MASTER

THE DEVELOPMENT OF MINIATURIZED
PROXIMITY FOCUSED STREAK TUBES FOR
VISIBLE LIGHT AND X-RAY APPLICATIONS

FINAL REPORT
(and progress for period of April-September 1977)

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Table of Contents

<u>Section</u>	<u>Subject</u>	<u>Page</u>
1.0	BASIC PROGRAM	1
2.0	PROGRAM ACTIVITIES	2
2.1	ENGINEERING DESIGN FOR THE VISIBLE PFST	2
2.2	TOOLING AND FIXTURING	7
2.3	DEVELOPMENT OF SPECIAL PURPOSE MICROCHANNEL PLATE COLLIMATORS	7
2.4	PROCESSING OF VISIBLE PROXIMITY FOCUSED STREAK TUBES	11
2.5	ENGINEERING DESIGN OF X-RAY INPUT SECTION	24
2.6	GOLD CATHODE DEVELOPMENT	36
2.7	PROCESSING OF THE X-RAY PFST	45
2.8	BIBLIOGRAPHY OF Be SEAL REFERENCES	51

List of Illustrations

<u>Description</u>	<u>Designation</u>	<u>Page</u>
PROXIMITY FOCUSED STREAK TUBE	FIG. 1	3
CATHODE FACEPLATE FOR VISIBLE PFST	FIG. 2	8
OUTPUT PHOTO OF PFST 251-3	FIG. 3	14
PROXIMITY FOCUSED STREAK TUBE 251-4	FIG. 4	19
PHOTO OF OUTPUT DISPLAY OF VPFST 251-4	FIG. 5	20
PROXIMITY FOCUSED STREAK TUBE	FIG. 6	22
OUTPUT DISPLAY - VPFST 251-6	FIG. 7	23
X-RAY WINDOW ASSEMBLIES	FIG. 8	26
HIGH TEMPERATURE VACUUM BRAZING ASS'Y	FIG. 9	29
INDIUM ALLOY BONDED BERYLLIUM ASSEMBLY	FIG. 10	33
SCHEMATIC OF FINAL PROCESS SYSTEM	FIG. 11	38
X-RAY PROXIMITY FOCUSED STREAK TUBE 251-5	FIG. 12	46
PHOTO OF X-RAY PFST 251-5	FIG. 13	47

1.0 BASIC PROGRAM

The primary objective of this program is to complete an engineering design from which a prototype tube can be constructed and to fabricate a visible and an x-ray prototype tube to be provided to LASL for test and evaluation. The program tasks are as stated in the ITT Proposal F5-153A dated July 17, 1976 and submitted to ERDA.

The following tasks were carried out to develop miniaturized proximity focused streak camera tubes for application in the visible and in the x-ray modes of operation. Each of the two tube designs shall consist of a modified 18 mm input section to incorporate a cathode faceplate and a microchannel plate collimator. The output section for each tube design shall incorporate the sweep electrodes and a fiber optic phosphor section enclosed in a 25 mm tube envelope. The overall length of each tube shall be approximately 2.5 inches.

Task I: Engineering Design for the Visible Proximity Focused Streak Tube (PFST)

Task II: Tooling and Fixturing

Task III: Development of Special Purpose Microchannel Plate Collimators

Task IV: Processing of Visible PFST

Task V: Design of X-Ray PFST Input Section

Task VI: Processing of X-Ray PFST

2.0 PROGRAM ACTIVITIES

2.1 Engineering Design for the Visible PFST

The tube design phase of this task was completed. The visible proximity focused streak tube design is as shown in Figure 1. Additional design modification for this tube only related to experiments with slotted ceramic sections intended to replace the glass envelope shown in the present structure. The results of these experiments and a detailed description of the materials used is presented in the following section.

2.1.1 Brazing of Metal Deflectors Into Slotted Ceramics

The first attempts were made using standard high aluminum ceramic rings that were initially slotted in our model shop then sent to Ceramaseal for metallizing of the slotted section. These were metallized by painting the inside of the slot with molybdenum, firing, then nickel plating.

One of the ceramics was evaluated by brazing a Kovar blade, approx .030" thick x .400" wide, into the slot. The blade was inserted through the slot and braze material, Cusil, copper-silver eutectic wire, wrapped around and pushed against inside of ceramic. The braze temperature in use for Nicusil 3 was reduced by 15° C. otherwise the same schedule used for Nicusil was followed. The braze material wet to the joint but was not leak-tight. Observation under microscope showed a pull-away

PROXIMITY FOCUSED STREAK TUBE

FIGURE 1

of the metallizing and a buildup of thickness at the ends of the slot.

One ceramic was slotted but not metallized and a Kovar blade brazed into the slot with titanium core BT. The joint appeared good but leaked. When the ceramic seal area was cut out, the bond to the ceramic was found to be weak.

