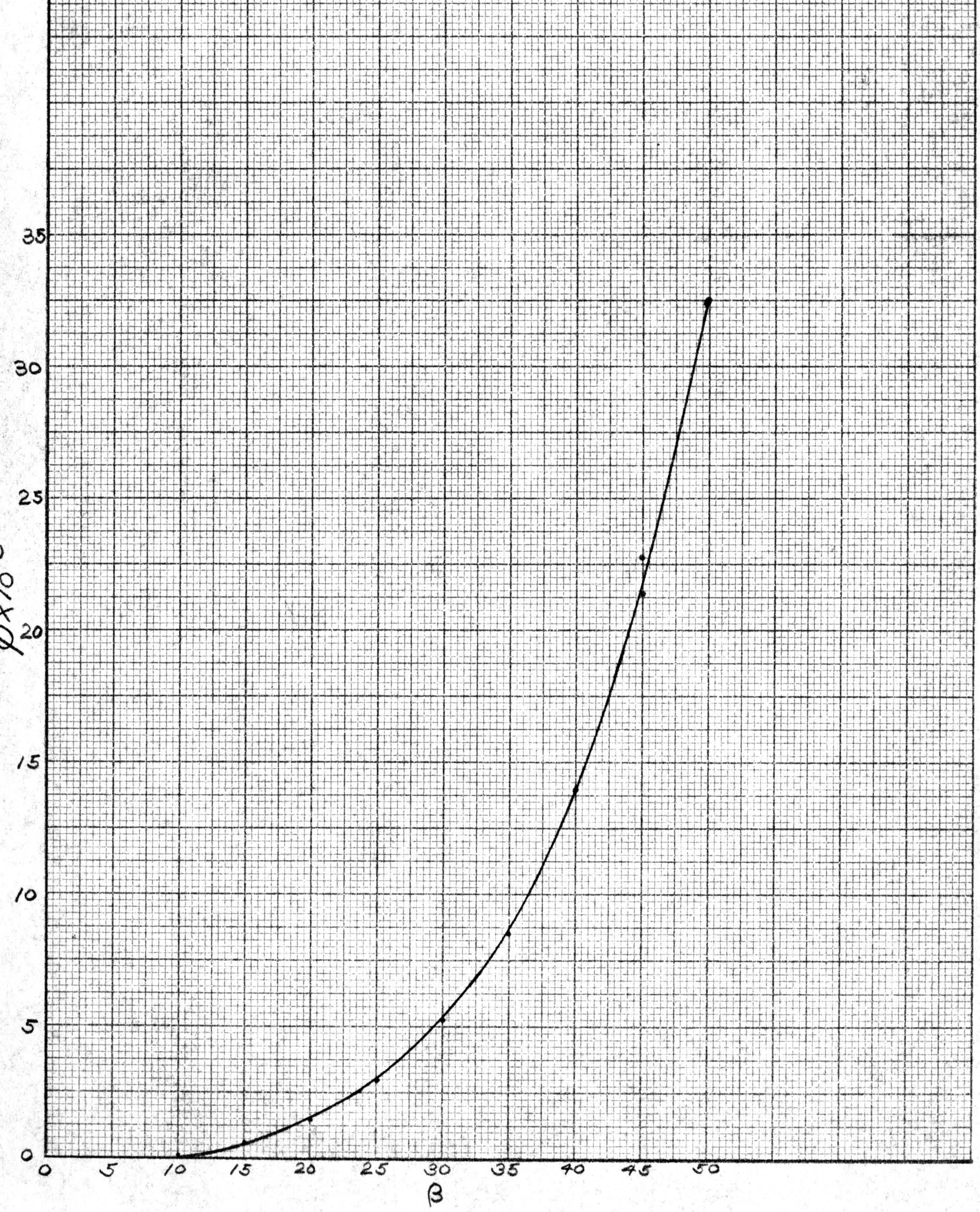


FIG XIII-4

Dimensionless "spot shift" variable ψ versus deflection half angle



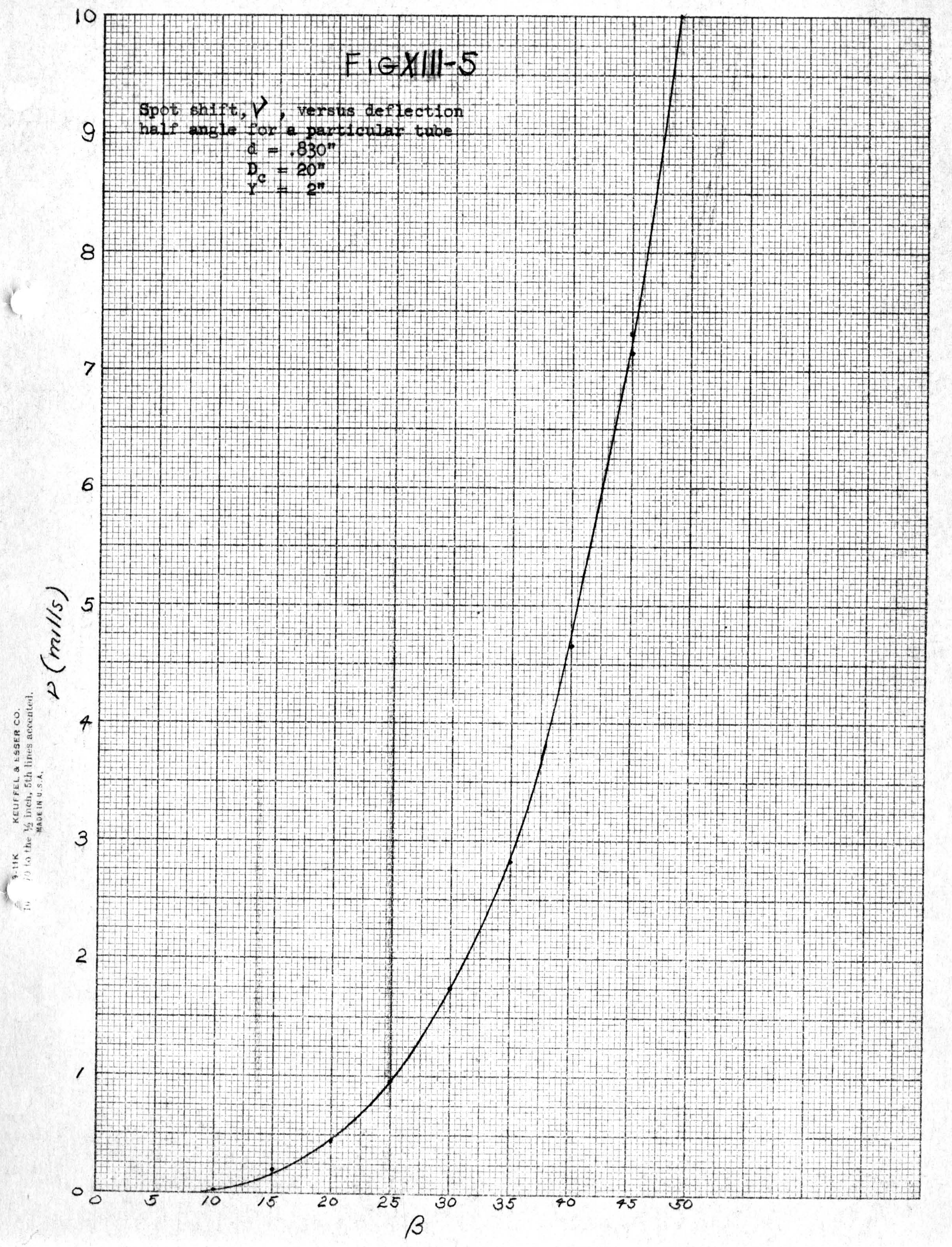


FIG XIII-5
Spot shift, ν, versus deflection
half angle for a particular tube
d = .830"
D_c = 20"
Y = 2"
ν (mils)
β
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
7
8
9
10
KEUFFEL & ESSER CO.
MADE IN U.S.A.

CHAPTER XIV CAPITAL S, LITTLE s, AND COMPROMISE PRINTING

This is to report on the different schemes of providing suitable prints for our color tube. At present, all tubes have compromise prints.

