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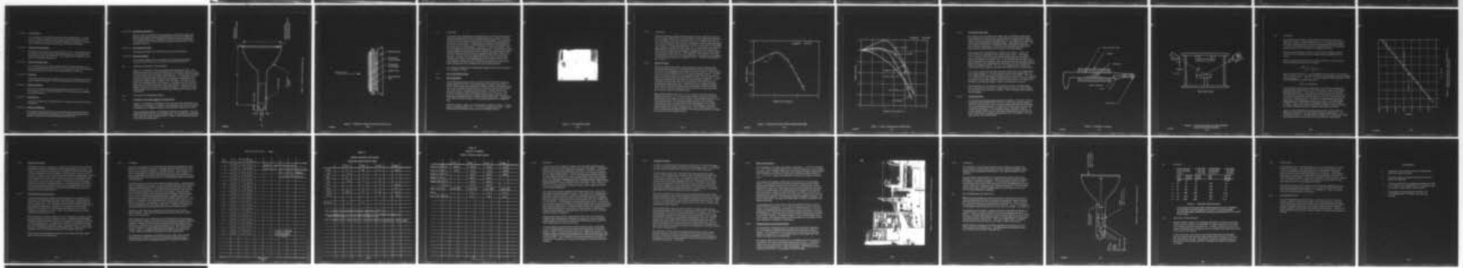

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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

ECOM-77-2639-1

HIGH CONTRAST CRT

Norman H. Lehrer
WATKINS-JOHNSON ~~COMPANY~~
440 Mt. Hermon Road
Scotts Valley, CA 95066

New
410583

January 1978

Interim Report for Period 1 January - 30 April 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this program is the development of a three-inch, high contrast, two color CRT employing evaporated thin film phosphors.

The initial green layers fabricated on CRT faceplates under this program exhibit luminous efficiencies approximately 25% of those previously achieved on layers fabricated on sapphire. This reduction results from the lower processing temperature required for use with the Type 1723 glass faceplates. Type 1720 glass originally envisioned for use in this effort and capable of higher temperature processing than 1723 glass was not available at the start of the program.

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DD1473 - Abstract (Continued)

Faceplates of 1723 glass and funnels of 7052 glass have been ordered to build and study fabrication problems.

Data taken on the laminarflo gun in a three-inch monochrome CRT indicates that the gun can achieve current densities on the order of 12 A/cm^2 at a screen potential of 12 kV and therefore should easily satisfy the requirements for a current density of 1 to 2 A/cm^2 at 10 to 20 kV to achieve the required brightness.

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1.0 CONFERENCES

1.1 3 March 1977 at Fort Monmouth

Report of Conference held at ECOM, Ft. Monmouth, New Jersey on 3 March 1977 with Watkins-Johnson Company concerning the progress made on Contract DAAB07-77-C-2639, High Contrast CRT.

Personnel Present:

Watkins-Johnson Company

Mr. N. Lehrer
Mr. T. Fry
Mr. J. Rowley

ET&D Lab - ECOM

Dr. E. Schlam
Mr. P. F. Krzyzkowski

The purpose of the meeting was to review and discuss progress under the recently awarded contract.

Although the contract has been in effect for three months, the subcontract with Lockheed Palo Alto Research Laboratory for fabrication of the phosphored faceplate with black absorption layer has not yet been finalized. Mr. Lehrer stated that the Watkins-Johnson management had approved the subcontract and that a DCASR audit of Lockheed had been completed but formal approval from the California DCASR had not been obtained. Mr. Krzyzkowski commented strongly on the unreasonable delay and recommended that the Watkins-Johnson contract office resolve the problem. Messrs. Lehrer and Fry promised to give this first priority upon their return to California.

Mr. Krzyzkowski recommended that W-J start fabricating experimental CRTs from glass envelopes and faceplates, as will be used in contract tubes, as a parallel effort, in view of the slow contract start, and also to determine potential problem areas. Mr. Lehrer agreed to this recommendation and will contact CORNING about the 703 type panels and the type 108P frit.

The Lockheed proposal to W-J was also discussed. Lockheed is to purchase the phosphor material from a Santa Clara company and the faceplates from CORNING about mid-April.

Mr. Lehrer described a change in the approach to the black absorption layer as originally proposed by Lockheed to be subcontracted out to LUXEL. Lockheed has developed their own black layer which indicates superior uniformity and repeatability. Lockheed will, therefore, be depositing their own black layer on the phosphor layers. Mr. Krzyzkowski requested the W-J personnel assess the possible risks in the phosphor material availability.

1.2 7 April 1977 at Lockheed and Watkins-Johnson Company

Report of contract meetings at Watkins-Johnson, Santa Clara, California and at Lockheed Research Laboratory, Palo Alto, California on 7 April 1977 concerning Contract DAAB07-77-C-2639, High Contrast CRT.

Personnel Present:

Watkins-Johnson Company

Mr. N. Lehrer
Mr. T. Fry

Lockheed Research Laboratory

Dr. R. Buchanan
Dr. G. Maple

ET&D Lab - ECOM

Mr. P. F. Krzyzkowski

The purpose of the meetings was to discuss contract status and plans.

As first priority of the discussion, Mr. Lehrer related that Lockheed has rejected the W-J subcontract as it was of the fixed buy type and not representative of the proposed Lockheed program. Mr. Lehrer resolved this with the W-J legal office and the subcontract will be modified.

Mr. Krzyzkowski toured the Lockheed facility and was shown newly deposited phosphor films on sapphire substrates with black layers. Electron beam excitation of a new film was attempted, however, the demountable vacuum system was severely limited in beam current and additionally the anticipated red cathodeluminescence was not achieved. Lockheed will further investigate the reason for this.

Upon review of the Lockheed demountable vacuum system, Mr. Krzyzkowski suggested that a Watkins-Johnson laminar flow electron gun be considered for use as it is capable of much higher beam currents and is the contemplated final CRT electron gun. Mr. Lehrer agreed to supply Lockheed with some laminar guns for this purpose.

Dr. Maple described the Lockheed black absorption layer fabrication. Tantalum was indicated superior over other metals tried for this purpose.

Mr. Krzyzkowski also toured the CRT facilities at Watkins-Johnson. The facility includes all the necessary processing and electrical and optical characterization equipment necessary to complete the contract CRTs.

2.0 INTRODUCTION

2.1 Background

Development of the high contrast two-color tube, which is the objective of this program, encompasses the fabrication of the screens and their assembly into the completed tube. The screens are being made by the Lockheed Palo Alto Research Laboratory under subcontract from Watkins-Johnson Company. Watkins-Johnson will assemble the completed screens into finished tubes.

The major thrust of this program is the screen fabrication effort, particularly the application of these screens to a thin film phosphor cathode-ray tube. Effort on the screens was late in starting because of the delay in awarding the subcontract to the Lockheed Palo Alto Research Laboratory.

This report covers the initial efforts at screen fabrication, including both the phosphor layers and the black, non-reflecting layer for use on CRT faceplates. Performance data is also presented on the Laminarflo Gun to be used in the three-inch, two-color tube.

2.2 Statement of the Problem

The basic problem addressed by this program is the ability to display information generated by various electronic systems with suitable high resolution in two colors with its legibility maintained under ambient illumination ranging from 10^{-4} to 10^{-3} fc.

Existing color tubes cannot satisfy the above requirement. Such tubes which employ aperture masks are severely limited in brightness and resolution by the aperture mask. Their brightness is limited because the aperture mask transmission is only 15 to 20 percent, therefore wasting 80 to 85 percent of the current. The wide spacing between holes degrades the resolution below that required in most military systems. Furthermore, the color purity of such tubes is influenced by their position with respect to the earth's magnetic field and it is therefore impractical to incorporate them in airborne systems.

The use of color penetration phosphors overcomes some of the problems of mask type tubes. The color purity is no longer affected by the tube orientation and the resolution is higher than that which can be achieved with a mask type tube. Conventional color penetration tubes which employ powdered phosphors cannot be used for daylight (high brightness) viewing because of their high reflectivity and low brightness, particularly in red, which produces a washedout low contrast display. The reflectivity of the phosphor is high because of its particular nature. The brightness of the red is low because most of the light generated by the red phosphor is scattered by the green phosphor before it reaches the faceplate of the CRT.

2.3 Technical Guidelines

2.3.1 Scope

These technical guidelines outline a program leading to the design and fabrication of a very high contrast CRT. The screen phosphors of this CRT are to be of the transparent film type and backed by a black light absorption coating. Therefore, a prime objective of this program is the incorporation of a phosphor-screen technology that will result in transparent film phosphors deposited on a substrate-faceplate which is an integral part of the CRT envelope. It is furthermore intended that the phosphor screen incorporate a two layer, penetration type multicolor structure. The phosphored faceplate is to be attached to available tube envelopes in a manner consistent with economical CRT manufacturing methods.

2.3.2 Applicable Documents

MIL-E-1 Manual

MIL-STD-1311A

2.3.3 Requirements

2.3.3.1 General - This program shall be directed toward the development of a high contrast CRT based on the use of high efficiency transparent phosphors. This capability is intended to be accomplished by the deposition of transparent phosphor layers on a suitable substrate that will be bonded to a standard CRT envelope in an economical manner. This program is intended to accomplish this by an extension of available phosphor techniques to CRT sizes now used in military equipment. Areas of investigation and performance will include, but not necessarily be limited to, the features outlined in the following paragraphs.

