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Title Page

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TITLE

Cathode Ray Tube Europeon Technical Survey

ABSTRACT This informal report describes the writer's visit at the behest of the Cathode Ray Tube Department to: E.M.I., Ediswan, 20th Century Electronics, Cinema Television, Telefunken, C.I.F.T.E. and C.S.F. Details of general engineering interest in entertainment and industrial, military cathode ray areas are discussed.

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[redacted] Abstract (cont'd.)

It is recommended that existing relations with E.M.I. and Telefunken be expanded and intensively exploited.

An increased effort in the electron optical field is discussed.

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents—drawings, photos, etc., and for distribution see page attached.

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GENERAL ELECTRIC COMPANY

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Technical Information Series

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INTRODUCTION

This report describes a survey made by the writer at the request of the Cathode Ray Tube Department. Three objectives were to be realized:

A. Practical knowledge of storage tube construction was to be sought.

B. Telefunken was to be contacted to discuss present and future cooperative work.

C. A general panorama was to be observed of cathode ray tube activity in Europe.

The report to follow is first summarized in some detail with the thought that this portion will suffice the requirements of most readers. There follows a detailed account of the visits to the various companies.

SUMMARY

OBJECT: This resume is intended to give a brief summary of the situation observed in the companies visited. A few recommendations for future contact follow. The comments are listed in approximately chronological order.

GENERAL: I was received with complete candor and no effort was made to be secretive about any of our areas of interest. The one thing that hampers a prolonged stay at any company is the zeal on the part of that company to be hospitable. The net result is that so many key people are occupied in the visit that the visitor wears out any reasonable welcome in a few days. This point is important, because in the future some attempt should be made in two of these companies to send G.E. personnel with a specific problem of mutual interest to G.E. and the Europeon company. This project could be worked on jointly, thus affording the visitor adequate time to observe and learn the fundamental approach being used by the company visited. The survey type visit similar to the one being reported necessarily deals more with finished projects and accomplishments. Such an approach eliminates the chance to learn "how" rather than "what" was accomplished.

COMPANY VISITS:

I. London - E.M.I. (Electrical Musical Industries)

The following people were contacted and the related field of endeavor follows the name:

Dr. L. Broadway	Director Engineering
J. A. Lodge	Storage Tubes Phototubes
R. S. Webley	Storage Tubes
Dr. H. G. Lubszynski	Camera Tubes (Vidicon)

Active work was dropped in this company on storage tubes 2 years ago. A great deal of know how is available here, however. The following products are completely engineered and could be made available for production with little trouble.

VCRX-350 - Electrical Read In-Electrical Read Out storage tube. This tube has a target similar to the Raytheon or direct view type.

VCRX-360 - Storage Orthicon - This tube uses a photo conductive target with the resulting time lag as a storage target.

Vidicon: This tube also uses photo conductivity to transduce from light to electrical energy. When the photo conductor is made thick the resulting lag may be made on the order of 20 seconds for storage work. EMI feels that its vidicon for television application is superior to RCA's. This may be accounted for by the fact that English broadcasting standards (50 field/sec.) allow a greater target capacity which in turn allows a larger target area. An increase in resolution is thus realized.

Photo-Surfaces: EMI makes a complete line of photo and photomultiplier tubes. (See "Recommendations")

CPS EMITRON: This camera tube is built in competition with the RCA image orthicon. It uses a four component photocathode originally developed by Summer (now of RCA). This cathode makes the Emitron, which has no image section, no worse than 5 times less sensitive than the image orthicon. One of the components prevents the cathode from being used in the image orthicon. The Emitron has a superior grey scale rendition and is remarkably free of shading. EMI has a studio demonstration that really strikingly displays the differences between the tubes.

Seven working days were spent at EMI where they demonstrated in the Laboratory the preparation of storage targets for the ECR 350, mesh preparations testing of storage tubes, etc. It is hard to overestimate the value of being permitted to actually witness techniques as they are being performed. Sample targets were brought to G.E. to serve as comparison standards for our work to come.

II. Cinema Television - The people contacted were:

Mr. Daniels - General Manager
Mr. Freeman - Supervisor Engineering Laboratory

This company originally was the Beard Electronic Company during the war. Part of the technical staff left after the Rank motion picture chain purchased the company and renamed it Cinema Television. The new management closed out the manufacture of television picture tubes and set the engineering group to work on projection tubes for theater television. The radar and scope tubes were left in the line but were not expanded. Today they run a factory making about 700 standard industrial or military cathode ray tubes per week similar to our 5, 7, 10 and 12 inch magnetically deflected tubes. They also make the 3KP1 and similar gun oscilloscope tubes. One spiral anode tube is made.

The visit to this company consisted of a factory visit and an afternoon of technical discussion with the engineering group.

III. <u>20th Century Electronics</u> - The people contacted here were:

Mr. Tomes	Director
Mr. N.B. Balaam	Chief Engineer
Mr. T. Jennings	Project Engineer phototubes

This is a small alert company about 10 years old. Tomes founded it after leaving Beard Electric to make Geiger counter tubes. These are still a major part of the production. The company makes:

1. Oscilloscope Tubes 1, 2, 4, 8 gun
2. Photomultiplier Tubes
3. Geiger counter tubes
4. Distillation of Boron 10 to Boron 11

Manufacture in this organization is strictly a job shop proposition. Process techniques are those of the laboratory. The engineering approach is strictly limited so far as development is concerned. Designs are chiefly copied. A goodly number of processing tricks were observed and the visit was fruitful.

IV. <u>Sieman's Ediswan</u> (Cosmo Works) - The people contacted were:

A. E. Cole	Engineering
P. A. Deegan	Engineering
K. Yates	Factory Engineering

This company spends most of its time in monochrome tube production. They run a few magnetic type radar tubes similar to our 5FP and 7BP lines. A few one gun oscilloscope tubes are made. The only special cathode ray tube work has been in the field of projection tubes.

One day was spent in engineering conference and one day in a factory visit. Quite complete factory processing notes were taken and will be reported later. A special low wattage cathode was observed and has been reported at G.E. where Mr. Campbell is evaluating.

V. <u>ULM, GERMANY</u> - <u>Telefunken</u> - The people contacted were:

Dr. Schaffernicht	Storage tubes - Monochrome Production
Dr. Gundert	High Gun Electron Optics
Dr. Dahlke	Cathode Life Test
Dr. Brueck	Director of Engineering
Mr. Otto	Storage Tubes
Dr. Bauer	Electron Optics

This was a most rewarding visit and is best related in chronological order. Dr. Brueck opened the sessions by introducing the people and arranging a schedule to speak to each individually. This system lasted but a short time and a more informal set of sessions followed.

Dr. Schaffernicht first discussed the Telefunken electrical read in-electrical read out storage tube. Complete mechanical drawings were furnished. I saw the tube in operation as a band width suppressor. The demonstration was most impressive.

D Dr. Gundert spoke at great length of the high Gm gun program. A revised set of specifications from Dr. Nonneken's was discussed. It was decided that the next logical step was to make a fresh attempt to build a distribution modulation gun using the new voltage allowances, then to study the final lens requirements peculiar to such a gun. Dr. Gundert's earlier work on electron beams and deflection systems was discussed at length.

Dr. Dahlke discussed his work on life test and cathode activation. This is an area that should be quite fruitful for cathode ray tube application.

A short factory visit was made and a general cathode ray session was held with Drs. Schaffernicht and Gundert. Spot size measurements and much of Dr. Gundert's work on both the high Gm gun and color guns was demonstrated.

VI. PARIS, FRANCE - C.S.F. the people contacted were:

Messrs. Guenard - Technical Director
Boulet
Choffart
Charles

This firm builds a complete line of storage tubes as well as many sundry magnetron, linear accelerations and other industrial tubes. The storage tubes include:

TCM 13 -	Barrier Grid Tube used for noise integration and as a moving target indicator.
TMA 403 -	Double ended electrical in-electrical out scan converter similar to RCA's graphicon.
MTV 100 -	Barrier grid tube featuring multiple read out used for band width narrowing.
TEI 500) TEI 1000)	Direct view storage tubes 5 & 7 inch similar to RCA direct view tubes.
OG 506 -	Post acceleration oscilloscope tube.

The visit was made to the CSF Research facilities. Most of the visit was spent in demonstration of the finished tubes. Data and published articles were furnished covering much of the same material as was discussed. The exact geometry and nature of the storage surfaces were discussed, although the processing details were not. G.E. has no agreement with this firm, but they were very cordial and frankly stated their preference not to discuss proprietary processes.

VII. LYON, FRANCE - CFTH - The people contacted were:

Mr. Kahn
Mr. Biolley

This is a new plant building about 1000 17 and 21 inch, 90 degree deflection tubes per day. Rather complete notes were made of the critical processing details. This company is licensed by RCA and uses RCA standardizing instructions as a guide. At the time of my visit they were experiencing extreme difficulty with RCA phosphor 287A. The blue component is too long in persistance for the French scanning system.

RECOMMENDATIONS:

A. Any G.E. work on photosurfaces would be enhanced by further contact with EMI. The CPS Emitron is worthy of further evaluation.

B. Cathode Ray Tube would benefit by having an engineer work for several months with Dr. Gundert of Telefunken on a problem of mutual interest to G.E. & Telefunken. G.E. would gain the experience and technique of this outstanding man and would get an electron optical problem solved. One excellent problem would be that of building an electron gun for use in a small neck, wide deflection angle tube. The person chosen should have an excellent analytical background in mathematics. Previous tube experience would help but should not be used as prime criteria. The program should be one of developing a working philosophy for future cathode ray tube gun work, and the engineer should be expected to continue the work as a speciality for some time after his return.

Telefunken was sounded out and seemed receptive to such a program for the second quarter of 1958.

DETAILS OF COMPANY VISITS

I. ELECTRIC & MUSICAL INDUSTRIES, LTD.

Dr. Broadway called the group together for preliminary discussion and our interest regarding storage tubes was explained. He pointed out that no current work was progressing at EMI, but he believed them to be in a product design situation with no immediate call for the product. EMI had had good success with several tubes none of which happen to be direct view tubes. Happily, the VCRx 350 electrial read in and read out storage tube is charge modulated and would be a direct view tube if the reading gun were replaced with a viewing screen. It was agreed that the writer should visit the laboratories of the gentlemen concerned one at a time and discuss their individual fields of interest. Actually, the whole group excepting Broadway trailed along and added bits of the information which follows:

A. VCR x 360 (Dr. Lubszynski) A Cathode Potential Stabilized camera tube

1. Screen: Antimony Trisulfide Photoconductive
2. Screen Thickness: about .5 microns
3. Screen electrode: transparent conductive coating

4. Operation: The antimony trisulfide is an insulator in the dark, becomes conductive in the light. The screen electrode is held positive 4-10 volt. The reading beam stabilizes one side of the target to cathode potential by scanning below the first crossover. When light impinges, the area receiving light energy becomes conductive and transmits a localized charge to the cathode potential face. In scanning, the potential is restored to cathode potential and a signal results in the gun circuit.

Two reasons are given for storage:

a. The target is so thin, it has very high capacitance and several scans are necessary to discharge any spot.

b. When light is discontinued on the target, current flows in the insulator for a considerable period of time before ceasing. (photoconductive lag). This second effect is probably the most important. The lag is controlled by the thickness of the layer. A thick layer has shorter lag and lower sensitivity than a thin layer.

5. Performance: The modulations at 400 lines in the center is about 85% at 2000 lines it is about 30%. I saw the tube operating on line and moving targets. The resolution was easily as stated. The response was very panchromatic and at least 10 grey levels were obvious even on colored objects. Storage times of about 1-2 minutes were demonstrated, but is was pointed out that the tube was old. No photopulse is present (as on photosensitive tubes like the image orthicon) because the target is not a cathode for electrons. This tube has no photomultiplier.

6. Construction: The bulb is made in parts to permit a graded seal from Kovar glass to pyrex. There is no magical reason for this except that they had pyrex faceplates and Kovar sealing stems available. (See Fig. I). The dimples are blown out against a form as are the wrinkles. This gives the component manufacturer accurate location spots to put on the yoke. The ion trap mesh sits inside the bulb on top of the wrinkles. The mount is sealed in with the tubing chucked over the dimples, so that the gun is accurately lined up with the focus coil and deflection yoke of the finished tube.

Instead of dag they use Bake Platinum Ltd. "Platinum Paste No. 1". The paste is cured by heating to 450°C in an oven. Webley says they use this, "because it looks pretty!" Three leads are brought in through the face to funnel seal via three platinum foil tabs. These tabs are sealed right into the seal. No R.F. is used. The glass blower simply uses a very fine hand flame. The faceplate is pyrex plate 56 mm in diameter 2½mm thick. The contacts are platinum. After cleaning the plate, a platinum contact band is painted on. Three coats are necessary with a bake (as above) each time. The conductive coating is formed by an irridising process. A solution of stannous chloride is sprayed through a mesh on the faceplate which is held at 540°C. The resistance is less than 3,000 $/in^2$.

The electron gun is like the triode section of the image orthicon. No modulation is applied to G1, so it is a rather large hole (.030"). G2 is a .002" aperture microscope aligned to G1. The gun is a triode.

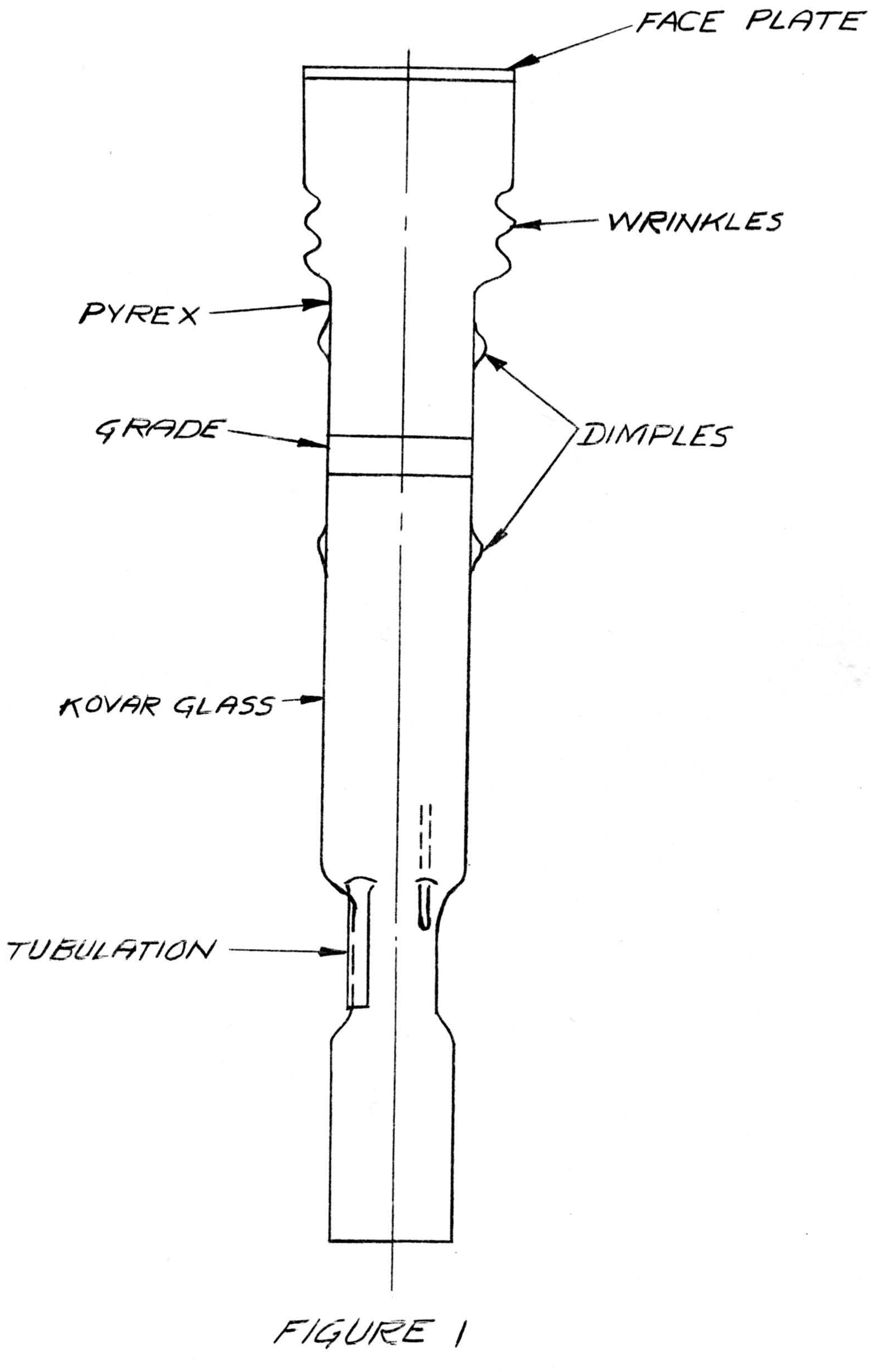

FACE PLATE
WRINKLES
PYREX
DIMPLES
GRADE
KOVAR GLASS
TUBULATION

FIGURE 1

Since the ion trap mesh will only stand 300°C, the tube is assembled without the mesh. Two tubulations are used. A sintered glass filter is mounted in the one not used for pumping to allow air to be later introduced sans dirt. The tube is baked at 450°C until pressure drops to 5 x 10 . (no activation). After cooking the tube is sealed off the pump and let to air through the filter.

