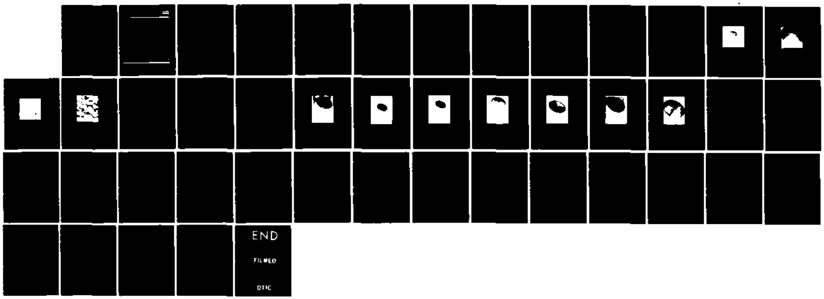
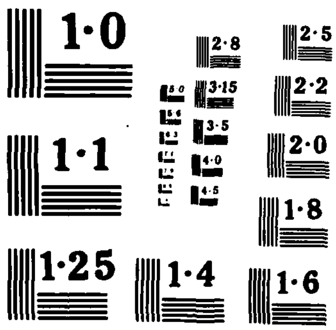
AD-A152 595 CONTINUED DEVELOPMENT AND TESTING OF TUNGSTEN CONTROLLED POROSITY DISPENSER CATHODES(U) HUGHES AIRCRAFT CO TORRANCE CA ELECTRON DYNAMICS DIV FEB 85 1/1

UNCLASSIFIED EDD-W-09514 N00014-81-C-2245 F/G 11/6 NL




1·0
2·8
2·5
3·15
2·2
3·5
1·1
2·0
4·0
4·5
1·8
1·25
1·4
1·6

(2)

HUGHES

ELECTRON DYNAMICS DIVISION

AD-A152 595

FINAL REPORT

CONTINUED DEVELOPMENT AND TESTING OF TUNGSTEN CONTROLLED POROSITY DISPENSER CATHODES

This document has been approved for public release and sale; its distribution is unlimited.

CONTRACT NO. N00014-81-C-2245

W-09514

FINAL REPORT

CONTINUED DEVELOPMENT AND TESTING OF TUNGSTEN CONTROLLED POROSITY DISPENSER CATHODES

CONTRACT NO. N00014-81-C-2245

FEBRUARY 1985

HUGHES AIRCRAFT COMPANY
ELECTRON DYNAMICS DIVISION
3100 WEST LOMITA BOULEVARD
P.O. BOX 2999
TORRANCE, CA 90509

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 OBJECTIVE

The objective of this effort was to continue the development and testing of Tungsten CPD Cathodes that had started on Contract N00173-80-C-0404. The results of the effort were to produce cathodes with emission levels approximately equivalent or better than those of standard metal matrix B-type cathodes but with the demonstrated advantages of uniform emission and long life.

2.0 BACKGROUND

Under NRL Contract No. N00173-80-C-0404, a tungsten controlled porosity dispenser cathode was developed and fabricated by Hughes Aircraft Co., Electron Dynamics Division (HEDD), using a flat laser-drilled tungsten foil emitting surface with standard Ba-Ca-Aluminate in a 5:3:2 Mole ratio and the same material with a 20 percent addition of tungsten powder in a reservoir. The foil, porous tungsten reservoir and heater chamber were fused together into the cathode structure. Initial testing and evaluation was carried out. In addition, foils were fabricated by tungsten deposition into Si molds produced by Si orientation dependent etching techniques.

The techniques pioneered by NRL to fabricate controlled porosity cathodes utilizes a thin perforated metal foil placed over a reservoir of barium compounds. The object of the prior effort was to develop a CPD cathode that used the same chemistry as that of a B Cathode, that is an all tungsten structure with barium calcium aluminate in the 5:3:2 mole ratio in the reservoir as the source of activating material. A further objective was to develop fabrication techniques for producing 25 micron thick tungsten foil with a precise array of pores 5 microns in diameter on 15 micron centers. Several techniques were studied: laser drilling, ion milling and orientation dependent silicon etch technology. The most successful effort turned out to be laser drilling. Foils were made that met objectives described above by using a computer controlled pulsed solid state laser that drilled up to 80 holes per second in 2.5 micron thick tungsten in the programmed pattern.

Diffusion bonding techniques were developed to join the laser drilled foil to EDM fabricated tungsten reservoirs. Several cathodes were fabricated and tested with very good results. Work functions as low as 1.964 ev (much lower than a conventional B Cathode) were measured. Cathodes are currently on life test.

3.0 TASKS

3.1 CONTINUED LONG LIFE TESTING OF PLANAR CATHODES DEVELOPED UNDER CONTRACT N00473-80-C-0404

Three test vehicles 877HB4, 877HB5 and 877HB6 were continued on life test. Data on emission versus time and roll or curves from space charge limited to temperature limited regions were produced. Data for HB4 and HB5 are shown in Figures 1 and 2. 877HB4 and 877HB5 have, as of this writing, gone 27,000 hours and show no cathode current degradation. The work functions are the same or slightly lower than when they started. 877HB6 has reached 20,000 hours with the same results as HB4 and HB5.

3.2 REFINEMENT AND IMPROVEMENT OF PROTOTYPE CPD CATHODE STRUCTURES AND MODIFICATION OF FABRICATION TECHNIQUES FOR OPTIMUM PERFORMANCE CHARACTERISTICS

The techniques developed in the previous contract which utilized diffusion bonding techniques to join laser drilled foil to a reservoir were considered to be not as desirable as some technique that would not expose the materials to the high temperatures required for the diffusion bonding. It was decided to make the entire structure, reservoir and dispenser, in one operation by chemical vapor deposition. A subcontract was let to San Fernando Laboratories. Figure 3 is a copy of the Statement of Work given to San Fernando Labs.

Eight integral emitter/reservoir assemblies were produced by chemical vapor deposition of tungsten. The emitter foils were 25 microns thick and the walls of the reservoir were 125 microns thick. These units were sent to J K Lasers