2.3.3.2 Detailed Program Objectives

2.3.3.2.1 Phosphor Screen Characteristics

1) Luminescent Material - The luminescent material shall be one that has a demonstrated high cathodoluminescent efficiency in transparent form. Since it is intended that bi-layer films be used, the demonstrated efficiency should be with various colors, particularly red and green. It is not intended that phosphor development work per se, be part of this program.

2) Phosphor Persistence - The transparent phosphors used in the CRT screen should have persistences in the range of JEDEC designations "medium short" to "medium". Trade-offs of persistence with other phosphor properties and characteristics should be determined.

3) Physical Characteristics - It is intended that a bi-layer type of phosphor screen shall be used in the CRT. In that event, each phosphor layer shall be transparent and may or may not be separated by a transparent dielectric layer.

4) Light Absorbing Layer - A requirement of this program is that the phosphor screens be backed, on the electron gun side, with a uniform light absorbing coating that can be effectively penetrated by the electron beam. Specular reflection from this coating, on the phosphor side, should be no greater than 1 percent. Diffuse reflectance shall be no greater than 0.25 percent. This coating shall not cause any substantial reduction in electron-current or electron-energy into the phosphor screen.

5) Phosphor Electrode - The phosphor electrode shall be a thin aluminum film, behind the black coating of 2.3.3.2.1-4), and electrically insulated from all other tube electrodes by means sufficient to withstand the operating levels within the tube without electrical breakdown or appreciable leakage current.

6) Phosphor-Screen Substrate - The phosphor screen substrate shall be capable of withstanding all necessary fabrication techniques of the transparent film screen without change of shape or curvature that would degrade the end result of a completed CRT.

2.3.3.2.2 CRT Characteristics

The goal of this program is a CRT that is physically and electrically replaceable with a currently existing CRT. To this effect, the envelope, deflection angle and means, focusing means, and basing should duplicate a Dumont KC3055 (formerly KC2626) CRT used in the AN/A PR-39. It is accepted that an improved electron gun may be used with this phosphor screen. To this effect, it is desirable that the final CRT be electrically interchangeable with the KC3055, as closely as possible, so that power supplies driving the KC3055 need not be replaced.

2.3.3.2.3 CRT Contrast

It is necessary that the CRT be legible in direct sunlight under its normal mode of operation, without the use of added contrast enhancement devices. Specific quantitative criteria to satisfy this requirement should be developed so that optical instrumentation tests may be used for its verfication.

2.3.3.2.4 Faceplate Characteristics

The faceplate size should be directed to the above CRT. The faceplates shall be bonded to the tube envelope by conventional means or use of graded seals. Glass-to-metal seals are undesirable. This program is not intended to support special envelope development.

2.3.3.2.5 Phosphor Voltage Range

The CRT should operate within conventional limits of anode potential. In no case should this potential exceed 20 kV. In the penetration screen configuration, anode potential shifts to achieve color changes should be minimized.

2.3.3.2.6 Resolution

A line width, taken at the half amplitude point of the spot distribution, of 0.012 inches or better is desirable. The line width should not exceed 0.016 inches.

2.3.3.2.7 Display Luminance

The CRT is to operate under ambient illumination from 10^4 to 10^{-3} fc. The CRT luminance is to be uniformly adjustable to provide satisfactory legibility under these conditions.

2.3.3.2.8 Writing Speed

A minimum writing rate of 50,000 in/sec for a single trace for all color fields is desirable.

2.3.3.2.9 Phosphor Maintenance

The transparent phosphors shall have high maintenance under normal modes of operation consistent with paragraph 2.3.3.2.3, and burn sensitivity tests shall be conducted on the screens incorporated into the CRT.

2.3.3.2.10 Reliability Consideration

Since the CRT's developed under this program are intended for tactical and airborne applications, adequate consideration must be given throughout the development program to the reliability of this tube for such environments. As an objective, the CRT should be able to pass the physcial tests for CRTs specified in MIL-E-1.

2.3.3.2.11 Environmental Testing

Environmental testing of the CRTs will not be part of this program.

2.3.3.2.12 Program Emphasis

The program emphasizes the investigative areas outlined in paragraphs 2.3.3.2.1-1), 2.3.3.2.1-4), 2.3.3.2.2, 2.3.3.2.3, and 2.3.3.2.7.

3.0 TECHNICAL APPROACH (TUBE DESIGN)

Figure 1 is a schematic of the proposed high contrast multicolor CRT. The physical dimensions are identical with that of the existing CRT (Dumont KC3055). The high contrast tube will employ a Laminarflo Gun. This gun offers advantages over the crossover gun and is described in Reference 1. The phosphor screen incorporates a black backed multilayer bicolor transparent phosphor film deposited on a substrate which is bonded to the CRT funnel. The details of this screen are described further in this report. In operation, the color of the display can be controlled by selection of the beam potential. At about 10 kV, the display will be red, at 15-20 kV the display will be green. With the exception of the focus and anode potentials, the operating voltage will be the same as the existing CRT.

4.0 THE THIN FILM PHOSPHOR SCREEN

4.1 Description of the High Contrast Two-Color Screen

Figure 2 is a schematic representation of the two-color high contrast film to be employed in this program. As shown in the illustration, the two-color phosphor is supported on a transparent substrate which forms the faceplate of the CRT.

The green-luminescent film is immediately adjacent to the substrate. The red-luminescent film resides on top of the green one. The opaque layer is deposited on the other face of the red phosphor film. Finally, a thin conducting aluminum layer covers the opaque layer.

