PROPOSED MANUFACTURING TECHNIQUES
FOR POF TUBES

Prepared for

GENERAL ELECTRIC COMPANY
Electronics Park
Syracuse, New York

by

PHILCO CORPORATION
Research Division
Philadelphia, Pennsylvania

October 12, 1955

PHILCO

RESEARCH DIVISION

PROPOSED MANUFACTURING TECHNIQUES FOR POF TUBES

PHILCO CORPORATION

INTRODUCTION

The POF tube presents a number of manufacturing problems of which the following are probably the most significant:

1. Printing of phosphor lines on the face, of such a shape and arrangement that the electrons will land exclusively on red, green or blue phosphors when they originate from the red, green, and blue guns respectively.

2. Alignment of the grille structure with the phosphor line structure.

3. Alignment of the tube neck with the grille structure.

4. Manufacture of grilles.

This report will describe two general approaches to the problem of printing phosphor lines, buth of which employ electronic methods to produce submasters. The submasters are then used to print phosphor lines by optical methods similar to those used with Apple. The report also discusses suitable methods for solving the remaining problems listed above.

1 (A) PRINTING OF PHOSPHOR LINES - first proposal

It is proposed to print phosphor lines by a combination of electronic and optical techniques. The original conception of electronic printing involved direct electronic exposure for each set of phosphor lines; this implies the assembly, reassembly and evacuation of each tube three times. At each assembly accurate duplication of both mechanical and electrical parameters is essential.

The present proposal avoids these problems. In the first place, a master front panel is exposed for all phosphor lines at once; this embodies in a single panel all the relative accuracy required of the phosphor lines. Submasters for optical printing are made by photographing this panel in a precision camera. Front panels are screened with phosphor by optical exposure in a precision projector. This part of the technique closely parallels Apple methods.

To be more specific about the method, it is proposed to have a demountable vacuum system in which to make the original front panel from which the optical submasters are made. This vacuum system provides (1) a kinematic mount for the front panel (2) a kinematic mount for a grille assembly. These two mounts should be on a common base; their purpose is to permit accurate placement and replacement of the panel and the grille, both relative to each other and to the base. This common base is, in turn, kinematically mounted in the demountable vacuum system in proper relation to the gun-neck assembly. This latter duplicates the corresponding part of the picture tube. Figure 1 shows a demountable system equipped with kinematic mount. Details of the kinematic mount are given in Figure 2.

The demountable system is first used to make a front panel containing information on the placement of all three sets of phosphor lines. This is done by coating a front panel with electron-sensitive emulsion. The panel is then placed on its kinematic mount, together with the grille adapter and grille, both then being on the common base and thus in proper relative location. The base is then, in turn, placed in the demountable on its kinematic mount, so it is properly located with respect to the gun assembly. All three electron guns, the deflection circuits, and the other supply voltages are then activated. The exposure is thus made; the electron focusing and exposure time being such as to give, on development of the panel, a set of opaque black lines with clear spaces between of approximately equal width. These opaque lines locate the positions of every phosphor line, although they do not identify its color.

To provide color identification and thus to enable separate submasters to be made, three more panels are exposed. The original panel will be referred to as panel number 1; the additional panels will be referred to as numbers 2, 3, and 4 respectively. Panel number 2 provides identification of the red phosphor lines. It is exposed similarly to the first panel, with the exceptions that (a) only the red gun is turned on and (b) the electron focus is rendered less sharp, the exposure time is increased, or by other methods the width of the black line on the panel is increased by a factor of about two. This second panel, when developed, will have black lines at the location of the red phosphor lines only; but these black lines will be somewhat wider (perhaps twice as wide) as the corresponding lines in the first panel. The third panel is made similarly, but with green gun alone turned on; while for the fourth panel only the blue gun is activated.

To make a red submaster, a precision camera is used. It has (a) a kinematic mount for the front panel identical with that used in the demountable (b) a photographic lens (c) an illuminant. It is illustrated diagrammatically in Figure 3. The first panel is placed on the kinematic mount, and a precision plate is placed in the kinematic plateholder. An exposure is then made, whereby the plate receives a latent image with lines corresponding to all three sets of phosphor lines. The plate is left in position in the plateholder, while the first panel is removed and the second substituted for it. A second exposure is then made; during this exposure the black lines of the second panel protect the unexposed regions in the plate which correspond to the red phosphor lines. The other unexposed lines are exposed or "fogged" out by the clear spaces of the second panel. Because the black lines of the second panel are somewhat wider than those of the first, minor inaccuracies (such as would arise from differing electrical conditions in the two exposures) can be tolerated, and will produce no inaccuracy in the final submaster plate. The plate is now removed from the plateholder and developed. It will have narrow clear lines determined exclusively from the location of corresponding black lines on the first panel. These clear lines will correspond in position to the red phosphor lines only. The intervening spaces, consisting of broad black lines, cover the virtual locations of the green and blue lines.

A similar process, involving a first exposure from the first panel and a second exposure from the third panel, will provide a submaster for the green phosphor lines. A further application of the method, using panels 1 and 4 in succession, will give a blue submaster.

The submasters are used to print phosphor lines on front panels by exactly the same process as used with Apple. In fact, the same precision projectors can be used, with slight modifications being required to adapt the kinematic mount for the cylindric faceplate used on the POF tube. A typical precision projector is shown, in diagram form, in figure 4.

It would be desirable, when designing the precision camera, to arrange that the front nodal point of the lens lies on the chord of the electron trajectory between grille and front panel. General Electric engineers have shown (at least for plane grille and panel) that this chord is a fixed line for any given arrival angle of the electron beam at the grille; and that it is not changed by moving the panel with respect to the grille. Thus minor variations of the panel surface would not affect the accuracy of line placement on the submaster plate if the nodal point of the lens is on this chord. The same principle should be observed in designing the printing projector by locating the front nodal point as suggested above; this corresponds to the practice, in Apple printing, of having the front nodal point of the projector lens at the effective deflection center. The chord of a given electron trajectory will intersect the axis of the tube in a point which will be called the effective electron center. General Electric engineers have pointed out that the effective electron center does not remain at the same point as the deflection angle increases, and that correction must be made for this when printing phosphor lines by optical simulation methods. It may be observed here that this is a much more important factor when endeavoring to provide complete optical simulation of the electron path, as has been ingeniously accomplished in the PA tube by means of a correcting lens, than it is for the method proposed here. In the former case it is necessary to keep the light ray in coincidence with the chord of the electron trajectory over the whole distance (about 1 inch) between grille and screen. But in the case of the combined electronic-optical method, departures of the chord only occur during the much shorter distances corresponding to the departure of the panel surface from ideal. Thus it is likely that a very satisfactory compromise can be obtained by placing the nodal point at some location representing the average position of the effective electron center.