Twenty-one (21) rings were purchased from Coors. Coors slotted and metallized these and the quality appeared good.

Test pieces of Ceramvar (formerly known as Ceramiseal) were evaluated with both Palcusil and Incusil 15. Ceramvar is a material similar to Kovar but having a thermal contraction characteristics more closely matching those of high temperature alumina ceramics. In three cases a vacuum tight seal was obtained on one of the blades but not on the second. (two blades were brazed 180° apart in the slotted ceramic ring).

Molybdenum blades were evaluated with and without copper plating. The wetting was not good on the unplated moly and peeling of the copper occurred on the plated blades.

Theoretically a metal having a slightly lower thermal expansion is desirable for the deflector blades at the point of braze

since this places the joint in compression and helps to balance out the greater expansion of the braze alloy. The braze alloy thickness should be kept to a minimum.

2.1.2 Problem Areas

1. The difficulty of matching metal deflector expansion to ceramic expansion exists. In all except the refractory metals, the expansion of the metal is greater than that of the ceramic, placing the seal in tension.
2. The difficulty in obtaining a smooth, strongly adherent, metallized coating in the inside of the slot exists. The metallizing is painted on and in many instances agglomerates are present at the corners and also, the nickel plating is not continuous.
3. The braze alloy cannot be placed in between the deflector blade and metallized ceramic surface. It must be placed around the blade in the form of wire or ribbon and pressed against the inner surface of the ceramic ring against the metallizing as closely as possible. During the braze cycle the outer surface becomes hot before the inner surface drawing the braze alloy through the joint and filletting the outer seal as well as the inner seal area. Even though the seal appears good it may leak.

2.1.3 Comments:

- a) This type of seal, metal inside of ceramic, is usually recommended only for small diameter wires.
- b) The best chance of obtaining a good seal of a flat metal electrode to a metallized slot appears to be using ceram-var blades with Incusil 15 - or as low a melting point braze alloy as possible. Handy & Harman Braze 603 VTC 720° C Flow - 600° C M.P. , may be suitable.
- c) The metallizing inside the slots is difficult to do and it does not uniformly bond to the ceramic. Where agglomerates of metallizing are present or where the metallizing is not well bonded to the ceramics, leaks are likely to occur.
- d) Of the 21 pieces ordered from Coors, 13 pieces remain. 8 were used for experiments.
- e) The thermal contraction match is more important than the expansion since on the cool down cycle contraction (tension) stresses in the seal occur.
- f) The fact that vacuum tight seals were achieved in three instances indicates that with good metallizing, proper choice of metals and braze alloys and careful control of the braze cycle, good vacuum tight seals can be achieved.

2.1.4 Input Faceplate Design - Visible Tubes

The input window used on the visible PFST was made of 7056 glass and was of a re-entrant design as shown in Fig. 2. The re-entrant design and the use of a small rectangular section .185 inches wide by .710 inches long for the active photocathode surface reduced the total surface area, thereby reducing the capacitance of the input sections. In addition, the reduction of the cathode surface area substantially reduced the total area in the input section that is subjected to the high field gradients required between the photocathode and the MCP collimator. All edges were radiused and polished smooth to minimize any potential source of field emission.

2.2 Tooling and Fixturing

All tooling and special fixturing, with the exception of X-ray input window tooling, required for this program was made and completed prior to this report period. Any special tooling or fixturing developed or used during this report period is discussed in Section 2.5 of this report.

2.3 Development of Special Purpose Microchannel Plate Collimators

The microchannel plate collimators used on this program consisted of a central rectangular section, .042" wide x .600" long, of approx. 8.9 micron square channels, sealed within a solid glass frame having overall dimensions of .812" x .244". The thickness varied from .016" for the

Cathode Faceplate for Visible PFST

Figure 2

visible tube to .097" for the X-ray tube. The collimators were evaporated with inconel in such a way as to obtain as deep a penetration into the channels as possible. The evaporation was continuous from front surface, around edges, to back surface, forming approximately a 10 to 20 ohm conductive coating.

Ideally the front surface and all front surface edges should be radiused and smooth; with no sharp corners or peeling of the evaporated inconel film. On some of the initial collimators received, sharp edges and peeling were in evidence. This caused the rejection of many of these units. The quality of plating improved in subsequent plates but the edge of the .016" thick collimators were radiused only slightly. The .097" and .060" collimators received toward the end of the program were radiused to an acceptable degree.