Introduction

T.I.S. 52-E-205-1 of Jan. 16, 1952, from page 2 second paragraph to page 6, will be helpful in understanding this memo, even though in 1951 we had not yet decided between dots or stripes and in the case of stripes they were drawn horizontally instead of vertically as they are printed now. Reference is made to figures and equations of this report.

The pattern transfer from mask to screen via electron trajectories can no more be fully described by an enlargement number. The patterns are not exactly similar. However, exact similitude is approached in the center of the picture (and again in the region close to 180 degrees deflection). The deviations are rotational symmetrical around a point at which the electron ray has perpendicular incidence. This we call the center of distortion. Because of this symmetry, a half plane containing the tube axis (and the center of distortion) is sufficient to show everything. In Fig. 1 of the T.I.S. the upper left side shows one such plane with the definitions for the graph. In the graph itself, straight lines mean similitude, their slope gives the factor of enlargement, , as formulated in equation (2). (For larger values of R/D approaching the equivalent of 180° sweep, the function would approach a horizontal line, similitude would prevail again, and there would no longer be any enlargement.

So, we see that the screen pattern in the center is enlarged by a factor

$$\mu = 1 + \frac{2}{\gamma} \frac{d}{D} \left\{ \sqrt{1 + \gamma} - 1 \right\} = 1 + K$$

and this factor decreases to 1, as the angle of sweep (off axis) increases to 90 degrees. Practical values of the factor K range between 2% and 4%.

If, as the first approximation, the center factor of enlargement prevails over the whole screen, then the point is dislocated at the sides where the angles of sweep are longer. These dislocations are plotted against R/D in graph 3 (as measured in the axial plane) and in graphs 6 and 7 (as displayed in rectangular screen coordinates for stripe-type tubes).

We see the density, Δ, of the pattern or the reciprocal distance between two pitches increases with sweep angle. This density is shown in graph 5, and it should be noted that it amounts to less than 1/2% and is negligible in most considerations.

So far, we have only considered one beam. The two side beam should be spaced in the plane of deflection such that they hit the screen one-third of the enlarged pitch apart from the plane where the center beam hits. Then, the screen area is properly filled in and if the printed line width equals this distance we have full coverage and we have provided the largest possible tolerances.

What do the post-acceleration distortions do to this picture? In relation (1) of the T.I.S., we have to replace R by $R \pm S$, where S is the color base and in the result there will be $r \pm s$ instead of r. In the center, the following relation holds:

$$s = KS$$

The exact rleation, however, reads

$$s = r(R) - r(R - S)$$

or if the difference is approximated by the differential quotient times the interval

$$s = \frac{dr}{dR} S = \left(\frac{r}{d}\right)' \frac{d}{D} S$$

One sees that the line distance decreases proportionally to the derivative $(r/d)'$, which is plotted in graph 4. The normalized curves, which start at the value 1, and only the solid ones should be considered. For the value of $\gamma = 3$ and an R/D value of 0.7 (equivalent of 35° deflection), we find that the line spacing drops by almost 20% to 0.8 of their center value. Of course, these curves hold only along the horizontal center line of the screen. For points off this line, they could easily be displayed in rectangular screen coordinates. This is a sizable effect and its influence on the pattern of the print is shown in Fig. 8. Between the stripe triads there appear areas of unprinted surface. To repeat, this is because the line-to-line distance within the triads shrinks by about 20%, whereas the triad-to-triad distance shrinks only by 1/2%.

S-Printing

The third paragraph on page 5 of the T.I.S. states already that there is no need for three different printing masters, but that in printing the two side colors the stencil should be moved by a distance close to S rather than by one line distance s. The exact value of shift is best found by introducting an integer, n, which is the number of complete stripe triads skipped when shifting from the center color to the side color print. To determine n: form $v = S/s$; find closest integer to v which is of the form $3n \pm 2$. To determine the shift, s' (which is usually a metal block in the printing bed), calculate $S' = (3n \pm 2)s$. Accuracy within .0002" is desirable more for the sake of over-all appearance of the print than for color purity reasons.

For good prints, it becomes essential to have the line width decrease toward the sides. This is achieved by employing variable density filters in the lighthouse. Sherwood Parker investigated this problem in his test assignment here, and wrote a report dated 8/14/53 which is available from CRT Dept. G. K. Wessel employed pre-exposure through the filter, a method which is superior because the troublesome effects of diffuse light from the filter plate itself is eliminated.

Fig. XIV-1 of this report demonstrates the pattern if S-printed in the upper half. (Bottom stripe means electron beam.)

s-Printing

s-Printing was used on the small sweep angle tubes, where the post-acceleration distortions are much less pronounced. In this scheme, the printing stencil is moved by s only. See the upper part of the lower half of Fig. 1 of this report.

Compromise Printing

During the development of the large tube, it became more and more desirable to provide most of the tolerances at the sides of the screen. This led to a scheme of printing, whereby tolerances are sacrificed at center screen in order to utilize the full area available for printing at the sides. s-Printing is used, the line width is the same all over the screen. The color base S, however, is enlarged such that the side color beams hit almost center of the lines at side screen and consequently hit their respective lines further outward at center screen.

The conditions are best understood by looking at Fig. XIV-1 of this report, bottom part of the lower half.

This scheme of compromise printing makes it necessary to use two values for the color base S. One is used in the actual tube, and the other one is used for calculating the tube geometry. The first one usually is a round number of units determined more by the gun design. The other one is an odd number determined by the amount of compromise chosen and within small limits varied such as to obtain a round number of units for the grille screen distance.

Fig. XIV-2 shows the relations again in a more quantitative form.