It should be noted that this method of screen application lends itself well to the current Apple techniques of separating phosphor lines by inert black lines. This gives substantial ambient protection by covering up the aluminizing in the spaces between the phosphor lines. It also aids the effective accuracy of phosphor line placement because the black spaces are laid down first, from a single submaster. The phosphor lines may then overlap the black lines, since their effective width is determined by the space between the black lines. A suitable submaster may be obtained from the first panel in the above process, by reversal development of the plate after the first exposure. Submasters for red, green, and blue printing could then be obtained by photographing panels 2, 3, and 4 directly.

2 (A) ALIGNMENT OF THE GRILLE STRUCTURE WITH THE PHOSPHOR LINE STRUCTURE

Alignment of the grille structure with the phosphor line structure represents a fundamental problem with the POF tube. There are several methods of approach. All seek to achieve the basic principle of placing the grille structure in the same position relative to the faceplate seated on its kinematic mount (a duplicate of that used in the demountable system) as was the master grille in the demountable. All assume that the working grille is identical to the master grille. Any departures will be accommodated by absorbing some or all of the tolerances remaining in the system after line application.

Location of any rigid body requires the absorption of six degrees of freedom. These may be thought of fundamentally as consisting of translations in three mutually perpendicular directions, coupled with rotations about each of these three axes. In the case of the cylinder defined by the grille wires, one of the axes may conveniently be chosen to coincide with the axis of the cylinder. Of the six restraints required to define its position, one is required to restrain it from motion along the cylinder axis (that is, in a direction parallel to the wires). This one is obviously not critical, and accurate restraint is not necessary. The other five degrees of freedom to be absorbed are (1) translation along the tube axis (2) rotation about the tube axis (3) translation along an axis perpendicular to the wires and the tube axis (4) rotation about this axis, and (5) rotation about the cylinder axis.

One method which appears to have possibilities is similar in general concept to a method originally proposed at the GE. Here the wires, strung on an accurate grille jig are cemented to suitable ridges moulded into the inside surface of the tube face. It is here proposed to modify this by providing the grille jig with kinematic mounting feet identical with those used in the demountable system; for preference the jig itself should be so designed that it can be used in the demountable in the process of making submasters. Such a grille jig is shown as an element of the complete jig system illustrated in Figure 2. It is further proposed to subject the tube panel to a preliminary machining process using a diamond wheel, whereby the tops of the ridges are accurately cut to a cylinder of the proper radius. The machining is performed while the panel is mounted on a kinematic chuck identical to the mount used in the demountable; the base of the same jig used in the demountable system could be used. In this way the axis of the cylinder is always determined accurately with respect to the kinematic mount. If the glass is accurately moulded, the operation need not remove much material. For preference the cut should go a little below the theoretical cylinder, so that in the following operation of cementing the wires in place, the cement may penetrate under the wires. It may be possible to attach the wires by fusing the glass ridge before the jig is lowered; for this purpose a low temperature glass could perhaps be precoated along the top of the ridge. This variation might eliminate the machining operation. It may be desirable to preheat the wires by passing current through them during the fusing operation. After cementing or fusing the wires in place, they are cut away from the jig and the jig is removed. If the wires were fused in place, a coating of conductive material must, of course, be applied.

A more recent proposal of GE is to mount the wires on a separate frame, which is then mounted from extensions of the sealing flange. Assuming that the surface on which the wires are secured is a true cylinder of the correct radius, this proposal poses a problem in mounting the wire frame accurately. It is suggested that a semikinematic mounting be used in which the six degrees of freedom are absorbed by six welds securing the grille in a manner to be described below. Alternatively, in place of welds, the well-known technique of glass beads can be used.

In practicing this method, six flat strips or wires project from the grille frame. These are welded or glass-beaded to six appropriately placed strips or wires welded to the metal sealing flange or inserted in the glass front panel. There are many possible arrangements which can be worked out, depending upon the exact mechanical characteristics of the front panel. Before the welding or beading operation is carried out, however, it is necessary to position the grille assembly with respect to the front panel. This is done by means of a jig having kinematic mounts; the jig could be the same unit as is used in the demountable. An additional unit carrying a set of microscopes is kinematically mounted from the base of the jig. The microscopes have positioning and focusing adjustments. Initially the jig is assembled with the master grille and the microscope unit. The microscopes are focused, and adjusted so that their crosshairs coincide with selected marginal wires of the master grille. The master grille is then removed from the jig base, and the working grille is substituted for it. For this purpose the working grille is secured to a kinematic mount exactly duplicating that provided on the master grille. The working grille mount has adjustments which enable the grille to be positioned with respect to the microscopes. By means of these adjustments, the working grille is positioned so that its wires are in identical space locations with respect to the base of the jig, as were corresponding wires of the master grille. The microscope unit is removed, a front panel complete with phosphor lines is installed on the kinematic mount, and the beads or welds are made. The working grille is thus permanently assembled to the front panel in exactly the right location relative to the phosphor lines. The completed front panel assembly is now removed from the jig, and is ready to be welded to the bulb and neck of the finished tube. It should be noted that both the grille wires and the phosphor lines are in standard relation to the kinematic mount that secures the front panel from its outside surface. The neck and bulb assembly can thus be sealed to the front panel accurately with respect to the cylindric axis of the grille wires.

