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NASA GLAST ACD PMT's

Proposal in response to RFQ5-09742 Amendment #3

Submitted by :

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Andrew W Allen 10/8/01

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1. General Overview

Hamamatsu Corporation is a world leader in the manufacturing and development of high performance photomultiplier tubes (PMT's). With over 40 years experience, Hamamatsu is fully capable of providing the design, assembly, and testing of PMT's to meet the critical requirements of the GLAST ACD instrument. We are very familiar with the Gamma-ray Large Area Space Telescope project. Hamamatsu's Solid State Division expects to provide a large quantity of custom Silicon Strip detectors for the primary Gamma-ray detector and has developed custom Si PIN devices expected to be used for the GLAST Calorimeter. In this respect the overall success of the NASA GLAST program is very important to Hamamatsu and it has high visibility with key technical and corporate managers.

The technical engineers responsible for this proposal have a thorough understanding of the key performance, reliability and performance issues related to the PMT's for the GLAST ACD project. We have proposed a cost affective solution for the GLAST ACD. The proposed PMT (R4443) is a ruggedized version of our standard R647 with solderable leads. A similar PMT(the R4444 --same internal/exterrnal construction, but different photocathode material) was used on space flight programs for SOHO GOLF project and EVRIS mission. This combination of a standard product design with modifications known to produce space qualifiable flight hardware is the basis for our cost affective proposal for a high performance, long life, ruggedized PMT to meet the GLAST ACD requirements.

The proposed R4443 is not represented by Hamamatsu as a fully space qualified component. However, It does essentially meet the key performance requirements listed in the ACD RFQ and it is sufficiently ruggedized to meet the listed environmental requirements for space launch. The modified mechanical design, enhanced visual inspections and recommended screening for "Level 2 " testing will ensure reliable PMT's capable of completing full "Space Qualification" at NASA. Hamamatsu has provided a number of PMT's for AMS, SAX, and SOHO missions that were based on the same or similar quality standards and these units were successfully flight qualified and launched by the respective agencies.

2. Technical Issues

2.1 General comments

The R4443 will be constructed using materials and assembly techniques based on two standard PMT's—the R647 ½" Bialkali photocathode PMT and the R4177 ruggedized ½" PMT. The R4443 will have opto-electrical performance essentially identical to selected R647 PMT's, since it shares the identical photocathode, dynode coatings and dynode configuration . The mechanical characteristics of the R4443 will be similar to Hamamatsu's standard R4177 PMT used in oil well logging application and designed for high shock/vibration environments. Hamamatsu has already supplied a similar PMT for space flight use—the R4444 --that was essentially identical to the R4443 except for incorporation of multialkali photocathode instead of bialkali.

The R4443 is a 10 stage bialkali PMT with Linear Focused dynode structure well suited for scintillation applications.

2.2 Physical Dimensions

A complete technical data sheet for the R4443 is shown in Table 2-A, with outline drawing in Fig 2-1. The R4443 meets the physical requirements of the ACD RFQ. It is a head-on type Bi-Alkali PMT with solderable leads. Diameter is less than 15.2 mm (actual 14.7 +-0.5 mm) with overall length less than 80 mm (actual 74+-2mm) not including leads.

2.3 Electo-optical Performance Parameters.

2.3.1 Gain and cathode sensitivity.

All tests for Current Amplification (Gain) and Cathode Sensitivity (Sk) will be done using the standard voltage divider ratio shown in Fig 2-1. All test specs are at 25C unless otherwise noted.

Cathode sensitivity for the R4443 will be minimum 90uA/lm (refer to page 36 of the Hamamatsu PMT Handbook [1)] for a description of Cathode sensitivity). This will correspond to a typical QE at 420 nm of 22%.

Gain of each PMT will be minimum 2E06 at 1250V, the max rated voltage of PMT. The R4443 will have a typical gain of 1E06 at 1000V, and each will be tested to have minimum gain of 5E05 at 1000V. Figure 2-3 shows typical gain vs voltage curve for R4443.

2.3.2 Dark Current

Anode Dark Current for PMT's depends on many factors and can be effected by temperature, previous light exposure, operating voltage, and other factors. The causes of dark current and the factors that influence it are described in Section 3.3.6 of the Hamamatsu PMT Handbook [1)] . The R4443 will have Dark Current Idb less than 10 nA when measured at high voltage corresponding to Gain of 5E05 @ 25C, with PMT in dark state for at least 30 minutes.

Dark Current has a strong temperature dependence, and Idb can be expected to increase at higher operating temperatures. See Section 3.2 regarding operating temperature range for more details. Because of these many influences on Idb, this parameter should not be expected to remain as stable as the gain or cathode sensitivity during/after life testing or environmental shock/vibration testing. Our understanding is that for the GLAST ACD Dark current stability is not a critical parameter as long as dark currents typically remain below 10 nA @ 20C.

TECHNICAL DATA

DEPT.#22
Aug.2001

PHOTOMULTIPLIER TUBE
R4443 (For ACD/GLAST)

For Scintillation Counting, Photon Counting, Ruggedized, 14.5 mm Diameter, Bialkali Photocathode, 10 stages, Head-on Type

GENERAL

Parameter		Description	unit
Spectral Response		300 to 650	nm
Wavelength of Maximum Response		420	nm
Photocathode	Material	Bialkali	-
	Minimum Effective Area	10	mm dia.
Window Material		Borosilicate Glass	-
Dynode	Structure	Linear focused	-
	Number of stages	10	-
Weight		Approx. 11	g
Base		12 pin Flying Lead	-

MAXIMUM RATING (Absolute Maximum vales)

Parameter		Value	Unit
Supply voltage	Between Anode and Cathode	1250	V
	Between Anode and Last Dynode	250	V
Average Anode Current		0.1	mA
Ambient Temperature	Storage	-80 to +50	°C
	Operation	-30 to +50	°C

CHARACTERISTICS (at 25 °C) with Standard Voltage Divider

Parameter		Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856 K)	90	-	-	μA/lm
	Quantum Efficiency at 420 nm	-	22	-	%
	Blue (CS 5-58 filter) Index	-	9.5	-	-
Anode Sensitivity	Luminous (2856 K)	-	80	-	A/lm
Current Amplification		-	1.0×10^6	-	-
Anode Dark Current (after 30 min. storage in darkness)		-	-	10	nA
Time Response	Anode Pulse Rise time	-	2.5	-	ns
	Electron Transit Time	-	24	-	ns

NOTE: Anode characteristics are measured with a voltage distribution ratio shown next page :
Dark current is measured at a high voltage, which gives the current amplification of 5×10^5.

Table 2-A: *Technical Data Sheet for R4443*

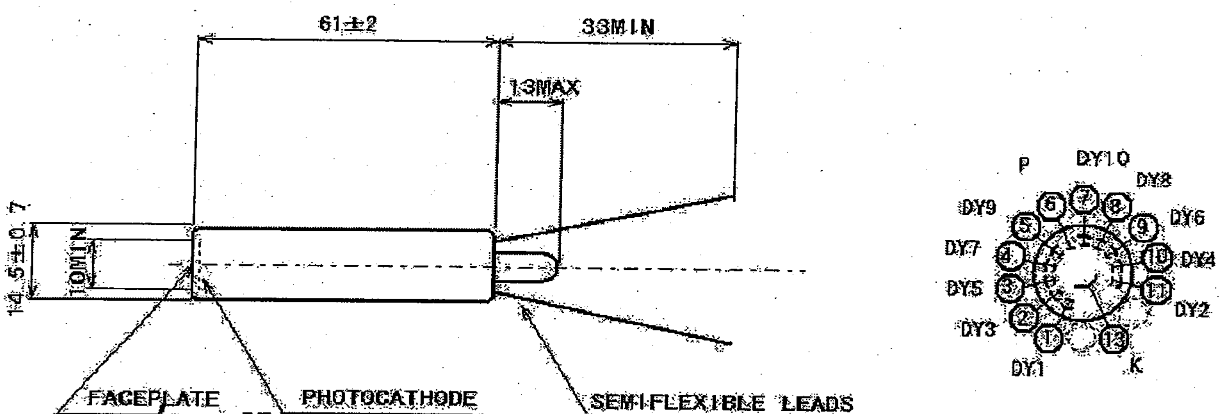
PHOTOMULTIPLIER TUBE R4443

Standard Voltage Divider and Supply Voltage

Electrodes	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P
Ratio		1	1	1	1	1	1	1	1	1	1	1