Figure XIV - 1

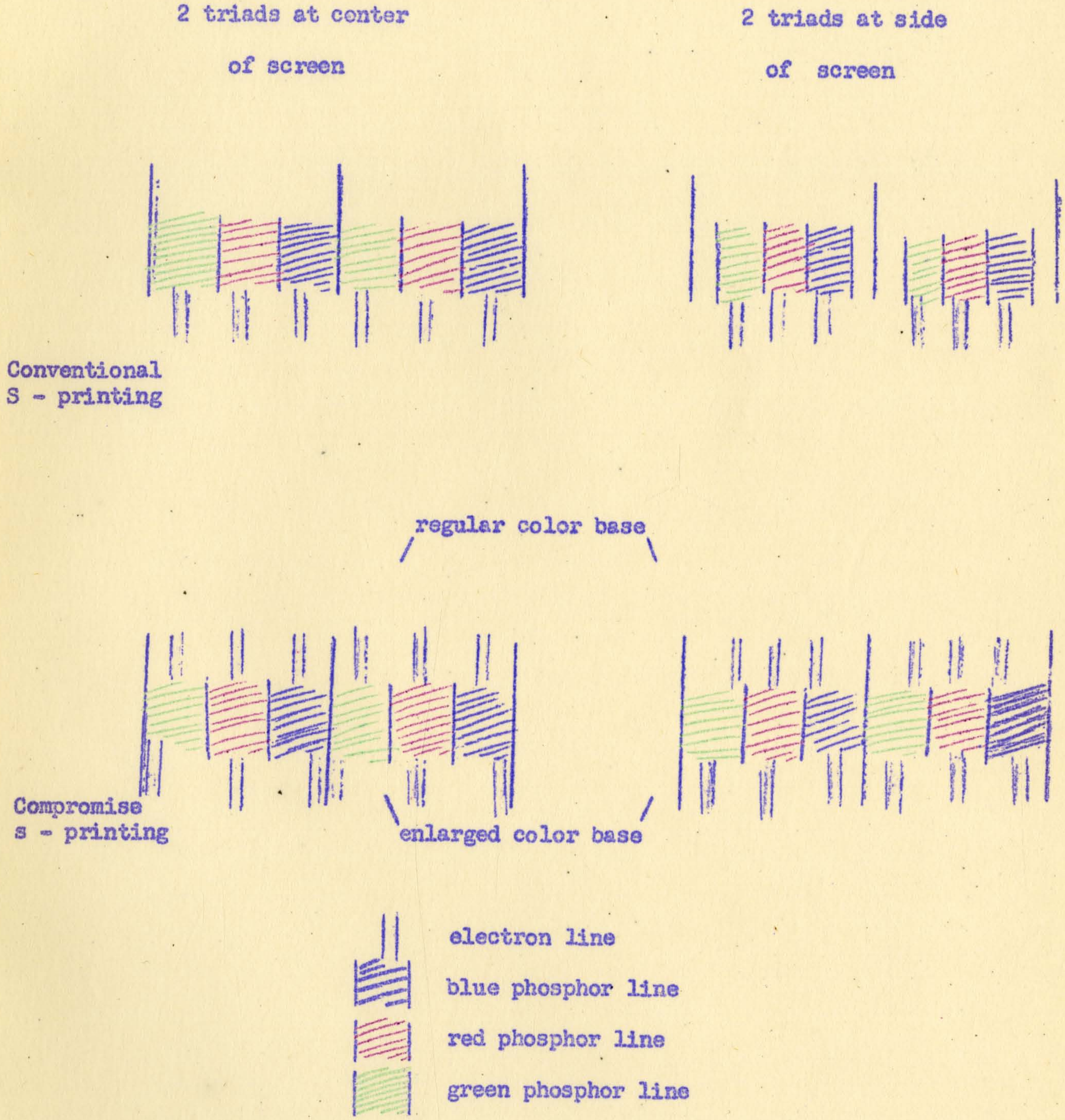
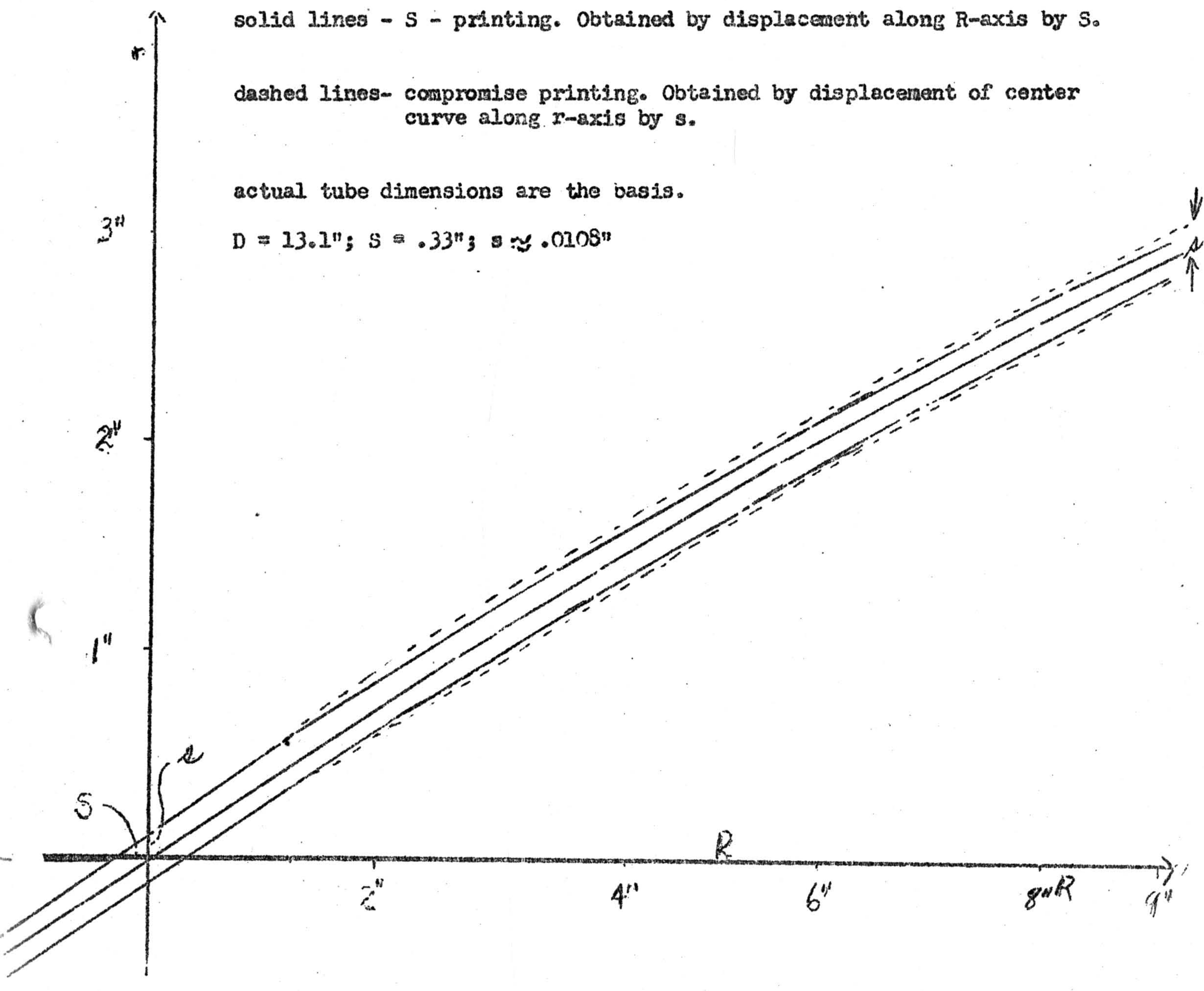

2 triads at center
of screen
2 triads at side
of screen
Conventional
S - printing
regular color base
Compromise
s - printing
enlarged color base
electron line
blue phosphor line
red phosphor line
green phosphor line

Figure XIV - 2

<u>Compromise and S-Printing</u>

in $\frac{r}{d}$ versus $\frac{R}{D}$ presentation



CH XV MAGNETIC EFFECTS ON COLOR PURITY

The purpose of this report is to analyze the effects of the always present magnetic field of the earth or of the steel frame of a building upon our color tube. Though smaller than 1 gauss, this field is sufficient to cause color impurities.

1. The Earth Field for a certain point of the earth's surface is traditionally described by the following three parameters:

a) Horizontal intensity H measured in gauss.

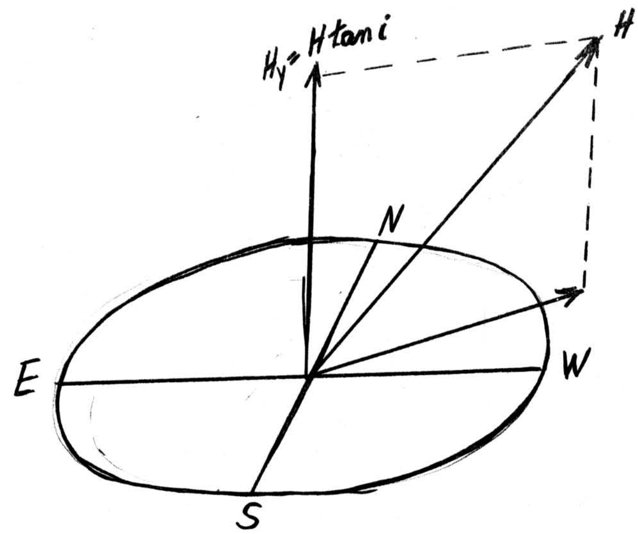


Fig. XV-1

b) Declination, the angle between the direction of H and the geographical north.

c) Inclination or dip, the angle between the magnetic field vector H and the direction of the horizontal intensity H. This angle changes in value from Florida to Maine from 57° to 76°.

The vertical intensity, which is mainly affecting us, can be taken from H and i.

$$\text{vertical intensity} = H \cdot \tan i$$

It is usually not listed in the literature. Its values for continental United States vary from .410 to .630 g.

For New York, we find i = 74°; H = .17; H tan i = .59. From International Critical Table (1929), Vol. VI, p. 445, see maps of H and i on p. 448.

2. Orientation of the tube and notations are shown in the figure: Tubes will always be mounted horizontally. They will all have the stripes in the y direction and consequently will be sensitive only to bends in the x direction. It is apparent that those are caused predominantly by the vertical intensity of the earth field H_y. It should be noted that a rotation of the tube around the Y-axis will not change the amount of color shift that results from H_y.