It is believed that three high power microscopes would be enough for the alignment fixture. Two of them would be focused on the central wire of the master grille, and would center it upon the cross hairs. The third microscope would be focused on a wire near the edge of the master grille. The working grille, when substituted for the master grille, would be adjusted until its central wire was in focus and centered on the cross hairs of the first two microscopes, and then the outer wire would be adjusted until it was in focus in the third microscope. The adjusting means would preferably be so arranged that the final adjustment rotates the working grille assembly about the central wire, so as not to disturb the adjustment previously made on the central wire. The first two microscopes take care of two degrees of freedom each (focusing and centering on cross hairs) and the third microscope adjusts one degree of freedom (focus). The sixth degree of freedom is that of motion along the direction of the wires; this does not need to be closely controlled, so a simple stop can take care of this.

An interesting variation of the above method would be to adjust the grille by observing the beat pattern formed when the grille is shadowed onto the front panel. For this purpose a point light source is arranged to be at the effective electron center. Since the location of this point varies somewhat with deflection angle, a true zero beat would not be obtained over the whole screen; but by adjusting for zero beat in the center section, and for symmetry in the outer regions, it should be possible to obtain proper placement of the grille. This method can only be used if the aluminizing is somewhat transparent.

Instead of using the technique of adjusting the working grille to coincidence with the master grille, it would be possible to make all grilles interchangeable. They could then be mounted to kinematic locators (for example, three vee grooves) cast into the inner surface of the front panel. The master grille could then be one of the working grilles. Because the grille is located from the internal surface of the panel, its location is not determined exactly by the external mount which must be used when assembling the tube. If it is desired to regain this location, the front panel could be chucked by its internal kinematic mounts, while six external spots are ground in accurate relation to the internal mounts. This operation would be required on all panels, but would not be difficult to do.

As an illustration of a method of mounting interchangeable grilles using location entirely from the external surface of the front panel, Figure 5 is presented. This shows a jig identical to that described earlier, to which the interchangeable grille is mounted by kinematic feet engaging the grooves provided on the grille adapter section, and originally used to mount the grille jig. This unit can be used in the demountable system to make submasters; having served that purpose, it can be used to assemble interchangeable grilles to phosphor-screened panels. The grilles are secured by glass beading, welding, or brazing to extension lugs forming part of the metal sealing flange. There are three lugs illustrated in Figure 5; it is intended to have clearance holes in these lugs, and stiff rods attached to the grille frame passing through these holes. The holes are sufficiently oversize for the rods to permit the location of the grille to be determined by its kinematic mounts. The location so determined is made permanent by beading, welding, or brazing. To render this practical, while still permitting adequate hole clearance for the rods, washers can be used; these fit the rods with small clearance, but are larger than the holes in the lugs. This will keep the clearance low so that capillary forces will be sufficient to retain the glass bead, or brazing metal.

1 (B) PRINTING OF PHOSPHOR LINES - Alternative Proposal

The first proposal closely parallels Apple techniques, and the equipment for Apple printing could be easily adapted for printing POF tubes. A second proposal, now to be described, illustrates some interesting alternatives.

The basic idea of the second proposal is to have cylindric or toric submasters, which duplicate the internal surface of the tube fairly closely, and in use are held a small distance away from the internal surface while exposure is made optically onto the sensitized front panel. Exposure is made from a point light source placed at a compromise electron center (possibly compensated by a correcting lens as used in the PA tube).

The cylindric submaster is made by electron exposure. Three submasters are required for red, green, and blue phosphors respectively. After exposure, these plates are developed and reversed. If a black line tube is to be made, a fourth submaster is made with all three guns turned on; this can be developed normally, not needing reversal. The black line technique is particularly desirable with cylindric submasters, because it enhances the precision by avoiding the variations due to the separate assemblies and evacuations required in making the red, green, and blue submasters.

In one method of making cylindric submasters, the grille structure is kinematically mounted from the inside of the front panel. All grilles are interchangeable, being manufactured by methods suggested below. Two of the grille frames have kinematic mounts for the submaster; one of these, equipped with grille wires, is used as a master grille; the second, with grille wires omitted, is used to mount the submaster plates during their use for printing the panel. The master grille, with an unexposed submaster plate mounted to it, is placed in a front panel which then becomes part of a demountable system with mounting facilities exactly as described in connection with the first proposal. Electron exposure is then made, using red, green, blue, or all three guns, as required. The exposed submaster is then developed and reversed as required.

In use, the proper submaster is mounted on the second special grille frame, installed in the previously sensitized front panel, and exposed in a lighthouse unit from a point light source. Whether a correcting lens is required depends upon whether a compromise light source location can be chosen. Inevitably the light rays suffer some refraction in passing through the submaster plate. This may cause the printed line to depart somewhat from the location it would have had if the electron beam had made the exposure directly on the inside of the front panel. Because of the glass refraction, the correction may be more or less than that required for complete optical simulation from a grille located in the working position.

A demountable system for making submasters by this technique is illustrated in Figure 6; while the setup for phosphor printing is shown in Figure 7. It can be seen that the vacuum system can use parts of the equipment used in carrying out the first proposal.

2 (B) ALIGNMENT OF GRILLE STRUCTURE WITH THE PHOSPHOR LINE STRUCTURE

Since the alternative method, as described, uses interchangeable grilles kinematically located from the inside of the panel, grille alignment is automatically obtained. It is, of course, possible to have variations from the method in the form described above. For example, the kinematic locators in the inside of the panel could be omitted, and both the cylindric submaster and the grille could be jigged from the external surface of the tube by means of the same fixture used with the first proposal. Methods of grille alignment would then be the same as those described under 2 (a) above, and would include (1) jigging the panel from the external surface (2) jigging the master grille from an external kinematic mount (3) adjusting the working grille by microscopes or beat pattern techniques (4) providing accurately machined cylindric glass ridges inside the tube to enable cementing the grille wires to the panel.

3. ALIGNMENT OF TUBE NECK WITH GRILLE STRUCTURE

The method to be employed here depends upon the accuracy desired, which in turn is controlled by the degree to which external compensations can be applied to the beams to correct for inaccuracy of neck and gun location.

It should be remembered that the grille axis is accurately fixed with respect to the outer configuration of the front panel; in those methods where external mounts are used, or where external ground locating areas are provided in true relation to internal locators, it is determined by the standard kinematic mounts that have been used in the various processes. If a similar mount is used during the sealing process, together with an integral jig unit for the neck, it should be possible to obtain good accuracy. The best grade of accuracy would undoubtedly be obtained if the seal is made in two operations, namely (1) seal the bulb to the front panel and (2) seal the neck to the bulb-panel assembly on a Chinese hat sealing machine as used for Apple. Where internal locators are used, and external ground locating areas are not provided, some loss of accuracy must result.