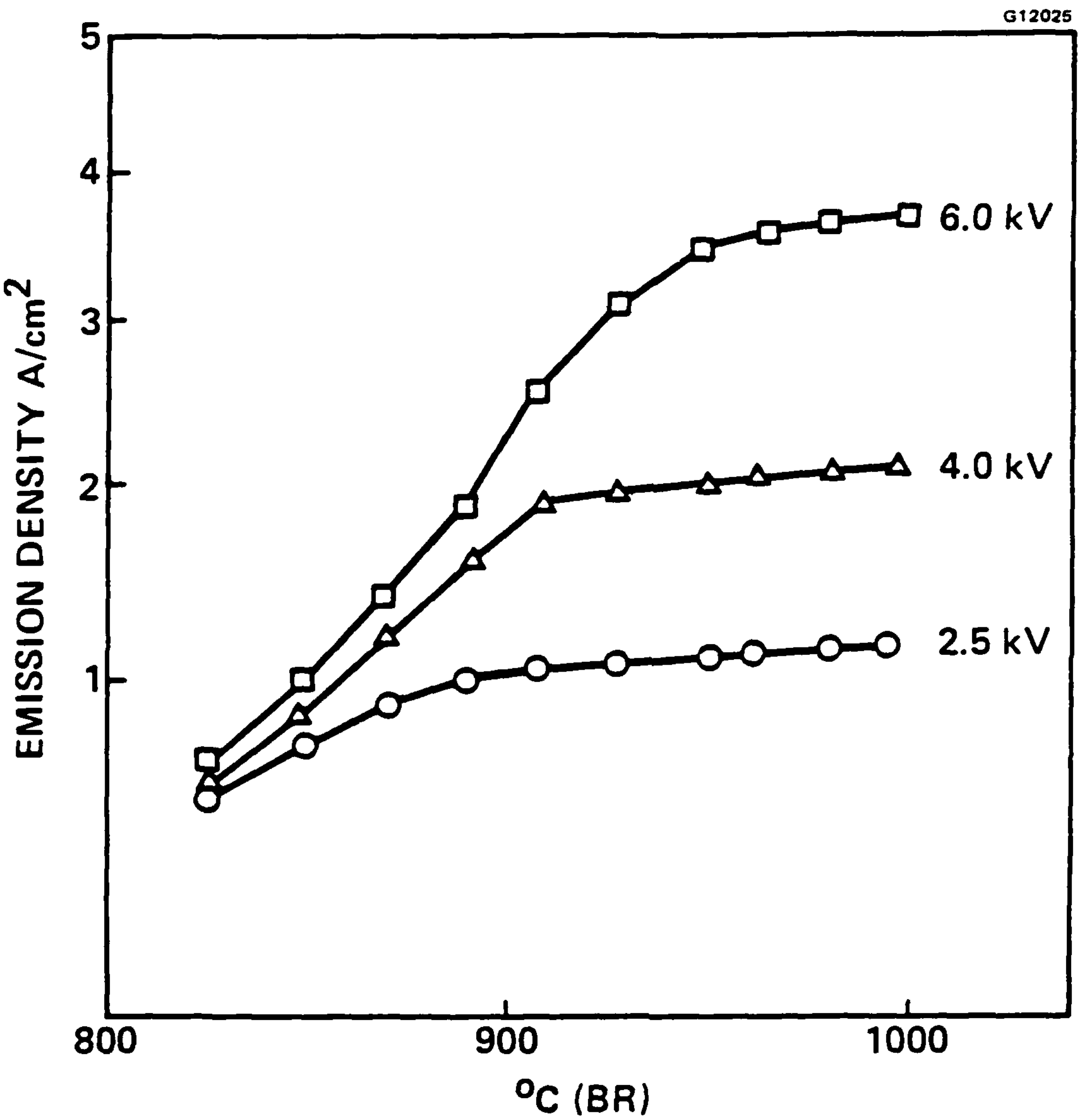


Figure 1 Emission density vs temperature CPD cathode HB-4 all tungsten structure laser drilled - overcoated with OS-RU (80-20).

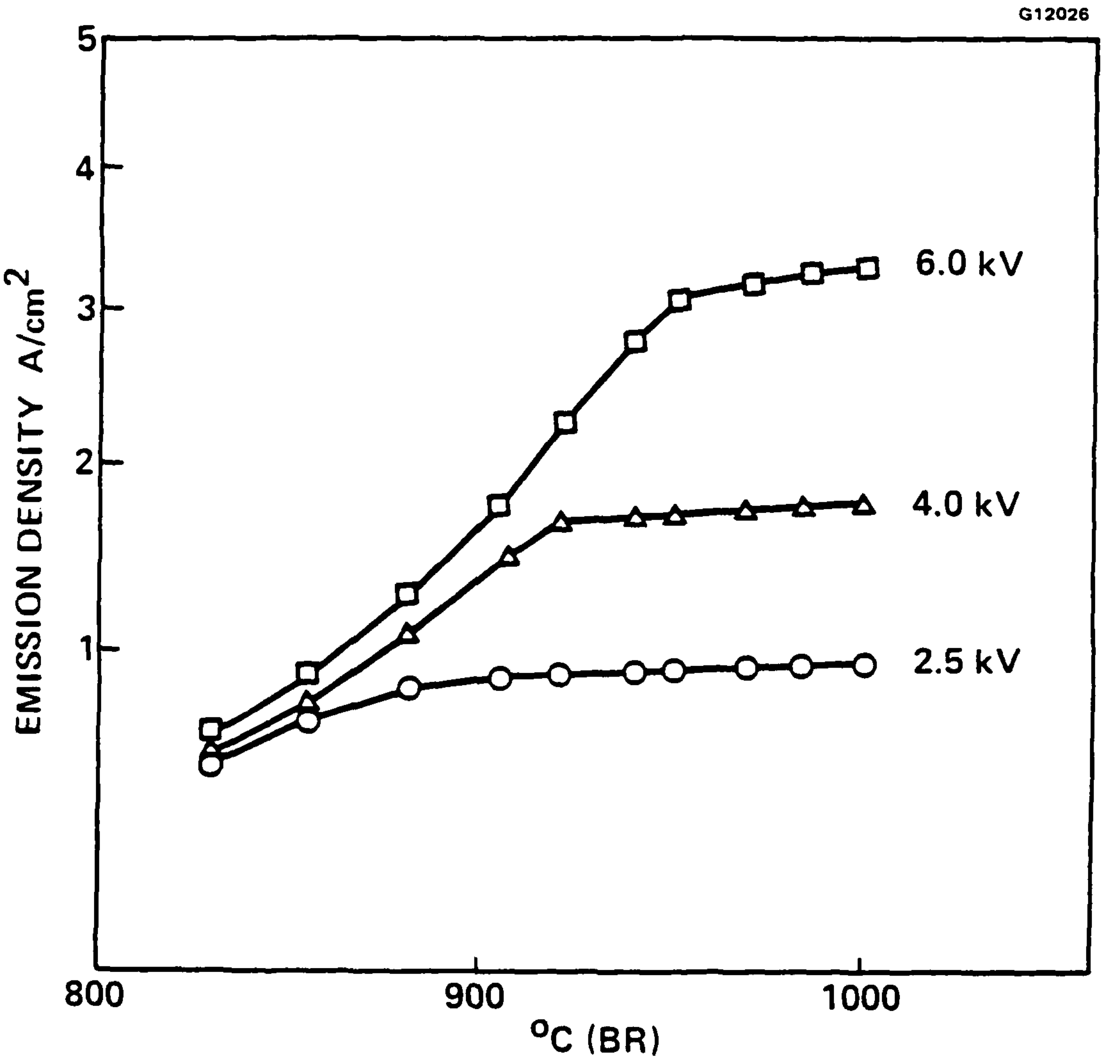


Figure 2 Emission density vs temperature CPD cathode HB-5 all tungsten structure laser drilled, overcoated with OS-RU (80-20).

STATEMENT OF WORK

1.0 OBJECTIVE

To develop CVD techniques to produce integral tungsten CPD foil and reservoir structures.

2.0 TASK DESCRIPTION

The subcontractor will devote their best effort to accomplish the following tasks:

2.1 Work out deposition techniques to produce 0.005 inch thick tungsten deposits on molybdenum mandrels.

2.2 Work out grinding techniques for the outside diameter.

2.3 Deliver a minimum of three coated mandrels with 0.005 $\pm$ 0.001 tungsten.

3.0 MATERIALS

Hughes will supply ten (10) mandrels with tungsten foil inserts.

Figure 3 Statement of Work to San Fernando Laboratories.

for drilling of the foil. Figure 4 is a SEM photo at 15X showing the emitter surface and the outside of the reservoir. Figure 5 is a 120X SEM photo of the inside of the reservoir and the backside of the emitter foil. This is felt to be a significant accomplishment since there is no need for high temperature brazing or diffusion bonding to join the foil to the reservoir, eliminating the problem of tungsten recrystallization. Figure 6 is a 3000X SEM photo of the emitter surface showing the fine grain size.

The emitter reservoir assemblies were sent to J. K. Lasers where they experimented with laser parameters to produce the desired pore pattern.

Some difficulties were encountered during the laser drilling process. Various degrees of cracking were experienced. An example of the cracking can be seen in Figure 7. Most of the cathodes experienced such bad cracking that they were not considered to be usable. The cracking problem was not seen in the drilling of rolled tungsten sheets in the previous contract so the CVD produced material needed further study to determine whether the problem involves stresses or grain boundary impurities or whatever other factor was influencing this behavior.

A second lot of planar cathodes was sent with the mandrels left in place and the results were considerably better with only a minimum of cracking.

3.3 FABRICATION OF PLANAR CATHODES FOR LIFE TEST

Cathodes using all CVD tungsten were fabricated in a planar cathode configuration for the 877HB and placed on life test. An additional ten cathodes were fabricated for life testing at NRL made to conform to V-7355 test vehicles. Figure 8 is a drawing of the cathode assembly. These were delivered to Varian for installation in the RADC life test vehicle and in the process of installation at least three of them were damaged. The remainder will be life tested by RADC. One vehicle has already gone 7,000 hours and 2 more are just beginning life test. Figure 9 shows the performance of cathode current versus temperature at 1 amp/cm^2 loading after 5,000 hours.

E4793

Figure 4   CVD emitter/reservoir.

Figure 5   Inside view emitter/reservoir.