Supply Voltage: 1000 V , K: Cathode, Dy: Dynode, P: Anode,

DIMENSIONAL OUTLINE AND BASING DIAGRAM



UNIT : mm

Figure 2-1: Dimensional Outline for R4443

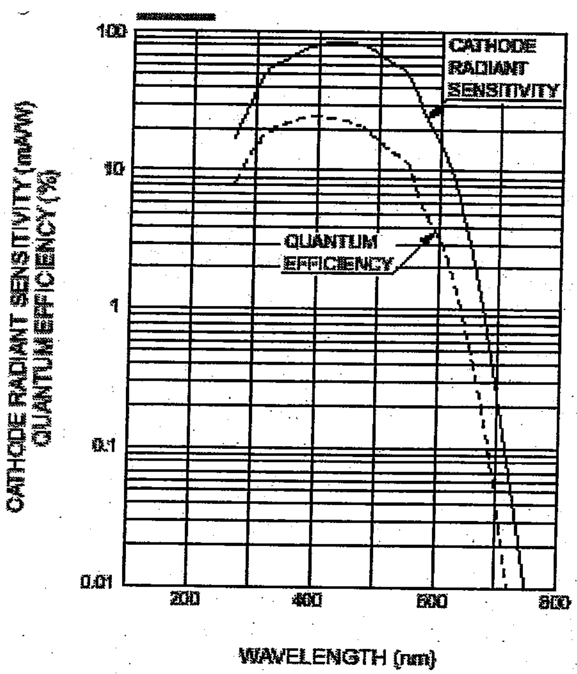


Figure 2-2 Typical Spectral Response

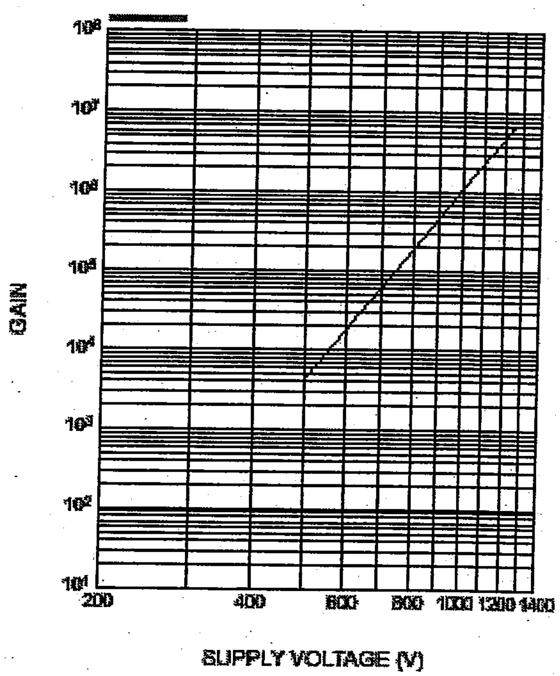


Figure 2-3 Typical Gain for R4443

2.3.3 Temporal Stability & Gain Degradation

Hamamatsu has extensive experience with PMT life testing and reliability. Our PMT Handbook [1)] has an entire chapter (Chapter 8) describing environmental resistance and reliability.

In normal operation the gain of the PMT can be expected to change over time due to sputtering of the dynode material at the last several dynode stages where current is highest. In most cases this will eventually result in the gain of PMT decreasing. However, gain of PMT can actually increase at first, since there is an optimum thickness for the dynode coating. For PMT's that have dynode deposition slightly thicker than optimum, the gain will actually increase at first, then begin to degrade (see sample #7 Fig 2-4).

Fig. 2-4 shows Relative Anode Current (i.e. Gain) vs operating hours for the R647 PMT, which has identical internal photocathode and dynode structure to the proposed R4443. This data was taken with initial anode current of 100uA for qty 62 PMT's. Fig 2-5 shows a histogram of this data ...each category represents the # of PMT's with the indicated % change of gain after 1000 hours @ 100uA anode current.

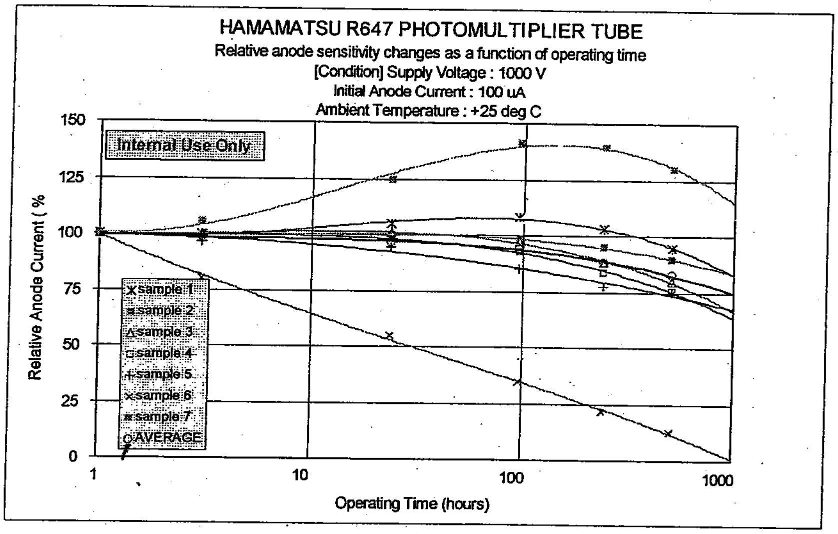


Fig 2-4 Gain Stability over operating hours for R647 PMT

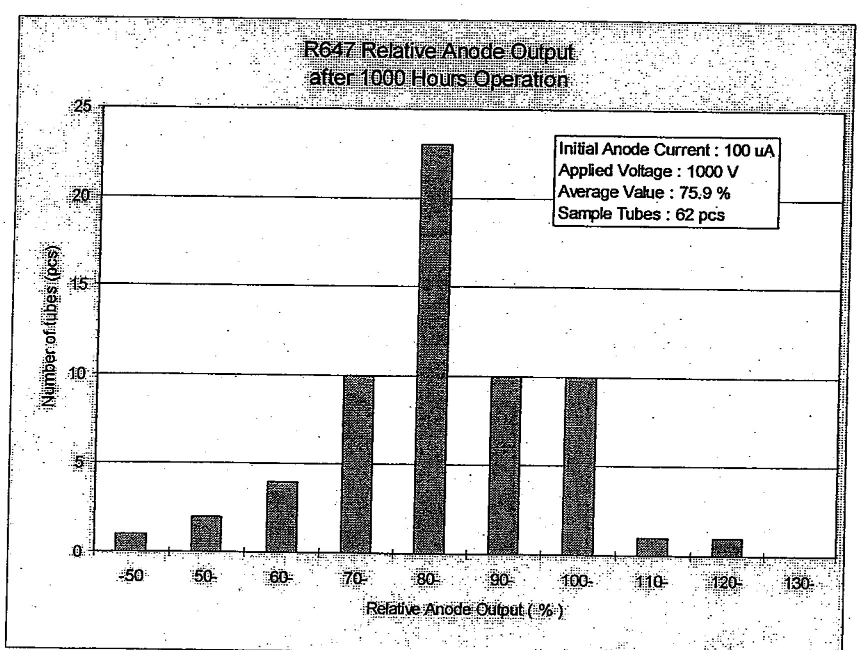


Fig 2-5 Histogram of Gain Change for qty 62 R647 PMT's over 1000 hrs at 100uA Anode current

For the GLAST ACD average anode currents are projected to be only 30nA. The gain degradation is caused by sputtering of material from the dynodes, and therefore the gain change depends strongly on the average anode current. Fig 2-6 shows the empirically derived relationship for predicting gain change for different average anode currents. This relationship for predicting gain change vs anode current has been determined from evaluation of many PMT's over many years. (It is not an exact model, but simply Hamamatsu's best estimate for predicting gain change at low anode currents over long time periods). At anode currents of 30 nA the acceleration coefficient would be 50x compared to 100 μA. Thus the gain stability lifetime would be increased by a factor of 50x for anode currents of 30 nA compared to 100 μA. The histogram of Fig 2-5 therefore also represents the expected gain degradation of the R4443 over a period of 50,000 hours at average anode current of 30 nA.