One of the problems, not satisfactorily resolved during this effort, related to the fastening of the collimator to the tube support plate. Early experiments were run using indium as a bonding material along with .005" x .025" Nichrome ribbon hold down tabs, welded across the ends of the collimator. The technique was to place the collimator in a centering recess formed in the support plate and fasten it in place with the hold down ribbons. The sharp ends of the ribbons and the spot welds were made smooth by lasering with a defocused beam to cause a melting

of the material where smoothing was desired. Indium of 99.999% purity was then pressed in the corners formed by the intersection of the edge of the collimator and the support plate surface. By careful tooling with a scalpel, a smooth fillet of indium was formed in this manner at each end. The assembly was then vacuum baked to 350° C. Depending on the length of the bake, the indium not only wet to the support and collimator at points of original contact, but diffused along the surface of the evaporated inconel and during the normal bakeout time for vacuum tube processing, diffused into the channel area, reducing the open area and causing potential shading. In the first visible tube having an .016" thick collimator bonded by the ribbon and indium technique, the indium spread fairly uniformly over the center collimators, including the channels, but did not fill the channels and no shading was noted. In none of the tubes using .016" thick collimators was the effect of diffused indium noted as shading in the tube output although some loss of overall tube performance may have resulted.

Development work was carried on experiments using chromium evaporations on the collimator in the area between the indium seal and the channels, to act as a barrier to the indium diffusion. However, the indium appeared to diffuse through the inconel, under the chromium and into the channel area..

The use of the indium bismuth eutectic, Indalloy #3, (90% Indium, 10% Silver) and Indalloy 11, (95% lead, 5% Indium) have also been evaluated with the Indalloy 11 having the least tendency to diffuse. The use of a rectangular flanged fastener, similar to that proposed and partially developed for the beryllium window assembly, was evaluated. Parts were fabricated for the .016" thick collimator but were received too late in the program to be used in a tube. Partial evaluation was by a mechanical sample and, with further refinement should be a satisfactory method of fastening the collimator to the support plate. With its use, no solder should be required and any sharp collimator edges will be covered by the flange radius edge and smooth retaining surfaces.

2.4 Processing of Visible Proximity Focused Streak Tubes

Three proximity focused streak tubes, for visible input applications, were processed during this report period. Two tubes were made with S-20 photocathodes and the third tube was made with a S-1 cathode. Two of the three tubes processed were shipped to LASL for test and evaluation.

2.4.1 Processing of PFST 251-3

Tube PFST 251-3 was fabricated with a collimator .016" thick, with 8.9 μ square channels. The tube

was subjected to a 350° C vacuum bake for ten hours, prior to photocathode formation. The microchannel plate collimator was outgassed continuously for nine hours with 10 KeV electrons, and at an input current of 2 μ a. An additional three hours bombardment was carried out at 10 Kv with an input current of 1 μ a. There was no measurable change in the sensitivity of the secondary photocathode used to provide the bombardment current during the twelve hour outgassing process. In addition, no discernible pressure change was observed when the bombardment current was increased from 1 to 2 μ a, nor were any other pressure bursts noted. The above indicates that the vacuum bake of the collimator was effective in removing adsorbed gases from the surface of the collimator. The electron bombardment is basically a surface cleaning process. In this case the collimator surface appeared to be effectively outgassed. An S-20 photocathode with a sensitivity of 134 μ a/l was formed, transferred and sealed to the tube envelope. The tube was operated in the system with 6 Kv applied between the photocathode and the collimator. A rectangular output display was observed on the phosphor output of the tube. After

removal from the processing chamber the tube was tested with the cathode at ground, and with all other tube elements at 6 Kv positive with respect to ground. A rectangular output display approximately .050" wide by .55" long was observed and photographed. The output photo of PFST 251-3 is shown in Fig. 3. This tube was subsequently lost while being removed from a potting mold. The MCP collimator and the deflector electrodes were salvaged.

2.4.2 Processing of PFST 251-4

Tube PFST 251-4 was fabricated with a collimator .016" thick, with 8.9 μ square channels. The tube was vacuum baked at 350° C for ten hours prior to photocathode processing. The MCP collimator was electron bombarded at 10Kv with an input current 1 μ a. A S-20 photocathode was formed transferred and sealed to the tube envelope. The final cathode sensitivity was 193 μ a/l. The tube was operated in the processing chamber with 8 Kv applied between the photocathode and the MCP collimator. A well defined, rectangular output display was observed on the phosphor output window. The tube was potted and operated with the photocathode at ground and all

Figure 3
Output Photo of PFST 251-3

other tube elements at 5 Kv. The phosphor screen in this tube has one half of its area evaporated with twice the normal aluminum film thickness relative to the other half. The boundary between the two halves is aligned with the sweep electrodes and orthogonal to the length of the collimator at its center. The internal spacings were as follows:

Photocathode to MCP collimator - .042"

Collimator output to sweep electrodes - .120"

Separation between sweep electrodes - .102"

A composite data sheet and outline drawings of PFST 251-4 are included at the end of section 2.4.3.

This tube was shipped to LASL for test and evaluation.