4. MANUFACTURE OF GRILLES

When all grilles must be interchangeable, some or all of the following methods must be used in their manufacture:

1. All grille frames must be provided with identical kinematic mounts. These could be three ball end studs accurately inserted into the frame. These studs would engage the kinematic grooves provided on the inside of the panel, or on the assembly jig.

2. The mounting surface for the grille wires should be machined to an accurate cylinder, precisely located with respect to the ball studs. If the mounting is to be from the inside of the panel, it would appear to be preferable to use the concave side of the frame for wire mounting leaving the convex side available for the mounting studs. Otherwise, the convex side should be machined, and the studs placed on the concave side.

3. Fine grooves for locating the wires could be photo-etched into the cylindric surface. Exposure for the photo-etching would be made with the frame located by its mounting studs.

4. Attachment of the wires would be made in exact relation to the mounting studs, either by means of method 3 above, or by using a winding machine with a chuck which locates by the mounting studs, or both.

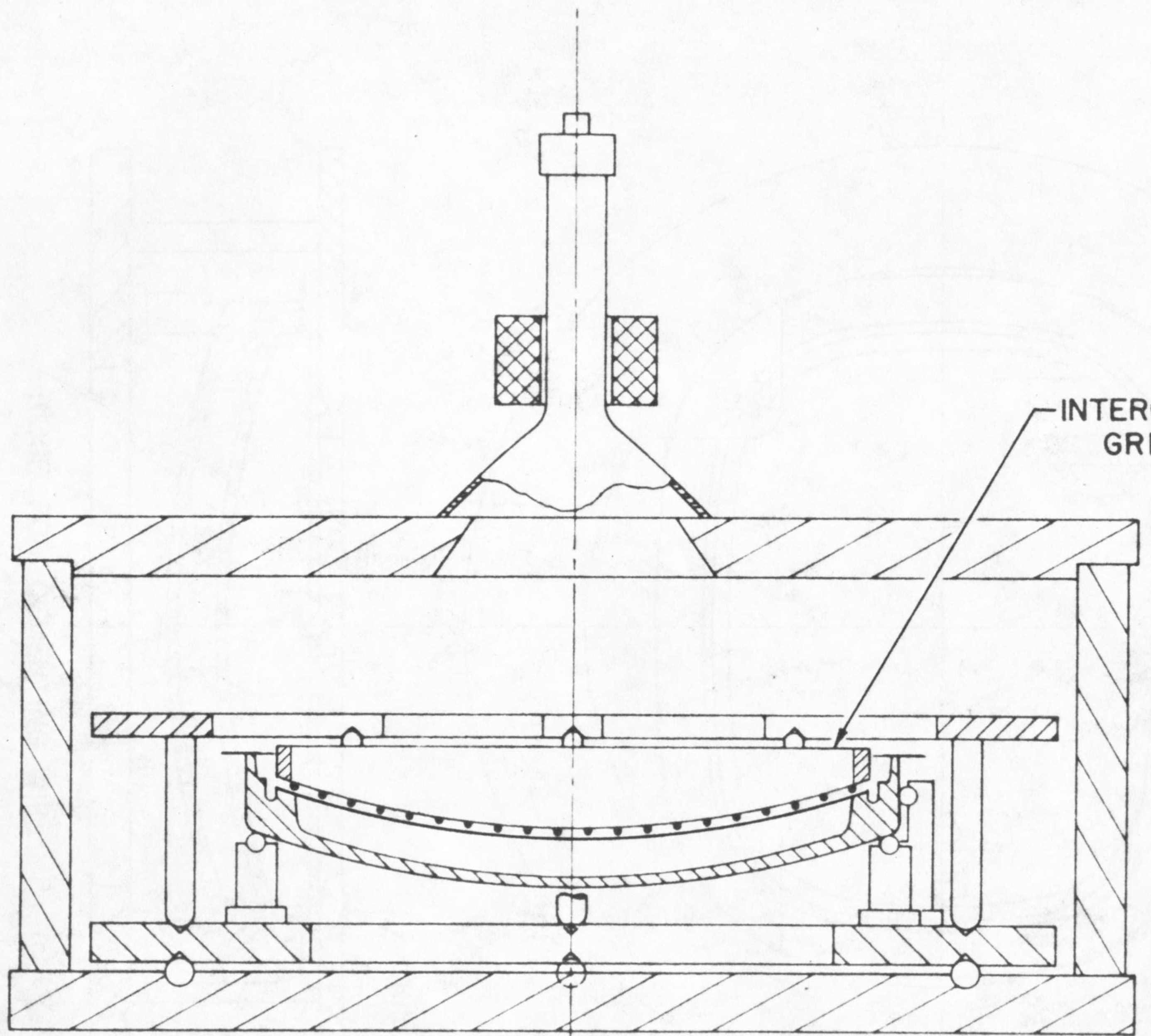
It would be desirable, in any form of grille structure, to use soft temper wire and subject it to stretching beyond its elastic limit sufficiently to provide a definite elongation. This would serve both to straighten and work-harden the wire. Probably less tension would be needed to make a satisfactory grille.

Methods of loading the grille wires onto a grille jig are worth study. It should be possible to weld the wires to a stainless steel wire of about .040 inches diameter clamped in a groove in the frame. The welding would be done by a spot welder indexed from wire to wire while they are held under tension in a loom such as is already in use at GE. The welder would be similar to the type used for welding grid wires to grid support rods. The 40 mil wire is discarded after it has served its purpose and the wires are cemented to the panel and cut away from the jig.

The method of welding could probably also be applied to construction of interchangeable masks on frames. By forming the frame of stainless steel, a very light construction could be achieved. It is even possible that the grille frame might be pressed integral with the tube sealing flange, and machined after the flange is sealed to the front panel; the machining operation being arranged to cut the cylindric surface in proper relation to the kinematic panel mount. The welding operation would be done while the wires are held in a grille jig used as previously described. This should make a very light but strong construction, though it would require somewhat more tooling than other methods.