From this Histogram data taken from Qty 62 R647 PMT's , we conclude for R4443....

- Useful to "reject" PMT's that show more than -10% gain change within first 12 hours burn-in
- From remaining PMT's average gain degradation @30 nA can be predicted to be about 23% over 50,000 hours
- More than 84% of PMT's should have less than 40% gain degradation @ 30 nA after 50,000 hours.

This is very close to Nasa's requested performance for projected gain degradation of 30% (1 sigma). Hamamatsu will therefore "reject" R4443 PMT's that exhibit more that -10% gain change during 12 hours of burn in at 30μA.

The R4443 temporal stability @ 30 nA average anode current should meet RFQ requirement for gain variation of less than 2% per 10 days at 20C based on this data.

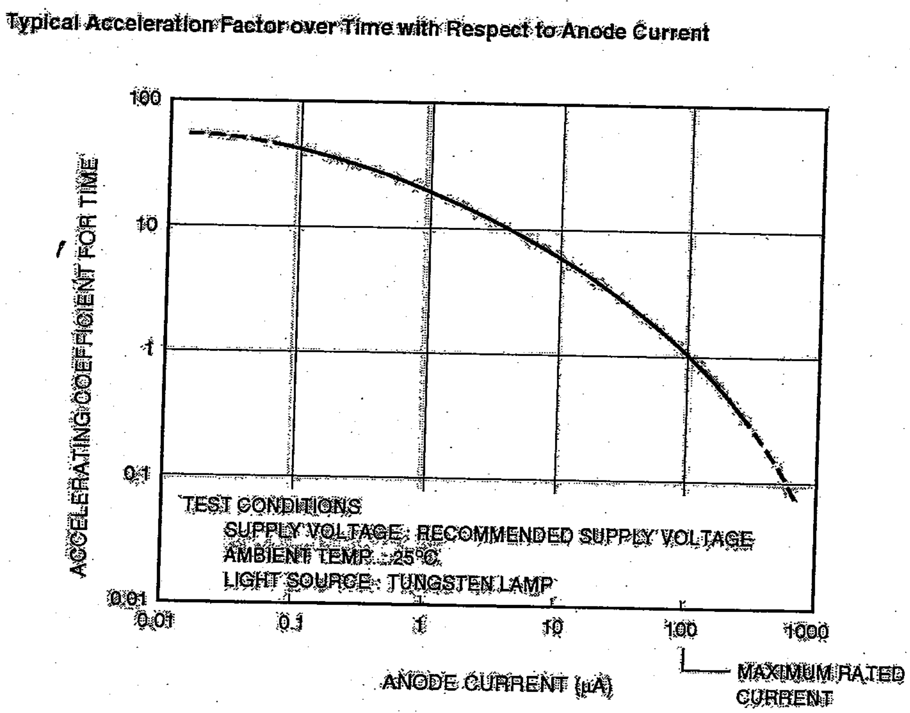


Fig 2-6 Accelerațiion Factor for Predicting Gain change as function of Anode Current

3. Environmental Performance

3.1 Vibration & Shock

The proposed R4443 is a "ruggedized" PMT designed to withstand the shock/vibration requirements of a Delta2 Launch environment. Hamamatsu has extensive experience making PMT's for harsh environment applications(see our Ruggedized High Temperature Photomultiplier Tube Catalog [2]). The R4443 will have similar internal mechanical construction to Hamamatsu's standard commercial R4177 PMT that is used in the oil well logging industry. The standard R4177 has already been shown to consistently withstand sine vibration levels of "20G, 50-2000Hz, 10 minutes/axis, 3 axes" and shock of "500G, 0.5 ms". We consider these levels more severe than the random vibration levels specified for the GLAST ACD. The R4443 will meet both the acceptance level and qualification level of random vibration required by the GLAST ACD RFQ.

Section 4.2 details the specific random vibration testing to be performed on the qualification units and the definition of acceptable "before and after" performance. Based on Hamamatsu's experience, a +-10% parameter change for the photocathode sensitivity SK and +-25% parameter change for Gain are suitable for defining "failed" PMT's. However, for Dark current Idb using 100% change for "before/after" failure criteria is not recommended. Dark Current can vary significantly for PMT's, with some R4443's showing dark currents below 0.1 nA and others as high a 1 nA. Nasa's proposed parameter change of 100% for Dark current is not suitable for the very low dark current tubes. Hamamatsu therefore recommends that "Limit on Performance Change Due to Shock, Vibration, or Radiation" for Dark Current Idb be defined as…

- Anode Dark Current @25C shall not increase by more than 100% if Idb is initially >= 1 nA, and shall not increase by more than 10 times if Idb is initially less than 1nA.

Section 4.3 & 4.4 detail the specific random vibration testing for the Engineering Models and Flight Models. Hamamatsu strongly recommends that at least the Level 2 Intermediate testing option be employed so that all PMT's have been properly screened to ensure they will meet the vibration requirements for the ACD.

3.2 Operating Temperature Range and Temperature Rate

3.2.1 Operating Temperature Range

The R4443 will be capable of a maximum operating temperature range of –30 to +50C, and storage temperature range of –80 to +50C. See Data Sheet Table 2-A. The storage and operating high temperature limit of the R4443 is due to the bialkali photocathode material. Care should be taken not to exceed +50C temperatures.

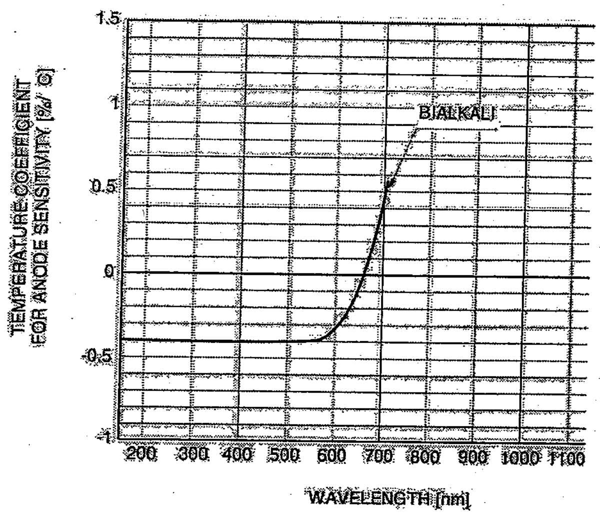
Performance parameters depend on operating temperature. Fig 3-1 shows the typical temperature coefficient of anode sensitivity for bialkali photocathodes @25C. This coefficient is generally -0.4%/C for wavelengths 300-500nm. Thus there could be a 5% decrease in anode sensitivity when temperature increases from +25C to +45C.

Dark Current Idb has an even stronger dependance on temperature. Fig 3-2 shows typical Anode Dark Current Idb as function of temperature. Idb increases more than factor of 20x from +25C to +45C. The dark current requirement of 10nA will be met at +25C, but note that Idb may exceed this 10 nA specification at higher temperatures.

3.2.3 Temperature Rate

R4443 will have no problem surviving temperature rates of change of 20C/hr for testing and 5C/hr under flight conditions. Standard R647 PMT's (similar photocathode and internal structure to R4443) have been tested for sudden temperature changes of –60 to + 50C over time frames of less than 30 minutes with no failures reported.