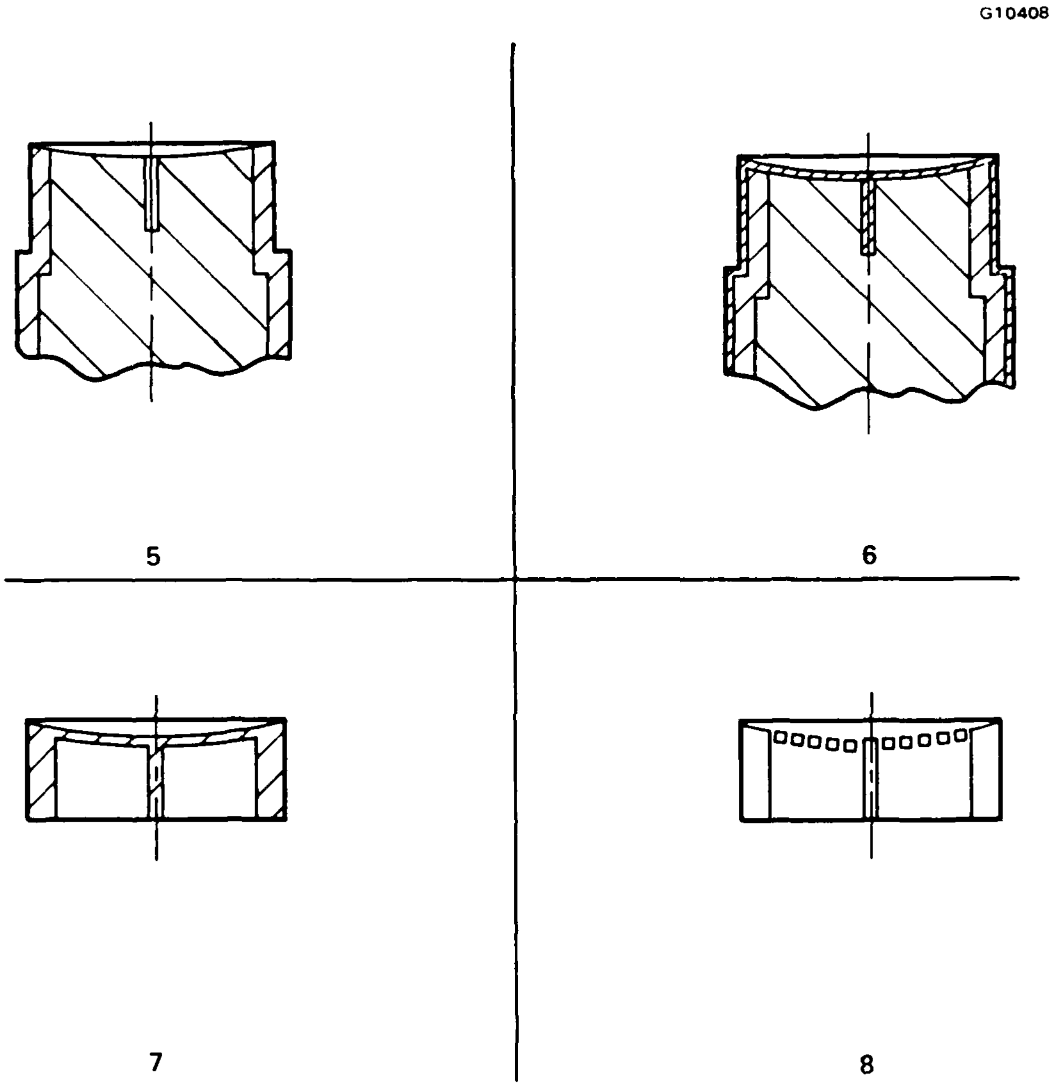


Figure 17 CPD cathode fabrication sequence (cont'd).

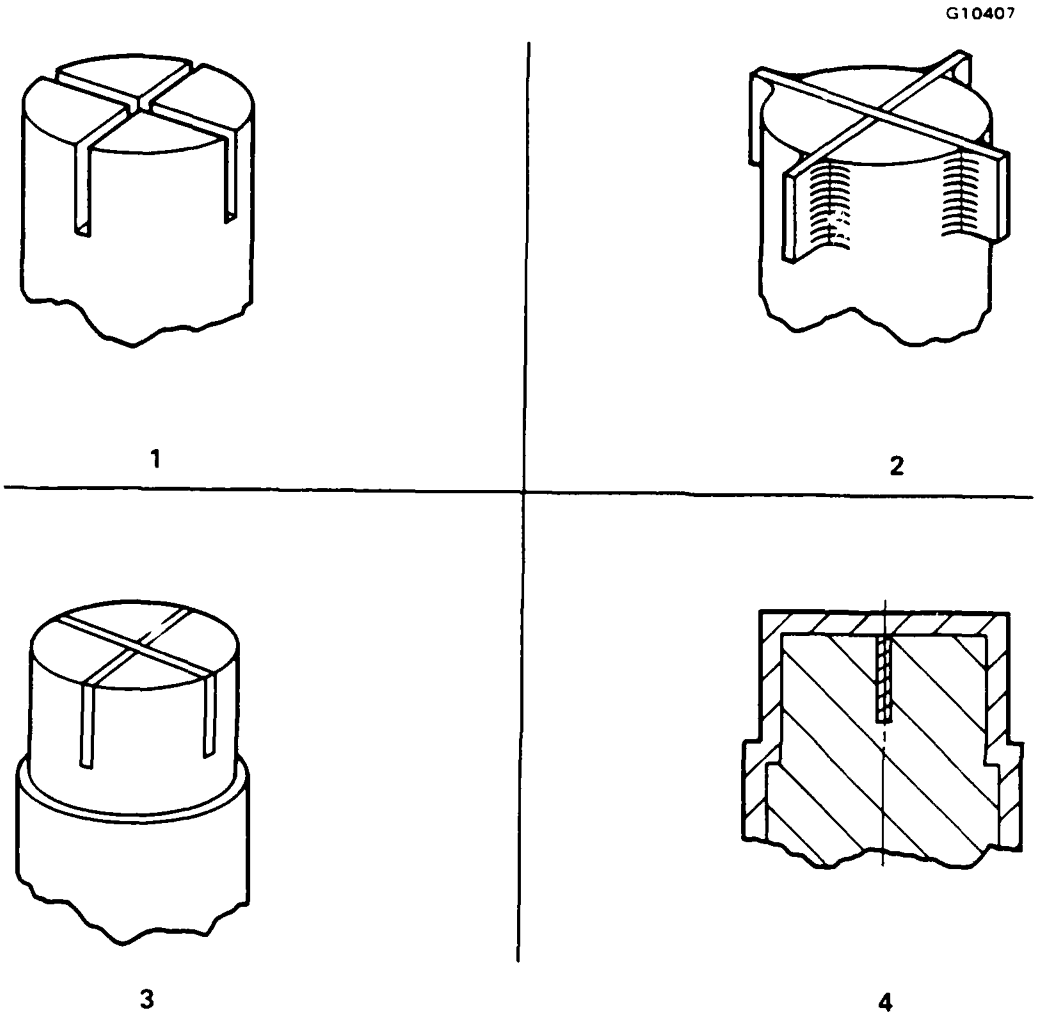


Figure 17 CPD cathode fabrication sequence.

E3776

Figure 16 Rear view CVD produced emitter/ reservoir.

E3775

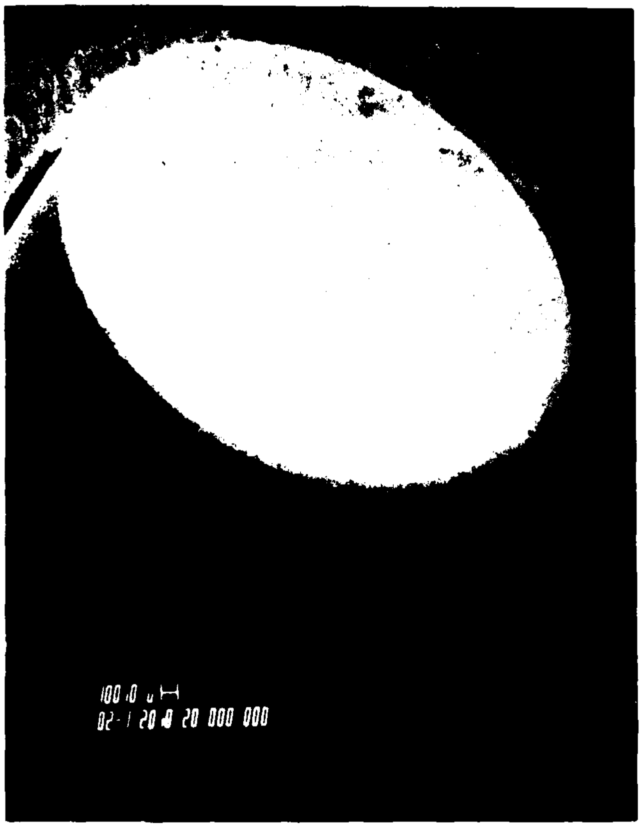


Figure 15 CVD produced emitter/reservoir assembly before laser drilling.