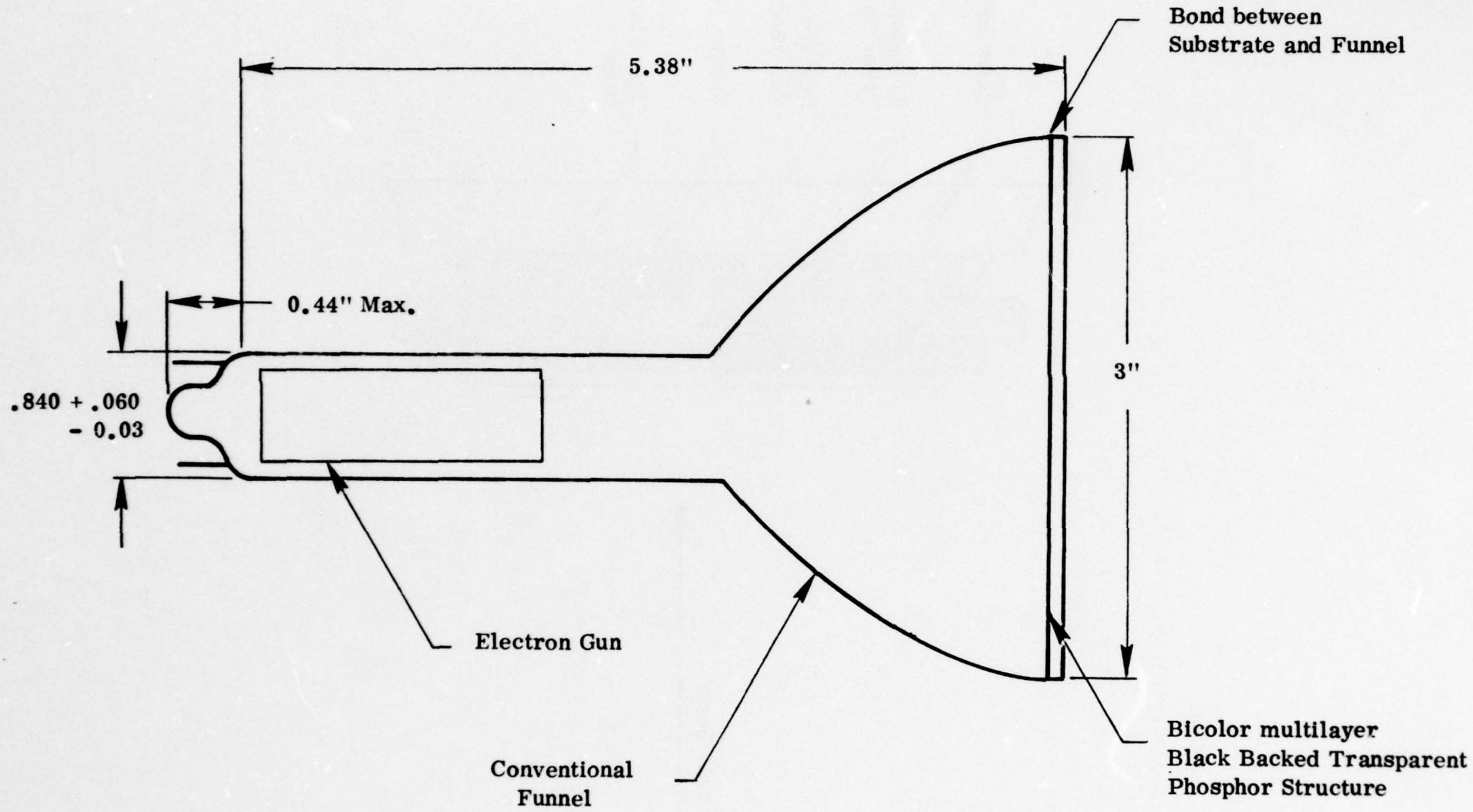

Figure 1. Schematic of High Contrast CRT

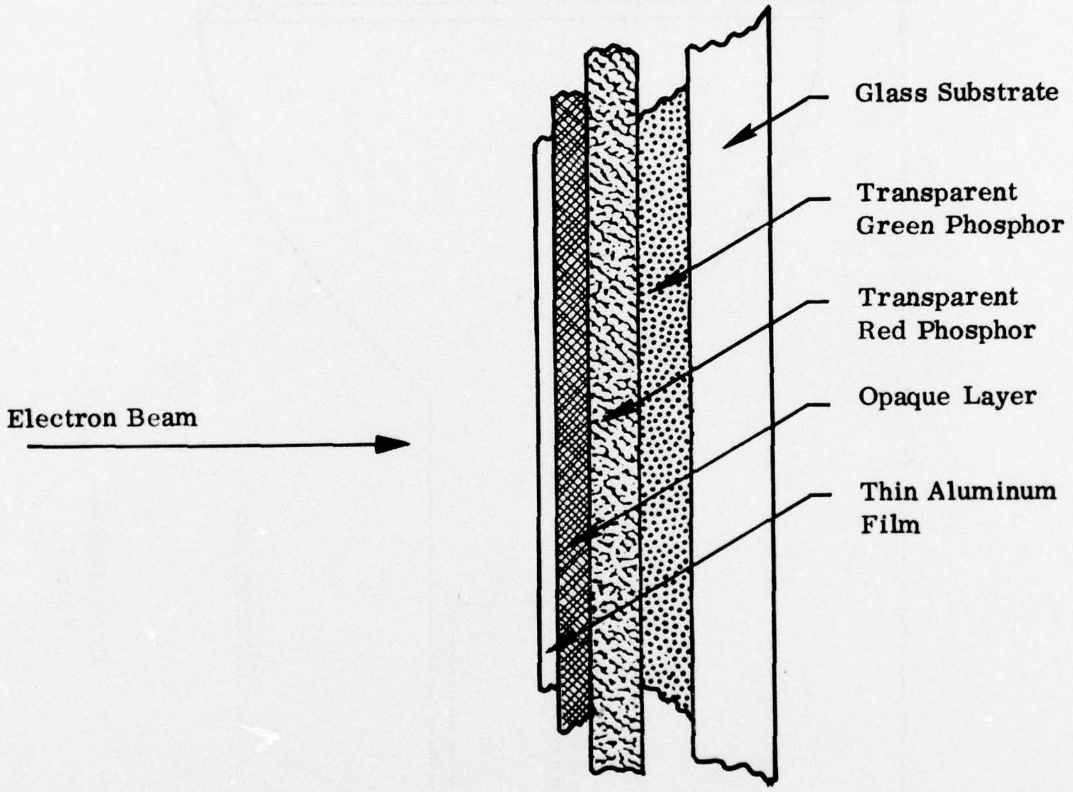

Figure 2. Schematic of High Contrast Two-Color Screen

4.1 (Continued)

In operation, the red phosphor layer absorbs most or all of the electron beam energy at potentials below 10 kV. At high potentials, for example, at 20 kV, most of the electron beam is absorbed in the green phosphor. At intermediate potentials, some electrons are absorbed by both layers, depending upon the exact value of the potential. (A mathematical description of the optimum film thickness is given in the proposal.) Therefore, at low beam energies, only the red phosphor is excited and the display appears red. At high beam energies, the green-luminescent material is more excited and the display appears green. Various mixtures of the two colors are obtained at intermediate values of the potential. Note that since the luminous efficiency of the red is much lower than that of the green, it is important that the red be placed closest to the electron gun to prevent color contamination of the red by the green. If the green film were closest to the gun, it would not be possible to excite the red without getting some color contamination from the green phosphor.

The operation of this screen in high ambient lighting conditions was discussed in our proposal, P-4583.

4.2 Screen Fabrication Efforts

4.2.1 Sputtering System

The RF sputtering system consists of an MRC Model SM-8500 RF sputtering module mounted on an NRC 6-in. diffusion pumped vacuum system, plus a Lepel 5 kW sputtering power supply and auxiliary impedance matching network. The system is capable of attaining bell jar pressures at the low end of the 10^{-7} Torr range within a reasonable evacuation period. Manual valves permit throttling the pump to obtain sputtering pressures of the order of 5μ. The pressure is established using an Alphatron vacuum gauge and subsequently monitored during sputtering with an MRC shielded Pirani gauge. A photograph of the system is shown in Figure 3, taken during deposition of an La_2O_2S:Eu film.

Matheson Ultrapure Argon is used as the primary sputtering medium. A small amount of hydrogen sulfide, 4.0×10^{-5} Torr, is added to the argon. Nupro bellows sealed micrometer valves are used to regulate gas flow.

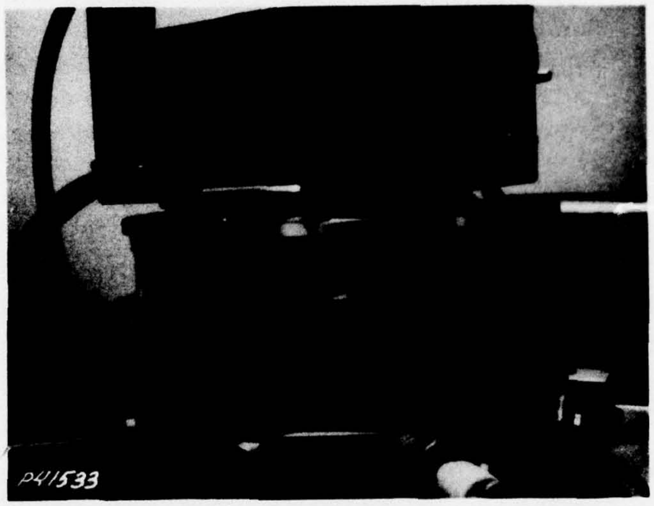

Figure 3. RF Sputtering Chamber

4.2.1 (Continued)

Activated lanthanum oxysolfide powders prepared in the Lockheed Missile and Space Company (LMSC) lab were used to make the sputtering targets (Reference 3). The targets, in the form of sintered discs, 5 in. in diameter and 0.25 in. thick, were pressed from the powder in a graphite die under an argon atmosphere at a pressure of 1920 psi and temperature of 1410°C, and allowed to sinter under these conditions for somewhat longer than 1 hr. As a precaution, the discs were subsequently dry lapped on 120 grit carbide cloth to remove the surface layer which may have reacted with the graphite, although there was no visual evidence of any reaction having occurred. The targets were then mounted on the target backing plates, using a silver-filled epoxy adhesive. Composition of the targets to be used for this program are $La_2O_2S:0.2\%$ Tb for the green and $La_2O_2S:6.5\%$ Eu for the red.

4.2.2 Sample Fixturing

Thickness measurements with a Varian Angstrometer on preliminary films deposited on glass microscope slides indicated a variation in thickness from the center of the substrate to the periphery as shown by Figure 4. The thickness at the center was 2,900 Å and at the 1/2" radius it measured 2,090A. To eliminate the thickness variation, it was originally thought it would be necessary to construct a special fixture that would rotate and oscillate the substrate. It was known that the shield which surrounds the sputtering target produces a concentration of equipotential lines near the periphery of the target; this has a focusing effect on the argon ions. It was believed that increasing the length of the shield be addition of supplementary rings might intensify the focusing effect, increase the sputtering rate near the target edge, and possibly reduce the thickness variation to acceptable limits.

Rings having thicknesses of 1/16", to 1/8", and 3/16" were fabricated from aluminum sheet stock. Two screws served to attach the rings to the shield. Measurements were made on a series of films, each deposited using one of the supplementary rings. The results are indicated by the curves of Figure 5. It was found that the 1/16" ring improved the distribution over the central 3 inch diameter area to within ±2 1/2% of the center thickness. The center thickness was 3,007 A and the thickness at the 1 1/2" radius was 30,086 A. This is considered sufficiently uniform for the program requirements, obviating the need for the more elaborate fixture.