The collector or ion trap mesh is of 1000 mesh of electroformed silver plated with gold. The mesh is then loosely glued to a round frame with paste. When the past is dry, the assembly is baked in vacuum to 320°C for 5 minutes. On cooling, the action of the gold on the silver is such as to render it taut.

The writer has the exact data for the antimony trisulfide evaporators, but it is of no immediate interest. It is of interest though, if we think about P10 or other screen which must be formed after the tube is sealed off.

The tube is cut open and the mesh and evaporators (one assembly) are inserted. The tube is reassembled and placed on exhaust. After pressure has fallen to 10^{-5}mm, the oven is turned on. The tube is brought to 300°C until the pressure drops to 5 x 10^{-6}mm. The gun is degassed with R.F. The filament is degassed, and pumping continues to a pressure of 2-3 x 10^{-6}. The tube is cooled and cathode activated. The getters are out-gassed and partly flashed. A real trick is involved. The getter is sealed into the spare tubulations. A magnet outside the glass pushes it up into the tube. R.F. flashes it and the coils are brought down as the slug is pulled down.

About 4 lineal inches of the neck are covered with getter. The tubulations are then tipped off between the withdrawn getter and the tube. Part of the getter is flashed before and part after the cathode is activated. See Fig. 2.

B. VCR x 350: Messrs. Webley and Lodge demonstrated this tube. It is probably Cathode Ray Tube's major interest at EMI. Notice that the target is the same as for a direct view (charge modulated) tube.

1. Operations: The read gun is scanned through the target below the first crossover and is deflected back to the insulator surface by gating the erasure mesh negative when the surface has reached read gun cathode potential, the erasure mesh is pulsed to collector potential and the writing gun charges the target positive in proportion to the writing gun modulation. Upon reading again, read gun electrons are either attracted through the target and collected or are returned. The resulting current is read in the read gun circuit. EMI's Dr. Lubszynski insists (he proves it analytically) that an electron multiplier does not assist because of noise etc. The read gun is the familiar orthicon triode, the write gun a high quality (high res.) gun.

2. Performance:

Storage - about 30 min. max. (voltage on.)
Erasure time - about 3 sec.
Writing Speed - 0.3 microsecond per picture element
Resolution = .2 x 10^{-2}x picture diameter
Signal to noise = 20 db

The following data describes the details of the VCRx 350:

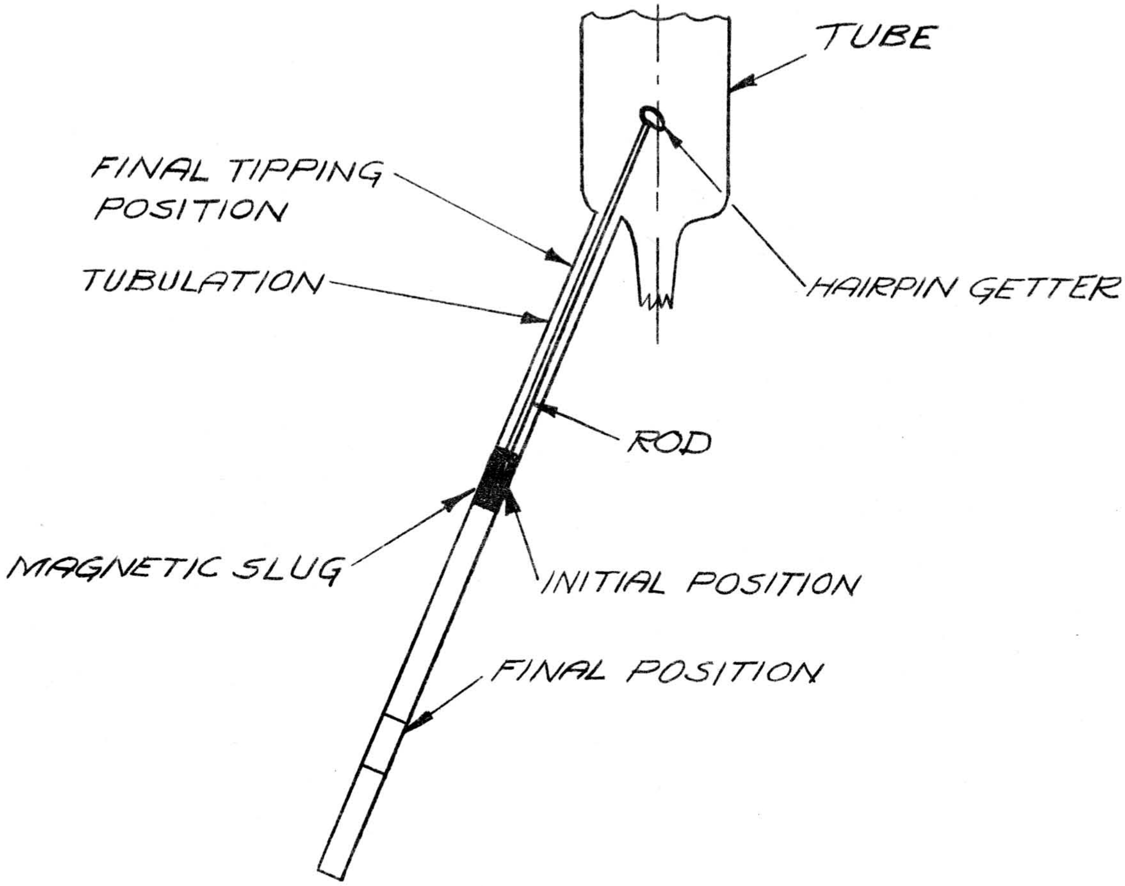
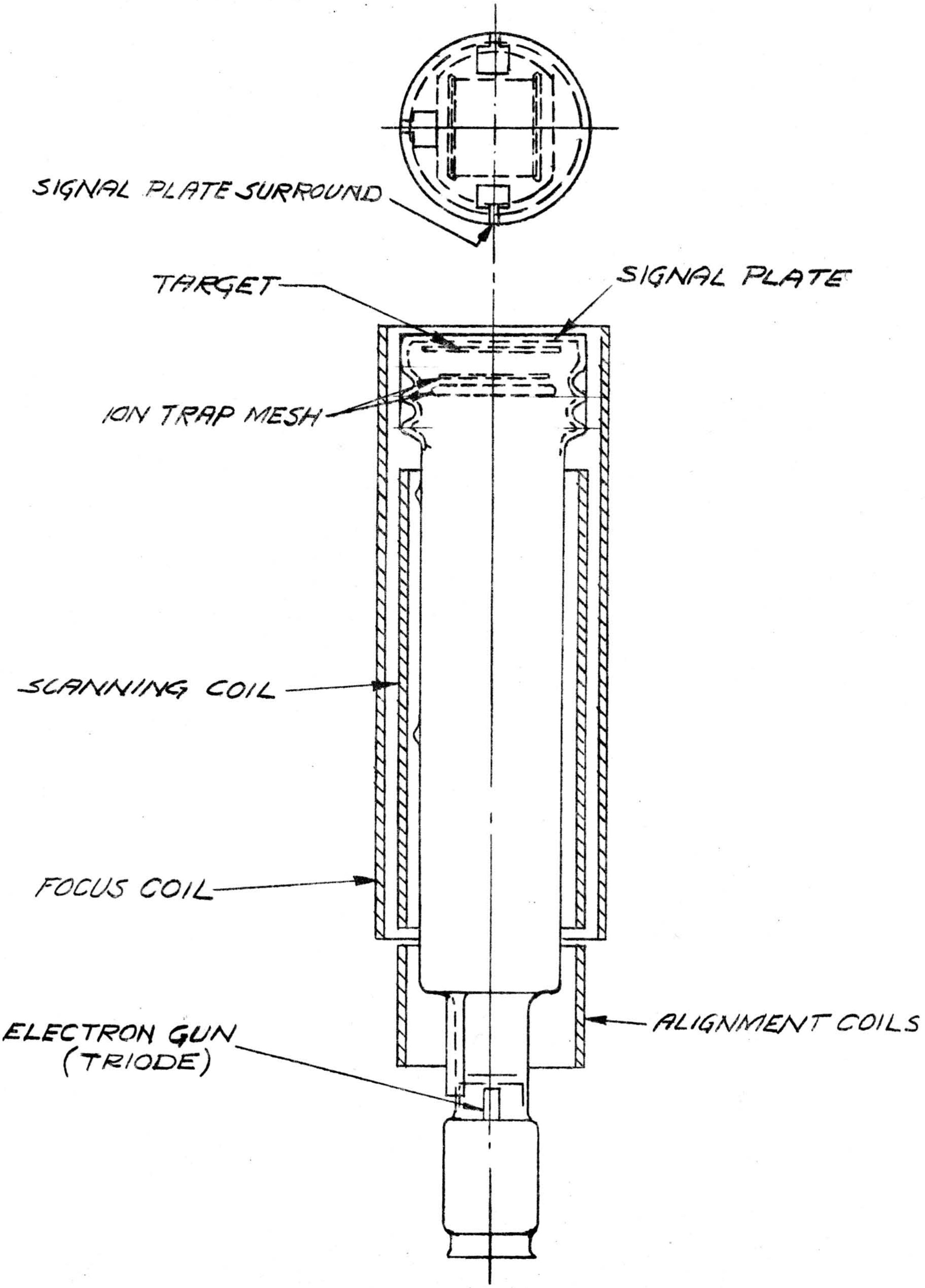

TUBE
FINAL TIPPING POSITION
TUBULATION
HAIRPIN GETTER
ROD
MAGNETIC SLUG
INITIAL POSITION
FINAL POSITION

FIGURE 2



PHOTOCONDUTIVE STORAGE TUBE
E.M.I. UCRX360
FIGURE 3

Reading Gun:

Pins 1, 4, 6	Limiter	
Pin 8	Modulator	
Pins 3, 7	Heater	
Pin 5	Cathode	8-pin Loctal
Pin 2	Wall anode (reading)	

Shoulder pins should be connected directly to pin 2 on gun base.

Heater V_H = 4-volt D.C. I_H = .85-amp.

Limiter voltage V_L 600 V* max., 500 V optimum

Modulator voltage for cut-off 80-150 volts

Wall anode voltage * V_W580 V max., 230 V optimum

*The tube must always be operated with V_W less than V_L

Meshes: neck pinch

1. Erasure mesh
2. Ion trap mesh
3. Uniformity mesh and writing wall anode
4. Decelerator
5. Storage mesh

The metal locating spigot should not be earthed, but be left floating.

The mesh potentials are all measured with respect to the reading gun cathode.

Storage mesh V_{MS} +10V to -10V Optimum 0 volts

Erasure mesh V_{ME} +300V to -300V (See text) $V_{ME_{max.}}$ 600V.

Uniformity mesh V_{MU} +300V to -300V (See text)

Ion trap mesh V_{MI} +10V (measured with respect to V_W)

Decelerator V_D +300V to -300V Optimum ca. -150V.

Writing Gun B7G

1. Internal connection
2. --
3. K
4. H
5. M
6. --
7. H

Heater V_H 3.5V A.C. I_H .75 amp

Maximum heater to cathode voltage 50 volts

Cathode 3 kV

Modulator voltage for cut-off ca. -100V (measured with respect to writing gun cathode)

Blanking

A 10 volt negative blanking waveform is applied to the storage mesh.

Focus Fields

Longitudinal focus field (reading section) 80-120 gauss: the length of the recommended coil is 14" and inside diameter 4".

The end of the focus coil should extend 3" beyond the shoulder of the tube, over the reading gun neck.

Alignment Coils

These are positioned with centres 1½" behind the shoulder of the tube over the reading gun neck. The axes of the two pairs of coils and the gun axis should be mutually perpendicular.

Setting-up the Tube

Apply the heater voltages and, after a warming-up period of 2-3 minutes, apply the reading and writing scanning and focus fields, the wall anode and mesh potentials and the reading gun potentials. Set the storage mesh accurately at the reading gun cathode potential and set the erasure mesh at about +300V. The tube is now in the long storage condition.

Turn up the reading beam until signals are just visible in the output channel monitor, and adjust the alignment currents until the signal is strong and uniform. Slight adjustment of the focus voltage (V_W) or the scanning fields should bring one of the meshes into view.

To locate the storage mesh, it is helpful to write on a charge pattern by turning on the writing beam momentarily; the breakthrough signal should be an indication that the writing beam is passing down the tube. The reading beam may now be focused on the storage mesh and realigned for maximum output signal. The picture may now be centered and the scan amplitudes adjusted to make use of the maximum useful storage area.

After the stored pattern is erased (by holding the erasure mesh at -150 to -300 volts for a few seconds), the tube is now ready for use, but it is recommended that the following procedure be applied in order to improve definition and completely to eliminate any residual shading.

With the tube in the long storage condition, drive the picture uniformly to peak white, by scanning the storage area several times with a steady writing beam. The reading beam may now be reduced to the point where the signal strength is just on the verge of falling; this is the optimum reading beam setting the the one at which the tube should be operated under all conditions.

Now erase the stored charge and write on a test pattern. The reading and writing beams should now be focused and the reading beam alignment currents adjusted for minimum shading and maximum signal strength, by a series of successive approximations. Finally, the entire process may be repeated until a satisfactory picture is obtained.

Shading

For minimum shading, it is essential that the storage mesh potential is approximately zero, the reading beam correctly aligned, and the current adjusted as described above. The reading wall anode potential V , and decelerator potential V_D, both have minor effects on the picture shading, but, if the recommended potentials are adhered to, no trouble should be experienced.

Longitudinal position of the scan coils also affects the shading.

Erasure

If the erasure mesh is held at +300 volts, the erasure rats is very slow and the stored picture can be continuously read for periods up to 30 minutes. Longer storage times are obtained with +600 volts on both the erasure mesh and the uniformity mesh, with as small a reading beam current as gives an acceptable signal/noise ratio.