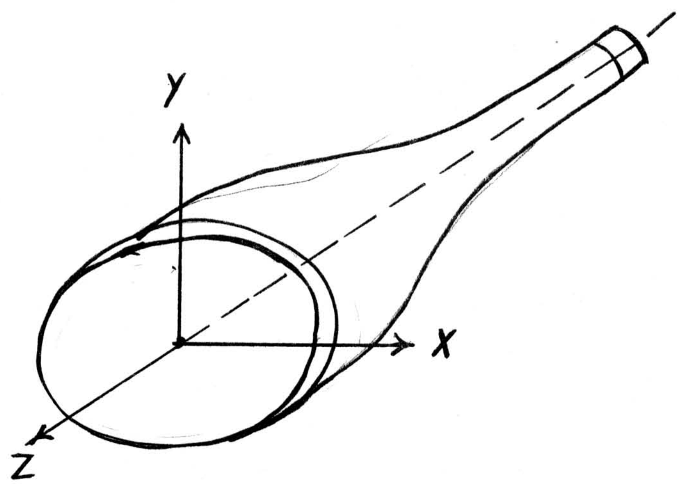


Fig. XV-2

The three field components read

$$H_x = H \sin \delta$$
$$H_y = H \tan i \qquad (1)$$
$$H_z = H \cos \delta$$

where is the deviation of the z-axis from magnetic north.

For the northern hemisphere, the bend is always towards the left for a viewer in front of the screen.

3. The main color shift T_o. We consider only the space between plane of deflection and grille and an electron traveling along the tube axis. For this electron only the H_y component can cause a color shift. Fig. XV-3 explains what is meant with shift of the color center. The undeflected path is dash-dotted, the actual path solid. A tangent to this path at the grille is dashed. AB marks the actual deflection at the screen; CD, which equals AB is the shift of the actual color center C to the apparent color center D.

The radius of the circle BC (not shown in Fig. XV-3) is according to Spangenberg, p. 113. $R = 1.35 \frac{\sqrt{V}}{H_y}$ (inches-volts-gausses)

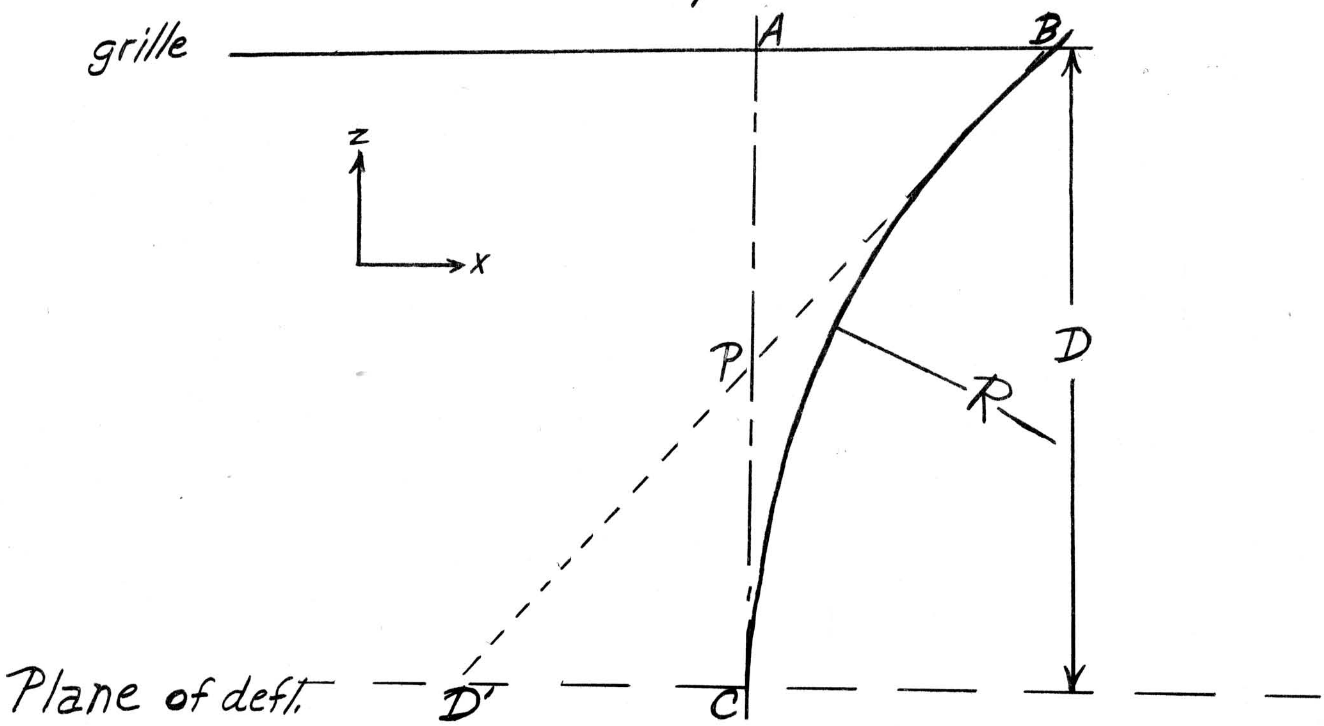


Fig XV-3

For normalized conditions with H_y = .600 G and V = 6000 volts, we find R = 174". T_o as taken from the geometry angle ACB equals half the angle of the circle arc) becomes:

$$T_o = \frac{1}{2}\frac{D^2}{R} = .370\frac{H_y D^2}{\sqrt{V}} = .523'' \qquad (2)$$

For the number it was assumed D = 13.5". So, the central electron spot is moved by .523" in the x-direction or the color center has been apparently shifted by .523" or by 1.75 color bases, or the electron dot at the screen moved by 18.9 mils.

4. a) Electron rays other than the axial one will also have velocity components in the y and x direction. If we introduce reduced screen coordinates

$$\xi \equiv \frac{X}{D}; \qquad \eta \equiv \frac{Y}{D}$$

the 3 velocity components as function of the screen coordinates ξ, and η, and the absolute velocity v read:

$$V_x = \frac{\xi v}{\sqrt{1+\xi^2+\eta^2}}$$

$$V_y = \frac{\eta v}{\sqrt{1+\xi^2+\eta^2}} \qquad (3)$$

$$V_z = \frac{v}{\sqrt{1+\xi^2+\eta^2}}$$

b) Forces: Together with the magnetic field components, these velocities produce certain forces on the electron. Only forces in the x-direction and in the z-direction* are producing color shifts. They are aside from a constant factor.

$$F_x = H_y v_z - H_z v_y$$
$$F_2 \quad H_x v_y - H_y v_x \qquad (4)$$

c) Transit time: For the duration of their flight, which - in good approximation - is assumed to be straight, the electrons gain velocity in direction of the acting force which is proportional to the transit time

$$\tau = \frac{D}{v_z} \qquad (5)$$

d) The velocity increments are

$$\Delta V_x \sim F_x \cdot \tau \quad ; \quad \Delta V_z \sim F_y \cdot \tau \qquad (6)$$

e) Fig. 4 relates this velocity increment to shifts of the color center. Above the line 'grille', a vector diagram of the velocities is shown; below the line, is the usual tube geometry showing the color shifts. One sees that

$$T_x = \frac{\Delta V_x}{V_z} D \; ; \; T_z = \frac{\Delta V_z}{V_z} \xi D$$

and (7)

$$T_z' = \frac{\Delta V_z}{V_z} D \quad ; \quad \frac{T_z}{T_z'} = \frac{X}{D} = \xi$$

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* These forces were omitted in a preliminary report on 1-15-54.