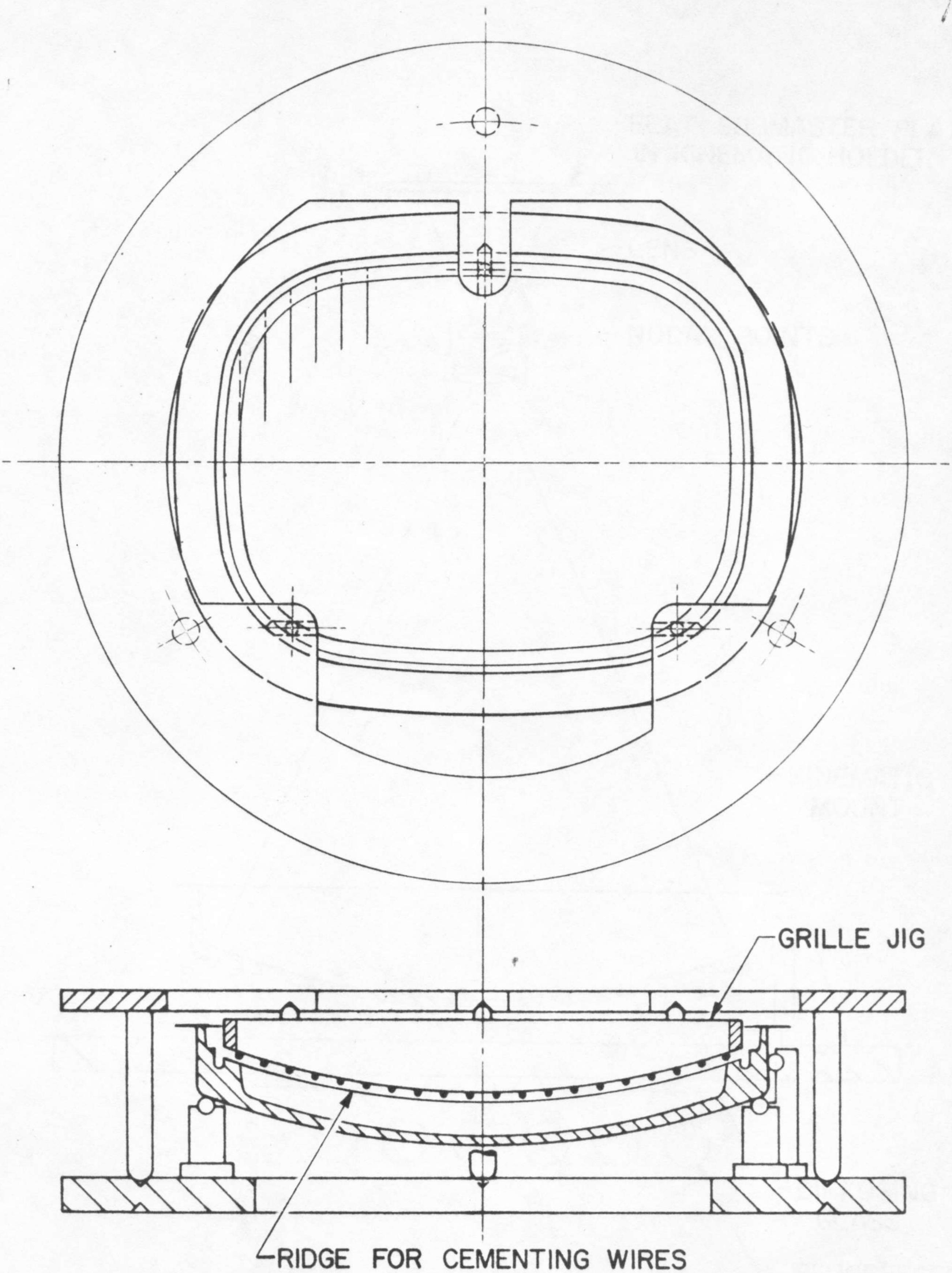
Proper tensioning of the grille wires is important. When the grille frame is released from the grille jig supporting the wires, their tension is applied to the grille frame. It may be desirable to attach and cut the grille wires one at a time (or a small group at a time) so as to permit their load to be applied gradually to the frame. The resulting strain or distortion of the frame will then not loosen previously attached wires. By choosing a proper order of attachment of the wires, together with preselected and different initial tensions on the wires in the jig, it should be possible to obtain a frame in which the wires have essentially equal tension.

