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MANUFACTURING METHODS & TECHNOLOGY PROGRAM

MINIATURE CATHODE RAY TUBE ASSEMBLY

FINAL REPORT: TOTAL PROGRAM SUMMARY
September 1980 - October 1988

Contract No. DAAK70-80-C-0168
CLIN 0003, CDRL Item A011

PREPARED FOR:

CENTER FOR NIGHT VISION & ELECTRO-OPTICS
U.S.ARMY COMMUNICATIONS-ELECTRONICS COMMAND
FORT BELVOIR, VIRGINIA 22060-5677

THOMAS ELECTRONICS, INC.
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This report describes Thomas Electronics' performance in establishing the Manufacturing Methods and Technology to fabricate 25mm CRT assemblies in support of the Army's integrated Helmet and Display Sight System (IHADSS).

The objective and overall structure of the program is first summarized. Each phase of design, confirmatory production, pilot production, and qualification testing is then sequentially described in detail.

This MM&T Program has accomplished the following essential objectives:

1--Design development of the CRT to conform to IHADSS specification established with delivery of five engineering samples;

2--Process development to facilitate volume production, established with delivery of ten (10) confirmatory samples;

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- Actual production capability demonstration, established with delivery of twenty (20) pilot run samples, demonstrating ship capability of (5) units per week;
- Full environmental qualification of the developed design;
- Reliability testing of the design in excess of the mean life requirement of 2,500 hours.

Successful achievement of these several objectives was described in detail to government and industry representatives at our Industry Presentation on October 5, 1988.

MINIATURE CATHODE RAY TUBE ASSEMBLY

MM&T PROGRAM

FINAL REPORT
FOR

Period September 1980 to October 1988

OBJECTIVE: The object of this MM&T program is to establish Processes, Procedures and Techniques to insure production capability to deliver five (5) miniature Cathode Ray Tube Assemblies in a five (5) day, 40-hour workweek.

CONTRACT NO. DAAK70-80-C-0168

PREPARED BY:

D. C. Ketchum, F. Bruno, B. Marianelli

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--Full environmental qualification of the developed design.

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1.0 PURPOSE

The work reported herein was performed under Contract DAAK70-80-C-0168 with the Center for Night Vision and Electro-Optics, U.S. Army Communications-Electronics Command, Ft. Belvoir, Virginia 22060-5677.

The essential purpose of this program has been:

ITEM	DESCRIPTION	CONTRACT ITEM
1	Establish design conformance to MM&T spec H799838, Attachment 2.	1AA
2	Establish production methods and procedures for mass production capability to the MM&T Spec.	1AB
3	Demonstrate such capability by a pilot production run.	1AC
4	Describe the design, production, testing, and qualification programs as performed under Contract Items 1AA-1AC to government and industry representatives.	2
5	Provide technical data in the form of assembly drawing, component drawings, manufacturing spec and process specs.	3

2.0 PROGRAM OUTLINE

This MM&T Program was divided into three phases, hereafter referred to as Engineering (Phase I), Confirmatory (Phase II), and Pilot Run (Phase III).

In addition, qualification testing was conducted on both Phase II and Phase III units. Finally, a program demonstration was presented to representatives of industry and government.

The sequence of these tasks is summarized in our MM&T Program History, Figure 1, showing sequence of progress in these three phases and related qual testing and demonstration. A detailed narrative of each phase and task is set forth in this final report.

3.0 PHASE I: DESIGN DEVELOPMENT

3.1 Deflection Coil Design

The first unit produced for submission, TE S/N 001, met MM&T Category I design requirements with the following exceptions:

Item	Parameter	Spec	Actual
1	Deflection Sensitivity: Horiz. : Vert.	.9A Max. .9A Max.	1.1 1.0
2	Geometric Distortion	1% Max.	>1%
3	Rear Shield Diameter	15mm	19.43
4	Overall Length	95.25mm	95.70

To increase sensitivity, two actions were required:

3.1.1 Redesign of the deflection coil with I.D. reduced from .660" Min. to .630" Min., and a corresponding reduction in CRT funnel O.D. from .630" Max. to .600" Max.

3.1.2 The reduction in funnel O.D. further resulted in reduced neck I.D. and corresponding increase in focus voltage. Slight extension (.100") in seal length restored focus voltage to the required range (930-1130V).

3.2 Fiber Optic Faceplate

To resolve barrel geometric distortion, faceplate internal radius was revised from 1.10" to 1.30" to conform to final deflection coil design.

The second submission of two units (S/N 002, 003) demonstrated corrected geometric distortion with the coil, funnel, gun, and faceplate design corrections described above.

Sensitivity continued to be out of spec, but was finally corrected by rework on S/N 003 by additional repositioning of the coil approximately .070" back (away from faceplate) to reduce the net deflection angle.