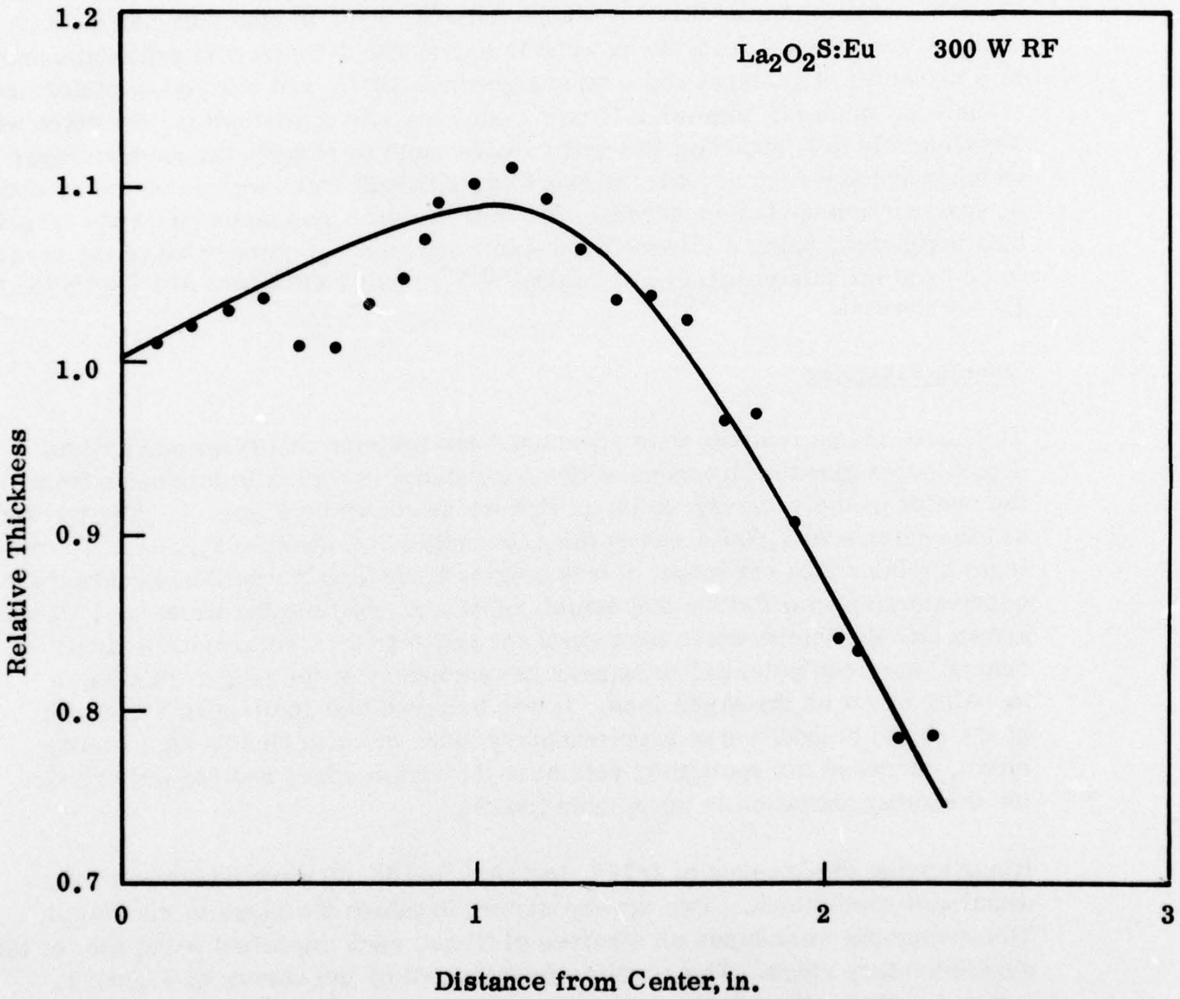

Figure 4. Thickness Variation Without Supplementary Ring.

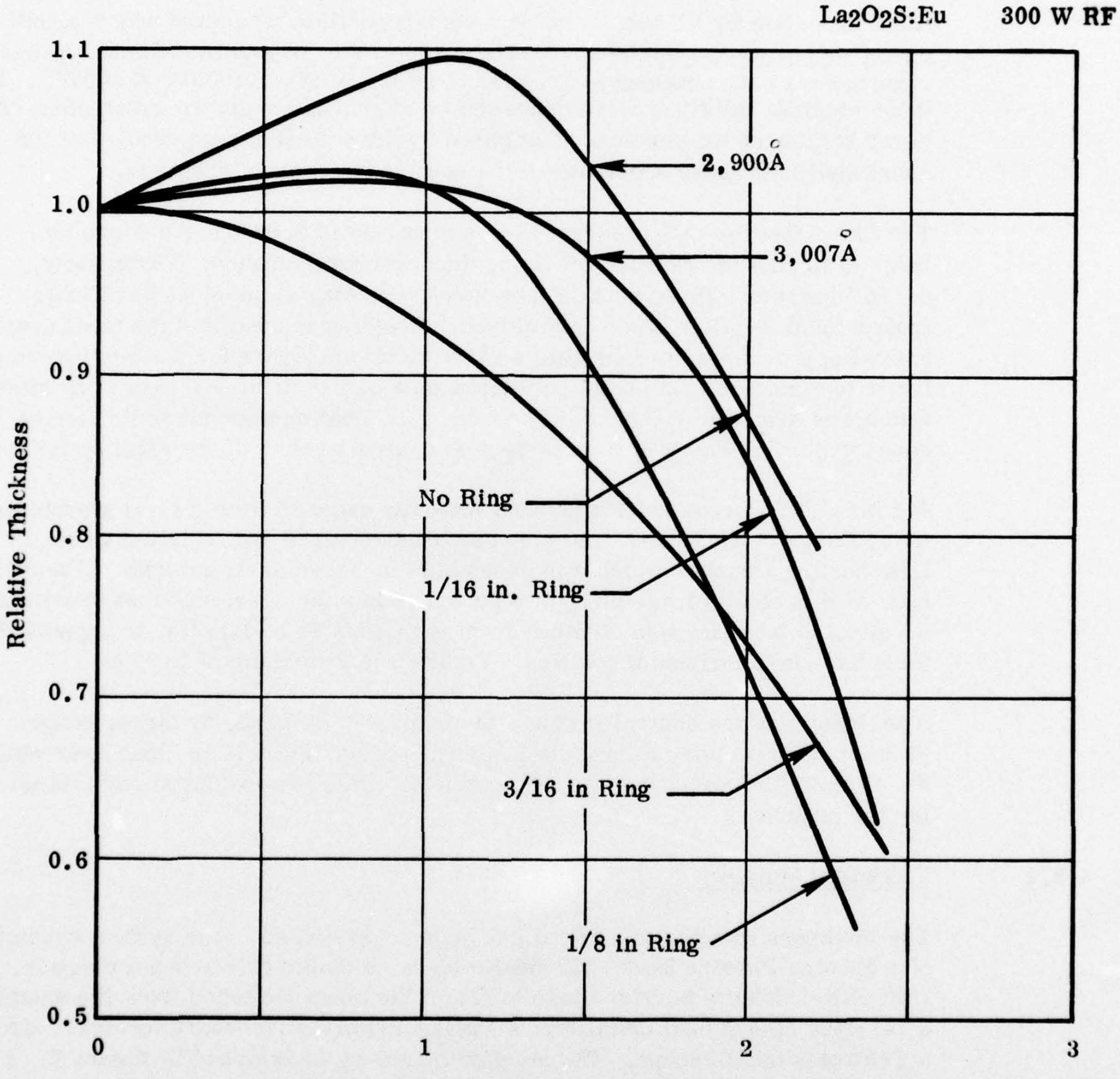

Figure 5. Effect of Supplementary Shield Rings

4.2.3 Four-Inch Reaction Tube

The results of previous studies have shown that it is desirable to subject the films deposited by RF sputtering to a post-deposition treatment which significantly increases the luminescent brightness of the oxysulfide films. Optimum results have been obtained by treating in an H_2 + SO_2 mixture at 1050°C. For these studies, the films were deposited on quartz and sapphire substrates. A lower treatment temperature is imposed by the softening temperature of the aluminosilicate glass substrates to be used in the present program.

The faceplates for this program have a diameter of 3.080 in., and are too large to fit into the existing 2 1/2 in. diameter tube furnace. Fortunately, a 4 in. diameter, three section tube furnace heating element was available from a local supplier at a minimal cost. It was concluded that the most economical approach was to fabricate a sheet metal enclosure for the heating element, lining the interior with insulating bricks plus blocks of LI-900 insulating material which was available in-house. The 4 in. I.D. heating element could then be connected to the electronic three section control system of the existing furnace.

A 4 in. O.D. vitreous silica furnace tube was ordered from a local glassblowing firm, Simpson Glass Co. The tube has been received and installed in the 4 in. I.D. heating chamber which was assembled in-house in the interim. The 3 1/2 in. I.D. of this tube is large enough to accommodate the 3.080 in. diameter faceplates. An alumino tube-dee was obtained from the Coors Porcelain Co. to support the faceplates in a horizontal position. Figure 6 is Schematic of Furnace.

After adjusting the control system, the furnace was found, by thermocouple probe measurements, to provide a central region about 12 in. long over which the temperature variation was $\pm 2^{\circ}$ at 900°C. This is considered quite adequate for the program.

4.2.4 Thickness Monitor

The thickness monitoring system has been reassembled. The system consists of a Spectra Physics Model 132 He-Ne laser, a motor-driven beam chopper, a UDT PIN-5 Schotty barrier diode to detect the beam reflected from the sample, a 741-type operational amplifier, a Varian 100 mV strip-chart recorder, and a Tektronix oscilloscope. The monitoring set-up is sketched in Figure 7. A second, identical diode placed in a light-tight housing adjacent to the beam detector diode provides an opposite polarity input to the 741 amplifier, to cancel noise pick-up in the coaxial cables.