2.4.3 Processing of PFST 251-6

This tube incorporated an MCP collimator .016" thick, with 8.9μ square channels. It was vacuum baked at 350°C for ten hours. The MCP collimator was electron bombarded at 10 Kv with $2 \mu\text{a}$, for five hours. A S-1 photocathode with a white light response of $23 \mu\text{a/l}$ was formed, transferred and sealed to the tube envelope. The tube was operated in the processing system with 5 Kv applied between the photocathode and the MCP

collimator. A rectangular output display was observed on the phosphor output window. The cathode sensitivity was monitored over a period of six days after removal of the tube from the processing chamber. No change in cathode response was measured, indicating good tube stability and vacuum integrity. The tube was potted and operated with the cathode at ground and all other tube elements at 5 Kv with respect to ground. The output display was photographed. This tube was shipped to LASL for test and evaluation. A summary data package for PFST 251-6 is included on the following pages.

ITT PROJECT 11-25100
Contract EY-76-C02-2809
5/11/77

DATA SHEET FOR PROXIMITY FOCUSED STREAK TUBE

S/N 251-4

EDRA CONTRACT EY-76-C-02-2809 - Development of Proximity Focused Streak Tubes

1. Tube Configuration

The tube has been fabricated in accordance with the outline drawing as shown in Figure 1. Note the copper photocathode tab has been designated as K, the microchannel plate collimator as A.

2. Basic Characteristics

- a. Photocathode S20 - 198 μ a/lumen
- b. MCP Collimator
 - 1. Active area: .6" x .040"
 - 2. Channel Diameter: 8 μ
 - 3. Length to Diameter Ratio: 50/1
- c. Phosphor - P20

3. Tube Spacings

- a. Cathode to MCP Collimator: .042"
- b. Collimator Output to Sweep Electrodes: .120
- c. Spacing Between Sweep Electrodes: .102"
- d. Collimator Output to Phosphor: 1.198"

4. Test Data

- a. The tube was operated in the processing chamber and the MCP Collimator was outgassed with 10 kV applied between the photocathode and Collimator input.
- b. To establish tube stability the cathode sensitivity was monitored. No change was observed over a period of six days.
- c. The tube was operated with the photocathode at ground and all other tube elements at 5 kV with respect to ground. The basic vacuum integrity of the tube was confirmed. The ability to collimate an electron beam through an ITT-MCP array was established. The output display on the phosphor showed an approximate 1:1 correlation with the active collimator length and 1.25:1 with the active collimator width.

- d. The phosphor screen in this tube has one-half of its area evaporated with 2X the aluminum thickness of the other half. The boundary between the two halves is aligned with the sweep electrodes and orthogonal to the length of the collimator at its center. This is shown in Figure 1 and in Polaroid print Figure 2.
- e. The dark spot in the output of the singly aluminized and brighter half of the phosphor image corresponds to a metallic appearing flake, attached to the collimator input surface.
- f. The MCP collimator active area is fully contained within the active cathode area and is parallel to it. However, it is off-set to one side by approximately .010" as indicated in Figure 4.

FIG 4

Figure 5 Photo of Output Display of VPFST 251-4

FIGURE 6

Fig. 7

OUTPUT DISPLAY - PFST 251-6

2.5 Engineering Design of X-ray Input Section

2.5.1 Beryllium Entrance Window Development

The requirements of this program included the development of an entrance window for the X-ray streak tube, 1.230" in diameter, having a re-entrant section to obtain the interelectrode spacing and a centered rectangular X-ray transmissive area of .001" thick beryllium, .003" wide by .600" long. Fig. 8 illustrates the design which consists of a relatively heavy support ring with the center section .040" x .600" x .001". The width was increased from .003" to .040" to facilitate fabrication of the center section. The heavier support material was required for mechanical strength and effecting the seal of the entrance window to the tube body.

The following methods of obtaining the X-ray window assembly were evaluated:

1. Machining a window from solid beryllium stock and reducing the center thickness to the required .001" x .040" x .600" X-ray transmissive area.
2. Bonding a thin beryllium window to a monel support by
 - a. High temperature brazing
 - b. Ultra-sonic welding
 - c. Glass frit sealing
 - d. Epoxy-resin bonding
 - e. Soft soldering.