Temperature Characteristics of Anode Dark Current



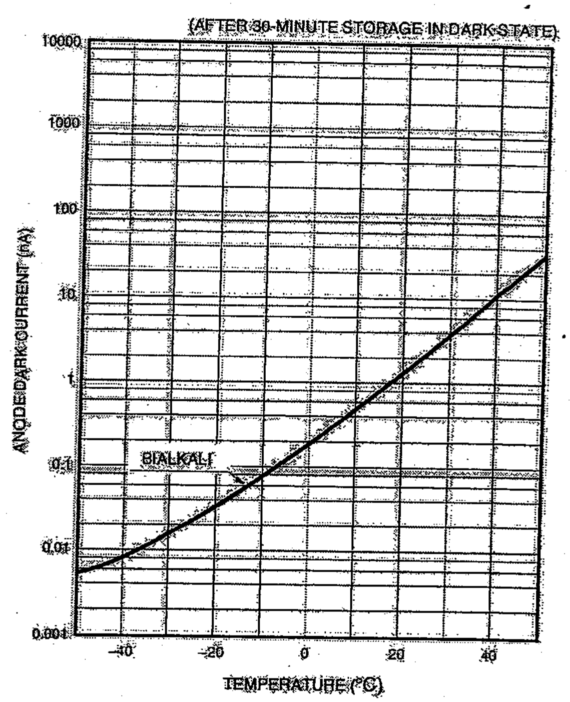


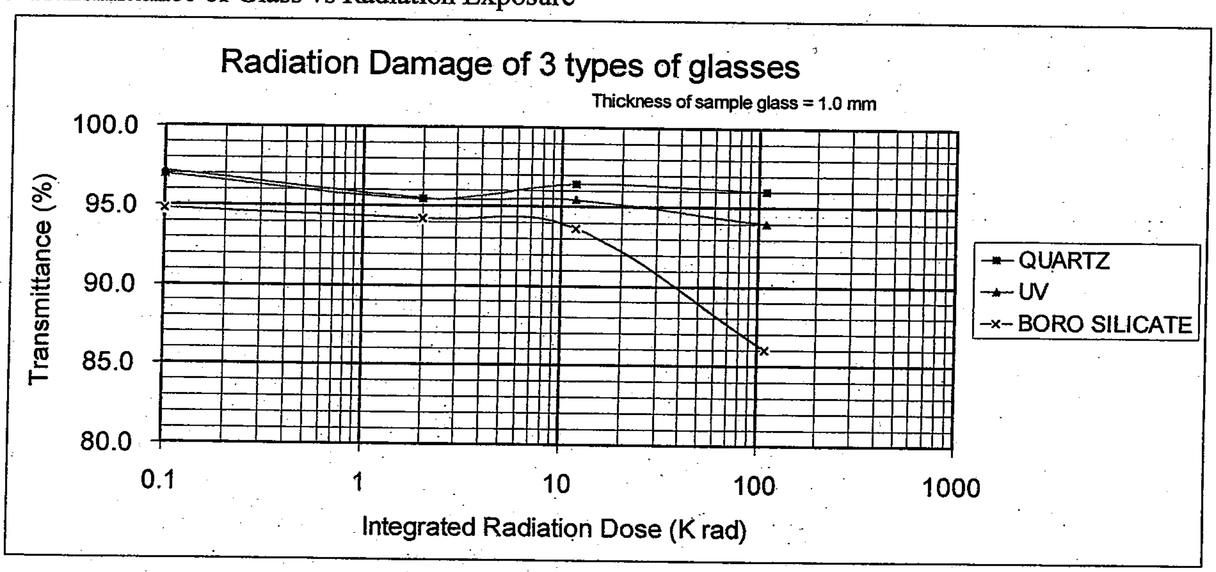
Fig 3-1 Temperature Coefficient of Anode Sensitivity

Fig 3-2 Temperature Dependence of Dark

3.3 Radiation Exposure

When Hamamatsu PMT's are exposed to ionizing radiation the cathode sensitivity and secondary emission (Gain) exhibit very little change. (See PMT Handbook[1)] Sec 8.6 for additional info). The primary sensitivity change from radiation exposure is due to discoloration of the window glass of PMT. Fig 3-3 shows typical change in window transmittance as function of radiation for 3 different types of window glass. From this data it is evident that the Borosilicate glass window can meet the +-10% requirement for 10KRad exposure. UV Glass does have better resistance to radiation damage, but risk of Helium penetration is increased—See Sec 3.4 below). UV Glass could be substituted for Borosilicate Glass if NASA feels that Radiation Damage effects are a more critical issue than He penetration.

Fig 3-3 Transmittance of Glass vs Radiation Exposure



3.4 Helium Penetration

It is well known that Helium gas penetrates through glass. The extent of penetration depends on the glass material and thickness. In principal even if the He partial pressure in the PMT increases to that of the normal atmosphere (5.3×10^{-1} Pa) no significant problem will occur. However, if He is present in greater amounts due to use of He leak testing or vented He gas, then the problem can be more severe. Fig 3-4 shows comparison of He penetration for Quartz, UV glass, and Borosilicate glass. Hamamatsu recommends Borosilicate glass for the R4443 since it meets the 10Krad radiation requirement and offers the best immunity to He penetration.

Every effort should be made to store PMT's in environment without excess He gas. He penetration can result in "afterpulsing" which will degrade performance of PMT for scintillation counting and energy analysis. In fact, Hamamtsu recommends "afterpulse" tests be performed on a representative sample of PMT's stored with engineering or flight units to ensure that excess He penetration has not occurred.

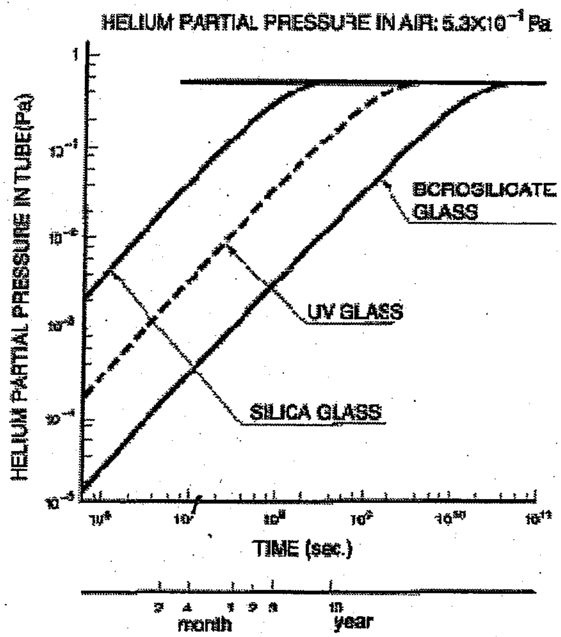


Fig. 3-4 Helium Penetration for Different Glass Material

4. Testing

4.1 General

Hamamatsu has extensive experience in testing PMT's, including both commercial PMT's for rugged environments (such as oil well logging) and PMT's designed for space flight use. The level of testing and tests to be performed usually depend on application performance requirements, environmental requirements, and budget considerations. From Hamamatsu's experience the key opto-elecrical performance parameters requiring individual test data for each PMT are…

- Cathode Sensitivity…. (S_K)
- Gain (Anode current/Cathode Current)
- Nominal Voltage corresponding to Gain of 5E05….(E_{bb})
- Dark Current @ Gain of 5E05…..(I_{db})

These parameters are important for proper operation of PMT for scintillation counting. Testing of each parameter is generally required to confirm PMT is operating within specifications and to screen out PMT's that have high noise or have insufficient gain.

For the GLAST ACD, stability of PMT anode sensitivity (Gain) over the mission life is also an important issue. Hamamatsu's experience has shown that a 12 hour burn-in period is useful for screening out PMT's that will eventually exhibit unusually high gain drift. (See Section 2.3.3 on Gain Degradation). Hamamatsu recommends that all PMT's delivered for GLAST ACD have the Gain tested before and after the 12 hour burn-in and that PMT's with gain change corresponding to greater than –10% be rejected to ensure the required long term gain stability. This screening for Gain degradation during 12 hour burn-in should ensure a predicted gain degradation @30 nA after 50,000 hours of better than 40% (1 sigma).

Visual Inspections are critical to ensure a high reliability PMT. Visual inspections are part of the standard manufacturing process at Hamamatsu. Because these PMT's are intended for Space Flight use, Hamamatsu recommends each PMT undergo specific visual inspections for window, glass bulb defects, loose particles, and internal structure. This visual inspection will be documented and pass/fail recorded for each unit. This documented visual inspection will be performed prior to each time the key opto-electrical performance parameters are formally tested.