E3774

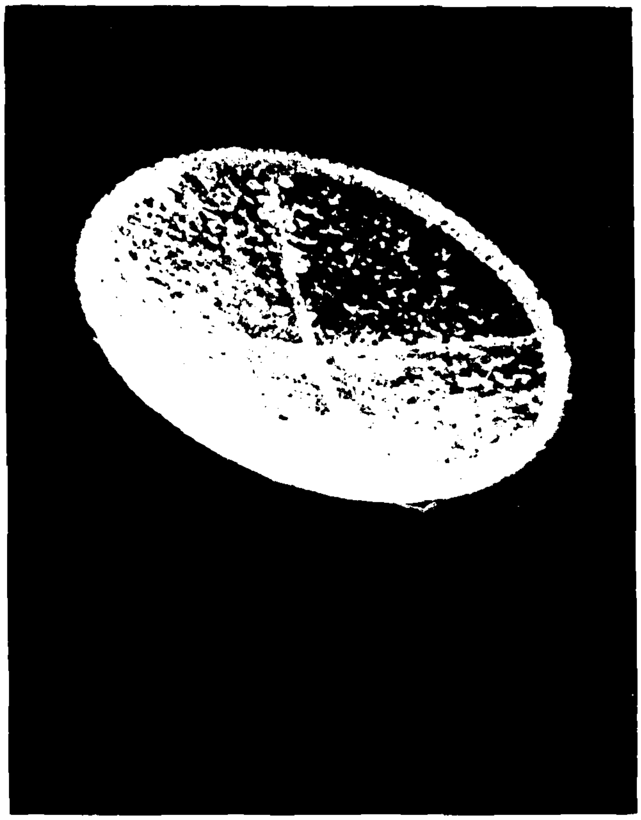


Figure 14 Spherically contoured mandrel.

E3773

Figure 13 Tungsten CVD coated mandrel and top machined.

E3772

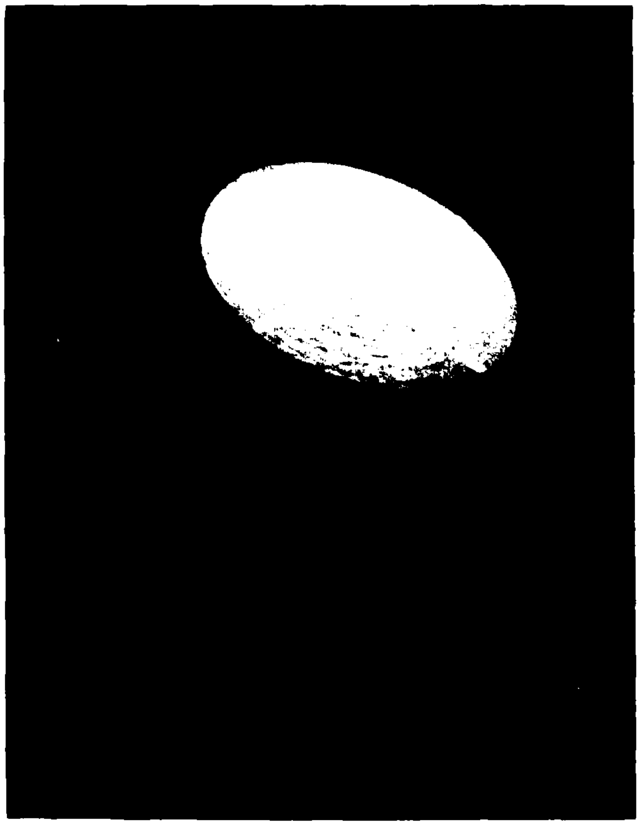


Figure 12 Mandrel prepared for CVD coating.

E3771

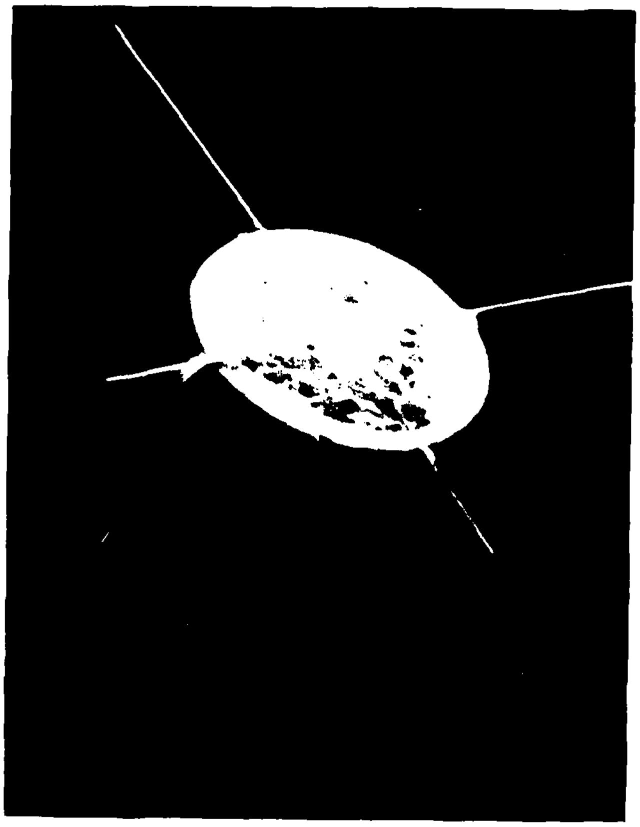


Figure 11 Moly mandrel brazed tungsten sheets.

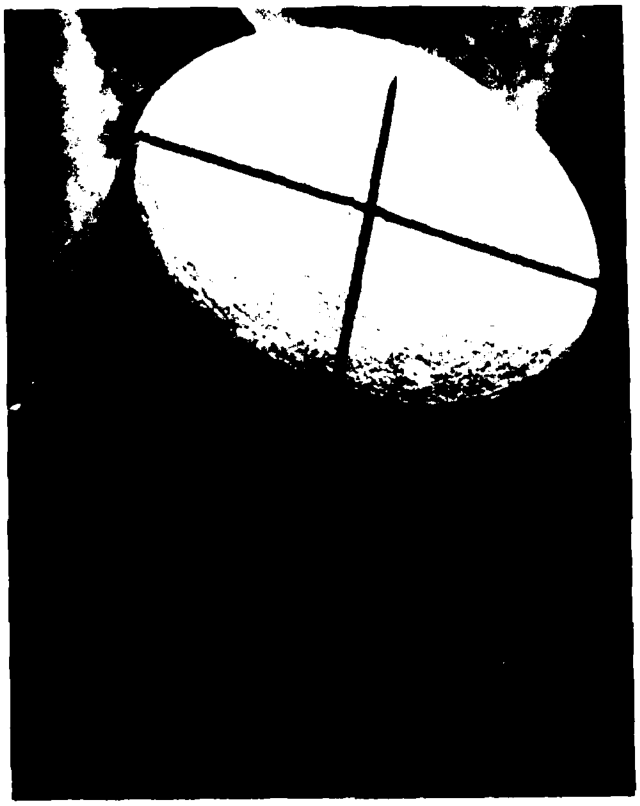


Figure 10   Molybdenum mandrel.

3.4 DEVELOPMENT OF FABRICATION TECHNIQUES TO PRODUCE SPHERICALLY RADIUSED TUNGSTEN EMITTING FOIL IN CONTRACT N00173-80-C-0404

Diffusion bonding techniques were developed to join the laser drilled foil to EDM fabricated tungsten reservoirs. Several cathodes were fabricated and tested with very good results. Work functions as low as 1.964 ev (much lower than a conventional B Cathode) were measured.