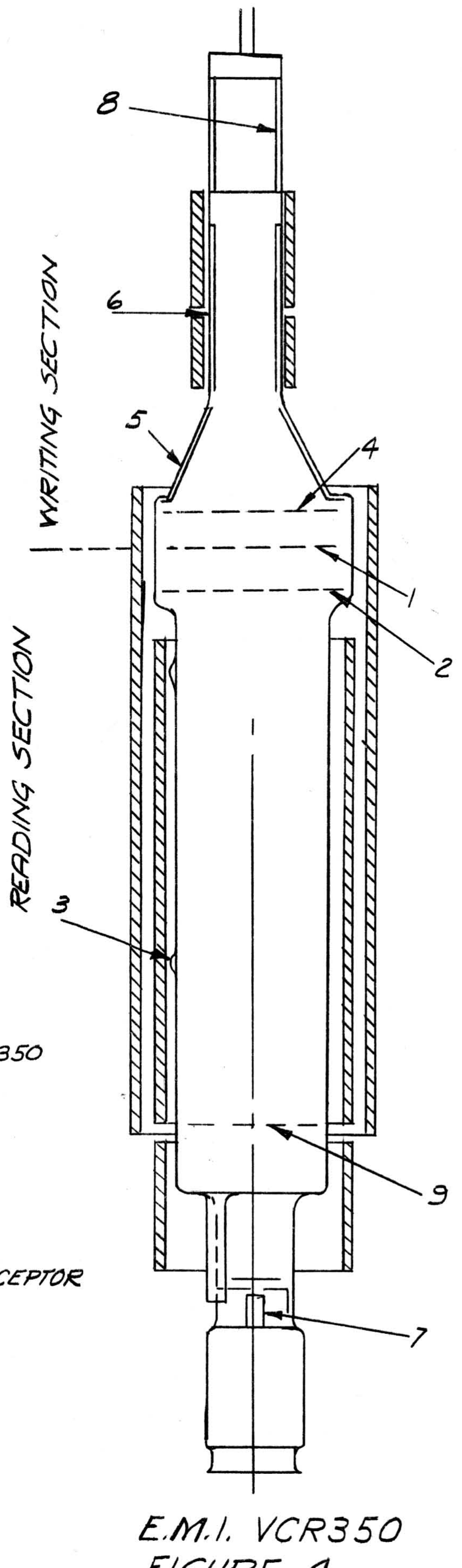
If continuous reading is not required, storage times up to 1,500 hours may be obtained if both reading and writing guns are disconnected from their respective supplies. The other tube potentials need not be maintained during this period, provided they are restored before reading is resumed.

The fastest erasure rate is obtained by applying -300 volts to the erasure mesh. With the reading beam current set to its optimum value as described above, the erasure rate time constant from peak white is about 3 seconds. For other beam settings, the erasure rate is slower.

Simultaneous Reading and Writing

The tube is very suitable for simultaneous reading and writing operation, and it is, therefore, particularly applicable where no time sharing between reading and writing operations can be accepted (as in certain radar applications).

The tube can be operated with any erasure rate decay time from 3 seconds to 30 minutes, with simultaneous reading and writing, merely by choice of erasure mesh potential. Caution should be exercised, however, if the erasure mesh or uniformity mesh potential is changed while the tube is in operation since such changes might necessitate a slight refocusing of the writing beam. Also, in order to maintain the required output signal strength, it may be necessary to adjust the writing beam current when the erasure mesh is varied from its storage condition to its erasure condition.



BEAM MODULATION TUBE VCRX350
1. STORAGE MESH
2. ION-TRAP MESH
3. WALL ANODE
4. ERASURE MESH
5. WALL ANODE
6. WALL ANODE
7. READING GUN
8. WRITING GUN
9. WRITING-BEAM INTERCEPTOR

E.M.I. VCR350
FIGURE 4

Owing to electrons from the writing gun striking the reading gun, a small spurious signal may be seen when the writing beam is turned on. This "breakthrough" signal occupies only a small fraction of the picture scanning period and is of opposite polarity to the picture signal, i.e. it is blacker than "black", and by suitable circuits it may be removed from the output signal, if necessary.

Change of Storage Mesh Potential

If, at any time, the tube is required to operate with a different storage mesh potential, it is advisable to restore the whole of the storage surface to cathode potential, by driving it to peak white by several writing operations, and then erasing.

Half Tone Storage Tube, Emitron 9503, Based on VCRx 350
Serial Number 235/2.

RECOMMENDED OPERATING POTENTIALS
(Design Center)

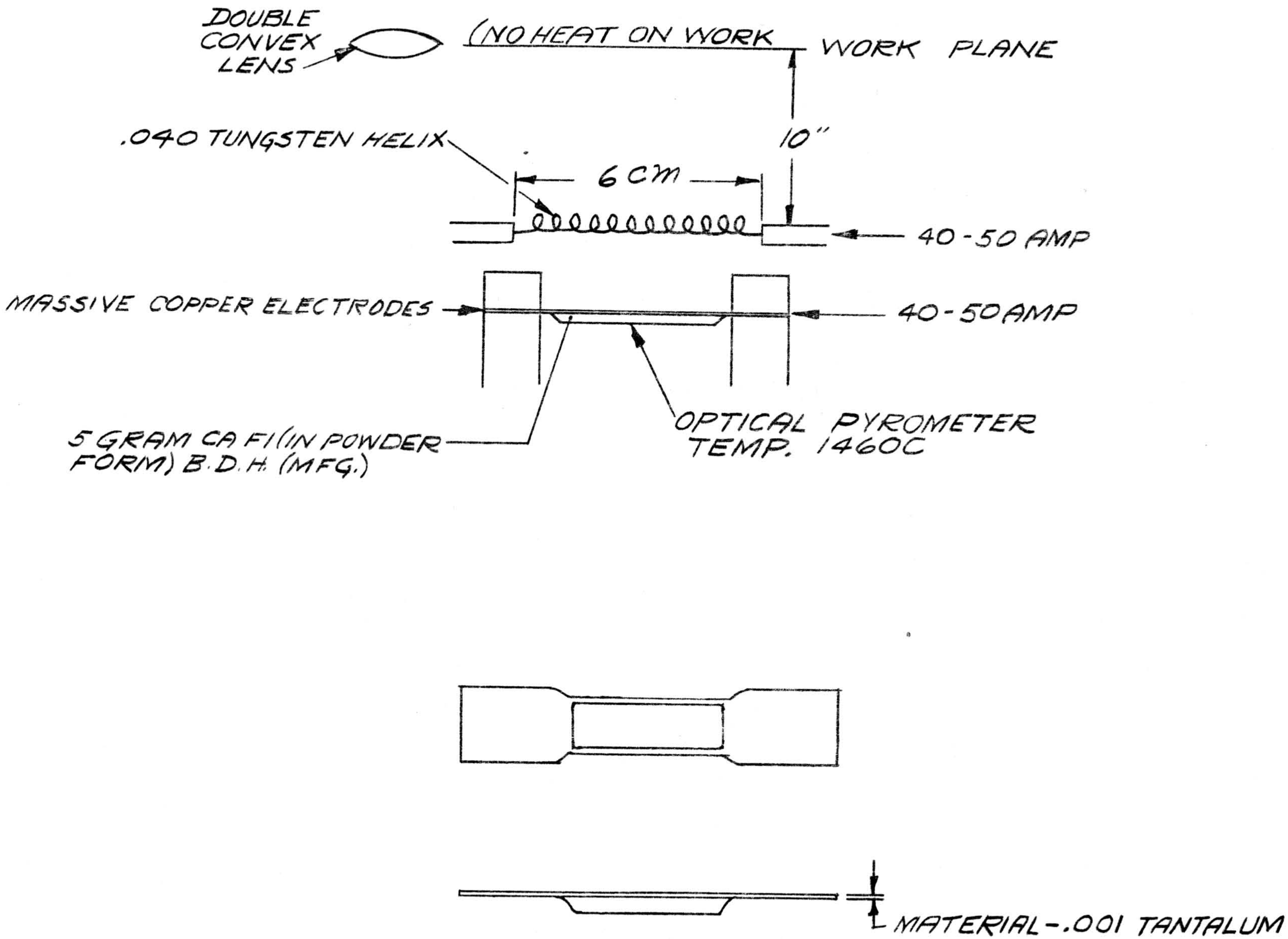
Reading gun	Vk	0 volts
	Vl	+500 volts
	Vw	+230 volts
	Vh	4.0 volts
	Ih	.85 amp.
Writing gun	Vk	-3.0 KV
	Vh	3.5 volts
	Ih	.75 amp.
Potentials	Vmi	+10 volts (with respect to Vw)
	Vd	-130 volts
	Vms	0 volts
	Vme	+300 volts (store or -150 volts (erase)
	Vmu	+300 volts

All voltages (with exception of Vmi) measured with respect to Vk.

C. The writer was afforded the privilege of utilizing the laboratory at EMI to evaporate CaFl on target meshes. The evaporator set up is pictured in Figure 5. Note the small double convex lens mounted with its plane aligned with the plane of the work surface. Observation of interference color orders during evaporation permits control of insulator thickness. The work is brought up to temperature very slowly (about 45 minutes)

The number of color orders are counted as they nicely appear on the little lens. About 8 orders gives the magical 1 micron. After each evaporation the little lens is simply cleaned and replaced. Thickness of between .5 and 1 micron are used. (Total time - about 2 hours)

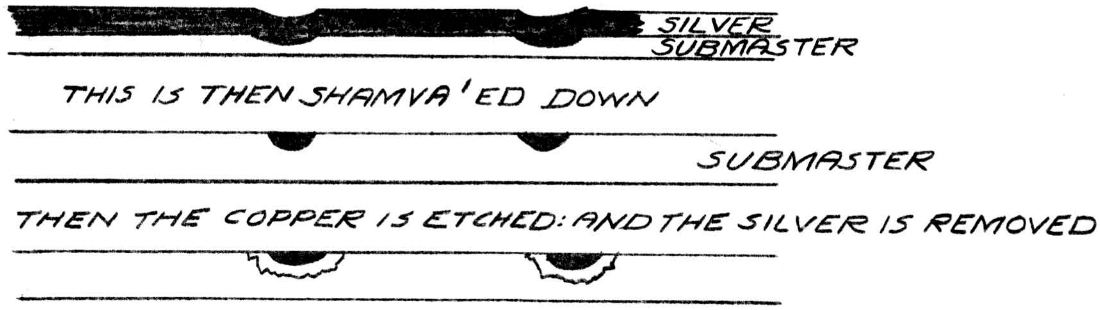
No cleaning is necessary on their mesh. (This won't be true of ours). They use a 1000/inch mesh of 70% transparency - material silver. The silver is a peculiarity of the mesh forming process.



EVAPORATION SCHEME
FIGURE 5

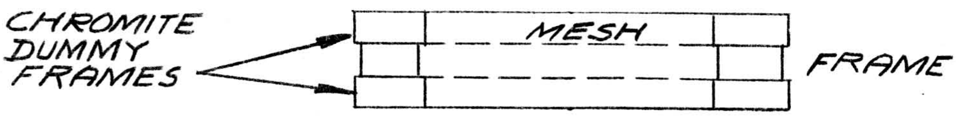
D. Mesh Making

The desired mesh is first ruled on a resist covered copper plate, just cutting the resist with a sapphire stylus. The plate is then etched through the cut resist. A reverse master is now made (ala phonograph master technique) From the reverse master a sub master is made. (All copper plating techniques) A heavy layer of silver is now plated on the submaster.



All very easy for people who make phonograph masters. This mesh is most painstakingly examined under a microscope and sections that cannot be used (filled holes, etc.) are rejected.

The frames are milled steel, silver plated. The mesh (speaking briefly) is layed across the frame. Weighted down with another dummy frame and fired as follows:



Airfire: 3 min. @ 600°C
Forming Gas: 8 min. @ 850°C

The choice of material for the ring and mesh, and the heating cooling cycle are all critical to give a properly tichtened mesh. This technique is used in the 3" camera tubes and vidicon as well. Some changes will have to be made for a 5" target, using nickel mesh.

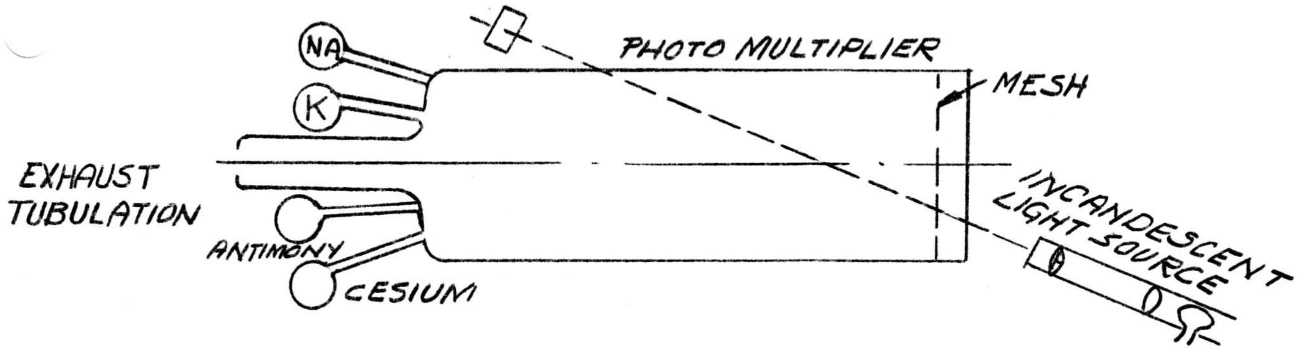
E. Photo Emission Screens (Photocathode)

If one remembers that the photocathode of the RCA image orthicon is Silver and Bismuth with Cesium the following comments will make more sense.

For camera work EMI is quite opposed to the I.O. for several reasons:

1. The target burns in
2. The gamma is poor (poor grey scale)
3. Charging under the collector mesh limits resolution.
   RCA (and others) have criticised the EMITRON for
   a. Poorer gain (10:1)
   b. Shading (a result of poor collecting of electrons from the photocathode)

A new photocathode jointly worked on by EMI & RCA has been developed. Summer started the work at EMI, later left to join RCA. Details of the techniques are published in the Journal of Scientific Instruments. The presence of Sodium in the formula prevents RCA from using it in the I.O. It has a better response and greater yield (2-3:1 better) than Silver Bismuth. This brings the sensitivity of the EMI tube to 5:1 of the RCA. The process is miserable. Remember that EMI pre-exhausts at high temperature all camera tubes then cuts them open to mount the meshes and photosurfaces. They then exhaust and bake at low temperature. The tube looks about as follows when ready for final exhaust.



The metals are in the chromate form in the glass bubbles. Just enough heat is applied to the bubble to evaporate a bit of the pure metal up the little constriction. A tungsten filament outside the constriction then finally evaporates the material. After the initial activation of the bubbles, the following sequence is followed:

1. Evaporate antimony until the exterior incandescent lamp gives a light emmission to the photomultiplier of about 50%.
2. The screen is raised to 180°C (inside)
3. With the tube now operating as a phototube, sublime in enough Potassium to bring the sensitivity to .5u amp Lumen.
4. Raise temperature to 200°C
5. Sublime in Sodium for maximum sensitivity (too much will cause the sensitivity to drop off)
6. Cool to 150°C
7. Flash in Cesium
8. Increase temperature and bake to maximum sensitivity (once again too much will cause sensitivity to drop)

The result is a truly fine photocathode.

They demonstrated the tube next to the I.O. and the grey scale rendition is lovely by comparison. Even when attenuation was added to the channel to simulate home receiver operation the difference was striking.

The early shading problems have been eliminated by the addition of a 1000/inch mesh 1mm from the photocathode.