For Level 1 testing, a PMT is determined to have failed if…

- PMT fails any visual inspection step
- Performance Parameter (SK, Gain, Ebb or Idb) does not meet specification @25C
- Degradation in Gain is more than –10% after 12 hour burn-in test

For Level 2 testing, a PMT is determined to have failed if…

- PMT fails any visual inspection step
- Performance Parameter (SK, Gain, Ebb or Idb) does not meet specification @25C
- Change in Sk is more than +-10% before/after random vibration test
- Change in Gain is more than +-25% before/after random vibration test
- Dark Current Idb changes by more than 100% before/after vibration (if Idb >= 1nA initially)
- Dark Current Idb changes by more than 10x before/after vibration (if Idb < 1nA initially)
- Degradation in Gain is more than –10% after 12 hour burn-in test

For Level 3 testing, a PMT is determined to have failed if…

- PMT fails any visual inspection step
- Performance Parameter (SK, Gain, Ebb or Idb) does not meet specification @25C
- Change in Sk is more than +-10% before/after random vibration test or 100 hr burn-in test.
- Change in Gain is more than +-25% before/after random vibration test or 100 hr burn-in test
- Dark Current Idb changes by more than….
    - 100% before/after vibration or 100 hr burn-in (if Idb >= 1nA initially)
    - 10x before/after vibration or 100 hr burn-in (if Idb < 1nA initially)

There are three optional levels of testing that can be performed and each is quoted separately for the Engineering and Flight Models. Qualification Models are tested to Level 2. Details of each test option are shown on the relevant Test Chart. For Level 3 testing the anode current (equivalent to gain since light level will be kept constant) shall be measured after 24, 48, and 100 hours of operation during the 100 hour burn-in test.

Any PMT undergoing Level 2 or Level 3 testing that fails to pass the Random Vibration Test or 100 hr burn-in test will be formally reported to the NASA technical officer. The failed PMT will undergo a failure analysis within 2 working days to ensure corrective action can be taken to help prevent any systematic problem. Results of failure analysis will be reported to the NASA Technical Officer at a mutually agreed time.

4.2 Qualification Units, Level 2 Testing

Qualification units will be tested to Level 2 Intermediate testing and will undergo "qualification level" random vibration (i.e—14.1 Grms). Visual Inspection and DC Measurements on Performance Parameters will be tested and documented before/after random vibration test and before/after 12 hour burn-in.
See…

- Table 4-A R4443 Test Chart Qualification Model with Level –2.

4.3 Engineering Models

Engineering Models can be tested to three(3) optional levels: Level 1, Level 2 or Level 3. Hamamatsu strongly recommends that at least Level 2 Intermediate testing be done on Engineering Models.

See...

- Table 4-B R4443 Test Chart (Engineering Model with Level 1), or
- Table 4-C R4443 Test Chart (Engineering Model with Level 2), or
- Table 4-D R4443 Test Chart (Engineering Model with Level 3).

4.4 Flight Models

Flight Models can be tested to three (3) optional levels: Level 1, Level 2 or Level 3. Hamamatsu strongly recommends that at least Level 2 Intermediate testing be done on all Flight Models.

See...

- Table 4-E R4443 Test Chart (Flight Model with Level 1), or
- Table 4-F R4443 Test Chart (Flight Model with Level 2), or
- Table 4-G R4443 Test Chart (Flight Model with Level 3).

R4443 TEST CHART (Qualification Model with LEVEL-2) QTY:10 pcs

Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible bubbles, inclusions, surface scratches and edge chippings in accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist no irregularities, surface defects, or any variations of condition at the glass envelope in accordance with internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Non-Metallic Particle; 1.5 mm Max for Accumulations of Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail

2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (μA/lm)	90 μA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

		Qualification Level		
3	Random Vibration	Frequency (Hz)	ASD Level (G2/Hz)	Max. Variation between #2 and #5
		20	0.026	SK = +/- 10 % Gain = +/- 25 % Idb = + 100 % (Note #1)
		20 - 50	+6 dB/oct	
		50-800	0.16	
		800-2000	-6 dB/oct	
		2000	0.026	
		Overall	14.1 Grms	
		Duration	1 min./axis, 3 Axes	

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times max..)

4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

6	12-hour Burn-in Test			
		Initial current Applied Voltage Temperature Warm-up Operating Time	30 μA 1000V room temp. 2 hours 12 hours	Max. Variation between #5 and #8 Gain = - 10 %

7	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
8	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if

1) PMT doesn't meet requirements at Item #5 after Random Vibration test (Item #3).
2) PMT shows parameter change specified in Item#3 after Random Vibration test (Item #3).
3) PMT doesn't meet requirements at Item #8 after Burn-in test (Item# 6).

Shipping Data = DC Measurement at Item #2, #5 and #8

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

R4443 TEST CHART (Engineering Model with LEVEL-1)

QTY:40 pcs
Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible bubbles, inclusions, surface scratches and edge chippings in accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist no irregularities, surface defects, or any variations of condition at the glass envelope in accordance with internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Non-Metallic Particle; 1.5 mm Max for Accumulations of Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail

2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (μA/lm)	90 μA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

3	12-hour Burn-in Test			
		Initial current Applied Voltage Temperature Warm-up Operating Time	30 μA 1000V room temp. 2 hours 12 hours	Max. Variation between #2 and #5 Gain = - 10 %

4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if
1) PMT doesn't meet requirements at Item #5 after Burn-in test (Item #3).

Shipping Data = DC Measurement at Item #2 and #5

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

R4443 TEST CHART (Engineering Model with LEVEL-2) QTY:40 pcs

Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible bubbles, inclusions, surface scratches and edge chippings in accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist no irregularities, surface defects, or any variations of condition at the glass envelope in accordance with internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Metallic Particle; 1.5 mm Max for Accumulations of Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail
2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (µA/lm)	90 µA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

3	Random Vibration	Workmnship Level		
		Frequency (Hz)	ASD Level (G2/Hz)	Max. Variation between #2 and #5
		20	0.01	SK = +/- 10 % Gain = +/- 25 % Idb = + 100 % (Note #1)
		20 - 50	+3 dB/oct	
		50-800	0.04	
		800-2000	-3 dB/oct	
		2000	0.01	
		Overall	6.8 Grms	
		Duration	1 min./axis, 3 Axes	

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times

4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

6	12-hour Burn-in Test			
		Initial current Applied Voltage Temperature Warm-up Operating Time	30 µA 1000V room temp. 2 hours 12 hours	Max. Variation between #5 and #8 Gain = - 10 %

7	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
8	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if

1) PMT doesn't meet requirements at Item #5 after Random Vibration test (Item #3).
2) PMT shows parameter change specified in Item#3 after Random Vibration test (Item #3).
3) PMT doesn't meet requirements at Item #8 after Burn-in test (Item# 6).

Shipping Data = DC Measurement at Item #2, #5 and #8

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

R4443 TEST CHART (Engineering Model with LEVEL-3)

QTY:40 pcs
Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible inclusions, surface scratches and edge chippings accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist irregularities, surface defects, or any variations of condition at the glass envelope in accordance internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Metallic Particle; 1.5 mm Max for Accumulations Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail

Item #	Test Item	Specification	Management of Test Result
2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (μA/lm)	90 μA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

Item #	Test Item	Wrkmshp Level		Max. Variation between #2 and #5
3	Random Vibration	Frequency (Hz)	ASD Level (G2/Hz)	
		20	0.01	
		20 - 50	+3 dB/oct	SK = +/- 10 %
		50-800	0.04	Gain = +/- 25 %
		800-2000	-3 dB/oct	Idb = + 100 %
		2000	0.01	(Note #1)
		Overall	6.8 Grms	
		Duration	1 min./axis, 3 Axes	

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times max..)

Item #	Test Item	Specification	Management of Test Result
4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Item #	Test Item			Max. Variation between #5 and #8
6	100-hour Burn-in Test			
		Initial current	30 μA	SK = +/- 10 %
		Applied Voltage	1000V	Gain = +/- 25 %
		Temperature	room temp.	Idb = + 100 %
		Warm-up	2 hours	(Note #1)
		Operating Time	100 hours	

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times max..)

Item #	Test Item	Specification	Management of Test Result
7	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
8	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if
1) PMT doesn't meet requirements at Item #5 after Random Vibration test (Item #3).
2) PMT shows parameter change specified in Item#3 after Random Vibration test (Item #3).
3) PMT doesn't meet requirements at Item #8 after Burn-in test (Item# 6).
4) PMT shows parameter change specified in Item#6 after Burn-in test (Item #6).