2.5.2 Machining Windows From Beryllium

The first attempt to fabricate the X-ray window assembly was by machining to the required dimensions from a solid disc of beryllium. Because of the toxicity of beryllium and the special precautions required in its machining, it was decided to obtain the windows from an outside supplier, the Beryllium Mfg. Corp., Amityville, L.I. N.Y. and five X-ray window assemblies were ordered to be fabricated according to ITT dwg. 4724889. All windows were to have the rectangular center section machined to .002" thick and to be leak checked for vacuum tightness at this point. The vacuum integrity, although essential for subsequent use in the Streak Tube, was an objective specification and reflected the difficulty involved in machining beryllium to the thinness required. One of the .002" windows, if vacuum tight was to be further reduced to .001". See Fig. 8a

The first window so fabricated was, initially, a leak tight assembly. However, before it could be assembled into a tube, and perhaps as a result of additional processing, a leak developed. In this instance the window had to be returned to the supplier for smoothing of sharp edges at the re-entrant section of the window and was subjected to an additional leak check operation after the rework was completed. Another .002" window leaked after being further reduced to .001" thickness. Of the three remaining .002"

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A - MACHINED FROM SOLID BERYLLIUM

B - HIGH TEMPERATURE BRAZED ASSEMBLY

C - GLASS FRIT SEALED ASSEMBLY

FIG. 8 - X-ray Window Assemblies

windows, one leaked after fabrication and two were delivered vacuum tight. After being cleaned by immersing in trichlorethylene and methyl alcohol one of these leaked. The other was sealed to F251-5 XPFST as the X-ray window for this tube. However, within 3 days after removal from the process system the tube became gassy and a leak was found in the thin beryllium section of the X-ray window. The leak detector used is the VEECO MS9 helium mass spectrometer type capable of detecting a leak rate of 10^{-10} std. cc./sec.

Although this approach was unsuccessful, it appears that windows can probably be machined to .003" and almost certainly to .005" thickness.

2.5.3 High Temperature Brazing

Contacts were made with various suppliers and fabricators of beryllium to determine the feasibility of obtaining .001" beryllium foil brazed to a suitable support ring for use as the X-ray window. The response was not encouraging because of the reactivity of beryllium with most brazing materials, and the thinnest beryllium which had been joined in this manner was .003". A search of the literature available on beryllium brazing confirmed this response. A bibliography of articles pertaining to beryllium joining is included in this report.

However, several experiments were completed at ITT in which rectangular pieces of .001" thick beryllium foil, approx. .250" x .875" were vacuum brazed to a support ring of Monel 404, an alloy having a comparable coefficient of expansion. Fig. 8b

Between 20 - 700°C the average coefficient of expansion of Beryllium is 17.8×10^{-6} in/in/°C while that of Monel 404 is 17.1×10^{-6} in/in/°C. The braze alloy used was Incusil 15, an alloy having a M.P. of 625°C and a flow point of 710°C and was chosen because of a reference in the literature * to successful use of this alloy with .003" beryllium and also because of the desire to keep the vapor pressure of the beryllium as low as possible during the braze operation.

Brazing was done in a LN trapped, Hg diffusion pumped vacuum system at a pressure of 10^{-5} mm.Hg. in a specially constructed flask, see Fig. 9. A molybdenum heater was used to bring the assembly to brazing temperature which was monitored by a chromel-alumel thermocouple. Several seals were made which were vacuum tight. However, pin-holes were found in the window area and deformation of the beryllium occurred causing it to become wrinkled.

Effort on this approach was stopped when other methods appeared to have greater promise.

- * Brazing thin Beryllium windows by J. P. Papacosta, D. M. Murdock and R. Wayne Crews - Rev. of Sci. Inst. Vol 33 No. 11 Nov., 1962.

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Fig. 9 - High Temperature Vacuum Brazing Ass'y

2.5.4 Ultrasonic Welding

An attempt was made by Sonics and Materials Inc. of Danbury, Conn. to bond beryllium foil to a monel support ring by ultrasonic welding. This technique requires very little heat and is applicable to thin foils. However, because of the power required, the area involved and the thinness and brittleness of the beryllium foil, the attempt was unsuccessful. Fracturing of the beryllium occurred when welds were attempted.

2.5.5 Glass Frit Sealing

Three X-ray windows were supplied by the LND Inc., Ocean-side L.I., N.Y. These were fabricated according to ITT dwg. #4724980 and consisted of a monel support ring to which was bonded an .001" thick beryllium window by means of a glass frit technology. Fig. 8c. Two windows were usable and the beryllium tested vacuum tight as received. However, after a 250°C vacuum bake one of these developed a leak and the other, although vacuum tight after this bake, developed a leak through the beryllium after processing as the X-ray window for tube #F-251-8. The third window was unusable as received because of incomplete machining of the monel support ring. This window may have been usable after

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remachining, but, because of the hazard to the thin window and the glass frit seal from a machining operation, this was not deemed feasible.

It was noted that the beryllium windows of these assemblies were stained and apparently had a heavy oxide layer. The vacuum bake possibly uncovered latent leaks temporarily sealed by moisture or oxide particles.

2.5.6 Epoxy - Resin Bond

An experimental seal was completed using an epoxy, #152Q Delta Resin Bond with D-4 hardener, purchased from Wakefield Engineering Inc. Wakefield, Mass.