3.3 Magnetic Shielding

The original CRT assembly design showed the high voltage anode lead exiting from the large diameter section of the assembly. TE requested an increase in the rear shield diameter to accommodate the anode lead inside the rear shield, affording greater protection for the lead itself and providing strain relief for the lead-CRT connection.

This improvement was accepted by the system manufacturer (Honeywell Avionics) and was incorporated into all TE sample submissions, as well as later system production.

The several design changes implemented over the Engineering Phase are summarized and illustrated in Figure 2.

3.4 Phosphor Analysis

The IHADSS Optical System required several phosphor characteristics:

--Narrow Band Spectral Emission

--High Luminous Efficiency Under High Current Density

--Superior Optical Resolution

The selected fine grain P43 phosphor was first optimized for particle size and screen density to match the requirements of the IHADSS CRT operating conditions. The optimized screen design was then pre-tested to establish suitability to meet the 2,500 hour life requirement. Our criteria was that the phosphor maintain at least 80% of original efficiency over this operational life, since the gun design can compensate with up to 20% increase in current with added modulation.

Two CRT test samples were made:

UNIT A) With clear, non-browning glass faceplate, to evaluate phosphor change independent of F.O. faceplate aging.

UNIT B) With fiber optic faceplate to evaluate combined F.O./phosphor screen aging.

A plot of net screen output decrease vs. accumulated charge density is given in Figure 3. The charge accumulation projected for the MM&T CRT over an operational life was calculated as follows:

Raster Area	= 1.70cm x 1.28cm	= $2.176 cm^2$
Screen Current	= (For 375FtL Area Light Output)	= 12.5×10^{-6} A*
Operational Life	= 2,500 Hours	= 9.0×10^{6} sec.
Cum Charge Density	= $\frac{(12.5 \times 10^{-6})(9.0 \times 10^{6})}{2.176}$	

$$= 51.7 \text{ coul/cm}^2$$

* Based on typical production data.

The life test confirmed that the F.O. faceplate and phosphor screen can indeed maintain light output well beyond the projected cumulative charge density of 51.7 coul/cm². As Figure 3 illustrates, phosphor screen performance degrades less than 10% at this "end of life" point, well within the 20% allowance provided by the gun design.

It is noted from Figure 3 that the fiber optic faceplate CRT showed a slower rate of decay in brightness than the clear glass faceplate CRT. Since the phosphor screens came from the same batch, the difference in aging is attributed to an excessively low estimate of fiber optic transmission, hence an excessively high estimate of actual phoshor brightness than exhibited by the fiber optic CRT.

3.5 Testing Methods

The IHADSS System required test equipment and procedures beyond the previously standard Thomas Electronics test format. This standard method for testing resolution and light output involves scanning a single CRT trace with a slit scanning photometer, such as the Gamma Scientific DR-2 System.

The IHADSS System requires a more inclusive characterization of raster resolution, namely the Sine Wave Modulation Response (SWMR) Test. With this test method, a pattern of bars is generated on the CRT corresponding to a required spatial frequency, expressed in "TV Lines" per raster width or height. The bar pattern is scanned with the slit scanning photometer and plotted with an X-Y recorder, giving a plotted sine wave response. The response is calculated as:

$$SWMR = \frac{\text{Max. Light Output} - \text{Min. Light Output}}{\text{Max. Light Output} + \text{Min. Light Output}}$$

The SWMR is expressed as a percent, with a minimum level required for each spatial frequency as follows:

SPATIAL FREQUENCY T.V. LINES	ON AXIS SWMR MIN. (%)	HALF FIELD SWMR MIN. (%)
10	92	91
100	89	88
200	84	83
400	64	50
600	40	26

The SWMR test requires a pattern generator, video amplifier and deflection amplifier matched to the operating voltages and impedances of the IHADSS CRT to obtain an accurate standard operating condition. This equipment was procured from the IHADSS System Contractor, Honeywell Avionics, and was successfully integrated into the Thomas Electronics Standard Test Console.

During the Engineering Phase, the SWMR test was implemented, with SWMR performance confirmed in accordance with spec requirement.

4.0 PHASE II: CONFIRMATORY PRODUCTION

With the completion of engineering sample submissions, a limited production run was initiated to confirm repeatability of laboratory design performance using standard production equipment, documented procedures, and production operators. Two problems were encountered and subsequently corrected during the Confirmatory Phase: High Grid 1 Cutoff and Phosphor Screen Blemishes.

4.1 Gun Adjustment to Correct G1 Cutoff

A lot of six (6) electron gun assemblies were initially produced to support confirmatory production. These initial six units confirmed a trend originally observed on design units toward high limit (-70V) on Grid 1 cutoff, with four of six units actually exceeding cutoff maximum. Cutoff is primarily controlled with cathode to grid 1 spacing. Revision of this spacing from .0040" to .0035" resulted in a second production lot with cutoff readings distributed about the center of the specified cutoff range.