Shipping Data = DC Measurement at Item #2, #5 and

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

R4443 TEST CHART (Flight Model with LEVEL-1)

QTY:210 pcs
Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible bubbles, inclusions, surface scratches and edge chippings in accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist no irregularities, surface defects, or any variations of condition at the glass envelope in accordance with internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Non-Metallic Particle; 1.5 mm Max for Accumulations of Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail

2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (μA/lm)	90 μA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

3	12-hour Burn-in Test			Max. Variation between #2 and #5
		Initial current	30 μA	
		Applied Voltage	1000V	
		Temperature	room temp.	Gain = - 10 %
		Warm-up	2 hours	
		Operating Time	12 hours	

4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if
1) PMT doesn't meet requirements at Item #5 after Burn-in test (Item #3).

Shipping Data = DC Measurement at Item #2 and #5

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

R4443 TEST CHART (Flight Model with LEVEL-2)

QTY:210 pcs
Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible bubbles, inclusions, surface scratches and edge chippings in accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist no irregularities, surface defects, or any variations of condition at the glass envelope in accordance with internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Non-Metallic Particle; 1.5 mm Max for Accumulations of Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail

2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (μA/lm)	90 μA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

3	Random Vibration	Acceptance Level		
		Frequency (Hz)	ASD Level (G2/Hz)	Max. Variation between #2 and #5
		20	0.013	
		20 - 50	+6 dB/oct	SK = +/- 10 %
		50-800	0.08	Gain = +/- 25 %
		800-2000	-6 dB/oct	Idb = + 100 %
		2000	0.013	(Note #1)
		Overall	10.0 Grms	
		Duration	1 min./axis, 3 Axes	

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times max..)

4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

6	12-hour Burn-in Test			Max. Variation between #5 and #8
		Initial current	30 μA	
		Applied Voltage	1000V	
		Temperature	room temp.	Gain = - 10 %
		Warm-up	2 hours	
		Operating Time	12 hours	

7	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
8	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if
1) PMT doesn't meet requirements at Item #5 after Random Vibration test (Item #3).
2) PMT shows parameter change specified in Item#3 after Random Vibration test (Item #3).
3) PMT doesn't meet requirements at Item #8 after Burn-in test (Item# 6).

Shipping Data = DC Measurement at Item #2, #5 and #8

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

R4443 TEST CHART (Flight Model with LEVEL-3)

QTY:210 pcs
Date : Oct./01/2001

Item #	Test Item	Specification	Management of Test Result
1	Visual Inspection		
	Window Material	The face plate shall be free of clearly visible bubbles, inclusions, surface scratches and edge chippings in accordance with internal spec.	Record Pass/Fail
	Glass Defects Check	Any observed Bubble: 1mm Max There shall exist no irregularities, surface defects, or any variations of condition at the glass envelope in accordance with internal spec	Record Pass/Fail
	Loose Particle Check	0.5 mm Max for Metallic Particle; 1 mm Max for Non-Metallic Particle; 1.5 mm Max for Accumulations of Particles	Record Pass/Fail
	Internal Structure	No observable structural defect in accordance with internal spec	Record Pass/Fail

2	DC Measurements	(SK = Cathode Sensitivity)	
	SK (μA/lm)	90 μA/lm Min.	Record Data
	Gain	2E+6 Min. at 1250V	Record Data
	Nominal Voltage (Ebb) for Gain of 5E+5	1000V Max	Record Data
	Dark Current (Idb) (nA)	10 nA Max. at Gain of 5E+5	Record Data

3	Random Vibration	Acceptance Level		
		Frequency (Hz)	ASD Level (G2/Hz)	Max. Variation between #2 and #5
		20	0.013	SK = +/- 10 % Gain = +/- 25 % Idb = + 100 % (Note #1)
		20 - 50	+6 dB/oct	
		50-800	0.08	
		800-2000	-6 dB/oct	
		2000	0.013	
		Overall	10.0 Grms	
		Duration	1 min./axis, 3 Axes	

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times max..)

4	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
5	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

6	100-hour Burn-in Test			Max. Variation between #5 and #8
		Initial current Applied Voltage Temperature Warm-up Operating Time	30 μA 1000V room temp. 2 hours 100 hours	SK = +/- 10 % Gain = +/- 25 % Idb = + 100 % (Note #1)

(Note #1 : If Idb is less than 1 nA, it shoule be 10 times max..)

7	Visual Inspection	Repeat Item #1 Again	Record Pass/Fail
8	DC Measurements	Repeat All DC Measurements in Item #2	Record Data

Failure Analysis Report

Failure analysis report will be provided within 2 working days, if
1) PMT doesn't meet requirements at Item #5 after Random Vibration test (Item #3).
2) PMT shows parameter change specified in Item#3 after Random Vibration test (Item #3).
3) PMT doesn't meet requirements at Item #8 after Burn-in test (Item# 6).
4) PMT shows parameter change specified in Item#6 after Burn-in test (Item #6).

Shipping Data = DC Measurement at Item #2, #5 and #8

Cathode Sensitivity (SK)
Gain at 1250V
Nominal Voltage (Ebb) for Gain of 5E+5
Dark Current (Idb) at Ebb

5. Quality Plan

5.1 ISO 9001

All manufacturing related to the R4443 for NASA GLAST ACD will be performed at Hamamatsu Photonic K. K. Electron Tube Center in Toyooka near Hamamatsu City, Japan. This facility is a ISO 9001 registered manufacturing facility, with original certification by JQA (Japan Quality Assurance Organization) on Feb 5 1997, certificate # JQA-1574. Quality Manager for Electron Tube Center (ETC) is Yoshiro Akai.

Hamamatsu Corporation USA in Bridgewater NJ will be responsible for all contract issues, order processing, invoicing, shipping and return processing. Hamamatsu Corporation USA is also ISO 9001 certified. Quality Manager for Hamamatsu Corporation USA is Yuji Shinoda.

Hamamatsu intends to manufacture the R4443 units in accordance with our ISO 9001 certified Quality Manual. This manual is written in Japanese not English. Many of the procedure documents are in Japanese. Hamamatsu may be able to translate a specific section of the Quality Document if need be, but the wholesale translation of the documents into English would be burdensome.

The Quality documents (GSFC 433-MAR-0001, SLAC LAT-MD-00039, & GSFC ACD-QA-8001) referenced in the RFQ are broad scope documents related to the entire ACD mission. To our knowledge Hamamatsu's Quality program is consistent with these documents. TheR4443 PMT proposed is intended to be "space flight qualifiable", but the ultimate responsibility for "space qualifying" these units must rest with NASA. Hamamatsu's responsibility will be to provide PMT's meeting all specifications outlined in this proposal and to manufacture units in a manner consistent with Hamamatsu's internal ISO 9001 Quality Manual, Standards Manual and relevant Production Procedure documents. These documents would be available for inspection by authorized NASA representative, but some are considered proprietary documents.

The following personnel will be responsible for making sure the Photomultiplier Tube meets the Quality, Safety, and Mission Assurance requirements.