EMI also makes photo tubes & multipliers by exactly similar processes with the following responses:

1. 3000-6200 A° SbCs (50ua/Lumen)
2. Same as above with much improved response below 3000 SbCs in Quartz (50ua/Lumen)
3. 3200-5700 Sb-Cs(s) (25ua/Lumen)
4. 3400-6500 Bi Ag Cs (30ua/Lumen)

F. Infra Red Pick Up Devices

Dr. Lubszynski has started a little work on improved red response for the EMI vidicon. When about 20% by wt. antimony triselenide is evaporated with the usual antimony trisulfide, about 25% of the resulting response is above 7000 A° . The only testing they have done so far is through a Wratter 87 filter. The resulting dark current is about .035 uamp. Some earlier work using Silver Oxide & Cesium in the EMITRON was poor.

G. Photo Conductors

Cds has been tried with little success in vidicon. Long lag - dark current - charge redistribution due to internal scattering were all objections. This led to the selenide work described under IV above.

H. Glass

A very interesting quartz to pyrex seal is being used on some photo tubes:

QUARTZ			PYREX
GEC	WQ31		Plouder & Thompson Dial 36
GEC	WQ34	Also	" " " 43
GEC	H428		7052 (Kovar sealing)
Pyrex			

Data on all glasses can be obtained from:

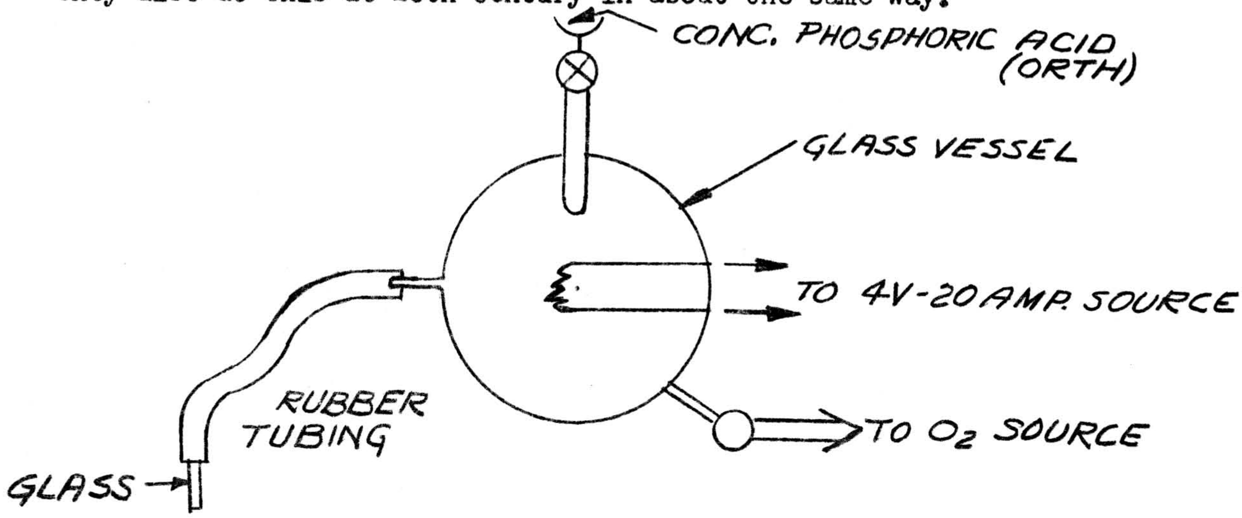
The British Glass Industry Res. Association
Elmfield
Northumberland Road
Sheffield 10, England

Unfortunately, all the glasses mentioned come in rod form; the EMI people make the tubing, then the seals.

II. Visit to Cinema Television, London, England

A. Processes:

1. Screening: They use the dry phosphoric acid process for all non-aluminized types. Although we know this approach, I'll review it here, since they also do this at 20th Century in about the same way.



The acid is dropped, drop by drop onto the hot filament, causing a dense cloud of smoke. A wee whiff of 02 is introduced and blows the smoke into a clean bulb through the hosing and glass tube. The bulb at this point looks as if someone had puffed cigarette smoke into it. The smoke is left stand 1 minute. A stream of air is used to clear the smoke. An excess of phosphor is dropped into the bulb and is rudely shaken about. The bulb is upended and slapped, tapped and cuffed until the excess powder is removed. Another whiff of gas is introduced as a sealer and the bulb is screened. Even double layer screens are done this way and repeated screenings are used to build the layer to the desired thickness. The resulting screens look a lot like electrostatically precipitated G.E. Pl screens.

They use barium nitrate and silicate and have the same poor edges on blown bulbs that we do. (This process is used only on aluminized versions). They float both nitrocellulose or methaculate depending on the mood they are in.

2. Inside Paint: They flood Atcheson Dag #660B with compressed air and then wash out the neck. A real messy process.

3. Exhaust: They bought a 40 head rotary machine from Enwhistle. It's a nice job, cleanly built. The only important feature is a long vertical glass tubing about 2' long between the oil pump and the compression head. This tubing is 3" diameter and supposedly works in conjunction with the pump baffel to reduce oil vapor in the tube. Silicone oil is used. Silver R.F. Oils are used and are said to outline copper 10:1.

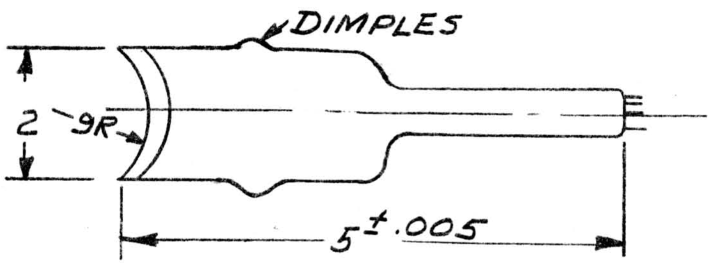
4. Guns: There they simply copy. No attempt is made to standardize pots or anything of the sort. They use ceramic rods, mica cages (ala DuMont) or whatever. They do make a triode section of standard mica and metal parts which is all mounted in a concentric array in a large cylinder. They have rather clever glass people and make a variety of stems and pinches, simply changing molds on a simple single head hand press.

B. Research Laboratory:

Freeman bemoans the fact that they have spent about all their time designing projection tubes. They use a scaled up version of the Phillips 3NP4 gun with the spark trap. No conducting bands are painted inside the tube however. They have the usual unhappy experience with P16, P24 phosphors. No answers for more red content in P24 which they would like to see.

1. Spiral Anode: They also use a counter balanced piece of tubing on an engine lathe. The tip is a converted pen from a LeRoy type lettering kit. A larger reservoir has been added. Atcheson R80 Dag is thinned with ethyl silicate. The neck of the tube is raised to 50°C by little radiant heaters. The resulting spirals draw about 80 amp @25KV. If the resistance is too high, they fill in the holes between stripes of the spiral with chrome oxide + water as far along as is necessary to drop the resistance within bounds.

2. Spiral Tube: They make one fine little tube. This is a high precision tube (P11) which is plugged in and out of an optical system without refocusing. The face is precision ground. It is mounted into the funnel which has been blown in a tube to put on the locating dimples after shrinking on a mandril to make it round. The neck is hypoderic tubing (ground inside). They locate on this inside surface with an expanding mandril and grind the outside concentric ± .001". The whole job is super accurate. The final spot is concentric to the dimples by ± .010".



3. Neck Down: They are in the habit of putting a constriction in the neck of high voltage tubes to give a convenient place to attach snubbers and reduce stray emission from the lower neck.

4. Adhesive: They use a solder cement for many things such as sealing faceplates to bulbs (temporary tubes) glass to metal etc.:

Cerrated Pasco Mining
Corroseal #35 (50-50 Tin & Indium)

II. <u>Visit to Sieman's Ediswan - Cosmo Works</u> (London)

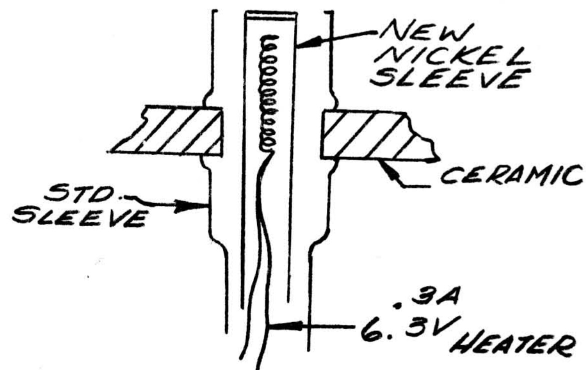
Messrs. Deegan & Yates work for Mr. Hirchner who succeeded to Mr. Price's job of development engineering head. Mr. Hirchner was on vacation. Mr. Cole is in what we would term Process Engineering. He will be visiting Syracuse about September 19, 1957.

A. General:

This company spends most of its time in monochrome tube production. They run a few magnetic type radar tubes similar to our 5F and 7B lines. A few one gun oscillograph tubes are made. The only special sort of work has been along the line of projection tubes. Their problems in the latter case consist of the familiar voltage breakdown and phosphor burning problems. After reading Feldmans work they had a go at evaporating P19 and Willemite (P1). No success. (They tried to do the work on an ordinary aluminizing head inside a pyrex bulb.) They have a good deal of trouble getting good P7, P14 screens and don't like P19.

Ediswan has a low wattage heater of simple design they are just testing.

The old sleeve is said to act as a heat shield. The whole thing operates at a little more than 800°C.



We discussed standard processing (mostly monochrome) step by step, the discussion follows:

Bulb Wash: 5% Hydroflouride + 20% caustic soda followed by tap and deionized water rinse. There has been a general trend toward using more and more volume although the exact amount is not known.

Screening: They use a barium acetate calcium metaborite process, with potassium silicate. The schedule takes about 20 minutes to settle, 5 minutes to pour off. No heat is used. Shrinkage runs about 20% at ultra-violet check. Three phosphors are used.

ZnCd Sulfide:	Cu
Zn Sulfide:	Ag (Weight use 6 grams for 17" tube)
ZnCd Sulfide:	Cu (a yellow)

These are blended by Levy & West to give x=.275, y + .304 tristimulas valves. A Donaldson type colorimeter is used and is standard in England. This resulting color is known as "Mullard Blue". They use a standard demineralizing plant and a water limit of 20,000 . They do no debugging.

Bake: Screens are air dryed - <u>no bake</u>.

Filming: Spray - Merthaculate

Aluminize: Pumps use Silicone Oil. Engineering doesn't approve. No gas ballast is used and water vapor is thought to be a problem. A typical machine has 16 heads (rotary) rated capacity 100/hour. A standard upright filament is used. 500-800A° aluminum thickness is shot for. They calibrate by observing color orders coming up on an unscreened bulb. An oscillator similar to ours is then calibrated and used for production checking. Actual flash time is stopped by operator at proper thickness.

Gun Seal: Use nitrogen flush to prevent G1 and cathode oxidation. Both hand and 12 position rotary gear is used. They find that G1 gets to 400°C and more during normal drop seal. This is thought to be bad.

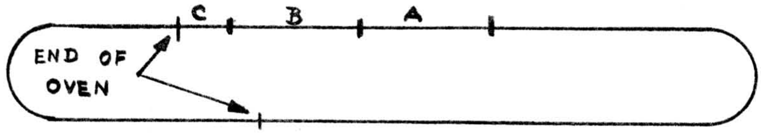
Exhaust: (Data per Mr. W. L. Jones Foremat)

1. Bakeout

Type Oven: Lehr-necks up
Speed: 8"/minute
Method of taking curve: Cemented Thermocouple using Savereisen
Peak Temperature: (1CF): 425°C
Time over 400 (1CF): 20
Time over 390 (1CF): 34 min.
Rate shot for: 10-11°/min. hot, 4°/min. cool
Exit Temperature: 150°C

2. Exhaust

Type Machine: In Line - circulated air oven - gas fired
Index: 1 min. on 21", 8 min. on 17"
No Oven Positions: 145 (They also have smaller machines w/125 & 99 buggies)
No. Buggies: 159
Type Pumps: Dow Oil 1405 - Back Pump
Silicone Oil - Diffusion Pump
Type Pump - Metro-Vickers
Peak Temperature: (1CF) 405° (21") 420° (17")
Time Over 400°C (1CF) 45 min. (21" 28 min. (17")



Activation:

			G1	If	R.F.
"A" area	10 min.		0	.35	61 750°C Max.
"B" area	4 min.		+5	.35	0
"C" area	60 sec.		0	.4	0

All this with the 12.3 volt heater (3 watt) sort of double If currents for GE equivalent.

Tip-Off: Bulb Temperature 100°C
Type - Radiant Electric, 11 amp. 10 volt
(They complain of short life of radiant heaters)

Aging:

Stem	Time	EG1	EG2	If
1	1 min.	0	0	20 volt
2	30 min.	+5	450	17 volt

Cathode:

Cap Material & Thickness:

"Wiggins Nidal" (Active) Deep tube .004" top

EM Mix Type: Triple Carbonate

Thickness: .0025 (8-10 milligram/cm^2)
Density: Unknown
Texture: Plough - no peel

Getter: Type: V Channel & pellet
Vendor: English Kemet
Direction of Flash: Crossfire (Mag.) Upfire E.S.
Total Material wt. 24 mg.

Cathode Temperature:

820°C Brightness (Optical)
870° Thermocouple

B. Ediswan Factory Visit:

The Cosmos factory had been in operation one day after a three day holiday. This plant is the smaller of two, the larger being at Sunderland with an alleged capacity of 10,000 tubes (television) per week. Mr. Hershberger, a new manager at Sunderland, visited with the group. The following is a more or less random commentary on what looked like important points.

1. Bulb Making: Ediswan seals funnels to faces using a corruption of the Corning Process. Three phase 50~ power is used. Only the power conducting fires oscillate with the bulb contour. The heat up fires are stationary. The Result is a little sloppy. Pressed funnels are used, so the necks are Chinese hatted on a multihead vertical sealer. All bulbs are Lehr annealed.

2. Bulb Wash: Standard gear. One machine is used only for rework. The factory manager Bill Jones was vehement against strong acid solutions. No one seemed to know what concentration and volume was being used at the moment.

3. Screening: (All Tilt Table) Their tables are simply dumped over against the action of a hydraulic dash pot. They buy Joseph Crossfield Grade 53 and run daily lot acceptance tests on silicate. Apparently they have trouble with Pot. Silicate because this piece of conservatism is not common to handling of barium acetate or phosphor.

It is the practice to roll 5% dry (by wt.) Calcium Borate with the phosphor before measuring the powder for dispensing. This is supposed to help wet adhesion. Machine lines appear when they eliminate this.

A typical formulation for a 17" bulb:

765 m. Barium Acetate (.55-.6 by volume in water)
6500cc Cushion
620cc 1.1 Kasil 22
6 gram (Phosphor + Calcium Metaborate)

The dispensing is done through a standard funnel with a uniform array of holes in the tip. Powder is weighed out for each tube and laboriously folded up in little papers. The scale is a home made self-balancing balance. Phosphor is introduced to one side of the teeter-totter, when it overbalances, a trip throws a micro-switch which dispenses the load to the operator's paper.

Screens are inspected from inside with incandescent lamp only. Vac check and U.V. stations exist but are not used for anything except engineering evaluation.

4. Filming (Three Operations):

a. The screens are loaded on a simple rotating head are are wet with water from a gentle hose up-tap.

b. An 8% solution of normal grade Merthaculate laquer is dispensed up through a piece of 1/16" I.D. tubing on a slowly rotating head. An awful excess of laquer is used. The amount is said to be non-critical. The bulbs are removed and piled on a rack to dry.

c. Before complete drying, the bulbs are placed on a third rotating head where a water wash is used to remove excess laquer from the funnel. Drying is then completed over air rods.

5. Aluminizing: Stationary buggies and carousels similar to ours are used. Silicone oil is used and is a matter of like controversey. Engineering uses observation of interference patterns when evaporating aluminum in a non-screened bulb to set the Al. weight and calibrate a grid dip oscillator. The operator then uses the oscillator to cut off the evaporation when the aluminum thickness reaches the equivalence of 700 A^{0}.