4.2 Screening Adjustment to Correct Blemish Condition

In addition to the cutoff rejections, screen quality was also observed on the first CRT production lot to be marginal to out of spec, exhibiting incidence of blemishes with size greater than maximum diameter allowed. The CRTs were disassembled and analyzed by comparing with faceplates in progress at each step of the phosphor screening process (refer to Process Flow Chart, Figure 4). From this analysis two corrective actions were identified:

4.2.1 Lacquering: Faceplates are wetted during the lacquer process and then covered with a tacky film of lacquer prior to aluminization.

During this phase, faceplates must be protected from any possible contaminants, either airborne or water-borne. Corrective action included installation of in-line water filters, laminar flow workbench, 2 μ water pre-filters, additional operator training in handling of materials, and vacuum-jar storage and transportation vessels for all components. These changes were incorporated into documentation for the lacquering process.

4.2.2 Screen Inspection: The blemishes observed at final assembly should have been identified at the in-process screen inspection stage. Critical review of the screen inspection method showed need for improved mounting of the faceplate during demountable inspection, to allow full screen comfortable viewing under 40X magnification. Corrective action involved redesign of the demountable funnel to match final faceplate design, improving vacuum seal and net light output during demountable inspection. With these corrections in place, confirmatory production was resumed and successfully completed.

5.0 PHASE III : PILOT PRODUCTION

The objective of this phase of the MM&T Program was to demonstrate capability of manufacturing, testing, and shipping five CRT asssemblies in a five-day, 40-hour work week.

5.1 Manufacturing Process

With completion of Phase II Confirmatory Production, the component and assembly drawings, manufacturing specification and processing procedures were documented and finalized between Thomas' Engineering and Manufacturing Departments. The finalized documentation was provided to the MM&T government/industry mailing list in advance of the rate capability demonstration. Figure 4 depicts the operational sequence, noting the specific TE procedure relevant to each step. Note that "Front End" and "Mount Room" stages can be performed independently, and depicted in parallel on the Flow Chart. The seal, exhaust, aging, encapsulation, and ATP stages are necessarily sequential.

5.2 Schedules and Yields

Each process step was assigned a yield value based on experience gained during the design, development, and confirmatory production phases. These yield values were then used to determine actual start quantities required at each step to yield the required weekly output of five units shipped. Table I summarizes the yield values calculated, start quantities, and actual process yields demonstrated at each manufacturing step during pilot production.

5.3 Capacity Analysis

Table I details the production capacities and yields by process step. The pacing processes are those with the lowest capacity-yield product. These processes are the final stages, with net capacities of 13 units per week and 14 units/week for ATP (Acceptance Test Procedure) and encapsulation respectively.

These rates well exceed the MM&T Program objective of five units per week. Production rates in excess of ten units per week have in fact been achieved in subsequent OEM (Original Equipment Manufacturer) production.

6.0 QUALIFICATION TESTING

Design qualification per MIL-STD-810 was required on both confirmatory and pilot production units for complete demonstration of design conformance to contract specification. Qualification testing was divided into two subgroups: environmental and reliability. All test procedures and results are reported in detail in TE Qual Test Report 770-247 (Confirmatory Qual) and 770-300 (Pilot Run Qual).

6.1 Environmental Tests

Five of the confirmatory samples (S/N 006-010) were sequentially subjected to the following tests:

6.1.1	Low Temperature
6.1.2	High Temperature
6.1.3	Altitude
6.1.4	Temperature-Altitude
6.1.5	Salt Spray
6.1.6	Solar Radiation
6.1.7	Temperature Shock
6.1.8	Acceleration
6.1.9	Mechanical Shock
6.1.10	Explosive Atmosphere
6.1.11	Vibration
6.1.12	Humidity
6.1.13	Fungus
6.1.14	Electromagnetic Compatibility

Five of the Pilot Run Samples (S/N 21, 23, 24, 27, 29) were later subjected to the identical tests. The only failures throughout the Environmental Testing occurred at the final stage, Electromagnetic Compatibility. Radiated emission between 7MHz-21MHz exceeded max. limits on all units tested, the worst case measuring 64dB at 14.0MHz on a pilot run sample.

Both original confirmatory data and final pilot run data were reviewed with Contracting Office, which concluded that the emission levels could be accepted over this frequency range without adverse impact on the IHADSS.

6.2 Reliability Testing

6.2.1 Confirmatory Samples: The balance of five confirmatory production samples <u>not</u> subjected to environmental testing were subjected to reliability life testing, specifically S/Ns 12, 13, 15, 17, and 18. The tested condition consisted of setting 375FtL area light output on each of three different raster sizes, as indicated in Table II. The various raster sizes were selected to determine the effect (if any) of different cathode current levels on observed life. At 648 hours, S/N 13 failed to achieve 375FtL on the full raster. A backup unit, S/N 19, was installed with 1/4 raster area, cathode current 5μA. After 1,353 hours, the test console failed entirely when exposed to a roof leak. This equipment failure resulted in arcing and unusual reduction in cutoff voltage and emission current on all five units. The testing was nevertheless continued to 2,501 hours to check for any continued instability in cutoff or emission. No changes, beyond measurement tolerance, were observed from 1,353 hours to 2,501 hours.