- Quality Manager for Hamamatsu Corp USA : Yuji Shinoda
- Quality Manager for Electron Tube Center Japan (ETC) : Yoshiro Akai
- Manufacturing Director for Head-on type PMT in ETC: Tetsuya Morita
- Chief Manager for R4443 Production in ETC: Shinichi Muramatsu
- Manager for R4443 Production in ETC: Masami Furuhashi
- Section Chief for R4443 Inspection in ETC: Hiroyuki Suzuki
- Director of Sales Department in ETC: Toshikazu Hakamata
- Manager of Sales Department in ETC: Naofumi Toriyama
- Manager for Application Engineering in ETC: Yuji Yoshizawa
- Technical Sales Engineer USA : Andrew Allen

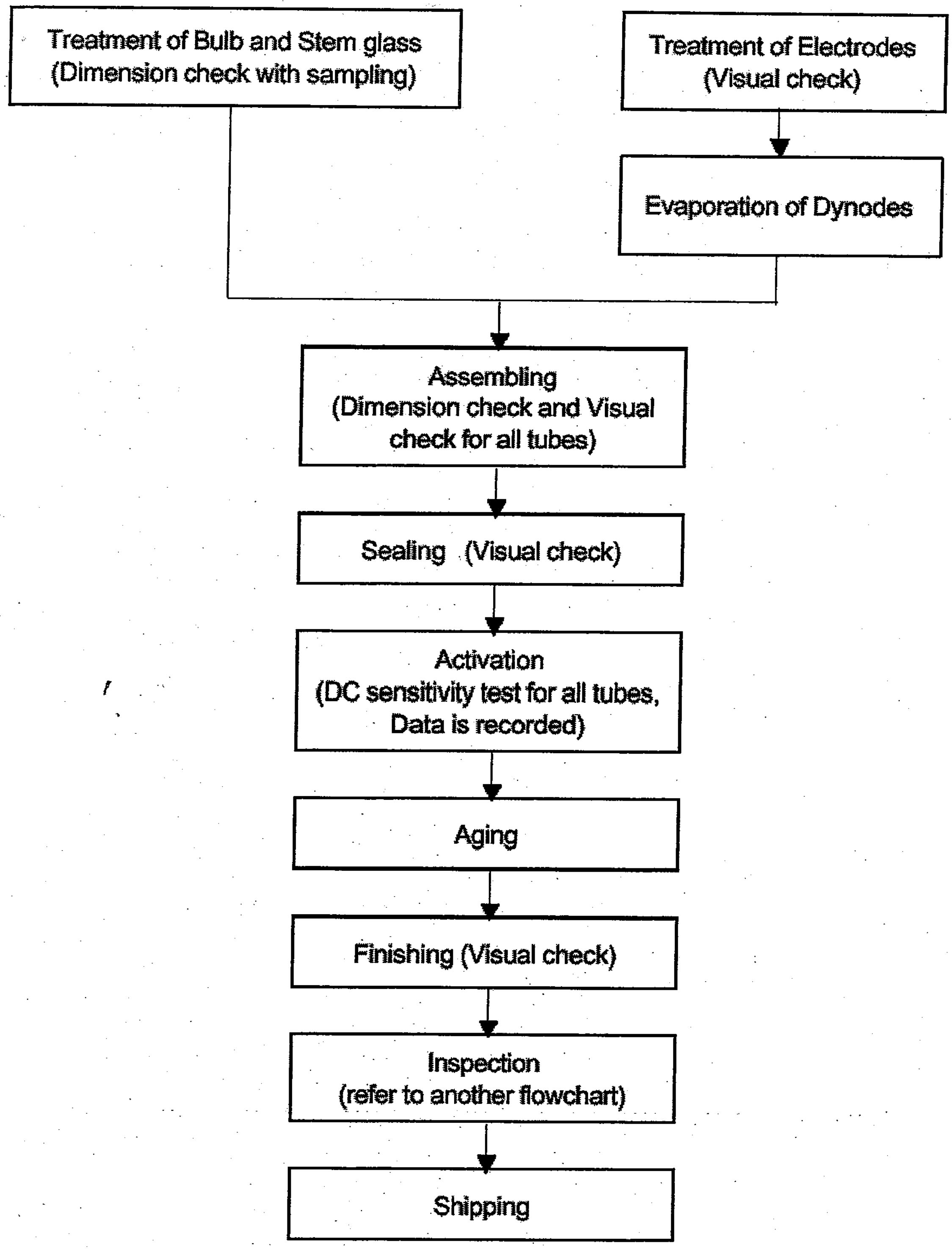
5.2 Hamamatsu Quality Documents specific to R4443

Figure 5-1 is a production flow chart detailing the steps in the manufacture of the proposed R4443. Table 5-A *R4443 Production and Inspection Document* lists some relevant procedure documents used by Hamamatsu for process control and quality assurance for the proposed R4443. The Production Flowchart and Production Process Inspection Document are intended to demonstrate the general level of process control used by Hamamatsu. Similar documents are available related to material control. The actual procedure documents referenced are written in Japanese. PMT's using similar materials and manufacturing techniques were flown on space missions for SOHO and the EVRIS Mission.

R4443 PRODUCTION FLOWCHART

Aug./2001

(Inspection Method)



Note : The work at each process is done according to the Standard Manual based on ISO 9001.

Fig 5-1: *Production Flowchart for R4443*

Table 5-A: *R4443 Production and Inspection Documents*

R4443 Production and Inspection Document			Date : Sept./2001
Production			
Process	**Document Title**	**Document Number**	**Notes**
Treatment of Bulb and Stem Glass	Procedure for Bulb Cleaning	TL0-01-0001	
	Procedure for Stem Cleaning	TL0-01-0010	
Treatment of Electrodes	Procedure for Burr Removal from the Electrodes	TL0-01-0030	
	Procedure for Chemical Polishing of the Electrodes	TL0-01-0031	
	Procedure for Oil Removable from the Electrodes	TL0-01-0032	
Evaporation of Electrodes	Procedure for Evaporation of the Electrodes	TL0-02-0043	
	Material List for Evapolation and Assemling	TL1-03-0001	
Assembling	Procedure for R4443 Assembling	TL1-03-XXXX	Document to be assigned [We already have document for R4444(R4443 with Multi Alkali PC:TL1-03-0033)].
Sealing	Procedure for Glass Sealling	TL0-04-0001	
Activation	Procedure for Bialkali Photocathode Activation	TL0-05-0004	
Aging	Procedure for Aging	TL1-05-0003	
Finishing	Procedure for Finishing	TL0-06-0001	
Inspection	Procedure for Inspection	TL0-09-0001	Please refer to each Inspection Item.
Shipping	Procedure for Wrapping	TC1-01-0001	
	Procedure for Packing	TC1-01-0005	
	Procedure for Overseas Shipping	TC1-01-0004	
Inspection			
Inspection Item	Document Title	Document Number	Notes
Visual Inspection	Procedure for Sensitivity Test	TL0-09-0003	
DC Measurements			
Random Vibration	Procedure for Vibration Test	TL0-09-0082	
Burn-In Test	Procedure for DC Stability Test	TL0-09-0076	
HAMAMATSU			

6. Delivery Schedule

Hamamatsu has the facilities, equipment, and manufacturing personnel to deliver PMT's within the timeframe requested in RFQ. We have prepared detail schedules for the Qualification Units, Engineering Models and Flight Models consistent with NASA GLAST ACD RFQ and Hamamatsu's available materials/resources.

6.1 Delivery of Qualification Units

Preparation of Materials will take 2 months ARO for Qualification units. Assembly and Test to Level 2 will require one additional month. For redundancy two complete inspection Lots of at least 10 units each are planned. Qty 10 Qual units could be delivered 3 months ARO. See Table 6-A: *Qualification Model (Level 2) Production Schedule.*

6.2 Delivery of Engineering Models

Preparation of Materials will take 2 months ARO for Engineering Models. Assembly and Test to Level 1 can be completed for all 40 units within additional 1 month. Testing to Level 2 or Level 3 adds some additional time, but even for Level 3 testing, all 40 units can be delivered within 4 months ARO. This means all Engineering Models could be delivered to meet NASA's request of June 2002.

6.3 Delivery of Flight Models

Preparation of Materials will take 2 months ARO. For Level 1 or Level 2 Testing approximately 50 units/month can be delivered beginning 3.5 months ARO. For Level 3 testing, the 100 hour burn-in will limit how many units can be processed/tested per week, due to limited burn-in test equipment.