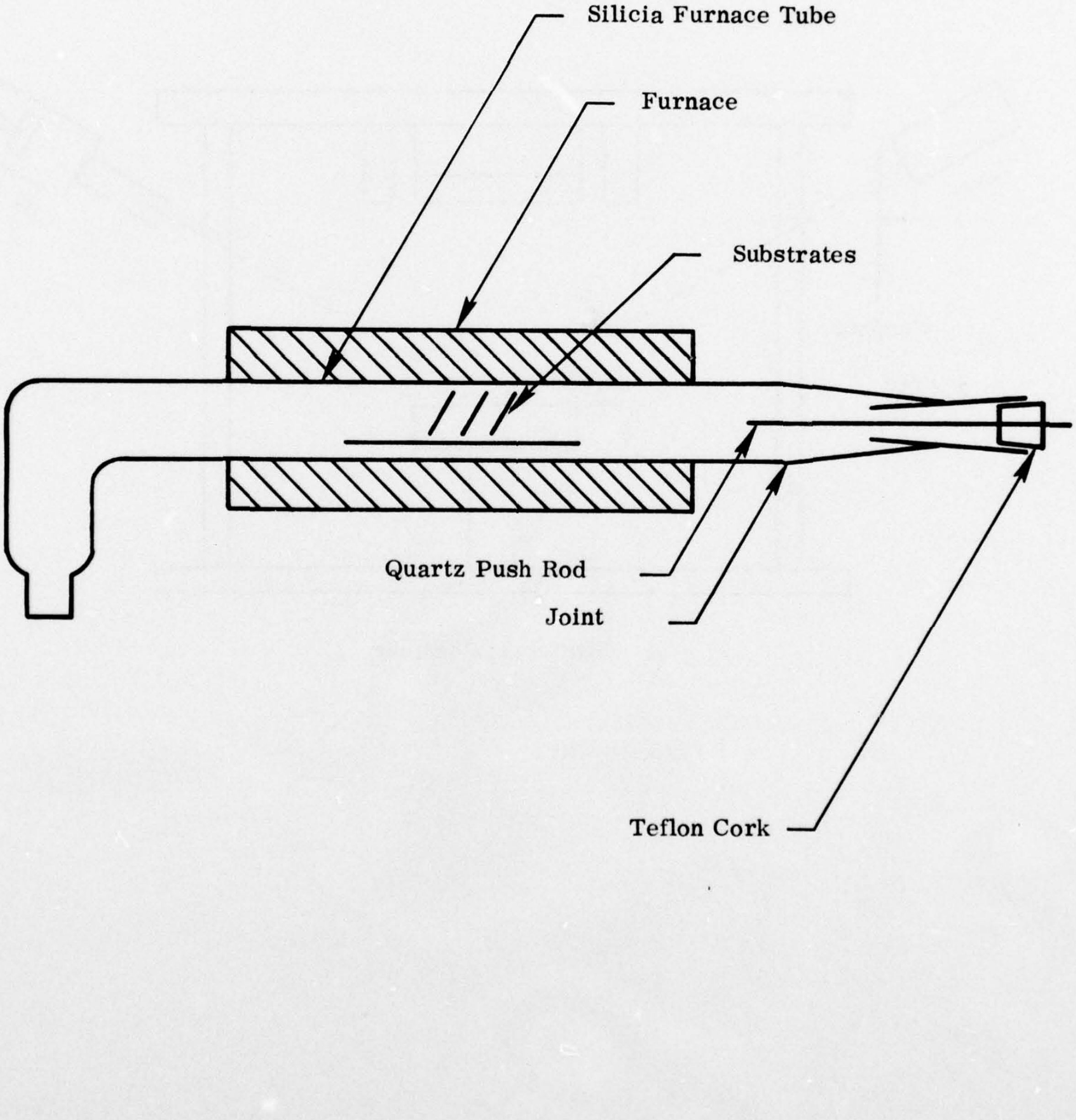

Figure 6. Schematic of Furnace

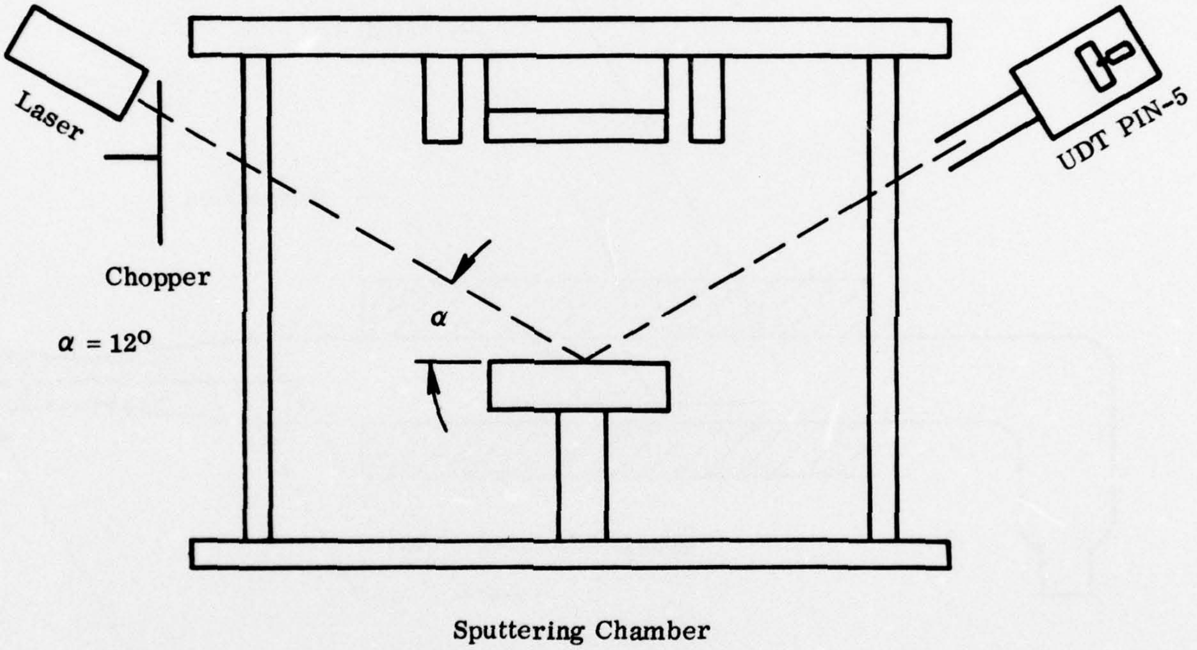

Figure 7. **Laser Interferometer for Film Thickness Measurement during Deposition**

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4.2.4 (Continued)

The reflected beam consists of light reflected from the film surface plus light reflected from the film-substrate interface. The strip chart recorder provides a continuous record of interference peaks and nulls during growth of the film. The oscilloscope provides a visual indication of the operational amplifier output and is a convenience in aligning the director.

The most precise thickness control is achieved by terminating deposition exactly at a null; termination between nulls results in somewhat less precision.

From the geometry and Snell's law, it can be shown that interference nulls will occur at thickness given by the equation

$$t = \frac{m\gamma}{4\left(n^2 - \cos^2 \alpha\right)^{\frac{1}{2}}}$$

where m is an odd interger, γ the wavelength of the laser light, n the refractive index of the film, and α the angle between the beam and the plane of the substrate. For this situation, $\alpha = 12^{\circ}$, $n = 2.196$ for La_2O_2S at 6328 Angstroms. With these conditions, the equation simplifies to

$$t = 804.63 \text{ m Angstroms.}$$

A more accurate determination of thickness can be made by multiple-beam interferometric measurements on the completed film, using a Varian Model 980-4000 Angstrometer. This requires removal of a part of the film from the substrate by etching or masking part of the substrate during deposition. A thin film of aluminum must then be evaporated over the step at the film edge to provide a reflecting surface. Thickness measurements with the Varian Angstrometer are considered to be accurate to ±40 Å. The Angstrometer mearsurements are also useful in determining deposition rate at constant RF power. Using care to duplicate deposition conditions, thickness may also be controlled by deposition time, probably at some loss in precision.

Figure 8 shows thicknesses determined using the laser interferometer vs. thicknesses measured on the same samples using the Angstrometer. The values agree within 6%. The difference is probably due to a difference between the refractive index of the film and that of stoichiometric bulk La_2O_2S.