Unfortunately, the equipment failure precluded thorough life analysis of confirmatory samples. Nevertheless, the test did indicate two significant points:

a) Test Console: The test console incorporated an IHADSS video amplifier with input limited to 0.7V, limiting modulation output to 27V to the CRT, or only 90% of the specified allowance of 30V. The amplifier was adjusted to increase signal input to 0.8V, resulting in full spec modulation allowance on future life testing.

b) Duty Cycle: The full area, DC raster units (S/N 13, 18) showed unstable cathode currents before and after equipment failure, probably due to the larger intercepted focus current. The resultant heating and outgassing of gun components could cause unstable cathode emission. As a result, the constant, full-on test condition was considered too severe. A cycle of 55 minutes on, 5 minutes off was established for future life testing, allowing CRT getter to function during CRT off periods, as normally occurs in field operation.

6.2.2 Pilot Run Samples

A second lot of five pilot run samples, S/N 20, 22, 25, 26, and 28, were subjected to life testing at the maximum light output requirement of 375FtL, to verify in-spec performance after 2,500 hours of operation. Results can be summarized as follows:

S/N	Result
20	Passed ATP after 3,629 hrs.
22	Failed ATP after 2,531 hrs.
25	Failed ATP after 333 hrs.
26	Passed ATP after 3,629 hrs.
28	Passed ATP after 3,629 hrs.

The two failures, S/N 22 and 25, were analyzed by dissection, visual examination, and electrical test. The cathode coating material on both failures had separated from the base cap, causing poor thermal and electrical conductance. The separation was attributed to improper surface preparation of the cap during the cathode vendor's manufacturing process.

Corrective action was implemented in the form of a component ATP developed specifically for cathode inspection. This ATP covers coating and base cap visual inspection, scratch testing for adhesion, and triode life testing on a sample lot basis.

The MM&T reliability testing confirmed that the CRT design was capable of operating nearly 50% beyond specified operational life, to at least 3,600 hours.

7.0 CONCLUSIONS

Performance under this contract has been successful in meeting each phase objective:

7.1 Design Development:

The original design criteria were met after several component and process revisions made during Contract Phase I.

7.2 Confirmatory Production:

Manufacturing processes were documented and successfully implemented on the factory production line, as witnessed by serial production of ten acceptable confirmatory samples.

7.3 Pilot Run Production:

Production rates and capacities for each process step were calculated to achieve the required output of five assemblies per week. This rate was then demonstrated to the Contracting Office during an actual pilot run which produced an additional ten acceptable samples.

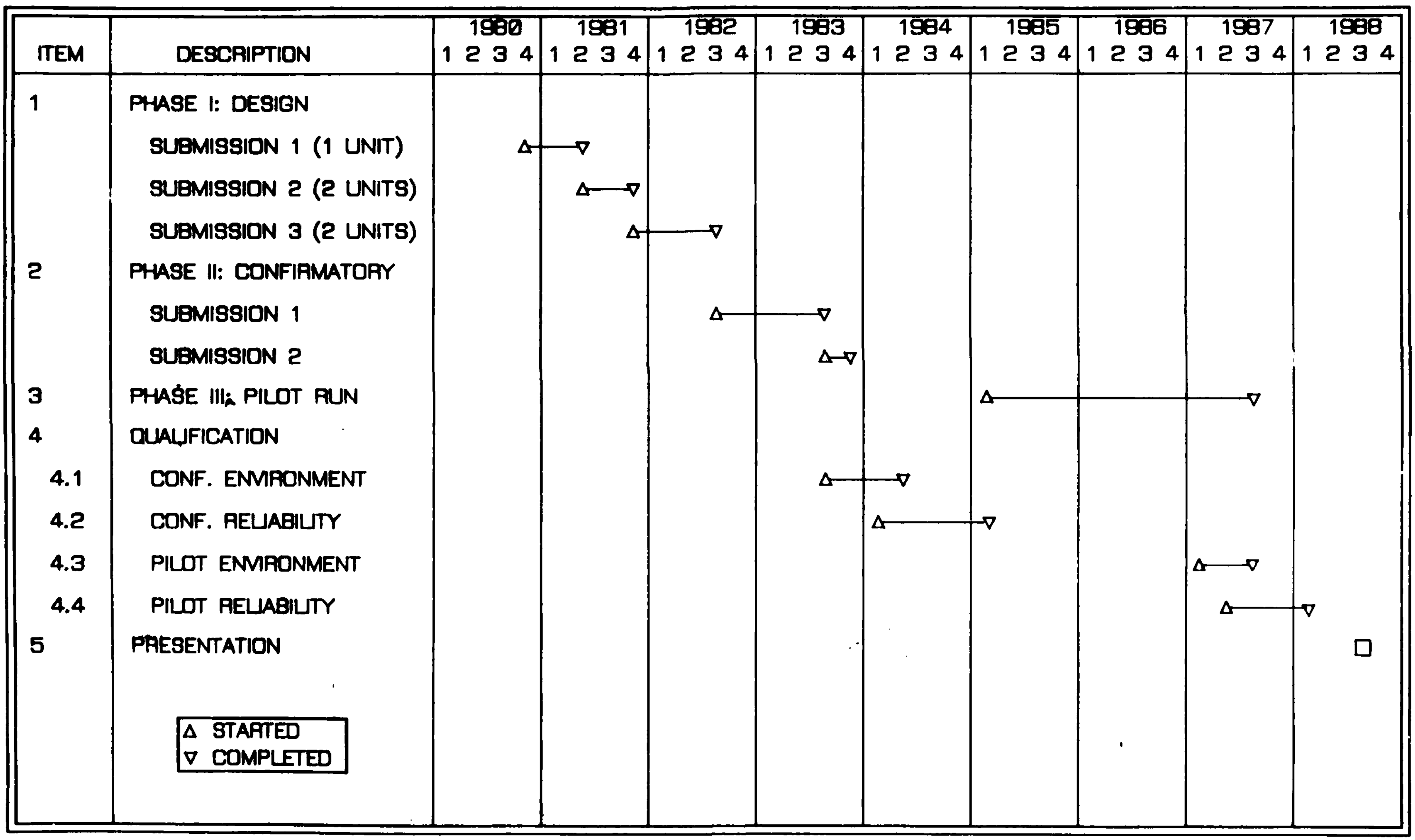
7.4 Qualification:

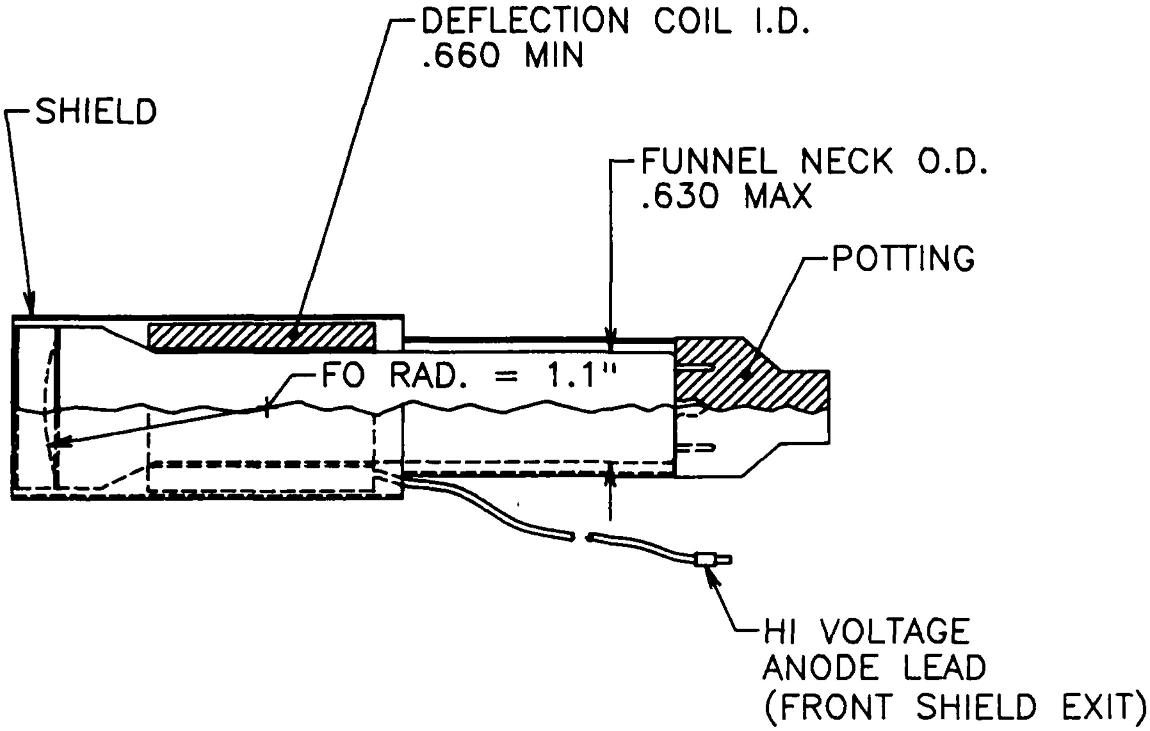
Environmental and reliability testing was performed on both confirmatory and pilot run samples. All units successfully passed environmental testing, with the one exception of EMI compatibility. Since these instances were judged to have no adverse impact on IHADSS performance, this test result was also accepted.