One problem encountered under Contract N00173-80-C-0404 was that, during the fusing of the foil to the reservoir, which took place at near 2,000°C, the tungsten recrystallized. This produced a relatively non-uniform surface to support emission and embrittled the material, facilitating potential cracking. To overcome this problem and to provide a more producible, economic means of fabricating CPD Cathodes, a method was devised to grow by chemical vapor deposition (CVD) completely integral tungsten structures, including the reservoir and the dispenser/emitter. This technique was successfully developed. Steps of the process are illustrated in Figures 10 through 16.

The process begins with a molybdenum mandrel (Figure 10) which contains slots to receive 0.002-inch tungsten sheets, shown brazed in Figure 11. Figure 12 shows the mandrel prepared for CVD coating. Figure 13 shows the mandrel coated and the top machined. Note the uniform deposit of tungsten, which will become the wall of the reservoir. Figure 14 shows the mandrel after it has been spherically contoured and is ready to receive the dispenser/emitter coating of 0.001 inch. Figure 15 shows the completed emitter/reservoir assembly after removal by etching from the mandrel. Figure 16 is a view of the rear of the assembly, showing the mechanical-thermal support.

This process appears in graphic form in Figure 17 through 19. In Figure 17 the first four steps are outlined. Step 1 is the molybdenum mandrel onto which the tungsten or other metals are grown. Step 2 shows the cross member thermal-mechanical support brazed in place in the mandrel. Step 3 shows the mandrel machined and ready for deposition. Step 4 shows the coated mandrel in cross section. In Figure 18, Step 5, the mandrel top is contoured by electrical discharge machining (EDM). Step 6 shows the emitter surface deposition.

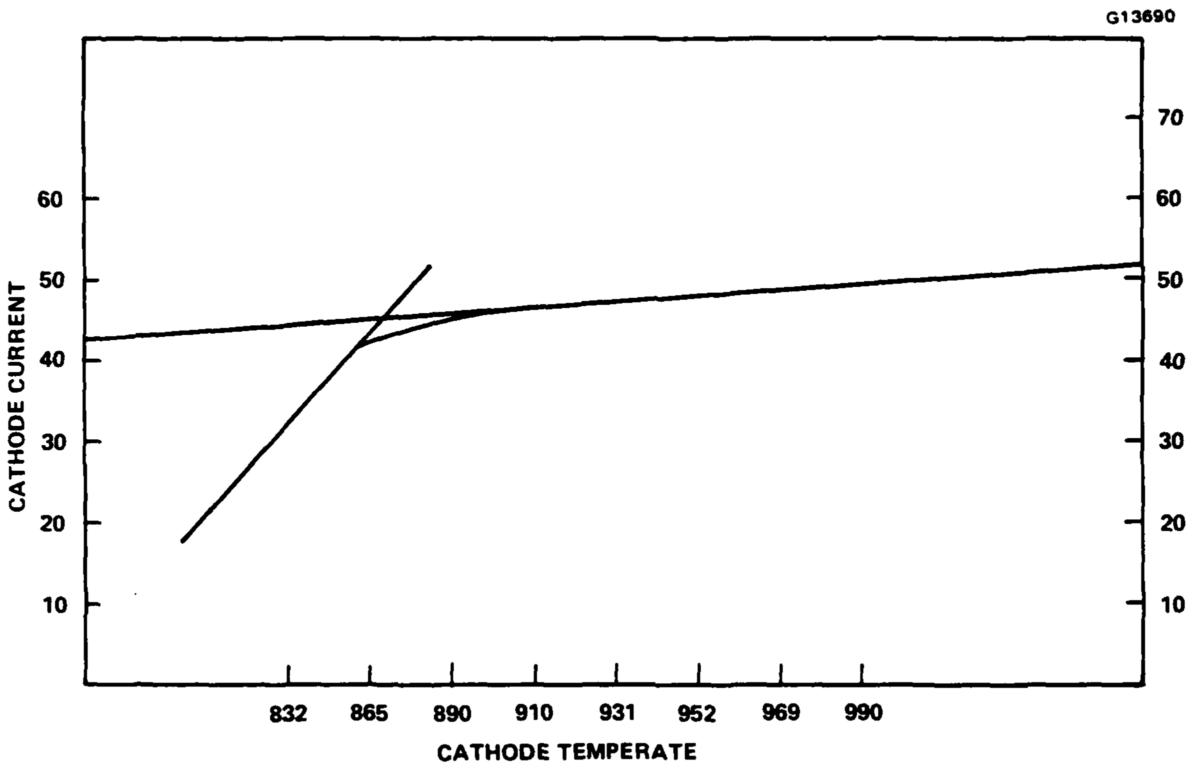
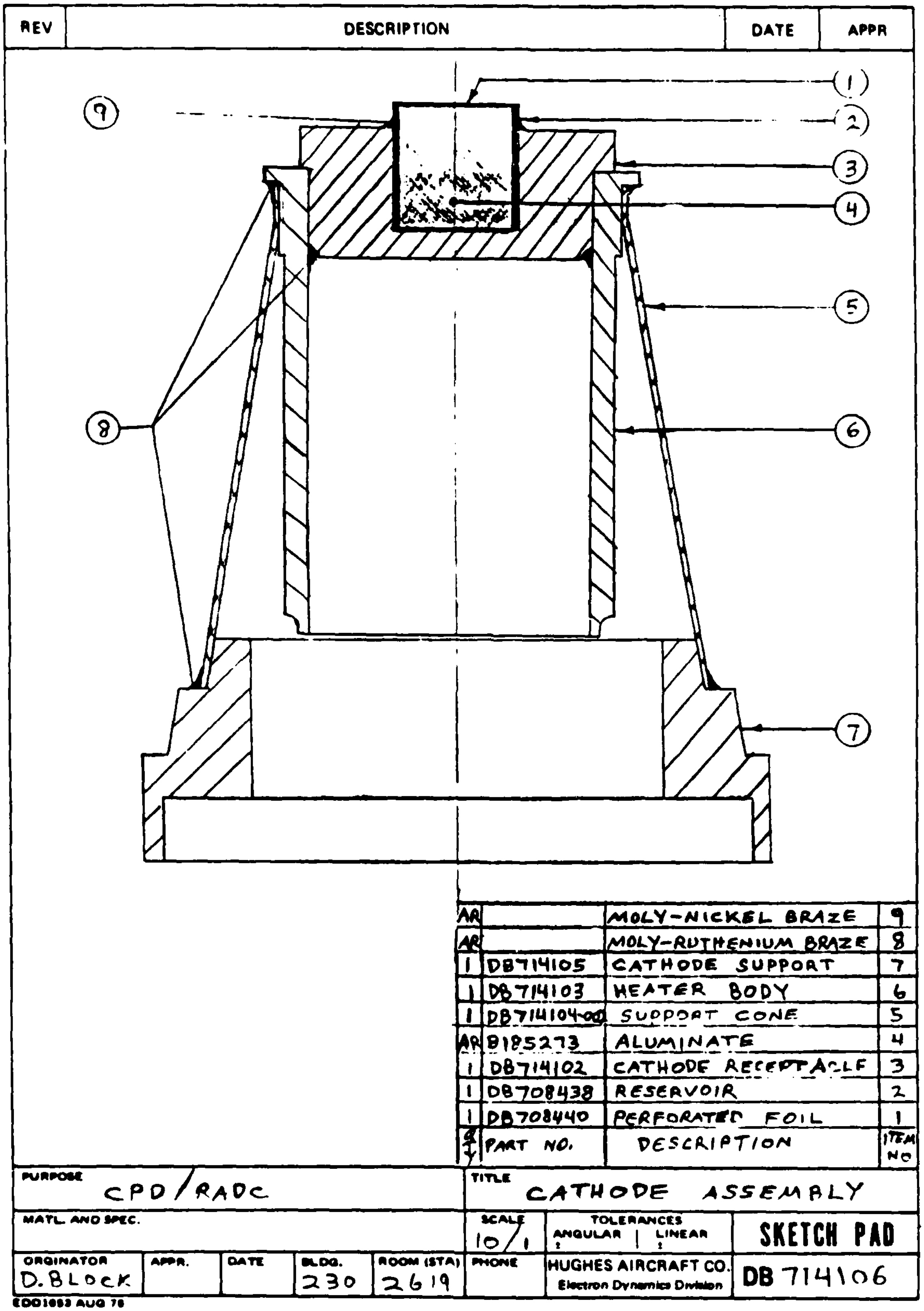


Figure 9 Cathode temperature vs cathode current V7355 Ser. No. 129.