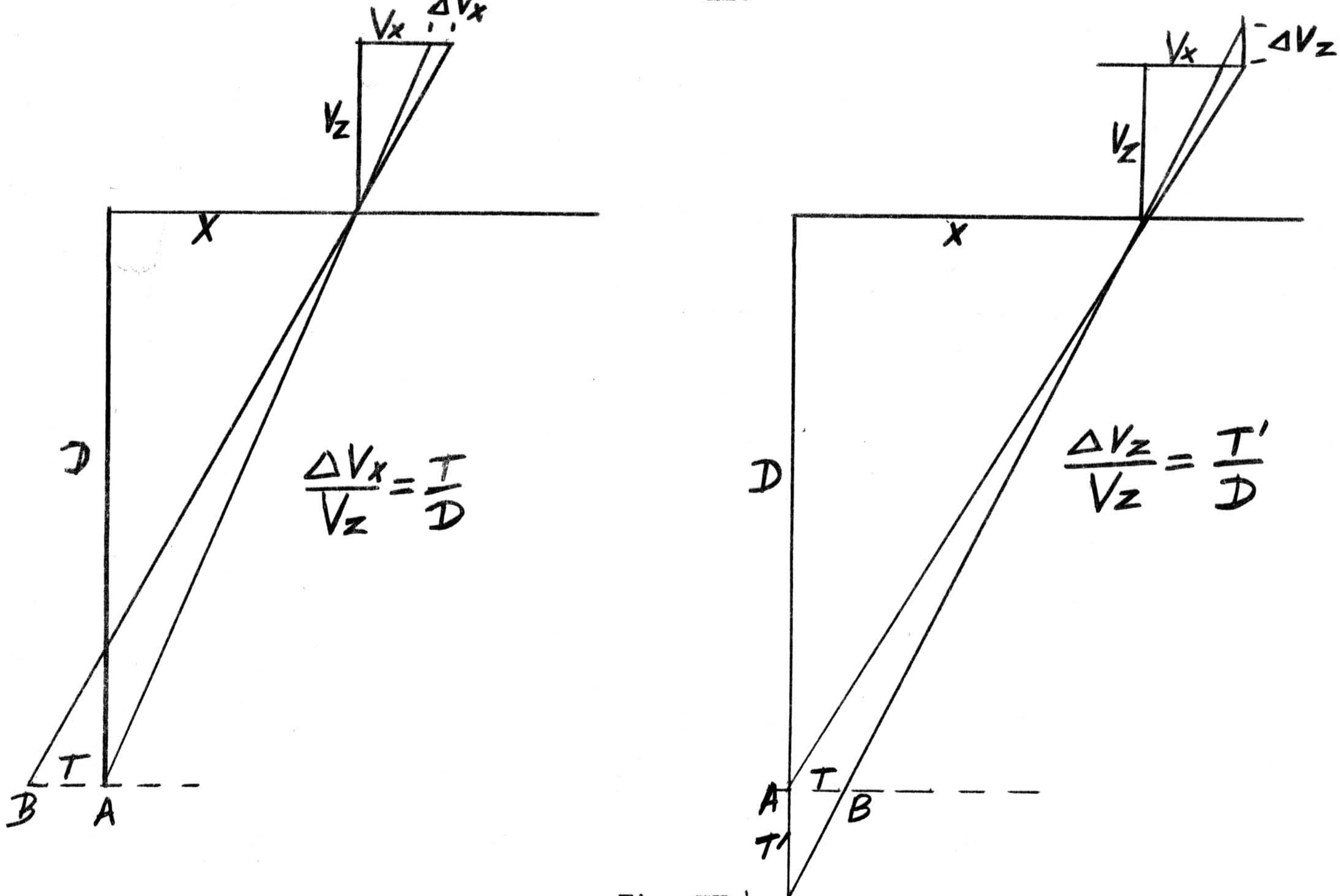

Fig. XV-4

If (6), (5), (4), (3), and (1) are plugged into (7), one finds

$$T_x \sim (\tan i - \eta \cos\delta)\sqrt{1+\xi^2+\eta^2}\,\frac{HD^2}{v}$$

$$T_z \sim (\eta \sin\delta - \xi \tan i)\sqrt{1+\xi^2+\eta^2}\,\xi\,\frac{HD^2}{v}$$

and

$$T = T_x + T_z = \left(1+\xi^2 - \eta\frac{\cos\delta}{\tan i} - \eta\xi\frac{\sin\delta}{\tan i}\right)\sqrt{1+\xi^2+\eta^2}\,\frac{HD^2}{v\tan i}$$

Since the color shift for $\xi = \eta = 0$ was obtained in the preceding paragraph, we can write:

$$\frac{T}{T_0} = \left(1+\xi^2 - \eta\frac{\cos\delta}{\tan i} - \xi\eta\frac{\sin\delta}{\tan i}\right)\sqrt{1+\xi^2+\eta^2} \qquad (8)$$

This derivation has made use of the fact that the deflections are small and that, therefore, the various contributions to T are superimposable. The exact paths of the electrons are portions of a circular spiral situated somehow in the tube coordinates. It is felt that our approach allows a fast survey of the variations in color shift and that the approximation is well justified.

5. Discussion of the Variations. Equation (8) shows 4 terms. Two of them are orientation independent (not containing δ). The shifts are always towards the color to the left and become larger towards either side of the picture, increasing about with the square of the distance off center, like

$$1+\frac{3}{2}\xi^2+\frac{1}{2}\eta^2$$

The two orientation dependent terms are substantially smaller because tan i is about 3.5 and is smaller than 0.5. The first one vanishes and changes sign along the X-axis. The second one vanishes and changes sign along the X-axis and along the Y-axis. The orientation dependence is such that if one of them has its positive or negative peak value, the other one vanishes. Peaks for the first term are at (magnetic) North-South and South-North orientation. Peaks for the second term are at East-West and West-East orientation of the tube axis.

For the present 21" sandwich tube and under normalized condition, the maximum color shift variations amount to ±57% or 10.8 mils at the extreme sides (first two terms). The third term goes to ± 14% or ± 2.7 mil at the top or bottom and the fourth term at either corner goes up to ± 7.9% or 1.5 mil, where opposite corners opposite signs.

6) Ways of Eliminating the Variations were discussed in the preliminary report of 1-15-54. They were employed for tubes to be operated without shield. They consisted of a proper shift of the center of distortion, a proper tilt between grille and screen, and two coils above and below the tube. These means allow one one to keep the dislocations within our tolerances of ± 1 mil. The magnetic shield does not fulfill these requirements as it does not shield the field completely and as it must by necessity be open where the screen is viewed. The author still feels that the shieldless approach is better and more economical.

CHAPTER XVI SECONDARY EMISSION AND BACKSCATTERING OF ELECTRONS

SECTION I SECONDARY EMISSION FROM THE GRILLE

The processing steps of the grille did not include steps of surface treatments of the wire in order to reduce secondary emission.

The post-acceleration tube is sensitive to secondary emission from the grille because secondary electrons once being in the post-acceleration field hit the phosphors unfocused with a velocity of about 15 KV and cause color dilutions and decrease of contrast. One way of reducing secondary emission is to coat the wire with a low emitting surface.

Experiments to find a suitable coating were performed by the Research Laboratory in Schenectady*, as well as by our own laboratory**.

Referred to Nilstain wire, the following metals show a higher secondary emission than Nilstain: Tungsten, Platinum, Gold, Piano wire; less secondary emission than Nilstain is shown by molybdenum, which seems to be questionable, and all carbon coated wires, such as lampblack, graphite, and aquadag coated wires.

Some measurements show the actual differences between some of these secondary emission properties. It has to be considered that the secondary emission ratio depends upon the material as well as on the surface structure of this material. A rough surface usually shows a lower secondary emission ratio than a smooth surface. The following table shows some results for different materials for 5 KV electrons:

Material		δ
tungsten	-	.67
platinum	-	.62
gold	-	.55
piano wire	-	.52
Nilstain	-	.47
surface Titanium	-	.42
" lampblack	-	.37
" aquadag	-	.34
" graphite	-	.28

If secondary emission of the grille is a serious problem, there is still a chance to reduce the secondary emission by spraying with or dipping

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* Memo Report #EC-94, 9-20-54, Lapourky and Whittier.
** Ahlburg, Almasi and Fischer-Colbrie, not yet published.

the grille in carbon emulsions. The maximum reduction of the secondary emission ratio between the presently used uncoated Nilstain and the best carbon coating is according to the experimental set-up about 60%. Although this figure cannot be just transferred into the final tube because of the different conditions like angle and field distributions, it might well show that there is a chance of improvement other than to insert another grille in order to remove the secondaries.

SECTION II BACK SCATTERED ELECTRONS FROM THE SCREEN

In our tube approximately one-tenth of the electrons strike the grille. With a collector potential of 100 to 150 volts about 80 per cent of the secondaries will be collected to the bulb wall. This means that for a secondary emission ratio of 1 we would get a ratio of 2% for the number of secondaries to primaries which strike the screen.