7.5 Demonstration:

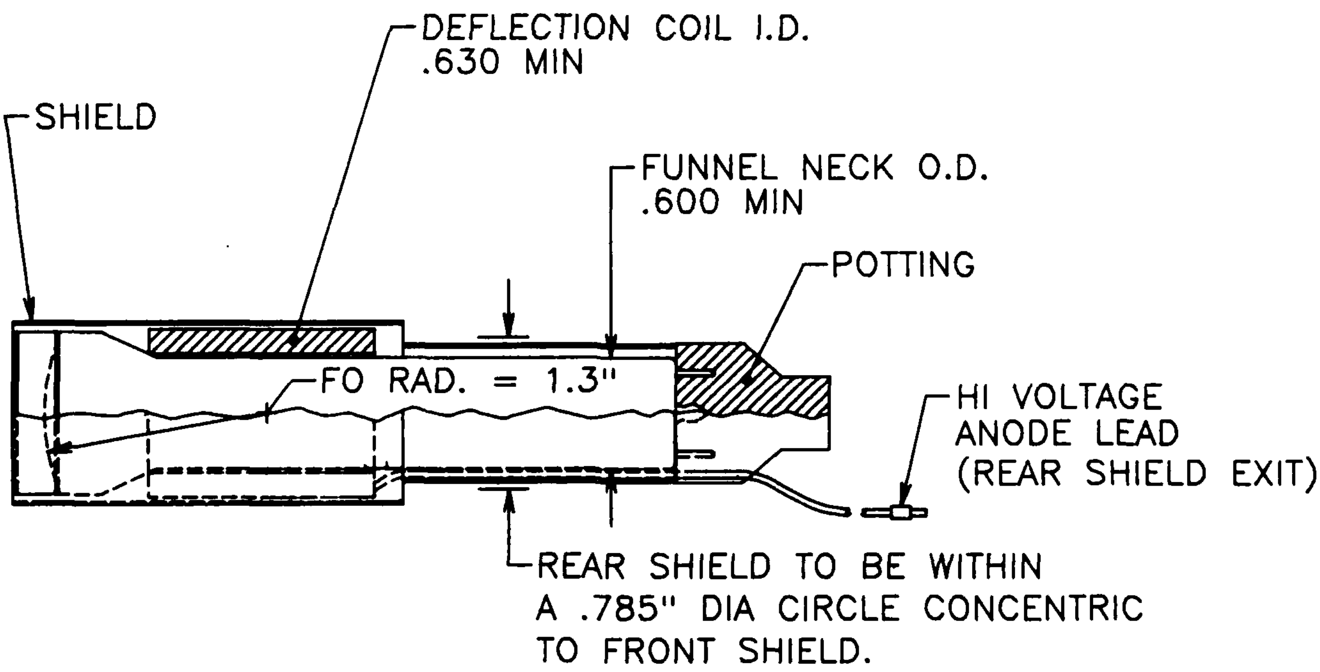
An industry presentation was given to representatives of government and industry on October 5, 1988. The presentation included a narrated VHS video tape of the manufacturing process as performed during the pilot run. Specific questions on design, production, and qualification testing were addressed to the satisfaction of all present. The design and manufacturing processes developed and demonstrated in this program are continuing to serve the IHADSS Program in serial production.