6. Inside paint was done before aluminizing. The job was done in a messy manner, using too much dag and requiring an excess of wiping afterward.

7. Gun Seal: Single head sealers. Rotating fires. Nitrogen flush is used to reduce oxidation of G1 and cathode.

8. Guns are made in Sunderland to our exact current $1\frac{1}{2}$" neck standards. They are not yet struggling with 110°or small necks.

9. Exhaust: Manually operated port valves on the fine vac. Tip-off is by hand. Parts are water cooled and protrude reasonably far up into oven trough.

10. Spark: Mostly A.C. (Tester Coil) D.C. is available to 30KV but is not used.

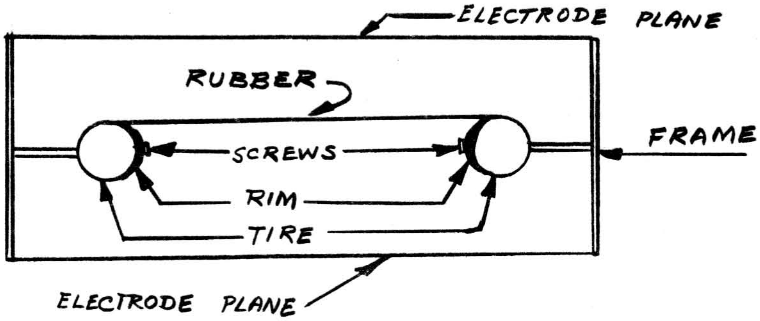
11. Test: Three positions are used to pre-load and preheat the tubes. The heads are mounted on a rotary table which cycles the tubes into the set for the operator. The screens are of very good quality by our standards. No signs of yellow centers or edges. A dot pattern is being installed in the equipment to try to control electrostatic focus tubes. A scheme for test and limits have not been set. No formal quality test is in force.

12. General: This plant is being used as an engineering pilot for Sunderland.

IV.. VISIT TO 20th CENTURY ELECTRONICS:

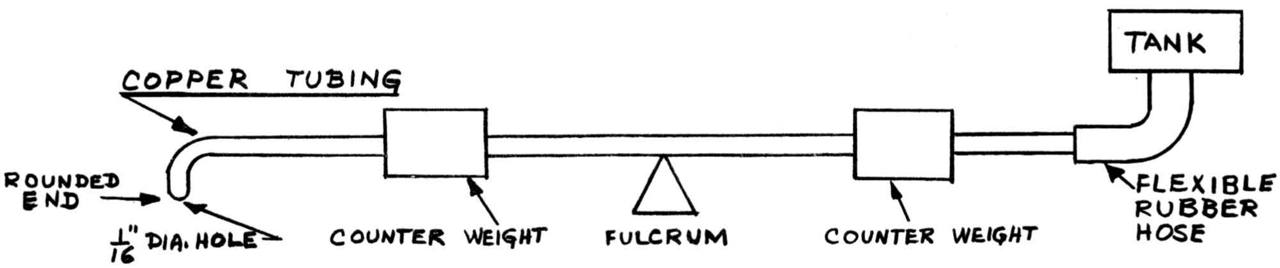
A. Interesting Processes:

A rubber membrane model is used to study photopultiplier anodes. An ordinary bicycle wheel is used to support the membrane. The spokes are removed and the tire deflated. The rubber membrane is loosely held over the tire and is screwed to the rim through the former spoke holes. Self tapping screws + washers are used as fasteners. The tire is then inflated. Presto! the membrane is stretched.



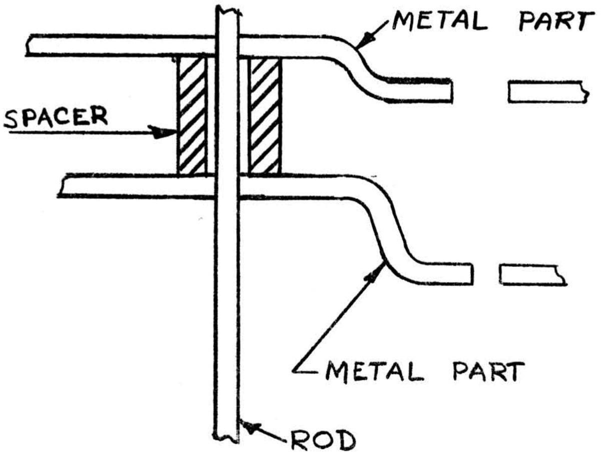
This device seems to work fine. Four upright posts support the wheel and two datum planes from which electrodes poke up or down. Since in multiplier tubes, they always assume negligible initial velocity, no ramp is employed. A 1/8" ball is brought to rest through a piece of tubing and is released by raising the end of the tubing. No recording apparatus is used to trace the path.

Spiral Anode: They make spiral anodes easily with the simplest device.



This device is mounted on a lathe crossfed in the position shown. The counterweight is adjusted so that a reasonable pressure is in the nozzle. The lathe is started (no feed). The tank is raised until a clean line appears. The feed is started. It works! The ink is Acheson Colloid Dag diluted with potassium silicate. The amount of dilution is pure art. A spiral anode of resistance about 300 megohms is the goal. They simply use a bare piece of glass and a dummy nozzle, then dilute the tank until the nozzle writes without spreading.

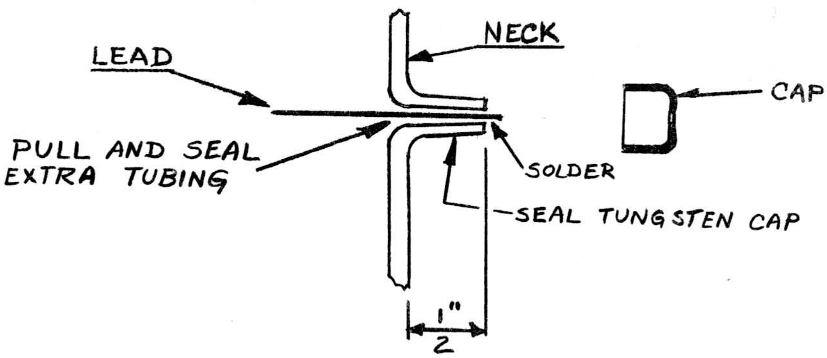
Gun Assembly: 20th Century do an amazing job of fabricating gunparts. Simple dies they make. Progressive dies they have made. In either case, they stamp out the part on the most primitive of presses. The parts look very good. They use a unique support construction.



All guns except one are using this construction.

The parts to make a complete gun are gathered in a fishing tackle type plastic box. (They call it the "mechano set" approach). The parts are simply dropped over the support rods and retainers are crimped at the assembly ends. Deflection plates have flanges which are also pierced to take the rods. Some rods have hollow centers and are used to bring out leads. They have a basic assembly for a double gun and then stack multiples of this to make 2, 4, 6 or 8 gun tubes.

They have an excellent glass shop. All bulbs are pyrex, mostly flat faced. Faceplates are affixed with no R.F. A few rectangular pressed faces were about. They show the same mechanical weakness as ours. Some screening is done by simply spraying 20% (vol.) solution of Phosphoric acid on face through an air brush. Half drying, then dusting and slapping off excess dry powder.



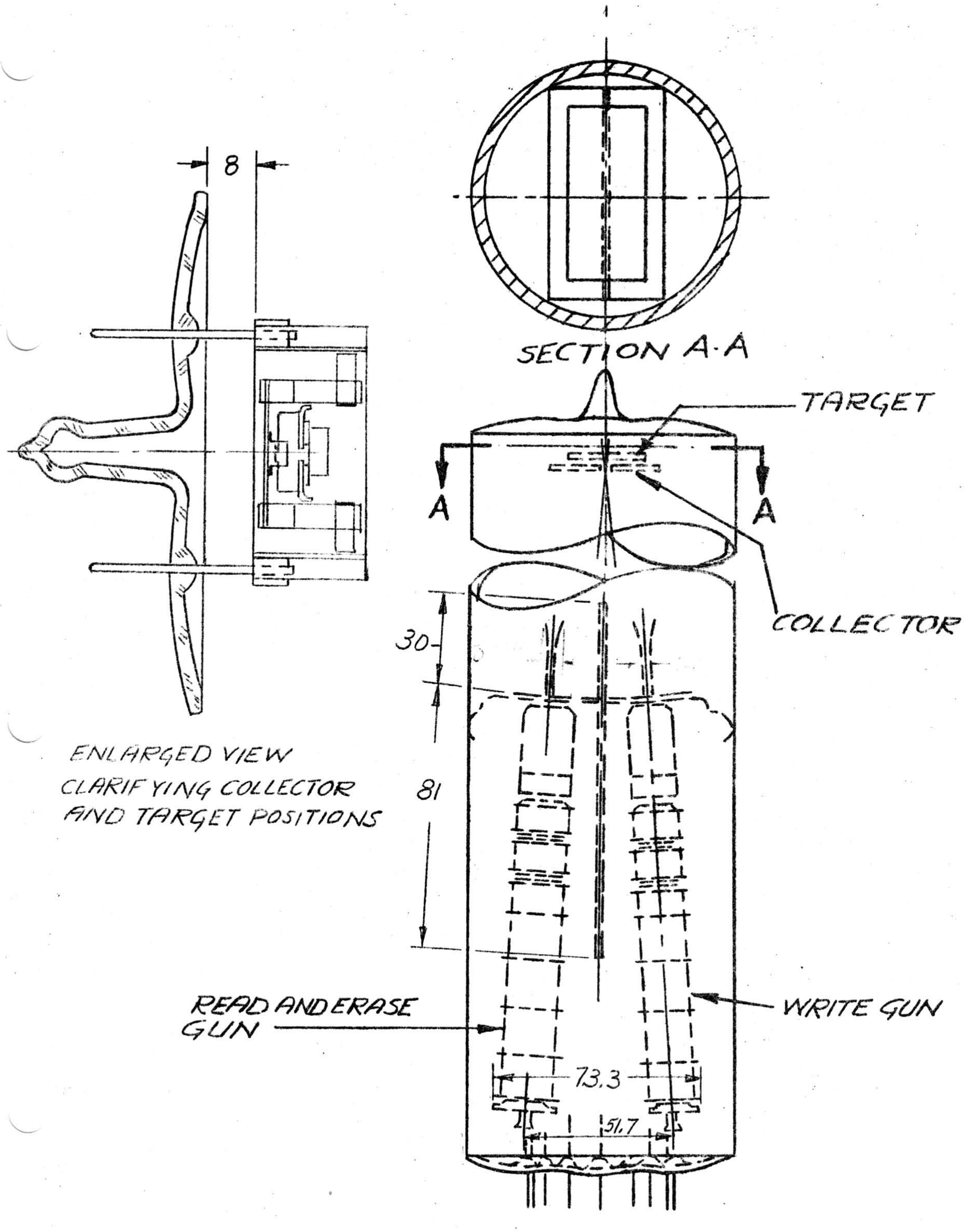
Leads are brought through neck as shown. As many as 32 of these stick out a single neck. The leads are button hooked out before the tungsten cap is sealed on with a sort of housekeeper deal. All hand torch work!

The structure will stand little heat and long exhaust (10-12-18 hours) is the substitute.

V. Visit to Telefunken - Ulm, Germany

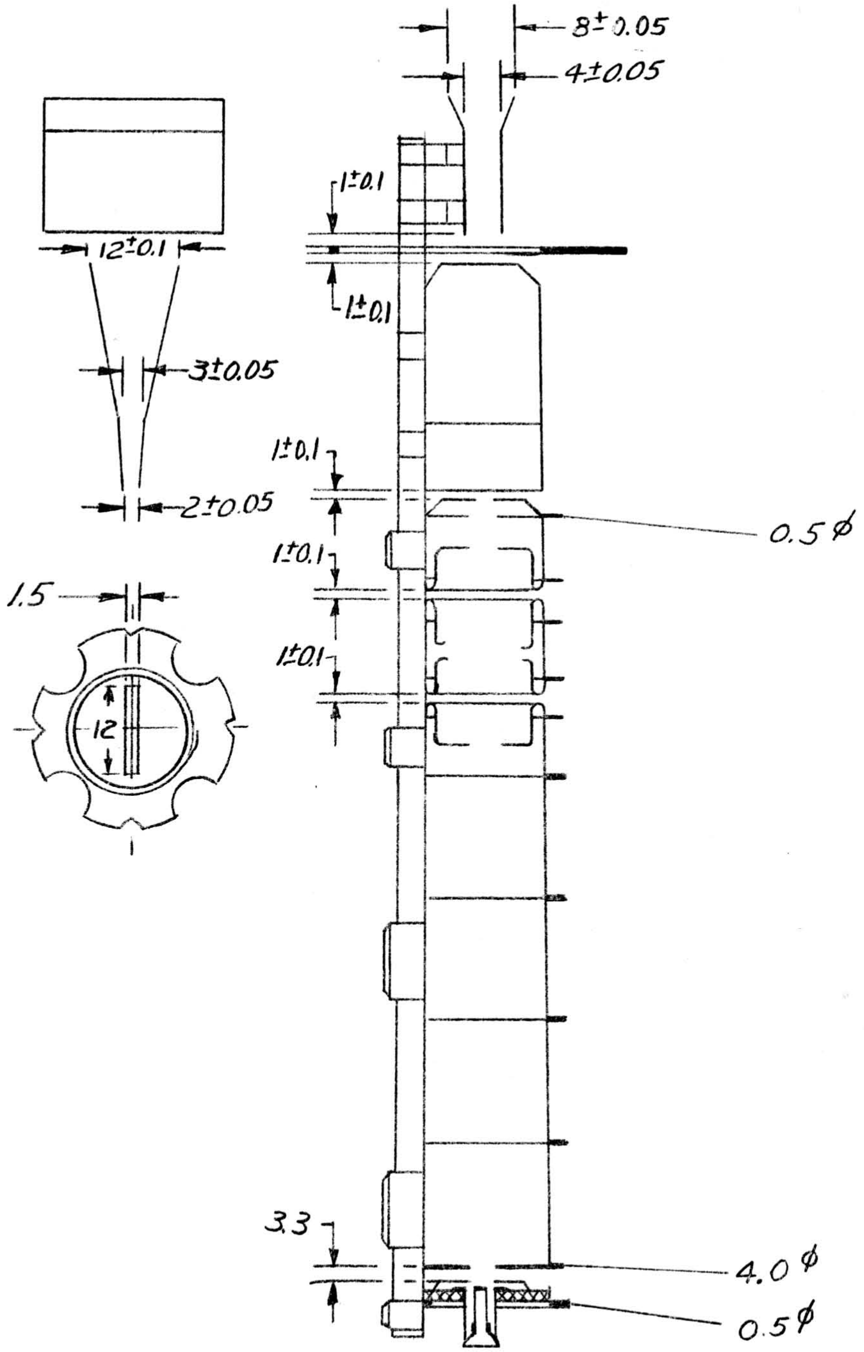
A. Radar Storage Tube

This tube provides an electrical read out storage function. The information is read in on an electrostatically deflected gun in a single line scan. The target



TELEFUNKEN
STRIP TARGET MEMORY TUBE

FIGURE 6



TELEFUNKEN STRIP TARGET STORAGE GUN

FIG. 7

is made with an aluminum oxide layer over an aluminum back plate. The nature of the processing of this layer is of interest since it is the common substitute for mica as a storage dielectric in Europeon tubes. Anodic oxidation is used to build up the oxide layer upon the aluminum substrate.

It should be remembered that electrolytes used for anodizing can be divided into two groups: 1. Those which have a solvent action on the oxide. 2. Those which have no solvent action.

The process used here is the former. It is characterized by a relatively low plating voltage and an oxide coating which is rendered porous by the solvent action of the electrolyte. This porosity makes it possible to continue building up the layer thickness without a large increase in anode voltage.