A more serious problem is the contrast deterioration caused by the back scattered electrons from the screen which turn and strike the screen again. The average mean energy of these electrons is one-half the energy of the primary beam. These electrons complete parabolic paths and strike the screen again forming a white halo about four inches in diameter. For the elements whose atomic weights lie below 30, it is found that the back scattering is independent of the primary beam voltage for voltages in the range we use and dependent directly on the atomic weight. The ratio of the back scattered to primary electrons is approximately the atomic weight divided by 100. Thus we see that the aluminum now used is one of the best materials for applying a reflective and conductive coating to the back of the phosphor. Boron and carbon are better by a factor of 2 on the back scattering.

CHAPTER XVII HOW TO CHECK FRONT ASSEMBLIES FOR COLOR PURITY

INTRODUCTION

This chapter will briefly discuss how to check a front assembly after it has been assembled and mechanically adjusted and aligned to the proper dimensions. This test is made electrically by means of a scanned electron beam and may be done either in the demountable station or with the final tube.

The discussion here will deal only with the check on color purity, that is, to determine if the scanned electron beam of one gun (preferably the center gun) hits only one system of phosphor stripes (e.g., the red one) or not. In the case of a perfect front assembly, the electron beam will always hit the center of the stripes. As the electron beam is only about 2 or 3 mils wide when striking the screen with its phosphor stripes (width 11 mils), it will still be possible to obtain color purity even if the beam does not hit the center of the stripes in some regions of the screen. It has to be decided from the check described below if the deviations from perfect color purity are tolerable or not.

A check on convergence of the three colored pictures on the screen, as well as a test on the proper color base, will be given in detail in a report by Richard Gethmann.

THE TEST

After all voltages are applied to the gun, the different components of the front assembly, and cone, the grille voltage should be set to a convenient value and held constant during the test. Then the focus should be adjusted to optimum condition (smallest line width) and G_1 should be set to give a convenient brightness on the screen. The supressor potential may be adjusted so that the secondary electrons from the grid are suppressed. Without any adjustment of the screen voltage, one should see colored bars alternating red, blue, and green and running parallel to the wires. From the appearance of this color pattern it is possible in many cases to determine defects of the front assembly causing color impurities. Some common deviations and their origins will be discussed later in detail.

The comparison of the phosphor line pattern with the line structure of the scanned electron beam has similarities to the check of the grille by means of "interference lines" which has been discussed in Chapter XI. Instead of light and shadows, we now have regions of different colors. The pitches of the two line systems are now not constant but decrease with distance from the center of the screen, thus giving the lines a slight curvature especially in regions close to the sides of the screen. The center of symmetry of the pattern is called center of distortion. For good color purity, the center of distortion has to be identical (tolerance ± 1/8") with the center of the scanned electron beam, that is the beam which hits the area of the screen perpendicularly. Furthermore, the pitch of the scanned beam can be linearly (in high approximation) changed by changing the voltage ratio ψ - i.e., the screen voltage if the grille voltage is kept constant. Thus, the above mentioned colored bars originate from a comparison of two line systems with different pitch*. In a perfect front assembly, these bars should be straight and parallel to the lines, equal in width for all three colors and the colored bars should neither overlap nor show black gaps between them.

Some common deviations are the following:

1) The colored bars are straight and parallel to each other, but not parallel to the lines. This is an indication that the wires of the grille and the phosphor lines of the screen are mechanically not adjusted parallel to each other. Note that the angle between the colored bars and the lines increases when the correct voltage ratio ψ is approached. For the correct ψ (i.e., equal pitch for the two systems), the colored bars run perpendicular to the phosphor lines** and alternate in the sequence of the colors.

2) The bars are straight but not parallel to each other. Cause: the planes of the grille and the screen are not parallel to each other.

3) The bars are very irregular in shape and width over parts on the whole region of the screen. This usually means that the grille frame or other magnetic components are not demagnetized. On non-aluminized screens with the phosphor lines printed on an SnO_2 coating, an irregular pattern might originate from electrical charges on the screen. A criterion for this case is a change of the pattern with increasing or decreasing screen current.

4) The bars are curved. Four common causes for this appearance are:

a) the screen is not flat, but bent;
b) the grille frame is bent (in most cases, saddle shaped);
c) the center of the electron beam does not hit the center of distortion of the screen;
d) magnetic fields distort the electron path.***

In the latter case, the field is often in direction of the tube axis originating from a magnetized grille frame or a magnetized metal flange of the glass envelope of the tube.

5) Irregularities of the bars close to the edges of the screen mainly close to the posts. Cause: fringe fields.

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* If one would compare two black and white line systems (Chapter XI) which are parallel to each other but have different pitch, one would see alternating black and white regions running parallel to the lines.

** This is exactly the case which has been discussed in detail in Chapter XI.

*** See Chapter XV.

6) If bars of different colors have different widths, the phosphor lines of different colors have different line widths.

7) Overlapping of color bars caused by overlapping of phosphor lines.

8) Gaps between color bars originate from phosphor lines which are printed too thinly.

9) Wrong colors showing up all over the bars come from contamination of the screen.

After the appearance of the colored bars has been checked, the screen voltage should be set to almost the correct value for Ψ. An adjustment of the color purity coil should then be undertaken to obtain a symmetric picture - e.g., if the main portion of the screen is red, one should see a green bar on one side of the picture and a blue bar of equal width on the other side. Note that this type of adjustment of the color purity coil is only possible with the center gun. According to the peculiarity of the "compromise printing"* the blue and green bars at the side of the picture should have different widths to obtain perfect color purity when using the side guns. Furthermore, do not try to adjust the "wrong" color with the color purity coil. That is, if using the center gun and if red is the center color, do not try to adjust a blue or green field over the whole screen. Neck shadows might show up and color impurities might be introduced as the center beam is shifted away from the center of distortion by strong fields of the color purity coil. The same is valid for shifting of colors by strong external magnetic fields perpendicular to the axis of the tube.

After the adjustment of the color purity coil, the screen voltage then should be adjusted to the correct value so that possibly the whole area of the screen has the same color.

It then has to be decided if errors of the front assembly are small enough to be tolerated or if the front assembly should be rejected.

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* See Chapter XIV.

CHAPTER XVIII VOLTAGE RATIO REGULATOR

The purpose of this regulator is to keep a constant ratio between the screen and grille voltages in order to preserve the color purity. The basic idea is to maintain the constant voltage ratio rather than to regulate the individual power supplies for constant voltages.

Fig. XVIII-1 shows the circuit of the regulator. This circuit is essentially a high-voltage cathode follower. Thus the cathode voltage follows the grid voltage which, in turn, can be adjusted and maintained at a constant fraction of the screen voltage by means of the potentiometer. Consequently, the output voltage at the cathode bears a constant ratio to the screen voltage. Due to the low output impedance of a cathode follower, the output voltage is essentially independent of load fluctuations and the regulation of the power supply for the cathode follower plate circuit.

Thus, with the circuit connected as shown in Fig. XVIII-1, the ratio between the cone voltage and the screen voltage is constant irrespective of the load variations due to the limiting aperture current to the anode of the gun which is internally connected to the cone. The grille voltage is proportional to the cone voltage. So the ratio between the grille voltage and the screen voltage is also maintained.

Several experimental high-voltage triodes were made for the cathode follower. Fig. XVIII-2 shows the experimental result of the measurement of one of the tubes at a constant load resistance. It is seen that the output voltage does follow precisely the grid voltages, and it is practically independent of the plate voltage variations even though the latter changed as much as 6 KV. For the same tube, the shift of the output potential at 6 KV was less than 100 volts when the load current changed from 560 μa to more than 2.5 ma. This voltage shift is significantly smaller than the simultaneous drop in the plate potential from 10 KV to 7.9 KV. The slight shift in the output potential can be contributed mostly to the small grid current of the experimental tube.

Fig. XVIII-3 shows the construction of the experimental tube. This tube was made with parts from 1X2-A tube and a mesh grid of about 40 meshes per inch. Similar tubes were also made in Owensboro Tube Works using parallel wire grids. This tube, if made available commercially, should be much cheaper than the conventional high-voltage shunt regulator tubes like 6BD4 when the power supplies of the screen and cone are regulated individually for constant voltages at about 27 KV and 7 KV.