QTY	PART NO.	DESCRIPTION	ITEM NO
AR		MOLY-NICKEL BRAZE	9
AR		MOLY-RUTHENIUM BRAZE	8
1	DB714105	CATHODE SUPPORT	7
1	DB714103	HEATER BODY	6
1	DB714104-00	SUPPORT CONE	5
AR	B185273	ALUMINATE	4
1	DB714102	CATHODE RECEPTACLE	3
1	DB708438	RESERVOIR	2
1	DB708440	PERFORATED FOIL	1

Figure 8 Cathode assembly.

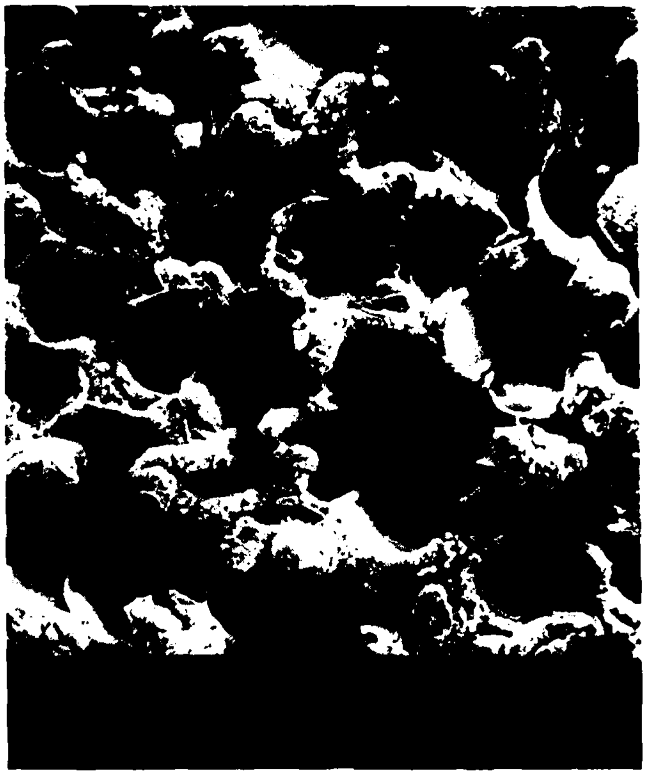


Figure 7 Laser drilled CVD produced planar cathode.

Figure 6   3000X SEM photo-emitter surface.

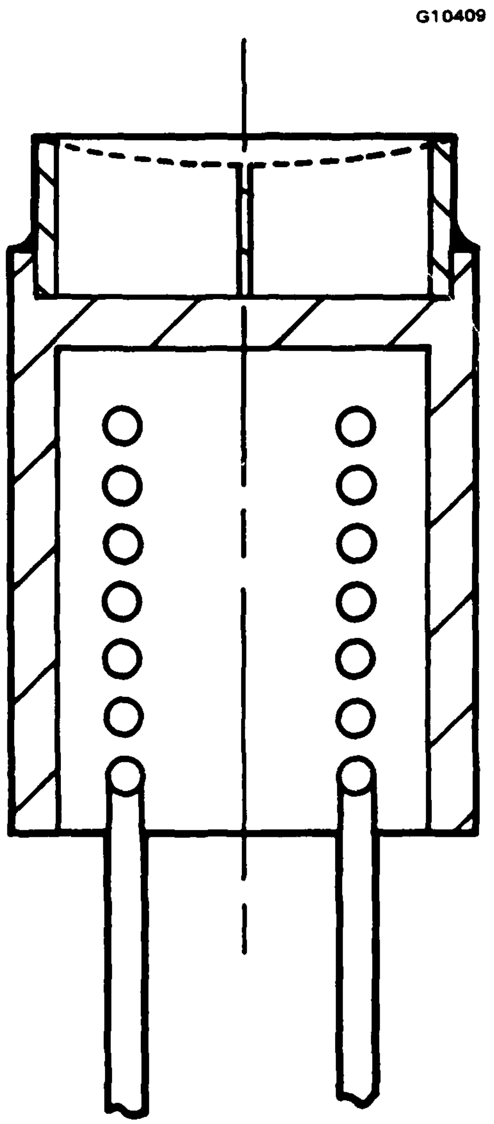


Figure 18   Final assembly CPD cathode.

Step 7 is the emitter/reservoir unit of the mandrel, and Step 8 represents the laser drilled structure. Figure 19 shows the final cathode assembly. After the reservoir is filled with activating material it is joined to a heater assembly by a relatively low temperature 1250 to 1300°C braze.

The best values of the laser parameters (such as pulse energy, pulse width and repetition rate, optical system parameters and most efficient method of workpiece handling) were determined by numerous tests and by production of a significant number of successful samples.

3.5 ESTABLISHMENT AND MONITORING OF SUBCONTRACT WITH A LASER MACHINING COMPANY TO DEVELOP AND REFINE TECHNIQUES FOR MAKING CPD FOILS USING LASER TECHNIQUES

A subcontract was let to J. K. Lasers in England to develop and refine techniques for laser drilling CPD foils. It was also expected that equipment would be specified for doing this work in the U.S. Figure 20 is a copy of the statement of work issued to J. K. Lasers.

The report on this effort is attached as Appendix A.

3.6 PURCHASE AND INSTALLATION OF LASER DRILLING SYSTEM FOR PRODUCING CPD CATHODES

As a result of the work in Task 3.5 it was possible to specify a laser drilling system for use in this program. Appendix B is the complete specification No. PSB180305 describing this system.

The system was received and installed. An Apple IIC computer was integrated into the system to control the x, y and z movements and the firing of the laser. Software programs were generated to produce a number of patterns using both round holes and slots as well as a variety of spacings between pores.

STATEMENT OF WORK

1.0 OBJECTIVE

The objective of this work will be to develop laser drilling techniques of tungsten foil 25 microns in thickness to produce an array of holes approximately 5 microns in diameter of uniform aspect on 15 micron centers. The drilling will be accomplished on both flat and spherically contoured foil.

2.0 TASK DESCRIPTION

The subcontractor will devote their best efforts to accomplish the following tasks:

2.1 Program the CNC equipment to produce uniformly drilled holes on a spherically contoured surface of 0.2 to 0.3 inch radius.

2.2 Optimize the laser parameters to yield either:

a) 3 micron diameter holes with a ±15 percent tolerance, or

b) larger (than 3 microns) diameter holes with a closer tolerance which can be uniformly reduced in size by deposition techniques.

2.3 Guarantee the delivery of 30 drilled pieces using procedures developed in 2.1 and 2.2 above.

3.0 PROGRESS REPORTING

Reports at three month intervals advising of progress to date will be submitted to Hughes by the subcontractor. Hughes will comment on the immediate work during the succeeding period.

4.0 MATERIAL

Materials will be supplied by Hughes and shall include sufficient scrap material for setting up purposes where necessary.

Figure 19 Statement of Work to JK Lasers

4.0 CONCLUSIONS

The use of chemical vapor deposition (CVD) has been successfully demonstrated, and units are currently under life test. Laser drilling techniques have been developed so that planar and spherically contoured cathode surfaces can be produced. Although laser drilling may not be perfect, it is the most expedient technique and the only one proven to be able to produce the objectives of 5 micron holes on 15 micron centers in 25 micron thick tungsten. All cathodes placed on life test in this and the prior contract will be continued on life test per contract requirements.

This program has shown that long life cathodes can be produced in a practical manner.

APPENDIX A

LASER DRILLING OF DISPENSER CATHODES

LASER DRILLING OF DISPENSER CATHODES

Table Of Contents

This report is provided to Hughes EDD as part of the requirements under JKL P.O. 3926 received from HEDD in Sept 1981. Prior to this order, JKL had processed various tungsten foil samples for HEDD.

J K Lasers Limited Somers Road Rugby Warwickshire CV22 7DG England
Telephone (0788) 70321 Telex 311540

A. 19.4.82 First of the Planar Cathodes

The requirement was to drill the Cathode leaving a narrow, undrilled border around the edge. Obviously it was going to be necessary to have a more sophisticated CNC program which could open and close the laser shutter in the correct place to produce a circular drilled area without the need for a mechanical mask.

A program was written for the NASCOM II which would calculate the lengths of chords, of a 2.54mm dia. circle, spaced 0.015mm apart. This was then modified to produce an output which could be stored on paper tape and used to program the Posidata.