F. J. Bingley



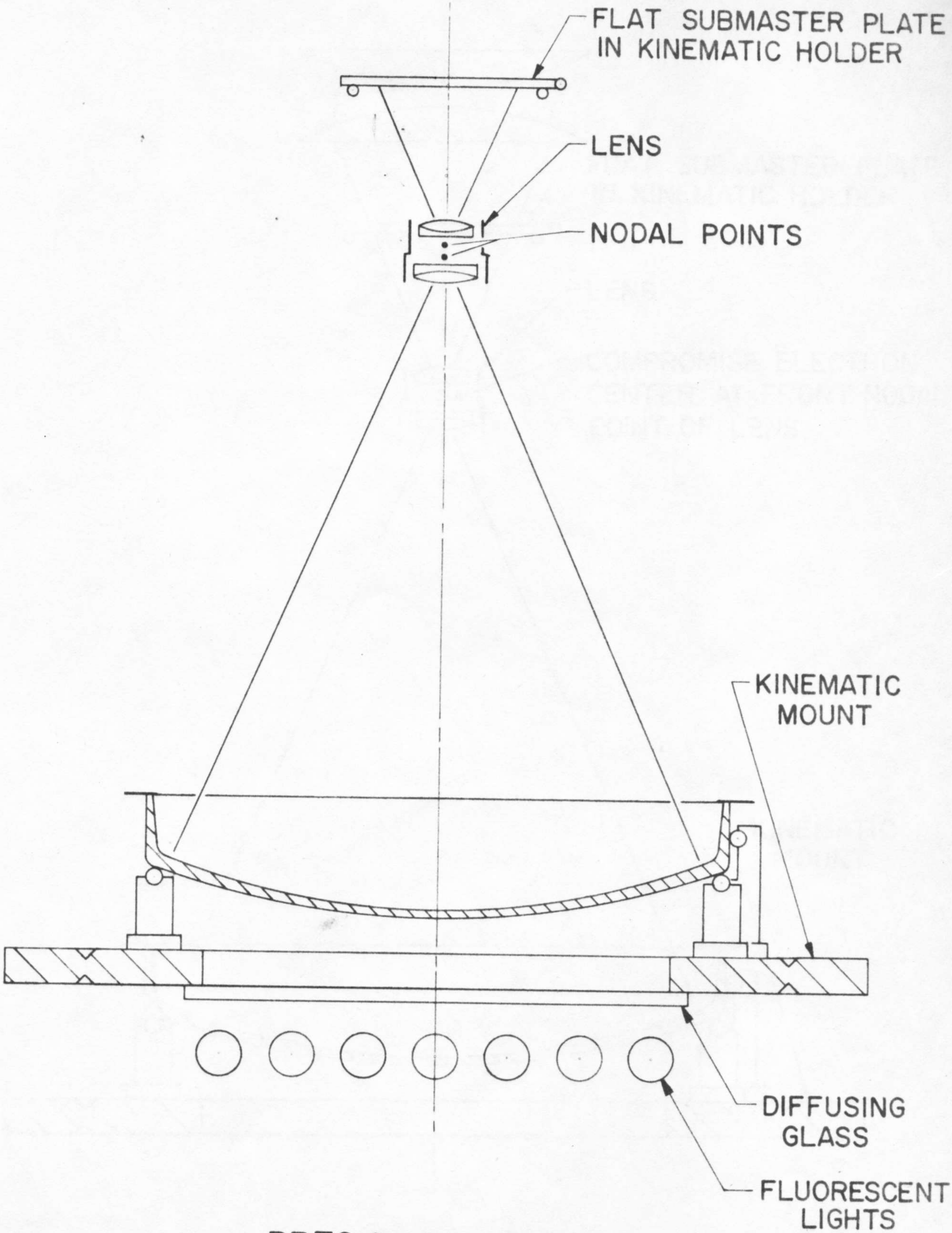
DEMOUNTABLE VACUUM SYSTEM

Fig. 1



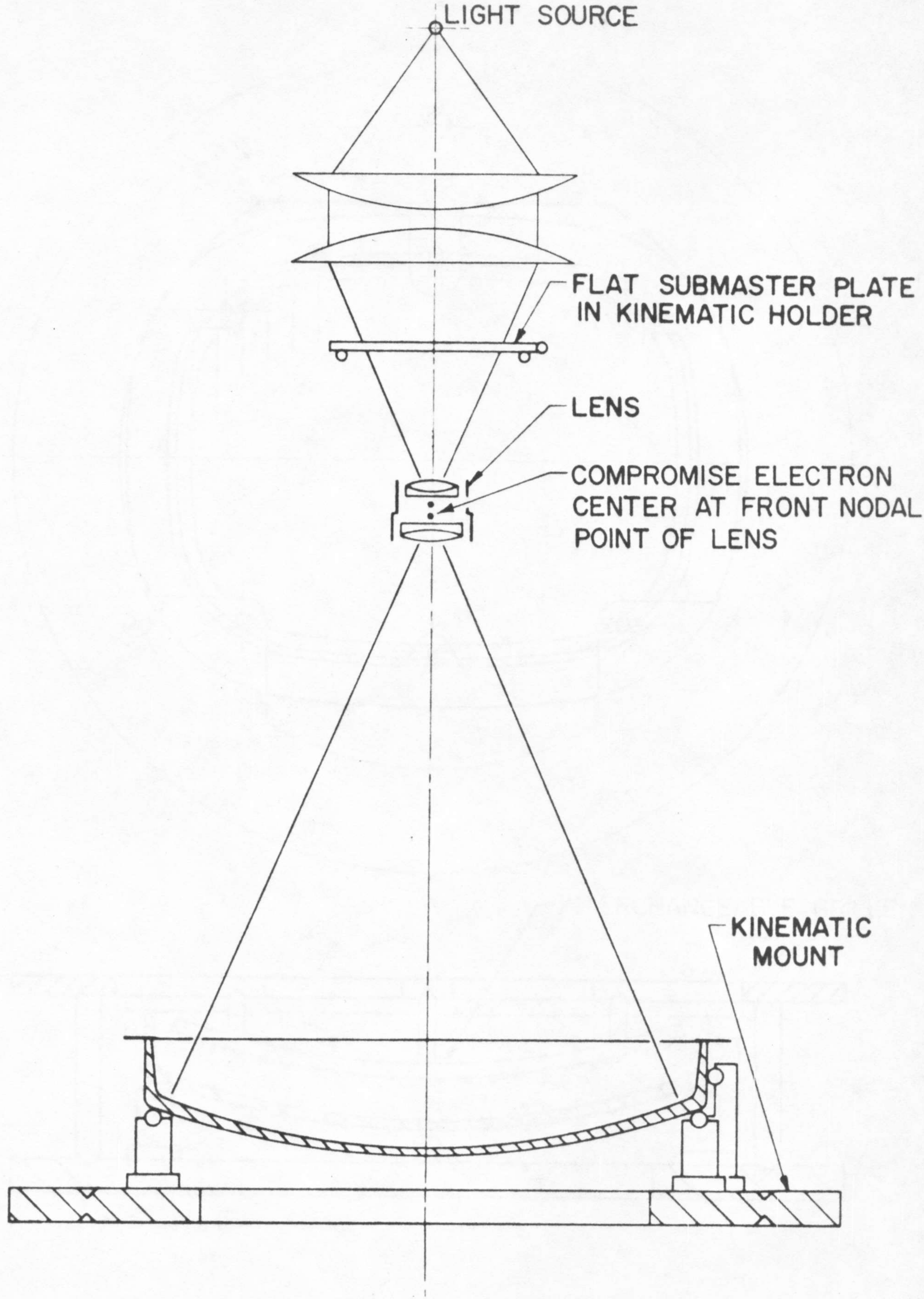
JIG FOR INSTALLING GRILLE
WIRES CEMENTED TO RIDGE INSIDE FRONT PANEL
(ALSO USED IN DEMOUNTABLE SYSTEM
FOR MAKING SUBMASTERS)