An alloy of 95% aluminum to 5% Manganese is used since it will take a higher polish than pure aluminum. The surface is first polished to a mirror finish using grits of decreasing size and ending up with Shamva. The oxide layer is plated to a thickness of 10-20 micron in a 6-7% solution of oxalic acid held at 80°C. The plating current is low, on the order of 1 amp. per 100 cm^2. This gives a very uniform fine grained oxide layer.

The information is read out by means of an identical gun.

Both guns write above the first emission ratio crossover point. A writing beam current of .01 μamp at 1500 volt writes a positive charge pattern along the line. It is followed by the reading scan operating at 0.1 μamp and 2000 volts which also erases the charge by redistributing the electrons along the scanned path. The target is thus returned to gun cathode potential after each scan. The guns can be adjusted to make the tube operate in different modes.

Notice that the drawings show a strip target with a slit collector between it and the guns. These are the only critical electrodes since the principle feature of the tube is simplicity.

The principle application is that of band width suppression of radar information for transmission over telephone channels. With a typical pulse rate of 1000 μsecond, the writing beam can be made to scan the target in 37 μsecond. The read beam can then scan in the remaining 960 μsecond, giving roughly 30 times time compression. Roughly 300 bits can be resolved at 250 μvolts output across 5K Ω output resistance. 10 steps of grey scale are discernable and the ratio of noise to poorest gradation step is about 3 times.

B. <u>Dark Trace Tube</u>:

This tube is electrostatically focused and deflected. Anode voltage can be between 2 and 4 KV. The beam is post accelerated with a spiral anode to about 14KV. The writing velocity is in the order of 50 to 100 meters per sec. Useful screens area is 8 x 8 cm. The screen is actually a mica sheet 20-35 microns thick covered on the viewing side with an electrical conducting tin oxide layer for heating the mica during erasure. The tin oxide layer has a resistance of 300 to 400 Ω. Erasure power is 60 watts and the time is about 10 sec. The screen is evaporated KCl 8 to 10 microns thick. A 5" diameter bulb with a plane faceplate is used. The overall length is about 10 inches.

C. LONG LIFE CATHODES

Dr. Dahlke has spent many years studying life of oxide coated cathodes. Fortuitously, he has used triple carbonate emission mixes on Superior cathode base nickels. He has compiled and reported (see Bibliography) on a tremendous number of extended life test experiments.

His data in all cases is carried out past 10,000 hours. He prefers the less active nickels. Tests are run at normal, below normal and above normal heater voltages. Data on mutual conductance, o bias emission and Schottke noise effect are taken with life. The latter has proved to be a reliable test for the degree of activation of the cathode. Since it in itself does not activate or destroy the cathode, it can be used for a useful tool to adjust activation and aging schedules. One simply starts with much underactivated schedules and keeps increasing activators until the test reveals a falling off point. It should be evident that this is superior to emission testing which in itself tends to activate the cathode.

A relationship has been found to exist between heater operating voltage and life. Either too high or too low a temperature is reported to give shorter life. This becomes comprehensible when one thinks about what happens inside the tube. The direct effect on the cathode is poisoning caused by gas. If the cathode is operated too cool the cathode is subject to condensation sort of gas poisoning. If it is operated at too high a voltage, evaporation takes place to the electrodes. These in turn gas up the tube when electron bombarded. Dr. Dahlke is busy with a special mass spectroscope to be used in conjunction with life testing to verify the assumptions stated above.

D. ELECTRON OPTICS

Dr. Gundert has studies the parameters of design for industrial type cathode ray tubes and has written a complete report on design criteria. (see Bibliography).

His method is to derive analytic functions no matter how watered down and then to use them as a basis of empirical experimental investigation. It is interesting to note that although laboratory experimentation is less expensive at Telefunken than under United States conditions, Telefunken still exhausts all analytical possibilities before a wheel turns in the laboratory. Dr. Gundert has been studying cathode ray beams since he wrote his doctorate thesis on the subject in 1939. He has published many articles on the subject. It is the intention of this report only to call attention to some of the simple relations which have not been commonly used at General Electric.

The writer is indebted to the translations and edition of Dr. Gundert's work by Dr. J. C. Nonnekens. Much of the material contained in the following paragraphs has been directly copied from Dr. Nonnekens memorandums. This is necessary as the discussions with Dr. Gundert were also based upon this groundwork.

One starts by drawing an analogy to the effect that electrons are bent as they pass through planes of changing potential much as light rays are bent as they pass from a medium of one refractive index to a medium of different refractive index.

$$\frac{r_1}{r_2} = \sqrt{\frac{V_1}{V_o}}$$

The square root occurs because of certain energy relationships. (See Coslett's "Electron Optics", Second Edition, page 10).

In light optics, the Helmholz-LaGrange relation gives the maximum light intensity B_2 in an optical system of source brightness Bo

$$B_2 = B_o \alpha^2 \left(\frac{r_1^2}{r_o^2}\right)$$

where α is the aperture angle at the image, and r_1 and r_o are the indices of refraction at object and image. The electron optical equivalent is obtained by substituting current densities for B_2 and Bo and using the voltage ratio for r_1 and r_o.

$$j_s = j_K \alpha^2 \left(\frac{V_1}{V_o}\right)$$

If we think of average current densities:

$$J_a = \frac{j_s \pi d_{opt}^2}{4}$$

where: J_a = beam current
J_s = average spot current density
d_{opt} = spot diameter in optical case

or

$$d_{opt} = \left(\frac{J_a 4}{J_s \pi}\right)^{\frac{1}{2}}$$

putting in js from equation (3)

$$d_{opt} = \left(\frac{J_a 4 V_o}{\pi j_K \alpha^2 V_1}\right)^{\frac{1}{2}}$$

If we allow $\tan\alpha = \alpha$ (for small angles

$$\alpha = \frac{ds}{2L}$$

where: L = distance from center of lens
ds = diameter of beam in center of lens

$$d_{opt} = \left(\frac{J_a 4^2 L^2 V_o}{\pi j_K ds^2 V_1}\right)^{1/2} = \frac{4L}{\sqrt{\pi}\, ds}\sqrt{\frac{J_a}{j_K}\frac{V_o}{V_1}}$$

which many readers will recognize as the formula Dr. Gundert commonly uses.

If something other than the whole spot is used the formula becomes:

$$d_{opt} = \frac{4}{\sqrt{\pi}} \frac{L}{ds} \sqrt{\frac{J_a}{j_K} \frac{V_o}{V_1} \ln \frac{1}{p}}$$

where $l_n \frac{l}{\rho}$ takes care of the shape of the spot and allows a correction for neglecting fringe effects.

Another limiting condition exists; that of space charge in the lens.

$$d_r \cong 0.14 \left(\frac{349 \, J_a \, ^{1/2} L}{d_s \, V_a \, ^{3/4}} \right)^{2.6} d_s$$

This derivation is long and can be obtained from the writer. Since the beam is not uniform in current density, Ja should be chosen as the peak beam current. Bo is an aberration constant discussed below.

The total spot size can then be expressed:

$$d_t = d_r + \frac{B_o}{16} d_s^3$$

$$d_t = d_{opt} + \frac{B_o}{16} d_s^3$$

depending on whether dr or d_{opt} is larger

Since dr and d_{opt} are functions of ds, equations 8 and 9 can be differentiated in respect to ds and set equal to zero. This will render the optimum ds to give minimum d_t, which after all, is the large problem.

The following summary of aberration considerations is copied verbatum from Dr. Nonnekens' unpublished memoranda:

Another necessary relation is that of aberration. The fundamental approach is based on the assumption that spherical aberration is the main contributing factor is the reproduced image (spot). Abbe's law gives for distortionless reproduction:

$$A_1 \sin \gamma \sqrt{U_1} = A_2 \sin \gamma_2 \sqrt{U_2}$$

$$A_2 = A_1 \frac{\sin \gamma_1}{\sin \gamma_2} \sqrt{\frac{U_1}{U_2}}$$

in which

A_1 = object size , A_2 = image size

J_1 = ray angle in object plane, J_2 = ray angle in image plane

U_1 = velocity in object plane, U_2 = velocity in image plane

The relation is completely dependent of the system, including the formation of intermediate images at U_3, U_4, etc.

Taking the cathode as object and A_1 the emitting diameter, we see at once that A_2 (spot) will be minimum by:

(a) decreasing A_1 (increasing cathode loading)

(b) increasing U_2 (higher voltage)

(c) increasing J_2

Fundamentally we cannot do too much about U_1 and J_1.

Increasing J_2 means with a given distance lens-screen, increasing the lens diameter. Here we are limited by spherical aberration and deflection errors.

Consider the reproduction of a point source on axis as in Figure 1, which shows spherical aberration. Later on, when we consider a finite size object, we can then arrive at spot size by adding the dimensions obtained from a distortionless finite size object, plus the aberration formed from the point source considerations.

The image point where rays very close to the axis meet determines the image plane. More diverging rays cross this plane at a distance (Δr_b).

Strictly speaking (Born, Optik, Berlin) (1933) for third order aberrations, which should be considered

$$\Delta r_b = Br^3 \text{ in which}$$

B is an aberration constant for the plane of r, in this case the aperture plane. B is also a function of lens form, object distance and the placement of the aperture plane. If we place the aperture plane in the substitution plane (nomenclature per Figure 8) then

$$\Delta r_b = B_o r_o^3$$

(B_o good for this plane only for a given system)

The substitution plane is the plane where a stright line as given by the beam travel in the image space, meets the emerging beam in the object space. Strictly speaking, this plane will be slightly covered but for all normal C.R.T.'s it can be taken as a flat plane.

The difficulty might now seem to know the exact location of this plane for further geometrical considerations. Beam tracing methods and rather involved mathematical computations are possible. However, as in well known beam tracing methods can easily produce severe errors. From a lot of practical measurements performed on different systems, Dr. Gundert (aberration in electron optical lenses, German thesis of May 1940) proposes a simple location of this plane. As per Figure 8, the location is given by $a^1 - 2 == 3/2$ R in which R is the radiûs of the bigger of the cylinders. The movement is towards the lower voltage (in Fig. 8 $U_1 < U_2$).

<u>Note:</u> This assumption seems maybe too simple to be true, but a measurement of 74 configurations, and voltage ratios by Dr. Gundert proves the assumption to be good enough for design purposes.

Assume an arbitrary fixed value of B_o and one obtains a curve similar to Figure 1 with different values of r. One can then draw the "caustic" envelope. In the image plane there results the well known spherical aberration picture of a bright sharp center and a diffused halo. Note also that minimum beam diameter is obtained not in the image plane but in a plane $Z_{Min.}$ where the outermost ray buts the opposite side caustic curve.

Putting in coordinates (r, Z) the equation of the rays on the image side is given by:

$$r = \frac{r_0 + B_0 r_0^3}{b} (b - z) - B_0 r_0^3$$

The caustic curve equation is then

$$r = \frac{Z\left(1 - \frac{z}{b}\right)^2}{\sqrt{B_0}\sqrt{27\left(\frac{z}{b} - \frac{z^2}{b^2}\right)}}$$

Multiplying (5) and (6) with $\sqrt{B_0}$ gives:

$$r\sqrt{B_0} = \left[r\sqrt{B_0} + \left(r_0\sqrt{B_0}\right)^3\right]\left(1 - \frac{z}{b}\right) - \left(r_0\sqrt{B_0}\right)^3$$

$$r\sqrt{B_0} = \frac{2\left(1 - \frac{z}{b}\right)^2}{\sqrt{27\left(\frac{z}{b} - \frac{z^2}{b^2}\right)}}$$

Because $r\sqrt{B}$ is dimensionless (B being 1^{-2}) as is also Z/b we can now plot (7) and (8) in normalized form, <u>valid for all values</u> of B_0 and b. For any value of $r_0\sqrt{B_0}$ we can also read $r_{min}\sqrt{B_0}$ (min. beam diamter) indicated in Figure 9 as points M_1; M_{08}; M_{06}; etc.

It is to be remembered that with the ever present spherical aberration in electron optical systems, we automatically adjust for optimum focus, by throwing not the image plane but the minimum beam diameter plane on the phosphor screen. The spot as obtained in the first case (image plane on the screen) has the characteristics of a small bright center with a diffused extended halo, the radius of which is given by $\Delta r = r_0^3 B_0$ or in normalized coordinates $(r_0\sqrt{B_0})^3$. When we project r_{min} on the screen, the lens is in reality made weaker to obtain the minimum <u>total</u> obtainable spot. For all practical guns one can assume that this spot radius is ¼ of the radius $r_0^3 B_0$.

A measurement of the halo radius enables us to determine B_0 for the total gun structure providing we know the location of the substitution plane and therefore r_0.

For construction Normalized Caustic Curve

z/b	$r\sqrt{B_0}$
1	0.
0.9	0.0128
0.8	0.038
0.7	0.075
0.6	0.126
0.5	0.192
0.4	0.283
0.3	0.411
0.2	0.615
0.1	1.04
0.05	

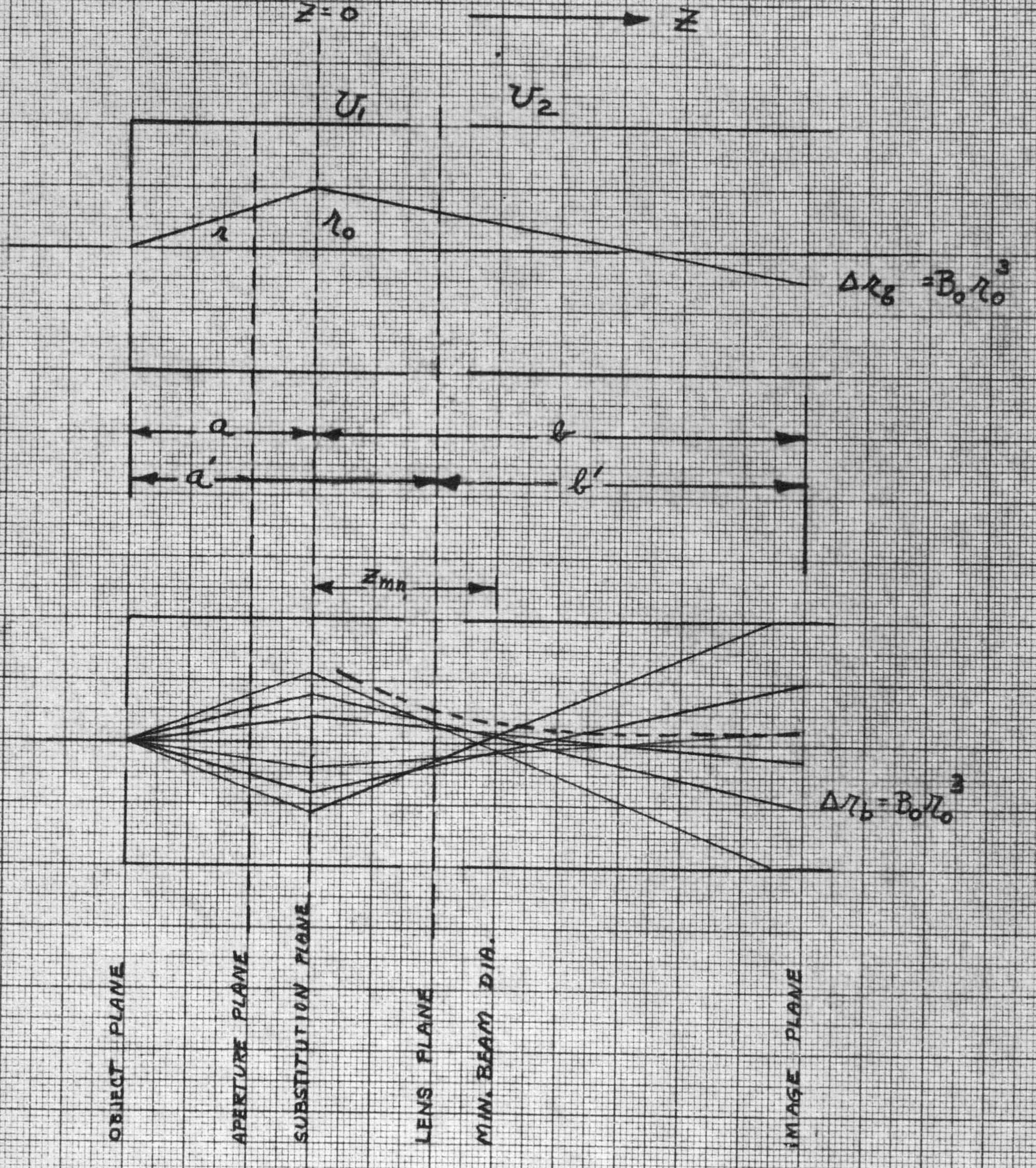


FIG. 8 BEAM PATHS IN ELECTROSTATIC LENS

FN-155 (8-50)
GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., U.S.A.
160X220 29/64 Inch Divisions