Fig. 1 :MM & T PROGRAM HISTORY





A. ORIGINAL DESIGN CONFIGURATION

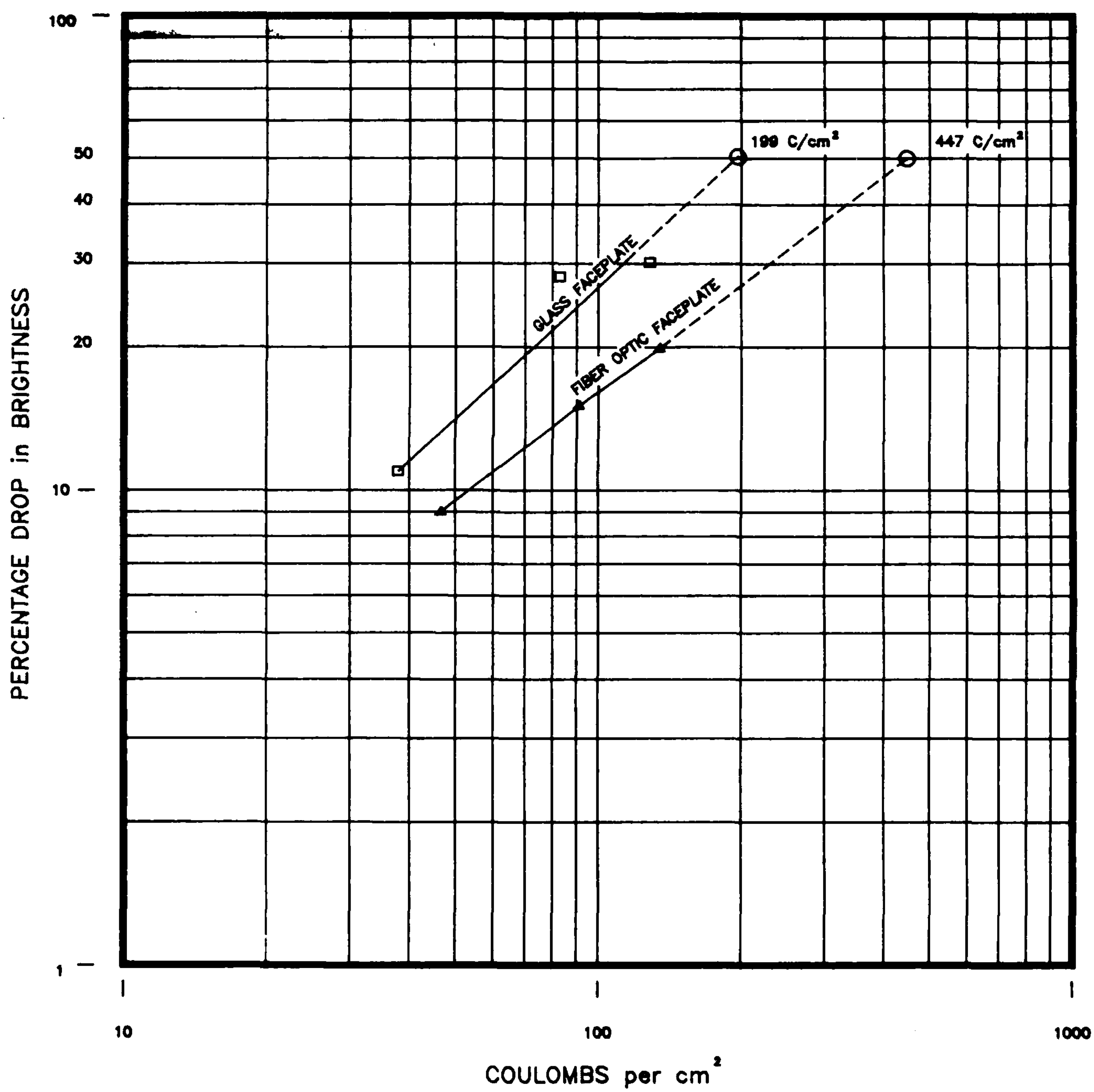


B. FINAL DESIGN CONFIGURATION

FIG 2: DESIGN DEVELOPMENTS, MM&T PHASE I

(DRAWINGS NOT TO SCALE) TEI P/N 1M40 P43 MFO

FIGURE 3 : P43 LIFE TEST DATA



1" MM+T - MANUFACTURING PROCEDURES

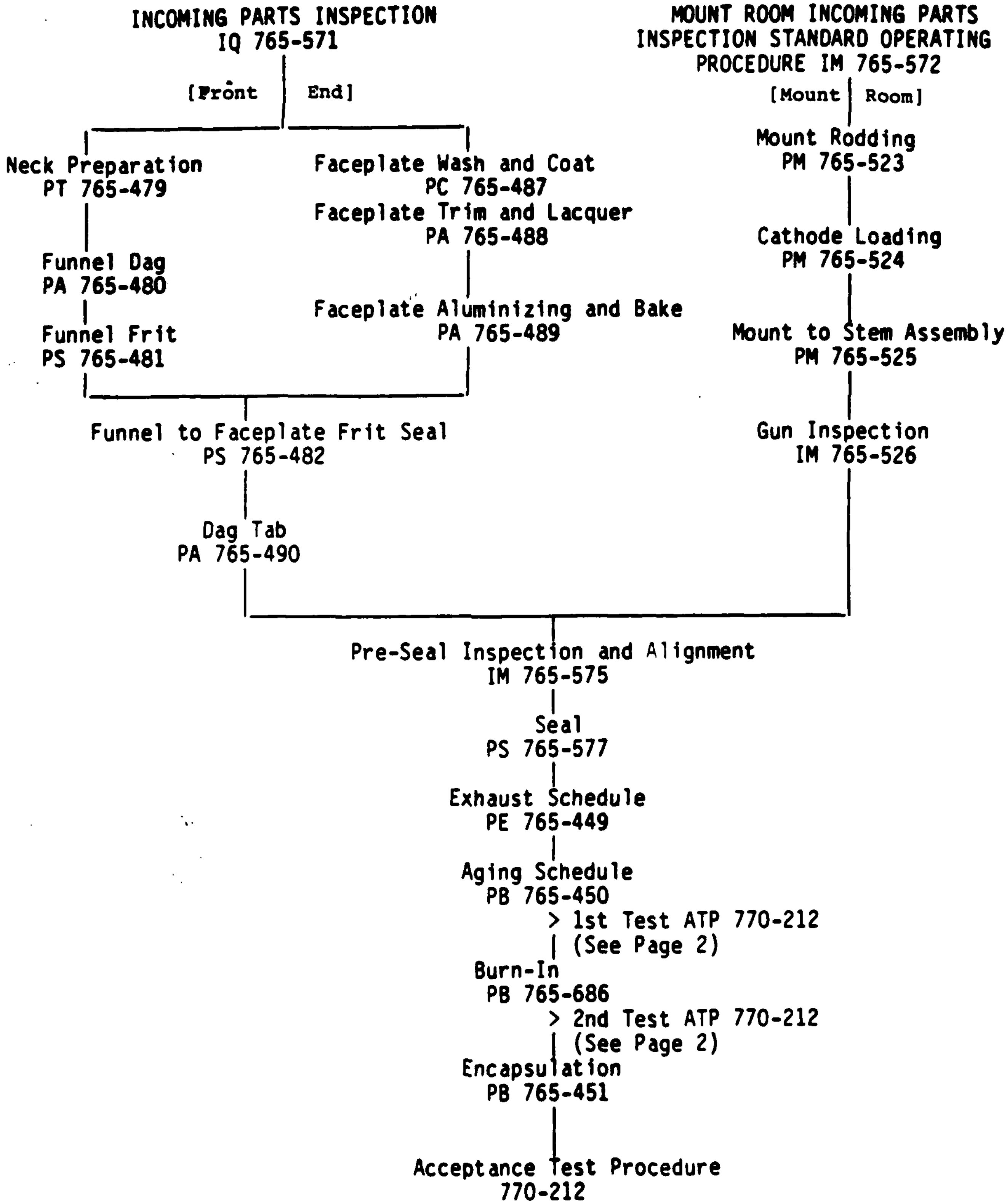


FIGURE 4

1" MM&T PILOT RUN PHASE III (0001AC)

CONTRACT : DAAK70-80-C-0168
THOMAS P/N : 1M40P43MFO
Section C.4.1.2 C/D

Operation	Procedure	Approx. Yield Per Operation	Capacity Per Week	Min. Requirement To Ship Five 1M40P43MFO Assys.	Actual Produced
Encapsulation	PT765-451	95%	15	5	10
Acceptance Test	770-212	33%	40	15	17
Aging	PB765-450	99%	80	15	17
Exhaust	PE765-449	95%	80	16	18
Sealing	PS765-577	95%	60	17	18
Pre-Seal	IM765-575	95%	60	18	20
Dag Tab	PA765-490	90%	60	20	20
Frit Seal	PS765-482	95%	30	20	20
Funnel Frit	PS765-481	95%	60	21	21
Funnel Dag	PA765-480	99%	60	21	21
Neck Preparation	PT765-479	95%	60	22	22
F.P. Aluminize	PA765-489	99%	300	20	21
F.P. Trim & Lacquer	PA765-488	90%	300	22	22
F.P. Wash & Coat	PC765-487	75%	225	30	27
Gun Inspection	IM765-526	90%	125	18	25
Mount to Stem Assy.	PM765-525	90%	75	20	27