By this method it was possible to generate a circular area of holes by defining the length of every line of holes within the area.

At this time it was discovered that the synchronous motor driven lens protector was rather prone to vibration which caused problems with the drilling. This was changed for the stepper motor driven system which is used at present.

Three batches of Cathodes were drilled at this time :

Batch 1. Appeared to have been fabricated by fixing a piece of foil onto a cylindrical body. These were drilled with the parameters as follows:

An MS25LD laser was used, having :

4" x ¼" Nd/YAG rod.

twin 92/4 lamps.

R = 30% O/P mirror.

R = Max, -10m concave rear mirror.

2X intra-cavity telescope.

"B" intra-cavity aperture = 1.8mm dia.

3X extra cavity beam expander.

10X Olympus focus lens.

Approx. 3mJ energy per pulse at f = 40Hz.

The workpiece was positioned in a V notch cut in an aluminium block, and was retained in the notch via a small steel leaf spring clip. A 60 watt soldering iron tip was inserted into a hole in the aluminium block and a temperature of 220°C was measured on the block a distance of a few mm from the workpiece.

Hole quality was poor because the surface was not flat and the laser was running out of focus. There were also problems with cracking.

Batch 2. These appeared to be of much better quality and obviously made by CVD. They were drilled in the same way as Batch 1 but it was necessary to increase the pulse energy to 5mJ, which suggests that the Cathode surface may have been thicker. Of this batch 4 appeared to be free of cracks and 3 wer cracked.

J K Lasers Limited Somers Road Rugby Warwickshire CV22 7DG England
Telephone (0788) 70321 Telex 311540

Batch 3. These were found to drill at 3mJ suggesting that they were thicker than Batch 2. There were problems with cracking straight away. Even with the spacings increased to 20 μm they still cracked. After consulting Lou Falce, it was decided that the Cathodes should be annealed, so the remainder of the batch was sent to EMI Varian at Hayes where they were annealed at 1300°C for 10 minutes in a Hydrogen atmosphere.

Unfortunately the annealing made the cracking problem worse. The entire batch was then returned to HEDD for examination. Batches 1 and 2 were shipped to HEDD by airfreight on April 20th, 1982. Batch 3 was shipped airfreight to JEC on May 19th, 1982 and then on to HEDD.

B.6.5.82 First of the Spherical Cathodes

A second program was written for the Nascom II which would generate a circular area but could also include circular interpolation in the Y + Z axes to give the spherical contouring.

The first attempt was made using a T & P Z stage mounted on the MT160 X-Y tables. This proved to be unsuccessful due to inaccuracies in the Z stage. The second attempt used a T & P linear slide to replace the Z stage, and although there were still problems with backlash it was possible to drill some cathodes with reasonable success.

J K Lasers Limited Somers Road Rugby Warwickshire CV22 7DG England
Telephone (0788) 70321 Telex 311540

The same laser parameters as listed under A. Batch 1 were used. Pulse energy was 4mJ. Some cracking problems were encountered but these were not as severe as with the flat cathodes.

There were also some problems with irregularities in the spherical surfaces causing the laser to run out of focus. This batch was shipped airfreight to HEDD via JEC on May 19th, 1982.

C.27.7.82 Further Batch of Planar CVD Cathodes

Same parameters listed under A.Batch 1 were used but pulse energy was approx. 1.5mJ. Serious cracking problems occurred. The Cathodes either cracked around the edge fairly early on in the drilling cycle or they cracked across the centre fairly late on in the drilling cycle. Subsequent examination of undrilled cathodes revealed cracking and surface defects around the edge of the planar surface. A portion of this batch was sent in the post to HEDD approx. 1st week of August, 1982. The remainder were collected by Glenn Breeze during his visit to JKL Sept. 27th - Oct. 1st 1982.

D.16.12.82 Planar CVD Cathodes - Modified

Four groups :

(i) CVD, no surface finish, without mandrel.

(ii) CVD, no surface finish, with mandrel.

(iii) CVD, electro polished, without mandrel.

(iv) CVD, electro polished, with mandrel.

Process parameters were the same as listed in A.Batch 1 except pulse energy which is noted below.

(i) CVD no surface finish, without mandrel - drilled at approx 1.0mJ There were serious problems with cracking around the edge and across the surface. Circumferencial cracking would generally start after the first few rows were drilled and would proceed during drilling. When drilling was completed typically about half the circumference would be cracked away from the body.

(ii) CVD.no surface finish, with mandrel - drilled at the same pulse energy as (i) but not possible to observe the results.

(iii) CVD.electro polished without mandrel - drilled at 4.0mJ pulse energy with much better results than in (i) but still some circumferential cracking.

(iv) CVD.electro polished with mandrel - drilled at 4.0mJ pulse energy with no obvious cracking, but again very difficult to observe the results.

During the drilling of (iii) above the fixture was modified to bring the workpiece as close as possible to the soldering iron and also to improve thermal contact but this did not have any noticable effect on the drilling results.

NOTE : We include this section for completeness, although a report on it was not specifically requested. The work was performed as an extension to our P.O. 3926.

Tony Pasternak
SENIOR PRODUCT ENG.

Pete A. Lumphreys
LASER APPLICATIONS ENGINEER

APPENDIX B

LASER MICRO-DRILLING SYSTEM

		REVISIONS		
AUTHORITY	LTR	DESCRIPTION	APPROVED PA	APPROVED ENGR.

SHEET	1	2	3	4	5
REV	-	-	-	-	-
SHEET					
REV					

APPROVALS	DATE		
PREP [signature]	10/7/82	HUGHES	FSCM NO. 73293
CHK [signature]	10 7-82	TITLE LASER MICRO-DRILLING SYSTEM	
PA [signature]	10 12 82		
APVD [signature]	10/12/82	END USE - CPD	
APVD		SHEET 1 OF 5	NO. PSB180305

EDD 1047F REV JAN 82

1.0 DESCRIPTION

Advanced version of the System 2000, Model MS25LD, Micro-drilling system manufacured by JK Lasers, Ltd. in Rugby, England. The system incorporates A) A pulsed Nd:YAG laser with low divergence resonator, focusing and viewing optics with 10X Olympus objective focusing lens. B) Automatic lens protection system. C) Work handling and control electronics to produce a range of planar and spherical shapes of variable diameter by means of an XYZ positioning system. D) Enclosed work station and support stand with twin interlocked sliding doors conforming to Class I laser safety standards. E) Output characteristics which conform to the following: Energy per pulse - variable up to one (1) Joule; Rated average power - variable up to 25 Watts; Pulse repetition rate - variable up to 50 Hz; Pulse duration - nominal 0.1 msec. F) Helium - neon alignment laser with adjustable mount.

2.0 OBJECTIVE

The laser micro-driller will be a complete turnkey system for drilling planar and spherically contoured dispenser cathodes of various diameters from 2.0-13.0 mm and a spherical radius of 5.0 mm minimum, with a pore size of 2-10 microns in diameter and a hole spacing of 10-30 microns. A nominal drilling parameter would be 5 micron pores with a 15 micron spacing, drilled in 25 micron thick tungsten or a similar refractory metal.

The system must be a reliable, consistent facility designed for operation on the production floor.

Exact design parameters subject to approval in a preliminary design review meeting to be scheduled with a Hughes EDD representative at the manufacturing facility in Rugby, England. Appropriate review and basic training on the system operation and maintenance will also be accomplished at that time.

3.0 SPECIFICATIONS

The laser micro-drilling system consists of an advanced version of the JK Lasers Model MS25 YAG laser, Model 2050 focusing optics and a workpiece handling and machine enclosure system.

3.1 LASER

The basic laser comprises a laser head, power supply and cooling unit.

3.1.1 Laser Head

The laser head consists of the following components: A) laser oscillator pumping chamber; B) front and rear mirror mounts and mirrors: C) intra-cavity safety shutter; D) intra-cavity beam expanding telescope; E) in-line energy monitor; and F) the optical mounting rail.

A) Pumping chamber: The pumping chamber incorporates a neodymium-YAG laser rod and a flashtube in a close-coupled diffuse single ceramic nontarnishing reflector. All reflector surfaces are glazed and all metal parts are stainless steel. Lamp connections are made outside the coolant path. The pumping chamber may be swung out of the optical train on needle bearing pivots, thereby allowing lamps to be easily changed without the need for optical re-alignment and without coolant leakage. The swinging lid is interlocked for electrical safety.