Fig. 2



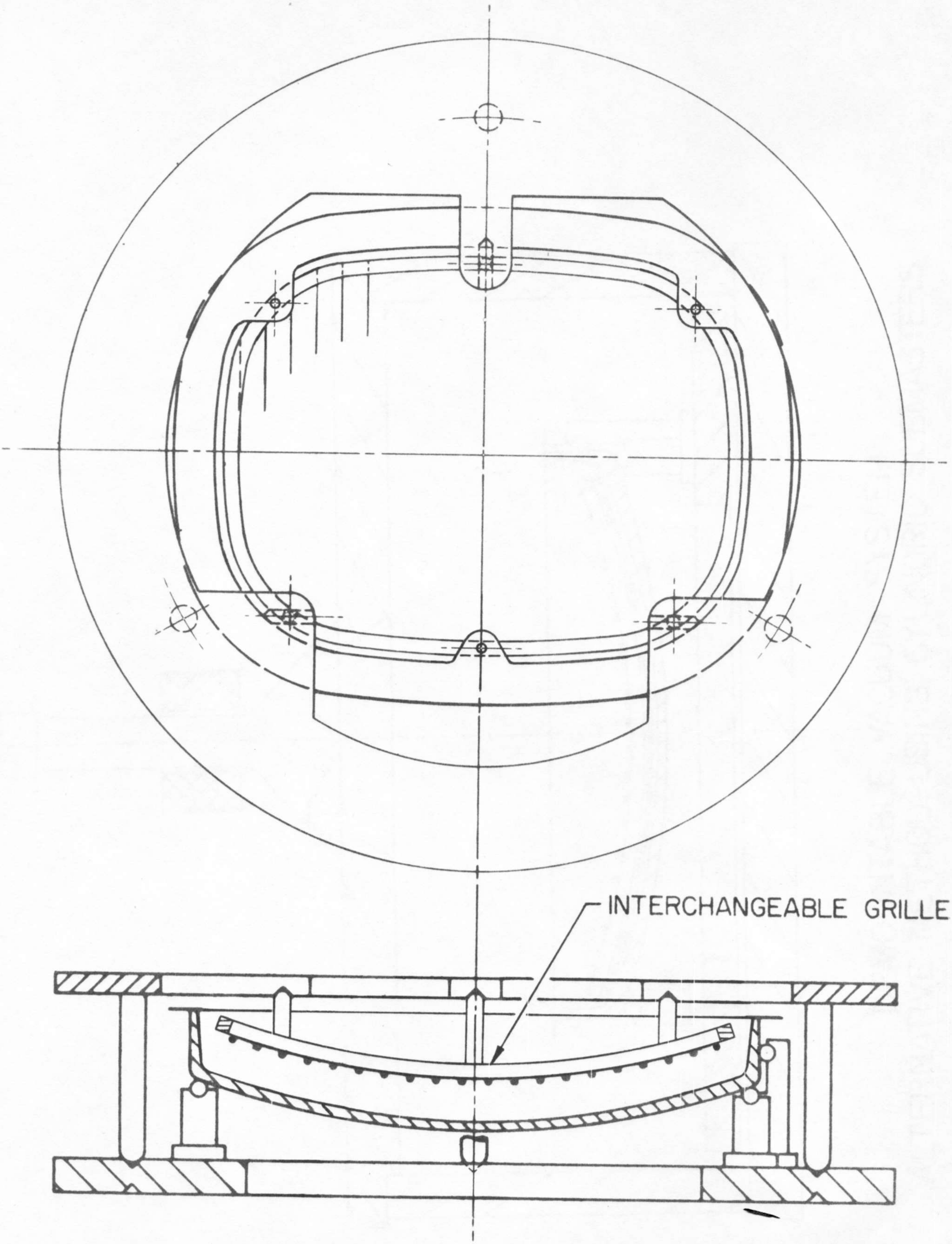
PRECISION CAMERA

Fig. 3



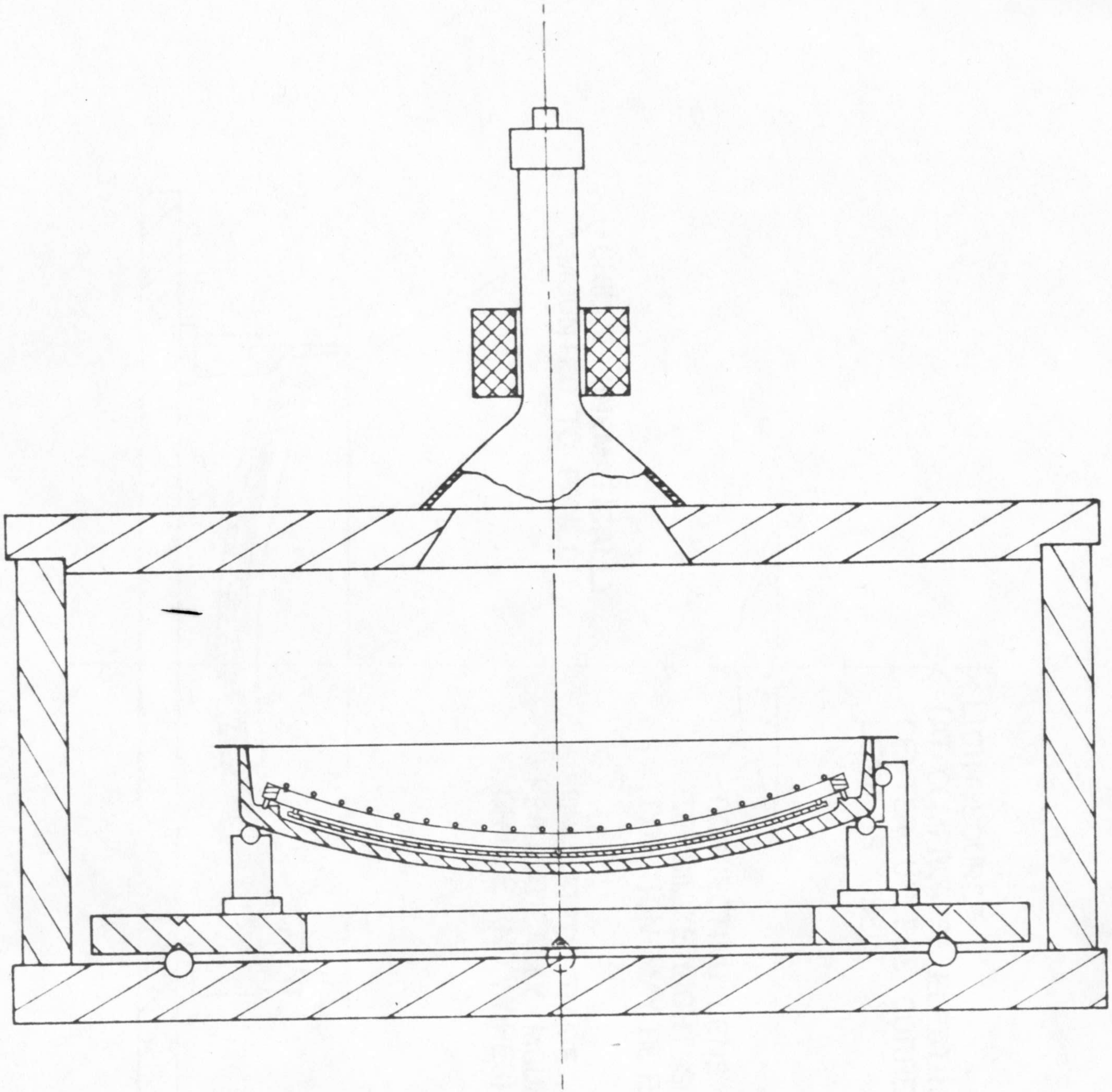
PHOSPHOR PRINTING USING FLAT SUBMASTERS

Fig. 4



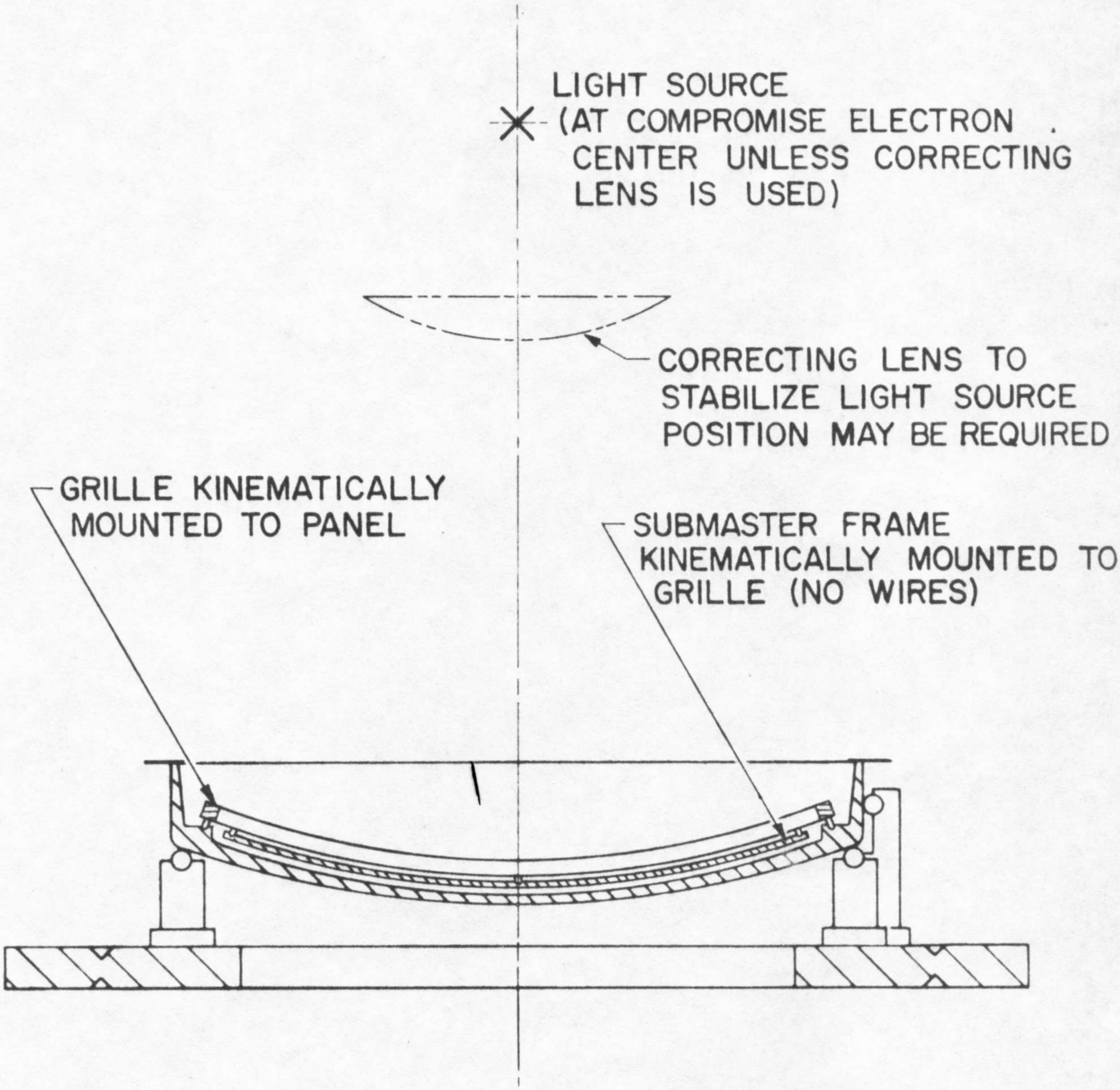
JIG FOR INSTALLING INTERCHANGEABLE GRILLE
(ALSO USED IN DEMOUNTABLE SYSTEM
FOR MAKING SUBMASTERS)

Fig. 5



DEMOUNTABLE VACUUM SYSTEM
ALTERNATIVE METHOD-USING CYLINDRIC SUBMASTERS

Fig. 6



PHOSPHOR PRINTING USING CYLINDRIC SUBMASTERS

Fig. 7