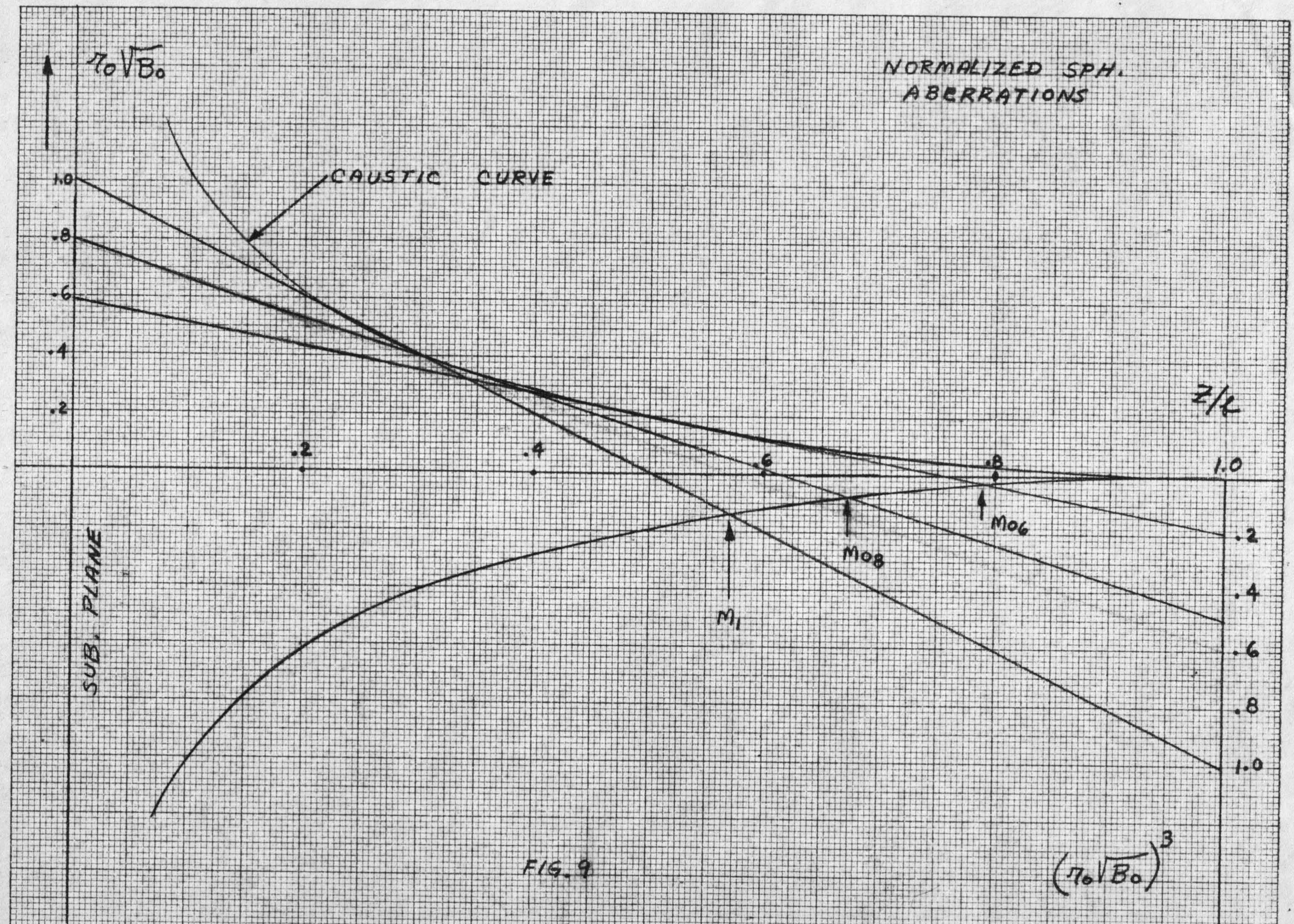


FIG. 9

E. High G_m Gun

This project has been reduced to a design which is to be experimentally verified in Syracuse. Since the design is completely reported elsewhere in Dr. Nonnekens' work, it will not be further discussed here. Suffice to say that the work has progressed very well.

F. Processing of Image Converter Photo Cathodes

Dr. Schaffernicht described the Silver oxide process thus:

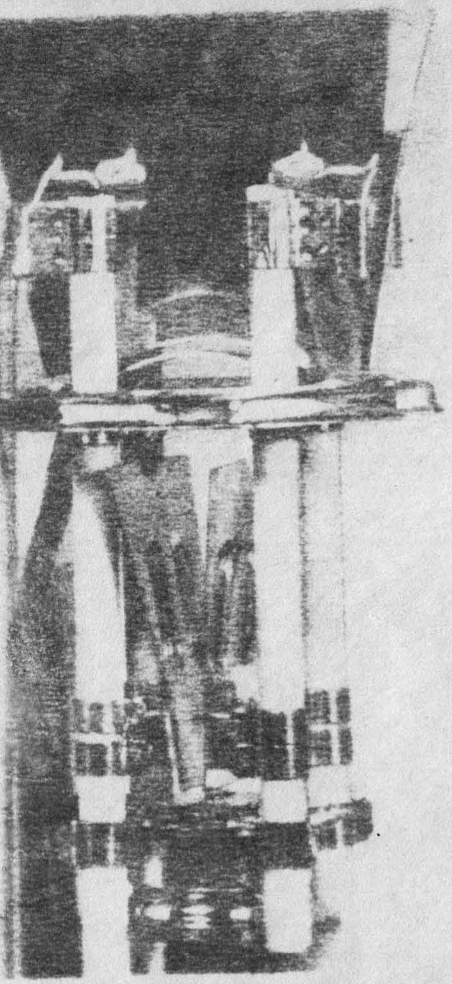
1. Pull vacuum
2. Evaporate pure silver until the surface appears blue. (This is about 10^{-5} mic. thick.)
3. Leak in oxygen and spark a gas discharge at 10^{-3} mic. pressure to oxidize silver.
4. Flash cesium.
5. Test, using device as photocell with evaporators still inserted.
6. Repeat 1-5 above as necessary.
7. Tip-off.

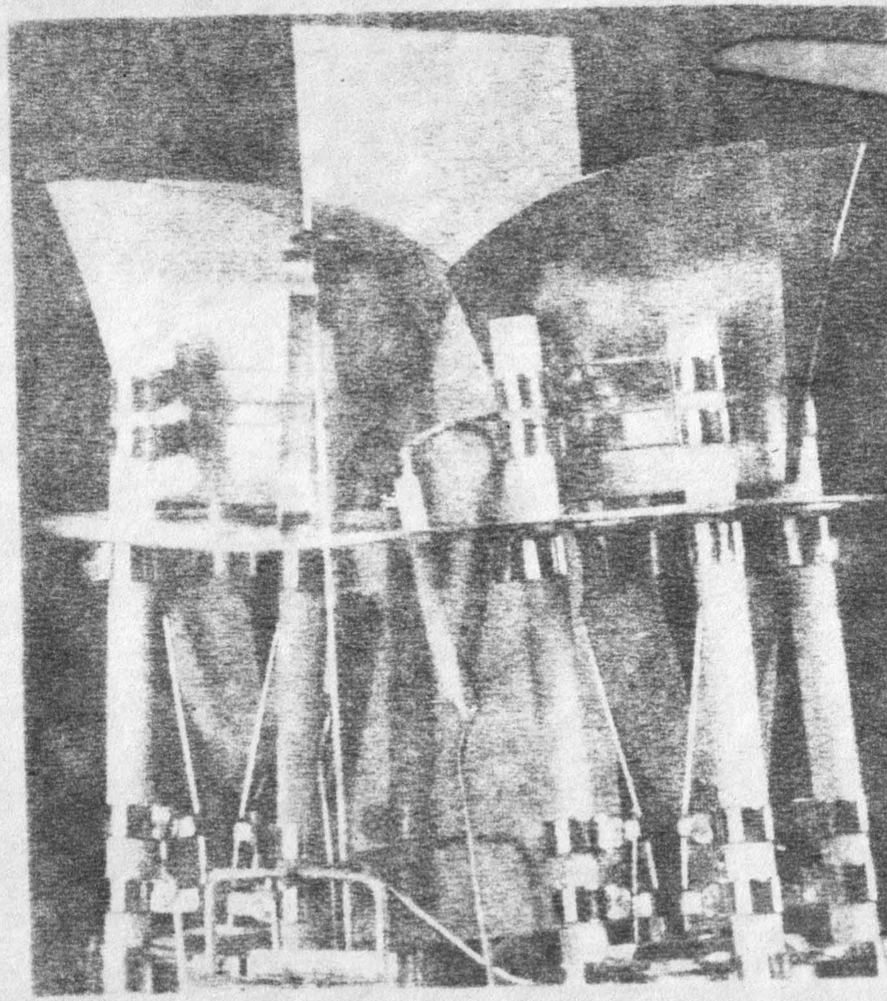
G. Electrostatic Deflection Plates

Dr. Gundert has given the problem of deflection defocusing in electrostatic deflection considerable thought. He has designed a unique set of $D_3 - D_4$ plates which correct for defocusing in the $D_3 - D_4$ plane. Figure 9 demonstrates the shape.

Since little can be done to the $D_1 - D_2$ plates (the beam has already been swept once). The spot is made elliptical in the correctable $D_3 - D_4$ dimension before entering the deflection system. This automatically helps the $D_1 - D_2$ plates and is corrected for the $D_3 - D_4$ direction. The pictures of Figure 9 show the plates corrected for raster distortion as well.

The graph Figure 10 is used to calculate deflection parameters.





CORRECTED DEFLECTION
PLATES
FIG. 10

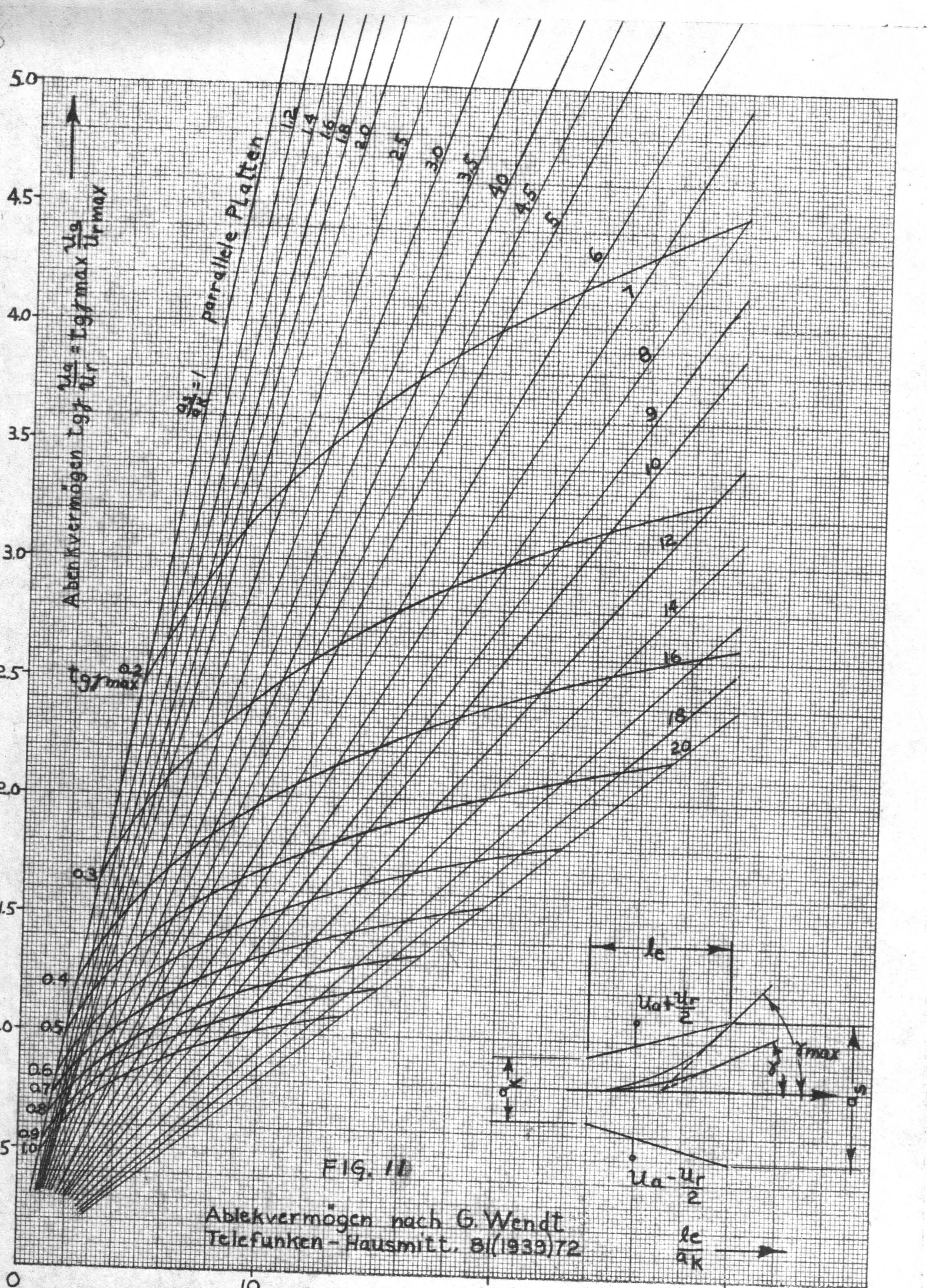


FIG. 11

Ablekvermögen nach G. Wendt
Telefunken-Hausmitt. 81(1939)72

VI. Visit To CIFTE

Le Cathoscope Francias (Division)
Lyon, France

This was a factory visit and the following simply were notes taken during the tour.

A. Water is demineralized using Phillips Equipment to 2 megohms. It is checked daily.

B. Screening:

1. Powder - RCS 287A - this phosphor was giving trouble because of the relatively long persistent blue component.

2. Weight - 3 grams for 17", 5 for 21". The bogey desired is 3 mg./cm^2.

3. Nitrate stock solution 4/1000 of barium nitrate.

4. Sample formula for 17":

Barium Nitrate	800 cc
Water	7200
Silicate	400
Phosphor	3 grams + 120 cc water
Water	100 (flush)

5. Silicate mole ratio: SiO_2/K_2O 3.35/3.55

6. Silicate Density 15° Boehme 1.11 @ 20° C.

7. Bulb Temperature (Also room) 26° C.

8. Formula Temperature 12-13° C.

9. Settling Time 20 Min. (17") 20 Min. (21")

10. Equipment - Tilt Tables

C. Filming:

1. Water rinse on rotary head using a limp plastic tubing to introduce water against the tube wall.

2. Lacquer solutions:

Solution I	102.5	gram	Nitrocellulose
	63	cc	butyl sebacate
	7450	cc	atyl acetate
Solution II	787.5	gram	Lucite 45
	13	gram	Acrolyte B72
	7450	cc	Toluene

Roll solution I & II 24 hours each, then roll together for 4 hours and filter.