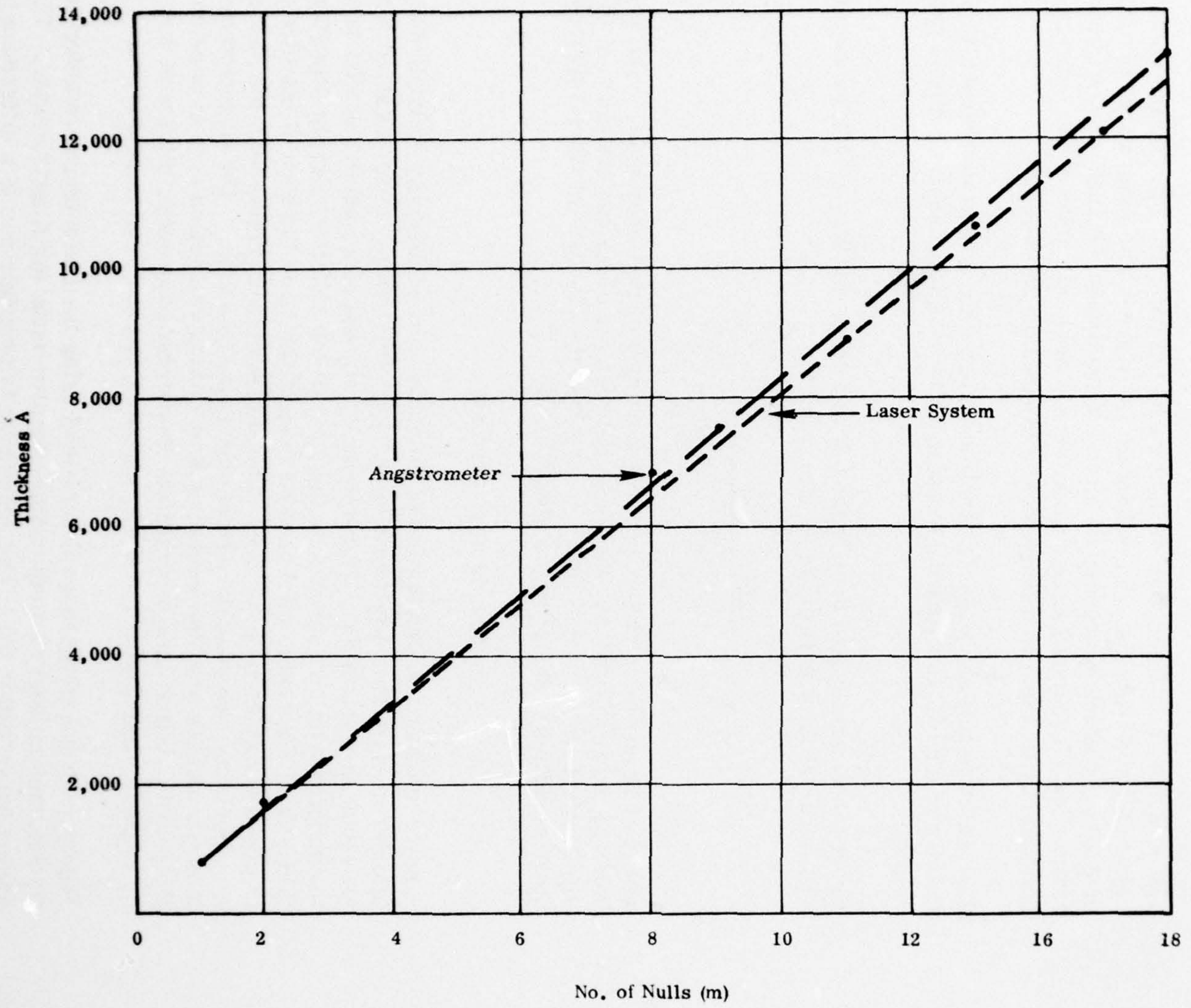

Figure 8. Thicknesses Using the Laser Interferometer vs. Thicknesses Using the Angstometer

4.2.5 Sputtering Conditions

Although the system is operational, it remains to be determined from spectral and brightness measurements whether further adjustments are necessary. For instance, a preliminary examination of an La_2O_2S: Eu film under electron beam excitation suggested an orange component, in the emission, in place of the expected red. As soon as the electron beam system has been reassembled, spectral measurements will be made, which will greately help in determining the cause of the orange color, which may be due to contaminants in the old three inch reaction tube or in the electron beam system. The new four inch reaction tube should not present any contaminant problem. On disassembling of the electron beam system, following the discovery of leaks, contaminant films were noted. The system has been thoroughly cleaned and will be helium leak tested on reassembly to insure proper vacuum.

4.2.6 Aluminosilicate Glass Faceplates

In the proposal originally submitted for this program, it was proposed to use Corning No. 1720 aluminosilicate glass for the faceplates. This was based on previous studies at the LMSC Palo Alto Laboratory which had shown that rare earth oxysulfide films on No. 1720 glass could be treated at 900°C to give 85% of the luminescent brightness of similar films on sapphire treated at 1050°C. A quotation on faceplates of No. 1720 glass having a diameter of 3.031 min. - 3.092 max. and thickness of 0.125 ± .005 in. was obtained from the Corning Glass Works on August 18, 1976.

When Corning was contacted in March, 1977 for the purpose of placing an order for the faceplates, LMSC was informed that No. 1720 glass was not available. Corning recommended glasses which were unsuitable for this program by reason of the low softening point. A quotation was requested on faceplates of Corning No. 1723 aluminosilicate glass which had a softening point only 7°C lower than that of No. 1720 glass, according to Corning data sheets. Some doubt as to the availability of No. 1723 glass was expressed by Corning at this time.

Other producers of aluminosilicate glass were also contacted but none would quote on the faceplate requirements.

4.2.6 (Continued)

A quotation on faceplates of No. 1723 glass was obtained from Applied Precision Optics Inc. of Monrovia, California. This firm had successfully located a distributor with a supply of Corning No. 1723 glass in stock. As Corning was very slow in responding to the request for quotation on the No. 1723 faceplates, an order in responding to the request was placed with Applied Precision Optics, Inc. The quotation, when received, proved to be somewhat higher than that of Applied Precision Optics.

The 20 faceplates were received from Applied Precision Optics. Measurements, (Table I), showed the diameters to be near, but within, the upper limit specified. Thicknesses ranged from .002 to .012 greater than specified, but were judged satisfactory for the program. It was observed when viewing the discs edge-on, that some appeared green while others were water-white. The green discs were returned to Applied Precision Optics as it was thought a mix-up in glass may have occurred during grinding and polishing. Applied Precision Optics contacted their supplier who guaranteed that all the glass supplied was No. 1723 glass. No explanation, other than possible lot-to-lot variation, was given for the green coloration. Presumably, it is due to an impurity, possibly traces of iron, associated with one of the glass constituents. Possibly, the glass manufacturer purchases constituents from different sources at different time.

Applied Precision Optics also supplied some scrap pieces of No. 1723, at LMSC's request. These will be used for practical tests at the 900°C temperature in the reaction tube.

Glass manufacturers do not ordinarily reveal the composition of their glasses. The information available in the literature has usually been obtained by chemical analysis. Variations in results have been noted between investigators for the same glass. This may be due to poor homogeneity of the glass manufacturer's melt or to differences in the analytical procedures used. The reported compositions, however, probably approximate the manufacturer's proprietary "recipe" within a few tenths of a percent for the major components.

The approximate compositions of Corning No's 1710, 1720, 1723, and 7059 glasses have been collected in Table II from different literature souces. Selected properties from Corning publications are reproduced in Table III.

#1723 FACEPLATE DISCS Table I

Disc No.	Dia. in.	Thickness in.	Edge Color
1	3.079	0.131	White
2	3.080	0.132	White
3	3.079	0.131	White
4	3.080	0.131	White
5	3.063	0.133	White
6	3.080	0.132	White
7	3.079	0.130	White
8	3.080	0.132	White
9	3.080	0.133	White
10	3.081	0.133	White
11	3.081	0.133	White
12	3.078	0.132	White
13	3.080	0.137	Green
14	3.080	0.134	Green
15	3.065	0.134	Green
16	3.080	0.135	Green
17	3.078	0.137	Green
18	3.079	0.136	Green
19	3.079	0.136	Green
20	3.078	0.135	Green

Supplier: Applied Precision Optics

Specifications: Type 1723 Aluminosilicate Glass

Dia: 3.031 Min., 3.092 Max.

Thickness: 0.125 ± .005 in.

Measured 5 May 1977

T. G. Maple

T. G. Maple

Table II

CORNING ALUMINOSILICATE GLASSES

Approximate percentage by weight

	#1710	#1720	#1723	#7059
SiO_2	57	62	57	50.2
Na_2O	1.0	1	-	-
MgO	12	7	7	-
CaO	5.5	8	10	-
BaO	-	-	6	25.1
B_2O_3	4	5	5	13
Al_2O_3	20.5	17	15	10.7
As_2O_3	-	-	-	0.4
Reference	1	2	2	3

1-E. B. Shand, Glass Engineering Handbook, McGraw-Hill, 1958. P. 4.

2-J. R. Hutchins III and R. V. Harrington, "Glass" in Kirk-Othmer Encyclopedia of Chemical Technology, Vol. 10, p. 542, John Wiley & Sons.

3-L. I. Maissel and R. Glang, Handbook of Thin Film Technology, McGraw-Hill, 1970, p. 6-8.

Table III

SELECTED PROPERTIES

CORNING ALUMINOSILICATE GLASSES

	#1710	#1720	#1723	#7059
Strain Pt (10^{14} ps)	672°C	667°C	665°C	613°C
Anneal Pt (10^{14} ps)	712°C	712°C	710°C	650°C
Softng Pt ($10^{7.6}$ ps)	-	915°C	908°C	820°C
Workng Pt (10^{4} ps)	-	1202°C	1168°C	-
Thermal Shock 1/8 in.	-	135°C	125°C	-
" " 1/4 in.	-	115°C	100°C	-
Linear Coeff. Exp.	42×10^{-7}/°C	42×10^{-7}/°C	46×10^{-7}/°C	45×10^{-7}/°C
Density	-	2.53	2.63	2.76
Refr. Index, 589.3nm	-	1.53	1.547	1.53

4.2.6 (Continued)

It appears that the chief difference between the 1720 and 1723 glasses is the presence of 6% BaO in 1723 glass and its absence in 1720 glass. Considerably more BaO is present in the sodium-free 7059 glass. An earlier study in the LMSC Laboratory had shown that 7059 glass was not well suited as a substrate for rare earth oxysulfide films. The low softening point precluded treatment at a high enough temperature to obtain a practical level of luminescent brightness. The maximum temperature to which 7059 glass could be subjected was found to be about 700°C. Extending the time of treatment in H_2 + SO_2 increased the brightness but the glass acquired a brown coloration. After ten hours at 700°C, the coloration became sufficiently intense so that brightness measurements became meaningless.