This material required a two step air bake for hardening. The initial cure bake, at 250^o F for two hours resulted in a vacuum-tight bond, blue in color. However, when subjected to the post cure 350^o F, 8 hr. bake the resin changed to a green, granular appearance and was no longer vacuum tight. This approach to a seal was not continued because of the temperature limitation to subsequent tube processing and the decomposition of the resin which is reported to occur at temperatures above 190^oC (374^oF) in vacuum.

2.5.7 Soft Soldering:

Initial attempts at low temperature bonding of beryllium to monel were made using pure indium. The method used consisted of the following steps:

1. Cleaning and hydrogen firing of the monel support
2. Cleaning of the beryllium window
3. Inconel and copper evaporation of the beryllium window seal area
4. Wet-in of indium to seal recess of monel support
5. Positioning of evaporated surface against indium
6. Vacuum bake to effect the seal at 350°C .

The use of pure indium was not satisfactory. Good bonds were not obtained because of the difficulty of confining the indium to the seal area. The indium, when molten, wet the monel surface, moving out of and depleting the reservoir of indium at the seal area.

The indium-bismuth alloy, Indalloy, 33.7% bismuth, which is eutectic at 72.1°C , was next evaluated. This alloy remained within the seal area during the vacuum bake and bonded well to the evaporated copper. The processing steps were similar to those for pure indium, and good seals resulted. Fig. 10

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Fig.10 - Indium Alloy Bonded Beryllium Assembly

Two other alloys were evaluated, Indalloy 11, (In 5% - Pb 95%) having a M.P. of 315°C and Indalloy 3 (In 90% - Ag 10%) having a M.P. of 230°C .

The Indalloy 3 reacted similarly to pure indium, spreading over the monel surface, depleting the seal area. It also appeared to have undergone a change in structure, perhaps a type of recrystallization, having a grainy appearance. The seal attempted with this alloy was unsuccessful.

The Indalloy 11 was less fluid than any of the solders evaluated, probably because of its high lead content, and it required a higher wet-in temperature. Its appearance was not as bright as the other solders but it bonded to the beryllium seal area and a vacuum tight seal was obtained.

The low melting temperature of the solders requires the use of a retaining flange to hold the beryllium foil in contact with the seal when the processing temperature exceeds the melting temperature of the solder.

It has been noted that the solders will not spread over a beryllium surface. In order to effect a bond it has been necessary to evaporate the sealing surface of the beryllium with inconel and copper. The non-evaporated areas of the beryllium are free of any solder as near as can be determined by visual examination.

An .001" beryllium window was bonded to a monel 404 support ring with indium-bismuth eutectic solder and sealed to F251-7 XPFST. The tube became gassy approximately two days after removal from the process system. The beryllium window assembly was removed from the tube and checked. The beryllium and beryllium to monel seal checked good. The monel to tube body seal appears to have been the cause of the leak. X-ray detectors having indium-bismuth seals have been constructed subsequent to this development effort and have maintained vacuum integrity for a known period of three months.

2.5.8 Conclusion

The successful development of a fluxless solder seal technique for bonding thin beryllium foil for use in X-ray detection devices has been achieved on this program. Advantages of this method include:

1. No flux is required eliminating the possibility of contamination.
2. All processing involving beryllium is carried out in high vacuum, eliminating the problem of oxidation and possible subsequent leaks through the transmitting area.
3. Solders and monel support are processed in hydrogen and

An .001" beryllium window was bonded to a monel 404 support ring with indium-bismuth eutectic solder and sealed to F251-7 XPFST. The tube became gassy approximately two days after removal from the process system. The beryllium window assembly was removed from the tube and checked. The beryllium and beryllium to monel seal checked good. The monel to tube body seal appears to have been the cause of the leak. X-ray detectors having indium-bismuth seals have been constructed subsequent to this development effort and have maintained vacuum integrity for a known period of three months.

2.5.8 Conclusion

The successful development of a fluxless solder seal technique for bonding thin beryllium foil for use in X-ray detection devices has been achieved on this program. Advantages of this method include:

1. No flux is required eliminating the possibility of contamination.
2. All processing involving beryllium is carried out in high vacuum, eliminating the problem of oxidation and possible subsequent leaks through the transmitting area.
3. Solders and monel support are processed in hydrogen and

The set-up used for in-system evaporation consisted of a gold evaporator and a tungsten filament light source contained within a cylindrical metal can having a specially designed cover to support the X-ray window and the glass faceplate monitor. The monitor was required since the beryllium window will not transmit visible light. This evaporation assembly was adjacent to the tube support and contained within the vacuum system bell jar. A photocell was located outside the bell jar facing a viewport through which the light for measuring film thickness was transmitted. The photocell current was set to give a full scale deflection on a micrometer by adjusting the current through the filament light source. See Fig. 11.