The voltage ratio regulator also serves as a protective device for the post-acceleration color tube. During normal operation, the screen potential is higher than the grille potential by the constant voltage ratio. As a result, the grille wires would collect only a very small fraction of the electron current. Thus there is no trouble about the power dissipation of the thin wires. Nevertheless, the situation would be entirely different in case the power supply for the screen becomes accidentally out of order due to, say, burning out of the rectifier tube filament. If the grille is still maintained at high potential, the wires would collect all the electron current and may become hot enough to break apart. With the voltage ratio regulator, the grille potential would always follow the variations of the screen potential. Thus, the grille potential would fall to zero if the screen potential drops out. The color tube is thus protected from the possible damage. The above consideration holds also in the actual receiver during the warming-up period as the color tube is protected even though the high voltage of the grille power supply is building up faster than the screen power supply.

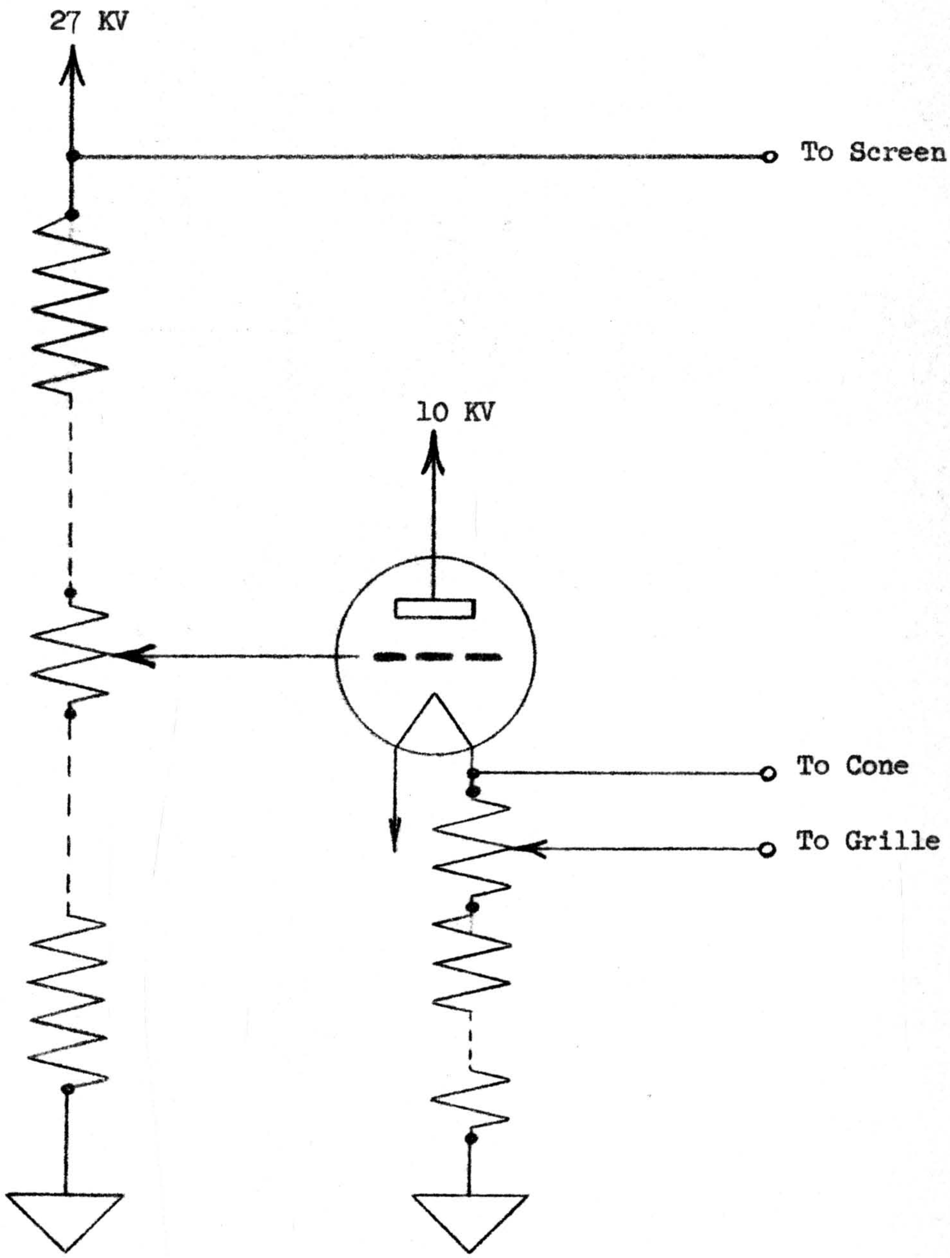


FIG. XVIII-1, VOLTAGE RATIO REGULATOR CIRCUIT

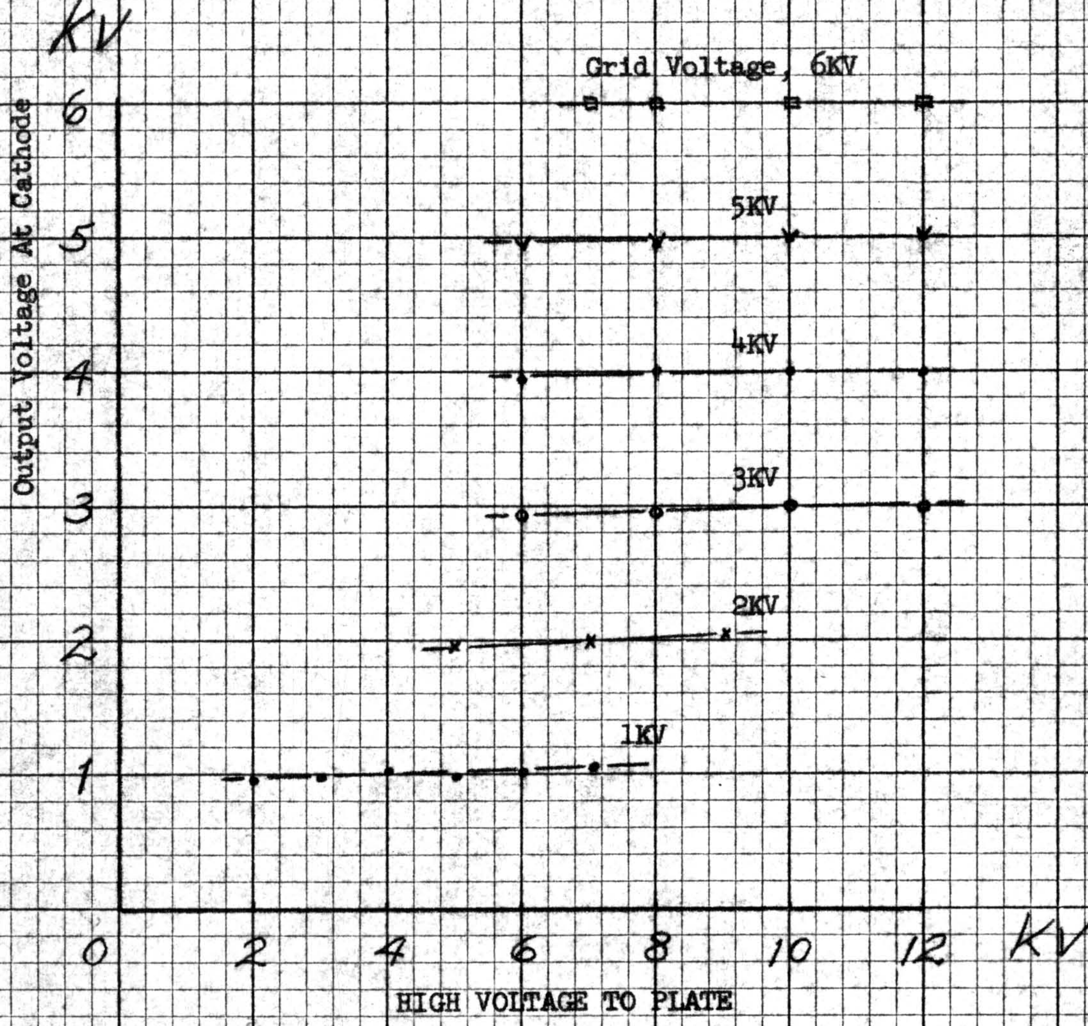
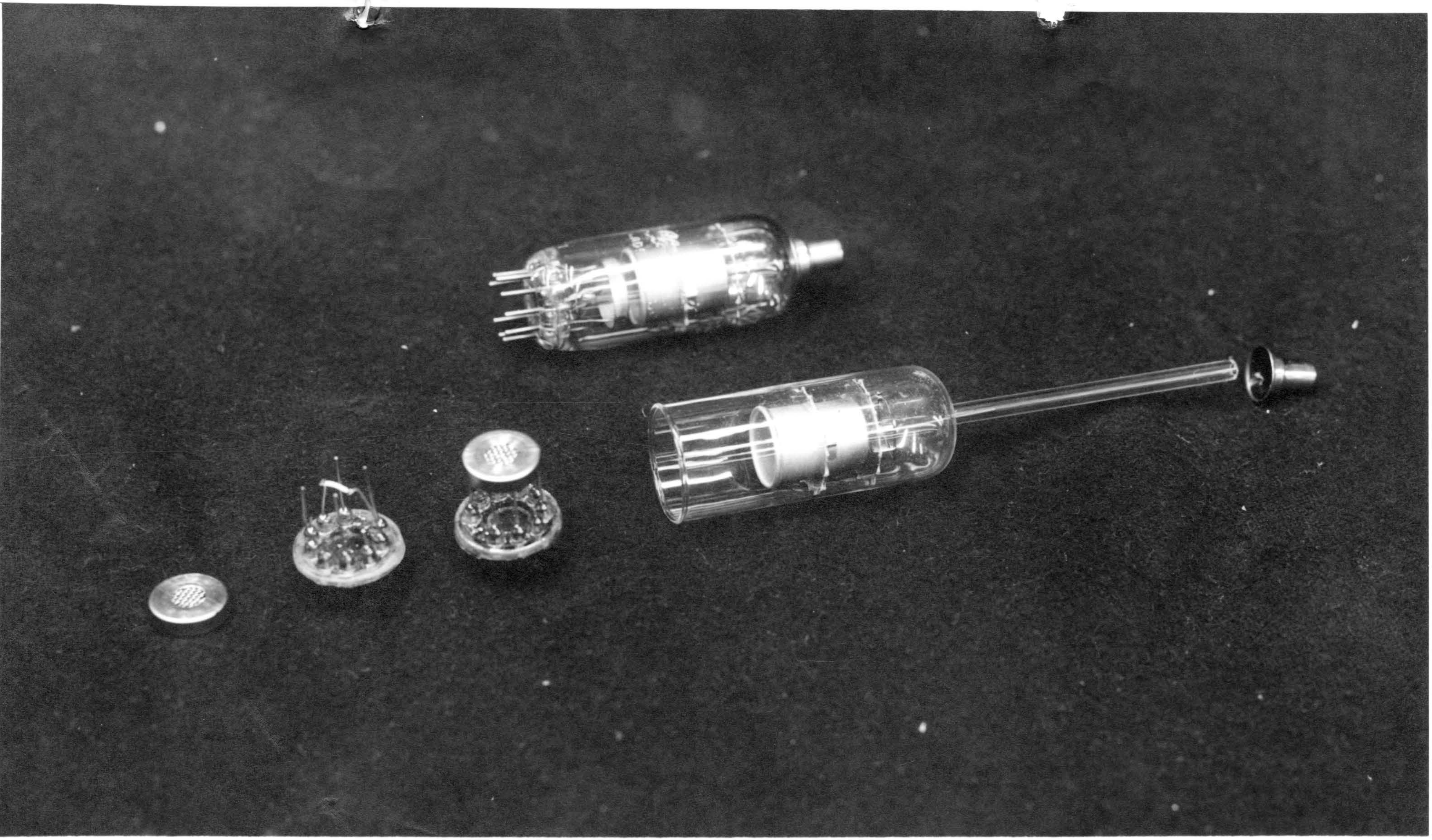


FIG. XVIII-2

Typical regulator characteristics showing the output voltage as being dependent mainly on grid voltage, not plate voltage.



Electronics DIV. 4-6778 VOLTAGE RATIO REGULATOR TUBE FIGURE XVIII-3

DOCKETS OPENED PERTINENT TO COLOR TELEVISION

Phosphor Plate - Grille Assembly for PA Color Picture Tubes - Evans - Seachrist

Quality Control Device - Wessel - Heil

Conductive Cement Suitable for Vacuum Tubes - Fischer-Colbrie

Voltage Ratio Regulator for Power Supplies with Application to Color TV Receivers - Hsu

Grid Mount for Rectangular Color Tube Face Plate - Fischer-Colbrie

Printing Methods for Color Tubes - Hans Heil

Variable Base for Color Tubes - Paul Gleichauf

Application of Dampers to Wire Grids - Almasi - Fischer-Colbrie

Method of Mounting Control Grid into Assembled Gun - Paul Gleichauf

Three Cathode Gun - Paul Gleichauf

Method of Reducing Secondary Emission from Grid Wires in PA Color TV Tubes - H. J. Evans

Method of Decreasing Phosphor Excitation by High Velocity Back Scattered Electrons in PA Color TV Tubes - H. J. Evans

Electron Shield Mount for Post-Acceleration Color TV Tube - H. J. Evans

Grid Mount for Rectangular Cylindrical Color Tube Panel - H. J. Evans