Cathode Loading	PM765-524	90%	75	22	28
Mount Rodding	PM765-523	75%	375	30	30

TABLE I

MM&T, H799838 TEI P/N 1M40P43MFO

1" MM and T ACCELERATED LIFE TEST DATA, 1M40P43MFO

LIFE TEST CATHODE CURRENT AT 375 FT.L. OR MAXIMUM LIGHT OUTPUT

SERIAL NO.:			012	013	015	017	018	019
RASTER:			1/2	FULL	1/2	1/2	FULL	1/4
HOURS	*	+	µA	µA	µA	µA	µA	µA
0	0	---	24	60	23	33	65	65
318	(318)	---	31	75	29	35	65	---
648	(648)	0	30	174	43	39	65	5
1072	---	(432)	27	---	40	40	195	5
1353	---	(713)	33	---	39	26	185	14
1749	(648)	(1109)	33	55	37	150	85	**
1841	(740)		25	135	27	37	140	---
1912	(811)		25	235	26	250	155	---
1985	(884)		34	250	46	150	150	---
2032	(933)		22	250	34	95	85	---
2078	(979)		29	205	31	40	75	---
2147	(1051)		47	---	42	250	150	---
2171	(1075)		155	250	43	250	250	---
2237	(1141)		46	220	34	250	220	---
2285	(1189)		110	190	105	250	190	---
2333	(1237)		220	220	35	250	220	---
2405	(1309)		150	200	38	250	200	---
2453	(1357)		65	190	34	250	190	---
2501	(1405)		---	---	---	---	---	---

*Hours for No. 13

+Hours for No. 19

** Equipment failure

TABLE II : CONFIRMATORY LIFE TEST

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