Using this approach required the determination of the light transmission through gold films - 150 to 250 angstroms in thickness. Two methods were evaluated:

1. Experimental determination at our laboratory.
2. Review of experimental results by others in the field.

2.6.2 Experimental Determination

Gold evaporations were carried out in the Electron Beam

Fig.11 - Schematic of Pinal Process System

Gold Evaporation and Tube Outgas

Vacuum Coating unit using glass window substrates and monitoring the film thickness by means of a Sloan crystal sensor, located the same distance from the evaporation source as the substrates. The frequency shift indicating the desired film thickness is determined by the approximate formula

$$T = \frac{2 \Delta f}{\rho} \quad \Delta f = \frac{T \rho}{2}$$

where

T = Thickness in angstroms

Δf = frequency shift (Hz)

ρ = density of gold (gms/cc)

Measurements were made at 200 angstroms and 250 angstroms thickness. The 200 angstrom value was first chosen as a logical center point allowing 50 angstroms plus or minus variation. Subsequently, after a review of other published experimental data, and realizing the Sloan formula was not exact, the frequency was increased to 2400 Hz, equivalent to 250 angstroms in the formula. The optical transmission of the evaporated film on the glass substrates was measured by means of densitometer, outside the evaporator, to give a correlation between film thickness as determined by the

crystal monitor and optical transmission. Following are some results:

<u>Gold Film Thickness</u>	<u>Freq. Hz.</u>	<u>Optical Transmission</u>
200 angstroms	1930	47%
250 "	2400	35%
250 "	2400	37%

2.6.3 Review of Experimental Results by Others

Comparison of the above transmission values was made with data taken from the Journal of Physics E: Scientific Instruments 1977,* Vol. 10 pp. 733-736, in an article "In situ determination of the optical and electrical properties of thin films during their deposition," by P. Gadenne and G. Vuye, and "Metal Film Transmission vs. Thickness" by W.L. Bond, J.O.S.A. -44 429 (1954)**

<u>Gold Film Thickness</u>	<u>*Ref. #1</u>	<u>**Ref. #2</u>	<u>ITT</u>
150 angstroms	47%	37%	
200 "	33%	21%	47%
250 "	24%		36%
155 "		36%	
185 "	36%		

From the above data it appears that the 36% optical transmission value falls within the 150 to 250 angstrom range with ITT and the other two quoted references data.

Two experiments were completed in the final process system to determine the accuracy of the in-system transmission measurements.

In the first experiment, gold was evaporated to 44% transmission in the system and then checked outside the system with the optical densitometer which gave a transmission value of 43%. The second experiment was similar with an in-system value of 35% and densitometer reading of 40%.

During gold evaporation in the final process system, the evaporator filament emitted light of sufficient intensity to increase the microammeter deflection and frequent corrections were required which increased the possibility of error in transmission measurements. Therefore the second approach, evaporating the gold film external to the tube final process system, was evaluated.

2.6.4 Gold Evaporation External to Final Process System

The second approach to obtaining the required cathode was

by evaporating the X-ray window with gold in the Electron Beam Vacuum Coating Unit using a crystal frequency thickness monitor and measuring the transmission of a co-evaporated glass window as previously described in the report.

Although this approach provided better film thickness control, it required that the X-ray window be vacuum baked after the gold had been evaporated on the beryllium. It was found that after a vacuum bake at 350°C , the usual bakeout temperature for tube processing, the gold had changed markedly in appearance to a green-gold hue which might indicate a diffusion of gold into the beryllium resulting, perhaps, in reduced cathode emission and increased danger of vacuum leaks through the window. The maximum bakeout temperature was reduced to 250°C at which temperature only a slight color change was noted. The process schedule was then modified to provide a 350°C vacuum bake for the final process system and all tube components except the entrance window. The system was cooled, and let to atmospheric pressure by introducing dry nitrogen. The gold evaporated entrance window was then inserted through a port in the bell jar after which the system was rebaked at 250°C .

The tube was then outgassed and the X-ray window sealed to the tube by standard in-vacuum assembly techniques.

2.6.5 X-ray Tubes Fabricated Re. Gold Cathode Deposition

Tube F241-5 was processed with a bi-alkali secondary cathode for tube outgas and an "in final process system" evaporated gold cathode on the beryllium window. The gold film, as measured through a glass monitoring faceplate located the same distance from the evaporation source as the beryllium window, was evaporated to a transmission of 35%. After the beryllium window assembly was sealed to the tube body and the process system opened the glass monitor was measured by the densitometer at 37% transmission.