3. Spray:

Pressure	2.8 kilogram/cm^2
Nozzel	#11,001 Spray systems Company
Time	6 seconds
Rotation	30 sec. @ 60 rpm

D. Aluminize:

1. Oil - Edwards Silicon Oil #403
2. Alum ut (21") .55 gram
3. Aluminum thickness (21") 700A min. @ center, 1000 at corner
4. Flash 90% of aluminum
5. Pressure during flash .2 - .3 micron

E. Bake:

1. Type - Lehr - bulb on side
2. Speed - 6 cm/min.
3. Thermocouple cemented to surface with Savereisen
4. Temperature:

   Peak Outside Center face 425°C
   Oven 400°C - 15 minute
   Exit 120°C
   Overall bake 2½ hours

F. Exhaust:

1. Capacity - 55/hour 17" 45/hour 21"
2. Type Machine - RCA in line
3. Oven - Electric Radiant
4. Oven Curve (Same as bake above)
   12°/min. heating cool 6-7°/min.
5. Pump Edwards 203 - Edwards 150
6. Pump Oil Edwards Silicone 203
7. Grid #1 Temperature (max.) 850°C 10 minutes
8. Tip off Temperature - 220°C

(Tip off is performed through a port in the side of the oven during the latter part of the activation schedule while the filament is on. The bulb continues in the oven until an exit temperature of 120°C is reached)

9. Activation:

.60)		
.70)		
.80)	10 min.	R.F.
.85)		
.85)		
.85)	5 min.	
.85)		
.70	($10VG_1$) 2-5 min.)	

10. Gas Ratio:

.4 - .5 after tip-off change pump at 1.00

11. Aging:

Step	Time	Ef	Eg_1	Eg_2	Ultor
1	½ min.	13.0			
2	25 "	10	+5	+500	-140

12. Cathode:

Cap Material - 220 Inco or Wiggins "O"
Sleeve Material - "Normal" Nickel

13. Emission Mix: French triple Carbonate
V.C.L.A.F. (RCA formula)

Thickness - .04 - .06 mm
Weight 16 - 32 mg/20 mm^2

14. Getter - English Kemet 61018F Total weight (2 getters) 24 mg.
Getters are crossfired up.

15. Cathode Temperature 850°C (Pyrometer)

G. Electron Gun:

This is the standard RCA electrostatic. They squeeze the field electrodes to the proper spacing after beading.

Spacing (mm)	Min.	Bogey	Max.
K-G1		.1	
G1-G2	.32	.4	.48
G2-A	2.8	3.0	3.3
Grid 1 hole	.64		
Grid 2 hole	.79		

They have no test at present for focus voltage or resolution.

H. Life Test

6.3 volt   17.5 KV   200 μamp.   500 volt
cycle 13 min. on - 7 min. off on all voltages

They put 1 or 2 tubes per day on life.

I. The screens and general quality of the tubes looked good at test. They have little trouble with Al leakage, but only test at 20 KV.

VII. Visit to C.S.F. Paris France

This company builds a complete line of Industrial tubes. Dr. Warnecke heads up both the manufacturing and engineering groups building magnetrons, linear accelerators, transmitter tubes and cathode ray tubes.

A. TCM 12-13, MTV 100 Barrier Grid Storage Tubes

The TCM 12 is an exact electrical replica of the RCA Radechon. Several improvements have been worked into its construction. By using precision glass tubing for necks, and jigging the gun carefully at gun seal, they are able to position the gun accurately in the neck. The target is mounted from the backplate lead which is sealed through the center of the face. This lead is in the form of a ¼ Kovar rod welded accurately orthoginal and centered on the back of the backplate. The face and neck are then sealed with the face chucked from the rod and the neck from the outside of the precision tubing. There results a tolerance of gun centering at the target of ± .05 mm. Shading is considerably reduced. Some of the advantage gained is in turn lost in that the aluminum oxide dielectric (similar to that described for the Telefunken storage tube) is somewhat more porus than the mica commonly used by R.C.A. (C.S.F. does not agree with this).

The oxide layer is on the order of 20 μ. The mesh has 60% transparency and 20 holes/mm. The tube resolves 100 bits per diameter.

The TCM 13 is different in that the backplate has been given a radius of curvature of 50 cm convex outward toward the gun end of the tube. This seems a paradox at first glance, since the curvature is opposite to that desired for orthoginal beam landing. Correction by means of electron optics is not bad, however, so long as good symmetry exists this, it will be observed, has been achieved.

The advantages are:

1. Greater strength (no microphones)
2. Better contact between mesh and insulater. The latter reason also allows the use of electroformed rather than woven mesh which yields a further advantage:
3. Lower noise.

The MTV 100 is mechanically similar to the TCM 12, above, except that it uses a thinner oxide layer, to give greater target capacitance, so that the tube can be used for multiple read out application.

The tubes are being used to compress band width from 12 to 6 megacycles.

B. TMA 403 Graphecon Type Double Ended Memory Tube

This tube uses a unique target. A 65 to 70% transparency 20 holes/mm mesh is first filmed by flotation method using nitrocellulose lacquer. An aluminum layer is evaporated on top of the lacquer film in a vacuum. A ZnS layer $\frac{1}{2}\mu$ thick is then evaporated on top of the aluminum. The target is then baked to burn out the lacquer. Some remanents of the lacquer diffuse into the ZnS and activate it making it conductive preferentially in the thin direction. Lateral scattering is, therefore, reduced and the tube is an improvement over the Graphecon.

The read gun is electrostatic and is built with precision similar to that described for the barrier grid tubes. The write gun operates at 10KV to penetrate the ZnS layer, induce conduction and cause the signal to appear at the aluminum backplate layer. It is magnetically focused and deflected. The write gun must be on a ratio of 9/6 better than the read gun in resolution, to make up for lateral conduction losses in the target.

The resulting tube is very good, it resolves 600 bits at 20% modulation and 450 bits at 50% modulation level. This is the tube being used as a scan converter at Orlay Airfield at Paris. The CAA in the United States are purchasing tubes to fill the sockets of some 25 pieces of equipment here.

C. TEI $\frac{500}{1000}$ Direct View Storage Tubes:

These two tubes are 5 and 10 inch versions of the standard RCA 6866. The electrostatic write and erase gun is mounted off axis and is electrostatically deflected and focused.

The targets are SiO_2 dielectric evaporated on 10 holes/mm 70% transparency copper mesh. Useful screen area for the TEI 10,000 is 180mm. This area will reportedly store 5 half tones at 50% modulation level and 400 lines of a television sort of presentation. The storage time is between 1-10 minutes.

The smaller TEI 500 has slightly less than $\frac{1}{2}$ this performance.

D. Mesh Fabrication:

CSF evaporates copper directly on a ruled glass master (no submaster is made). The master is polished down to the glass surface. (The lines are left filled with copper.) The plate is then electroplated up to the desired weight. (transparency). Finally, the mesh is stripped off the master. Typical transparency is 70% mesh fineness of 20/mm.

E. McS Processing

1. Tubes are pumped for 72 hours.
2. All storage tubes use tantalum as well as barium getters.
3. Dr. Huber has experimented widely with impregnated cathodes (See Bibliograph). His most successful design uses Barium Tungstate in Stoichiometric proportion with Tungsten powder. Loadings of 2 amps/cm^2 at 1900°C have been achieved with excellent life in transmitting tubes operating at very high voltages. No cathode ray tube applications have been explored.

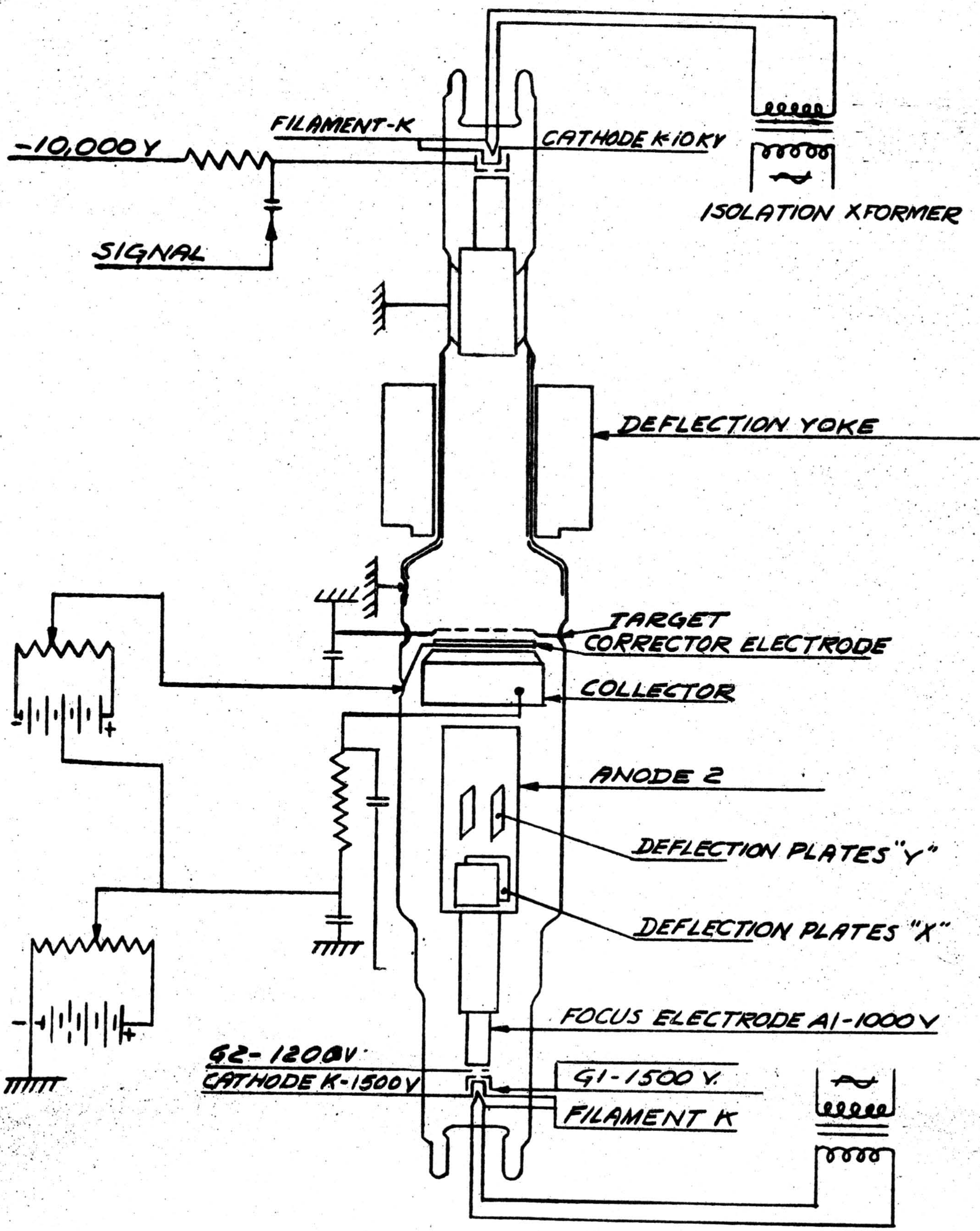
F. OG506 Oscilloscope Tube

This tube was built to compete with the spiral anode post accelerators made in the United States. The tube uses a metal grid 10/mm at 80% transparency spaced .5 cm from the inside of the face. A second grid turned 45° to prevent Moire is spaced 10mm toward the gun and is used as a suppressor. The faceplate is ground inside and out to optical flatness. Typical operating voltages are:

A1 (also post accelerator screen)	2000V
A2 (Focus)	500-800V
G1 (Cut-off)	-35 - -60
A4 (Screen)	15,000V
A3 (Suppressor)	2,200V

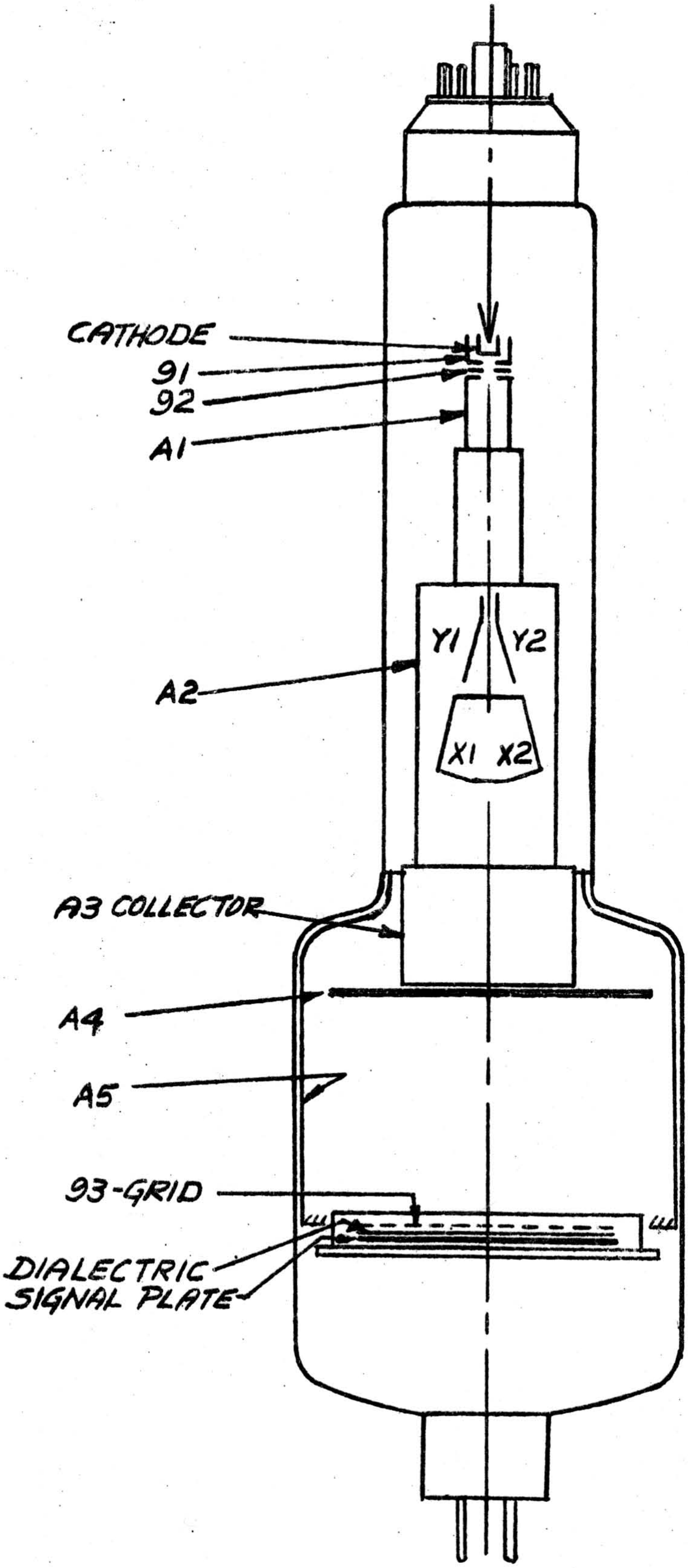
Reflection Sensitivity:

.1V/mm /1000V of A1



CPS TMA403

FIGURE 12



CONSTITUENT PARTS OF TUBE TCM 12 X CPS

FIGURE 13

B I B L I O G R A P H Y

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