High Voltage Regulation Color Tube - R. Gethmann

Grid-phosphor Plate Assembly for a Rectangular Bulb - H. J. Evans

Devices for Elimination of the Magnetic Shield for Color Television Picture Tubes - Hans Heil

Devices for Convergence of Electron Beams - Hans Heil

A Gated Beam Detection Tube for Color Television Synchronous Detection - Hsu

Color Tube Guns - Gleichauf

Electrode Design to Minimize Defocusing Caused by Modulation in an Electron Gun - Gleichauf

Modified Tri-Color Gun for Post-Acceleration Tube - Gleichauf - Evans

Attachment of Wires to a Frame - Van Velzer

Supports for Mask in Color Tube with Phosphor Deposited on Face Plate - Gleichauf

Thermostatic Grid Frame - Van Velzer

Elimination of Optical Alignment Procedure in Color Tubes with Phosphor Patterns Printed on Face Plates - Gleichauf - Buchwald

Printing of Phosphor Patterns on Face Plate of Color Tubes - Gleichauf

Aperture Frame for Color TV Tube - H. J. Evans

Methods of Fastening Grid Wires to Color TV Aperture Frame - H. J. Evans

Fringe Field Compensation in Color TV Tubes - H. J. Evans

Post-Acceleration Field Corrector - Hans Heil

Spacers to Center Tri-Color Tube Gun Assembly - C. G. Lob

Procedure for Making Photographic Master for Screen Plates in PA Tubes - Hans Heil

Sweep Velocity Modulation in Servo Sweep Tube - Lob - Nonnekens

Electron Gun - Gleichauf - Lob

Preparation of Aperture Mask for Post-Acceleration Color Television Picture Tube - Leyshon

Processing of Secondary Suppressing Masks for Post-Acceleration Color Tubes - Hans Heil

Thermal Conductor to Maintain Uniform Temperatures Throughout a Color Television Tube - H. J. Evans

Use of Space Charge Grid in Cathode Ray Tube Gun Structures - C. G. Lob

Compensated Aperture Mask - C. E. Buchwald

Reservoir Type of Hollow Cathode - H. J. Evans

Improved Cathode Ray Screens - Hans Heil

Method of Mounting Phosphor Screen Plate in Color Picture Tubes - C. E. Buchwald

Aperture Mask-Phosphor Plate Assembly for Rectangular Color Picture Tube - H. J. Evans

Phosphor Plate-Aperture Mask Assembly for Color Television Tubes - Evans - Seachrist

Grid for Suppression of Secondary Electrons in Color Television - H. J. Evans

Internal Grid Control Hollow Cathode for Small Solid Beam - H. J. Evans

One-Piece Hollow Cathode for Cathode Ray Gun - Seachrist - Evans

High gm Cathode Ray Gun - C. G. Lob

Color Picture Tube - Procedure of Producing Photographic Masters for Screen Prints in PA Tubes - Hans Heil

Screens for TV Color Picture Tubes - Buchwald

Color Picture Tube - Hans Heil

Electron Gun - P. H. Gleichauf and C. G. Lob