The reason for the brown coloration of 7059 glass is not known. None of the components form brown sulfides or sufates. By contrast, No. 1720 glass does not acquire a brown coloration. However, preliminary tests with 1723 glass show some brown coloration similar to but less intense than that of 7059 glass. The discoloration of 1723 does not occur when heated in air, even at 900°C, but occurs in the H_2 + SO atmosphere st temperatures above 825°C. It is believed the coloration results from the presence of BaO because both 1723 and 7059 contain BaO, whereas 1720 does not. This presumably would be some impurity normally associated with BaO which reacts to give a colored product. Examination of reagent chemical suppliers' catalogs indicate that traces of iron is a common impurity in barium compounds.

Reagent grade barium dioxide contains about 0.02% iron. For economical reasons, glass manufacturer's probably use materials of lesser purity than reagent grade. Ferrous sulfide is known to be black-brown and is a likely result of sulfurization of traces of iron oxide.

A second problem was also observed in the preliminary tests of 1723 glass. A piece of 1723 glass placed across a quartz boat and inserted into the tube furnace at 900°C for 30 minutes was found to have sagged into complete conformance with the inside wall of the quartz boat. This means that the H_2 + SO_2 treatment of films on 1723 faceplates must be carried out at some temperature lower than 900°C. Some reduction in luminescent brightness is therefore to be expected. A matrix test is in process to determine a suitable temperature and time.

4.2.7 Cleaning Faceplates

To insure good adhesion of the deposited oxysulfide film to the glass faceplate, the latter must be thoroughly cleaned prior to depositing the film. The following procedure has been found to give good results in the LMSC Laboratory.

The faceplates, in lots of six, are loaded into a specially fabricated glass carrier. The faceplate discs are stood on edge, with adequate drainage space between faces of adjacent discs. The carrier is placed in a glass beaker, a few mililiters of an Alconox detergent solution is introduced into the beaker, and the beaker is then filled with deionized water. The beaker is then placed on a hot plate and heated to the boiling point. If the parts to be cleaned have diret which is stubborn to remove, the beaker may be transferred to an ultrasonic bath, but this is not ordinarily necessary. In some cases, a preliminary degreasing in hot trichoroethylene may also be advisable.

The beaker with the hot detergent solution is usually maintained at the boiling point for 30 minutes, after which the detergent solution is poured off and the beaker refilled with deionized water. This rinsing is repeated for a total of five changes of water, care being taken to rinse down the walls of the beaker each time. The carrier is provided with a handle so that it may be lifted out of the beaker before discarding the liquid contents.

After the fitth water rinse, the carrier is placed in a beaker of cold chronic acid cleaning solution, then placed on a hot plate to heat to 100°C. After 30 min. at temperature, the carrier is removed and placed in a clean beaker to cool. Cooling avoids cracking of the faceplates due to thermal shock. After cooling, the faceplates are given five rinses with deionized water, as before. Finally, the parts are covered with transistor-grade isoprophyl alcohol, the carrier agitated somewhat by hand, then removed and the alcohol discarded. The carrier is then replaced in the beaker and the latter transferred to a drying oven. When dry, the beaker is removed from the oven and allowed to cool, then covered with a piece of aluminum foil.

For deposition, the discs are removed individually from the carrier, using flat-faced tweezers; the surface is blown free of any possible dust with a freon jet, and the disc is placed in the sputtering chamber. The edge-mask is then placed over the disc and the chamber closed, after which the chamber is evacuated to less than 1×10^{-6} Torr.

4.2.8 Sputtering Procedures

After evacuation of the sputtering chamber to less than 1×10^{-6} Torr (typically $6 - 8 \times 10^{-7}$ Torr), the high vacuum valve is partially closed to serve as a dynamic pumping throttle. Hydrogen sulfide gas is then admitted through a bellows-sealed valve in series with a micrometer valve and the chamber pressure adjusted to 4.0×10^{-5} Torr. Argon is next admitted to bring the total chamber pressure to 5μ.

A pre-shutter RF discharge at 300 watts is then initiated to clean the target surface of any adsorbed material and also the inside surfaces of the chamber. Hydrocarbons normally present in air are known to be adsorbed when vacuum chambers are open to air; it has been found in the LMSC Laboratory that unless removed by presputtering, these hydrocarbons will contaminate the oxysulfide films and produce a degree of optical absorption in the films. During the presputtering period, the substrate discs are protected by a shutter from receiving sputtered target material. The presputter period is ordinarily 45 minutes. At the end of this period, the shutter is rotated aside to expose the substrate to the sputtered material.

A deposition period of 120 minutes is required at 300 W RF power in order to deposit 7000 Å of $La_2O_2S:Tb$. At the end of the deposition period, the RF discharge is extinguished and the work allowed to cool for 30 minutes. The sputtering gases are then shut off and the chamber brought to atmospheric pressure with nitrogen gas, after which it may be opened and the faceplate discs removed to a dust-free enclosure. If another workpiece is not to be immediately placed in the chamber, the chamber should be closed promptly and evacuated, to minimize adsorption of atmospheric contaminants.

4.2.9 Cathodoluminescence Measuring System

The demountable cathodoluminescence system used at the LMSC Laboratory for measuring the cathodoluminescent brightness of phosphors is shown in Figure 9. The initial design of this system has been described by Anderson and Weaver (Reference 4). A new sample holder to accommodate the 3 inch diameter faceplates has been fabricated.

The system, which had been inactive for a few months prior to this program, was found to have a poor vacuum when again placed in service. Leaks were found at some of the seals The system was therefore disassembled for the purpose of replacing the seals. During disassembly, contaminant films were noted inside the system, necessitating a thorough cleaning.

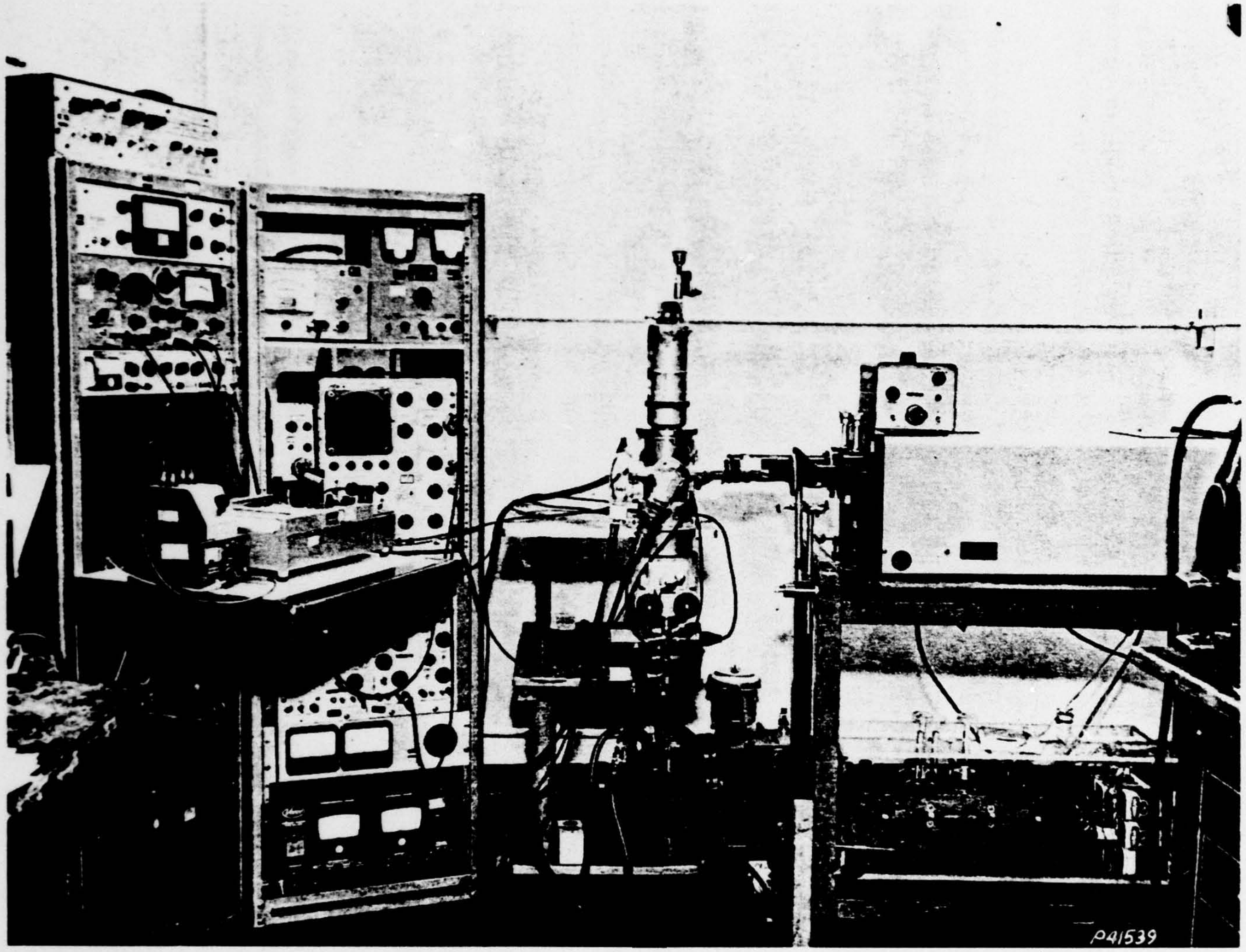

Figure 9. Demountable Cathodoluminescence Measuring System

4.2.9 (Continued)

The possiblity of incorporating a Watkins-Johnson Company Laminarflo Gun into the system is under consideration, since this would permit higher current densities and writing speeds representative of the intended application of the faceplates.