B) Mirror Mounts and Mirrors: The external dielectric mirrors are mounted in adjustable mounts which provide for the angular adjustment of the mirrors in two orthogonal directions to an accuracy of better than 0.1 milliradians. The kinematic design uses micrometer controls which act directly on precision bearing surfaces for accurate and easy adjustment.

C) Intra-Cavity Safety Shutter: The ceramic cylinder safety shutter is normally at rest blocking the optical cavity. When the laser system is ready to fire, the shutter swings out of the optical cavity thereby enabling the laser to be fired.

D) Intra-Cavity Beam Expanding Telescope: The System 2000 intra-cavity beam expanding telescope fits directly on the System 2000 optical rail. It includes fine screw adjustments to give the 4 degrees of freedom necessary to align the axis of the telescope to the axis of the laser beam. One standard mechanical assembly accepts all the standard lens combinations which have been designed specially for low spherical abberation. The axial separation of the lenses can be adjusted with a micrometer control to alter the focus condition of the laser, while maintaining a properly focused viewing image. All standard optics are anti-reflection coated for low loss.

E) In-Line Energy Monitor: The energy monitor is designed to monitor the output of each laser pulse. It is used for day to day monitoring of laser performance by indicating that the system is operating within specification, and for optimization of alignment. It is mounted on the optical rail and consists of a 45° fused silica beamsplitter, an alumina ceramic diffusing screen, attenuating filters and a photodiode unit.

F) Optical Rail: The Series 2000 optical rail is an inverted "T" cross section design which allows the optical elements to have the lowest possible axis. The design also separates electrical cables and cooling water hoses from the optical train and yet leaves them readily accessible for servicing.

Size of the laser head is 1550 mm long x 200 mm wide x 130 mm high. Weight is 50 lbs.

3.1.2 Power Supply and Cooling Unit

To enable the Model MS25LD to operate at up to 50 Hz, an efficient resonant charging technique is used. The standard System 2000 resonant charger has a mean power capability of one (1) KWatt, and it operates at voltages up to one (1) KVolt. The resonant charging process takes place from an intermediate DC capacitor band and may be operated at any repetition rate. The flashtube is triggered only once with the high voltage pulse to start a DC simmer current flowing in the flashtube of approximately 50 milliamps. The discharge of the main storage capacitor into the flashtube is then initiated by a series thyristor switch.

A main console with twin interlocked front doors is used to house the main power supply unit, the triggering system and the cooling unit; while the controls for the whole system are located in a separate small instrument case. Controls provided include direct dial setting of voltage, an internal pulse generator and full external triggering and gating facilities. Each charging network is supplied with a relay operated dump circuit. This automatically discharges the network through a high power resistor whenever any of the safety interlocks are opened, or the main circuit breaker is switched off. In addition, there is a manual probe which can be used to discharge the power supply through a second high power resistor.

The cooling unit circulates deionized water around a closed primary circuit incorporating the laser head. Heat is extracted from this circuit by main tap water via stainless steel cooling coils mounted in the primary reservoir tank. Usage of water is restricted by a valve which regulates water flow according to the temperature of the primary coolant.

Size of the power supply and cooling unit is 1400 mm high x 1054 mm wide x 500 mm deep. Weight is 500 lbs. Electrical hookup required is 1 phase, 210 VAC, 60 Hz, 35 Amps, 7 kVA. Water consumption is 1.5 gal/min., at 30 psi (min.), at 20°C (max.).

3.2 MODEL 2050 FOCUSING OPTICS

A beam expanding telescope with micrometer control is incorporated in the optical system to reduce the effective focal length of the drilling lens while leaving the working distance unchanged.

After exiting the output laser mirror, the laser beam enters the Model 2050 focusing optics which deflect the beam vertically downward. Design features associated with this unit are as follows:

- Attachment to the laser rail is by means of an adjustable clamp thereby allowing the optics to be rotated through 360° about the incident laser beam. This will allow delivery of the laser output onto the workpiece at the most suitable angle and allow the optics to be centered on the beam.

- The 45° mirror is in gimball mounting on the intersection of the lens and laser axes, ensuring that the beam is coaxial with the lens and that abberations are minimized.

- The focusing nose runs in pre-loaded linear ball bearings driven by the micrometer focus control. The adjustment is free of back-lash or axis wander and has a range of 13 mm.

- All standard optics are anti-reflection coated for low loss.

- The focusing nose is fitted with a 10X Olympus objective focusing lens and an automatic lens protection system.

- Workpiece viewing is by means of a Nikon binocular viewing head fitted into the top of the Model 2050.

3.3 WORKPIECE HANDLING AND MACHINE ENCLOSURE

Workpiece handling is accomplished by a positioning system with 100x100mm XY movement and 10mm Z movement complete with stepping motors and Digiplan 1054 drive and Model 1000 translator. Resolution is 2 microns with an accuracy of 2 microns.

The work fixture will be fitted with a heating element to maintain workpiece temperature at 200°C minimum.

Workpiece front and back lighting will be accomplished with a 150 watt fiber optic light source.

The system is provided with a fully enclosed metal work station and support stand with twin interlocked sliding access doors. The work station is fitted with a safety viewport; measuring approximately 6" x 4" incorporating a safety filter conforming to Class I laser requirements and suitably positioned for viewing machine operations.

The machine is designed, manufactured and finished in a suitable manner for operation in a production environment; and will conform to all applicable BRH Class I laser specifications.

Size of the work station enclosure and support stand is 1250 mm wide x 1100 mm high x 1350 mm deep. Weight is 450 lbs.

4.0 INSTALLATON

Final acceptance of the MS25LD Laser System by the Project Engineer to be performed at Hughes EDD after installation and training by a JK Lasers representative.

A service contract will be negotiated with the United States representative of JK Lasers for routine and unscheduled maintenance to be performed on the laser system.

STARTING Unit 2
Page 339 Message #58
RX TWX:*
HACEDYN TRNC

RCA OCT 20 1046IL
ATTN: GLENN BREEZE, ELECTRON DYNAMICS DIVISION

QUOTATION NBR. 10307/1 TO HUGHES AIRCRAFT COMPANY, ELECTRON DYNAMICS DIVISION, FOR A LASER MICRO DRILLING SYSTEM.

1. COMPLETE TURN KEY SYSTEM FOR LASER DRILLING SPHERICALLY CONTOURED DISPENSOR CATHODES WITH A MATRIX OF 5 MICRON HOLES ON 15 MICRONS CENTERS COMPRISING:
A. MS25LD ND:YAG LASER WITH LOW DIVERGENCE RESONATOR FOCUSING AND VIEWING OBJECTS WITH 10 BY OLYMPUS OBJECTIVE FOCUSING LENS AND AUTOMATIC LENS PROCTECTION SYSTEM.
B. WORKPIECE POSITIONING SYSTEM WITH 100 BY 100 MM XY MOVEMENT AND 10 MM Z MOVEMENT COMPLETE WITH STEPPING MOTORS AND DIGIPLAN 1054 DRIVE AND MODEL 1000 TRANSLATOR. RESOLUTION OF 2 MICRONS AND ACCURANCY OF 2 MICRONS.
C. ENCLOSED WORK STATION AND SUPPORT STAND WITH TWIN INTERLOCK SLIDING DOORS CONFORMING TO CLASS 1 SAFETY STANDARDS.

LASER OUTPUT CHARACTERISTICS PER QUOTATION 10307 PREVIOUSLY SUPPLIED.
PRICE: 71,800 DOLLARS

2. HELIUM-NEON ALIGMENT LASER AND ADJUSTABLE MOUNT PRICE: 1,350 DOLLARS

3. INSTALLATION AND TRAINING AT HUGHES AIRCRAFT PRICE: 3,900 DOLLARS ALL INCLUSIVE.

TERMS: NET 30 DAYS, FOB SADDLE BROOK NEW JERSEY.
DELIVERY: 18-20 WEEKS ARO
VALIDITY: 30 DAYS

JEC LASERS INC.
JOHN H. WASKO
REPLY TLX 226000 ETLX UR
ATTN: BXJ2500 JEC LASERS

HACEDYN TRNC

Page 351 IS HIGHEST
Page 351 IS NEXT
time 200753 DISCONNECT
connect 240 secs listed 07:53 PDT 10/20/82

END

FILMED

5-85

DTIC