Tube F251-7 was processed by in-system evaporation of a gold secondary and primary cathode. The secondary cathode was evaporated to a 50% transmission and excited by an external U.V. source through a sapphire port in the vacuum system. The primary was evaporated to 22% gold transmission. Extraneous light leakage from the evaporator filament caused an error in measurement resulting in the heavier gold layer. The 22% transmission value was determined by checking

the monitor on the densitometer after removal from the process system.

Tube 251-8 was processed with a pre-evaporated gold cathode, deposited in the Electron Beam Vacuum Coating Unit and monitored by the Sloan Crystal to a frequency of 2400 Hz. The transmission of a glass window positioned at the same distance from the source was 37%. The in-system tube outgas was by U.V. excitation of a secondary gold cathode evaporated to approximately 28% transmission.

2.7 PROCESSING OF THE X-RAY PFST

The design of the X-ray PFST is identical to that of the visible tube with the exception of the input faceplate section and the type of MCP collimator used. The design test and evaluation of the beryllium input window used for the X-ray PFST is discussed in detail in Section 2.5 of this report. The following is a description of the three X-ray tubes that were processed on this program.

2.7.1 Processing of X-ray PFST 251-5

This tube was processed with an input window made of a solid beryllium faceplate with a milled slot, .002" thick located in the center of the faceplate. The MCP collimator was .095" thick to provide an l/d ratio of 270 to 1. The spacing between the gold cathode and the MCP collimator was .102". An outline drawing of PFST 251-5 is shown in Fig. 12. The tube was vacuum baked at 350° C for fourteen hours. The MCP collimator was electron bombarded with 10kV applied between the cathode and the collimator input. Bombardment current was 2 ua. Total bombardment time was five hours. A gold cathode was evaporated on to the Be input window. The beryllium input faceplate was then transferred and sealed to the tube envelope.

Figure 12

X-ray Proximity Focused Streak Tube 251-5

Figure 13

Photo of X-ray PFST 251-5

The tube was removed from the processing system. Initial tests were made with 5 kV applied between the gold photocathode and the collimator input. The tube appeared to be vacuum tight and 4×10^{-11} amps of photocurrent was measured from the gold cathode, with a UV input signal of high intensity used as an input source. After three days no photo-emission could be measured and a glow was observed within the tube envelope with 5kV applied between the gold cathode and the MCP collimator. The above tests indicated the tube was slowly going to air. The tube was mounted in a vacuum system and the beryllium cathode faceplate was removed from the tube envelope. The tube envelope was leak checked. No leak was found in the tube envelope. Test of the solid beryllium input window showed evidence of a leak through the thinned out .002" thick center section of the window. An output photo of the completed tube is shown in Fig. 13.

2.7.2 Processing of X-ray PFST 251-7

This tube was processed using an input section consisting of a .001" thick beryllium window sealed to a Monel 404 support plate with an indium bismuth alloy and fabricated in accordance with the techniques as outlined in section

2.5 of this report. An MCP collimator .061" thick was mounted in the input section. The tube was vacuum baked at 300° C for ten hours. A gold cathode was evaporated on to the beryllium window. A 22 per cent change in transmission was measured during the gold evaporation. The MCP collimator was electron bombarded for five hours with a bombardment current of 2 ua. The input window assembly was then transferred and indium sealed to the tube envelope. The tube was removed from the processing chamber. The tube was initially operated with 6 kV applied between the gold cathode and the collimator. A cathode current of 8×10^{-9} amperes was measured using a high intensity UV source. After three days no photoemission could be measured, and the input voltage was limited to 3 kV. The tube was subsequently taken apart to evaluate the condition of the input window assembly. No leak was found in the tube envelope. No leak was found in the beryllium input window. The cause of the tube leak is believed to have been in the seal of the monel substrate to the tube support plate. The significant data point obtained from the processing of PFST 251-7 is the fact that the beryllium input window remained leak tight throughout all phases of tube processing and that the technique used to seal in the beryllium

window provides a bakeable, .001" thick input section for X-ray applications.

2.7.3 Processing of PFST 251-8

This was the last tube processed on this program. The prime objective of this process was to evaluate the use of the LTD frit sealed beryllium input window. The details of the input window fabrication are discussed in section 2.5 of this report. The tube was processed using a .095" thick, MCP collimator. The tube was vacuum baked at 350° C for eight hours. A gold cathode was pre-evaporated on to the beryllium input window. The MCP collimator was electron bombarded for four hours with 2 us, and with 10kV applied between the bombardment cathode and the MCP collimator input. The faceplate was transferred and indium sealed to the tube envelope. The vacuum integrity of the tube was maintained for less than twenty four hours. Subsequent tests on the tube assembly revealed a leak in the beryllium window seal. The frit seal of the beryllium to the monel substrate did not successfully withstand the tube processing cycle.

2.8 The following is a bibliography of articles researched during the investigation of beryllium joining technology:

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