Data presented in proposal Figure 3-14 indicated about 2,000 ft-lamberts of luminance for an electron beam power density of 9 watts per square centimeter for lanthanum oxysulfide on sapphire. The electron beam energy was 13 kV. Preliminary tests on similar films fabricated on Type 1723 glass indicate a luminance of 300 to 500 ft-lamberts under comparable conditions. Thus, the films initially fabricated on Type 1723 glass appear to exhibit only 25% of the efficiency of those fabricated on sapphire.

5.0 THE LAMINARFLO ELECTRON GUN

Watkins-Johnson Company has already developed 3" monochrome CRTs incorporating Laminarflo Guns which are capable of providing the required currents with a spot size below .012" as measured to the 50% points. These 3" CRTs are physically interchangeable with the Dumont KC3055. They are electrically interchangeable with the exception of the anode and focus voltage. See Figure 10.

As discussed in the proposal, a display brightness of 500-1000 foot lamberts is required to achieve a contrast ration of 2:1 in direct sunlight assuming 1% reflection. It was also shown that electron beam current densities of 1 to 2 A/cm^2 are needed to achieve that brightness range at a writing speed of 50,000 inches/second and a 60 Hertz refresh rate. This can be achieved with a 1 milliamp electron beam focused into a spot size of .005" to .006" at 10 to 20 kV.

Watkins-Johnson Company has developed Laminarflo electron guns used in 3" CRTs capable of such performance. The following data was obtained in such a 3" monochrome tube using a Laminarflo Gun.

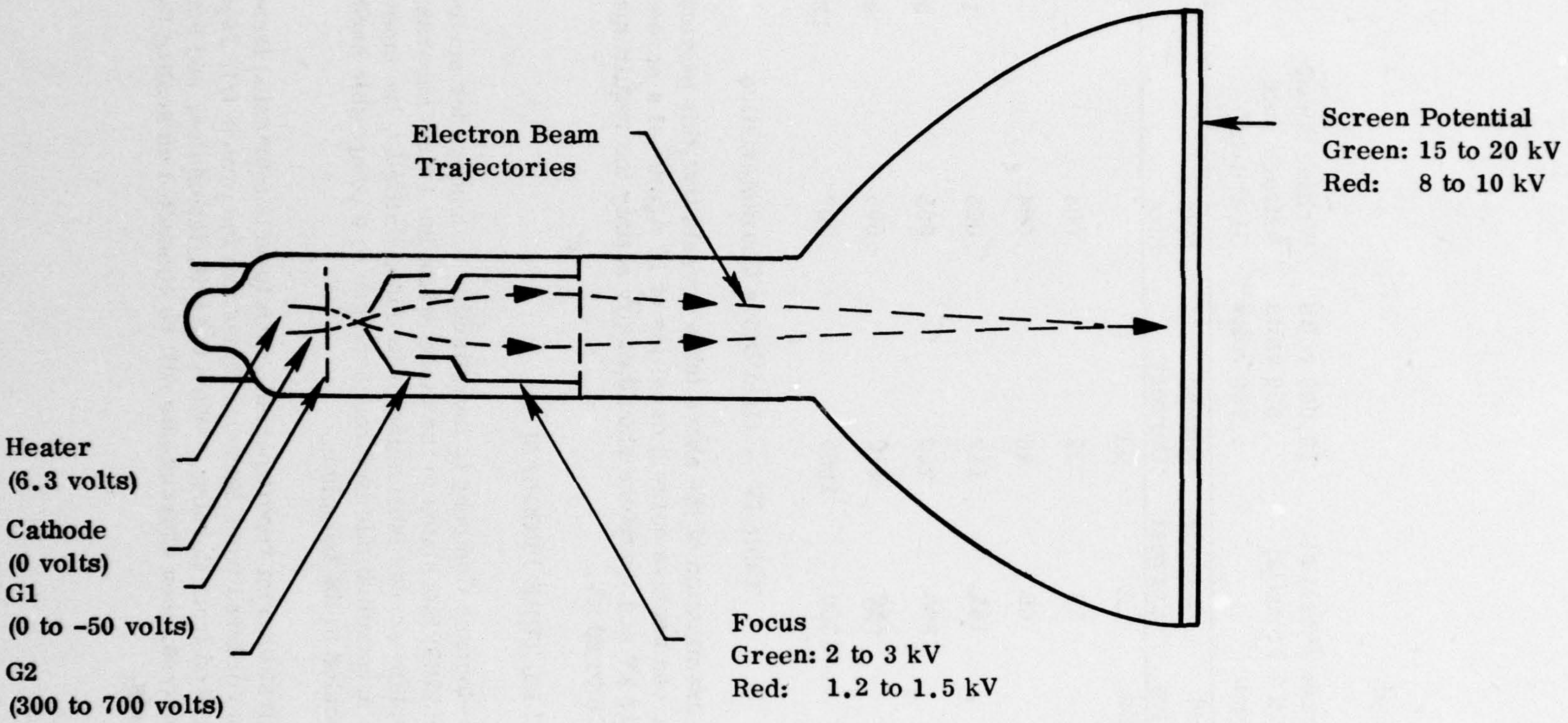

Figure 10. Schematic of Laminarflo Gun CRT

5.0 (Continued)

Screen Potential	12,000 volts	Writing Speed	1,800 in/sec
Grid 2 Potential	500 volts	Refresh Rate	60 Hertz
Focus	1,760 volts	G1 Cut-off	-69 volts

	Grid Drive volts	Cathode Current µA	Screen Current µA	Spot Size	Current Density A/cm^2
1.	16	12	12	.004	.15
2.	23	60	46	.004	.57
3.	33	165	112	.005	1.4
4.	45	390	250	.005	3.13
5.	54	630	410	.005	5.12
6.	69	1300	1000	.007	12.5

Table IV - Grid Drive Characteristics

An examination of the above table reveals that this particular Laminarflo Gun can achieve current densities of 12 A/cm^2 at a screen potential of 12 kV and therefore should easily satisfy the requirement for 1 to 2 A/cm^2 at 10 to 20 kV.

6.0 PARALLEL TUBE PROGRAM

Watkins-Johnson Company is investigating techniques for sealing the hard glass (1720 or 1723) faceplates to the funnel while the LMSC Laboratory is developing the faceplate-screen fabrication procedure. Initially, the most attractive technique to accomplish this is through the use of a compatible hard glass funnel which is frit sealed to the faceplate.

In this first interim report period, such funnels fabricated from 7052 glass have been ordered from Berkeley Glass and the proper frit Type No. 7594 has been ordered from Corning. When the frit, faceplates, and funnels have all been received, then experiments will be conducted on sealing the faceplates to the funnels.

7.0 CONCLUSION

Type 1720 glass was not available and therefore No. 1723 glass had to be used for the CRT faceplate. The requirement to use 1723 glass in place of 1720 limited the maximum processing temperature to below 900°C. Therefore, some reduction in luminescent brightness was to be expected. Films initially processed on 1723 glass faceplates exhibit luminous efficiencies only 25% of those fabricated on sapphire. The ultimate suitablility of the 1723 glass remains to be determined since it is possible that extending the processing time may compensate for the lower processing temperature.

The data taken on the current densities achieved with the Laminarflo Gun confirms that it is capable of achieving the 1 to 2 A/cm^2 required at 10 to 20 kV screen potential for the 500 to 1000 ft. L. of brightness. These calculations are based on data provided in the proposal.

8.0 RECOMMENDATIONS

It is recommended that an effort be made to accelerate the effort so that the original schedule of completing this phase of the program by year end be met. This acceleration is primarily concerned with the work being done by Lockheed because the phosphor films must be successfully fabricated before Watkins-Johnson Company can incorporate these films into finished tubes. This acceleration is presently under way and it appears possible to complete this program on schedule.

REFERENCES

1. "Application of the Laminar Flow Gun to Cathode-Ray Tubes" by Norman H. Lehrer

2. Proposal to Fabricate a High Contrast Two-Color CRT file no. W-J 76P-4583

3. "Growth and Properties of Lanthanum Oxysulfide Crystals", by L.E. Sobon, K.A. Wickersheim, R.A. Buchanan, and R.V. Alves, J. Appl. Phys., 42, 3049 (1971).

4. "Demountable Cathodoluminescence System", by E.E. Anderson and J.L. Weaver, App. Spec. 24, 91 (1970)

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