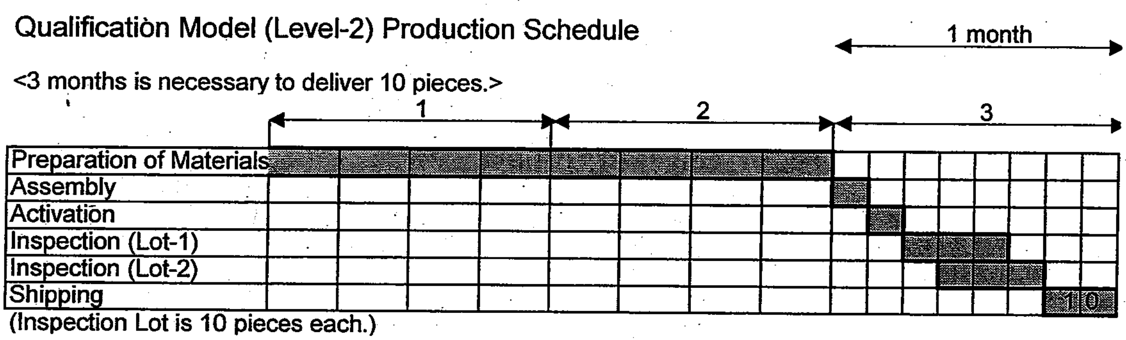
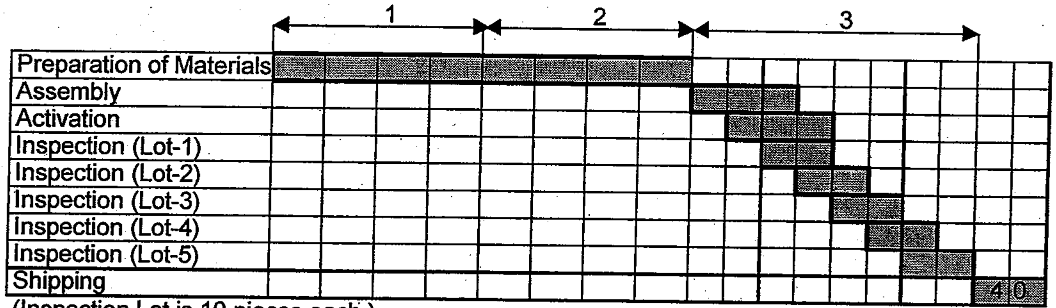


Table 6-B; Engineering Model (Level-1) Production

1 month

<3 months is necessary to deliver 40

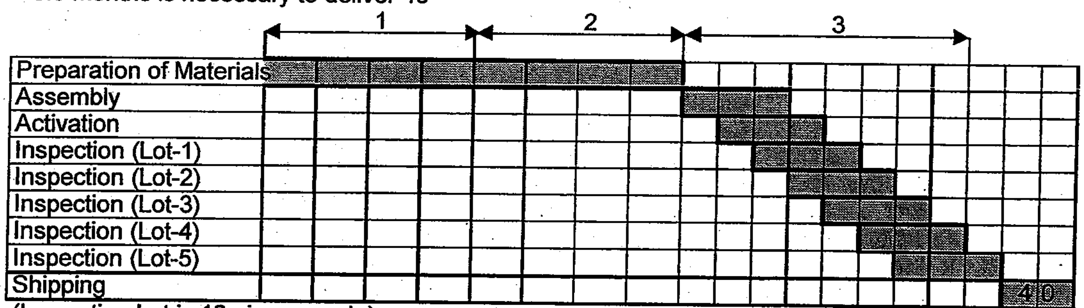


(Inspection Lot is 10 pieces each.)

Table 6-C: *Engineering Model (Level-2)*

1 month

<3.5 months is necessary to deliver 40

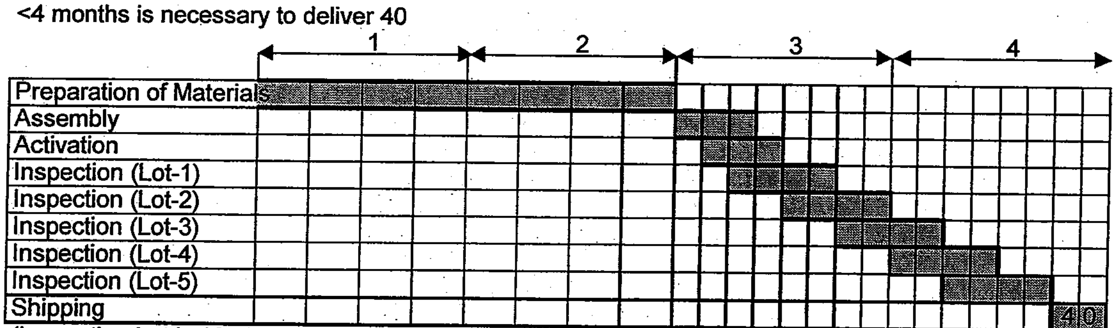


(Inspection Lot is 10 pieces each.)

Table 6-D: *Engineering Model (Level-3)*

1 month

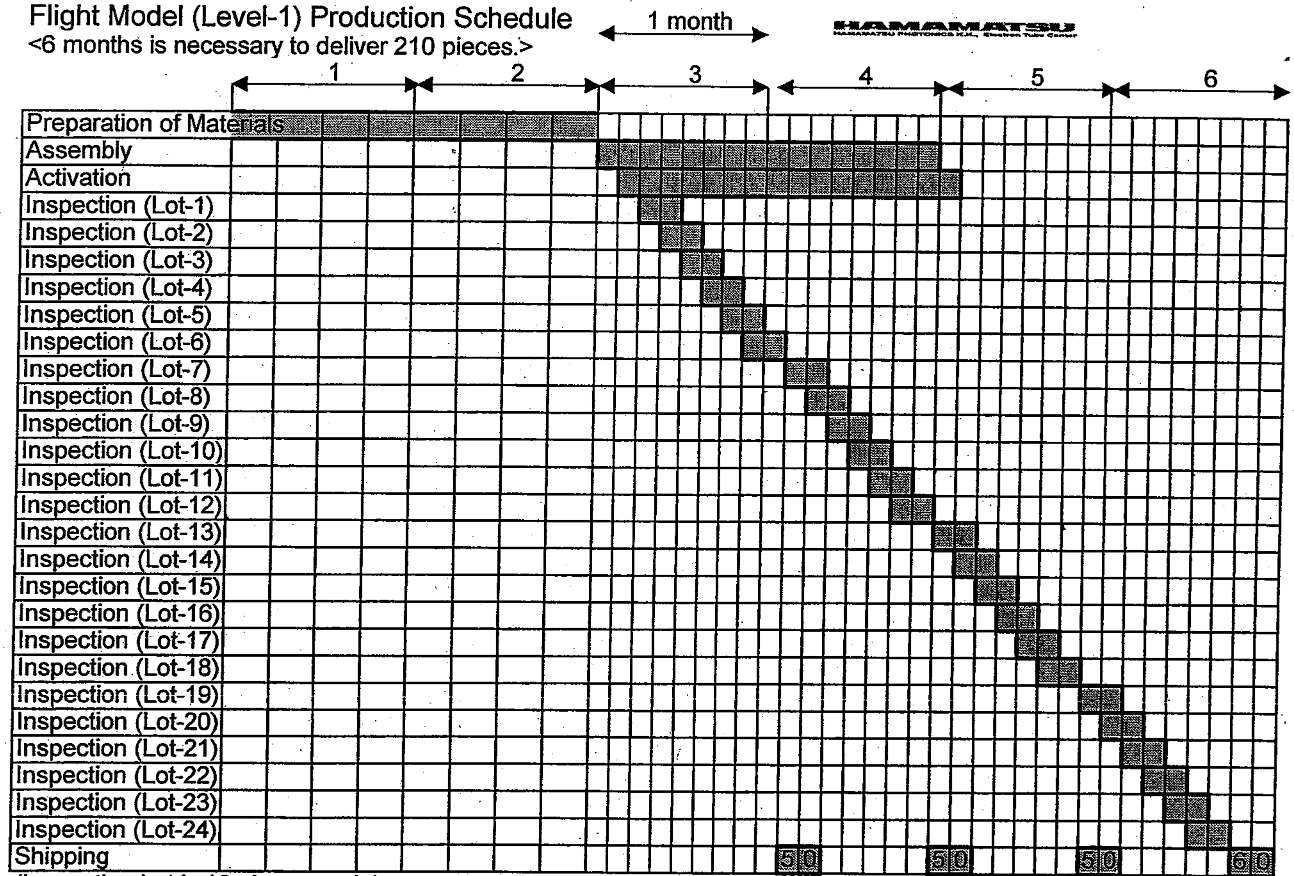
<4 months is necessary to deliver 40



(Inspection Lot is 10 pieces each.)

Flight Model (Level-1) Production Schedule

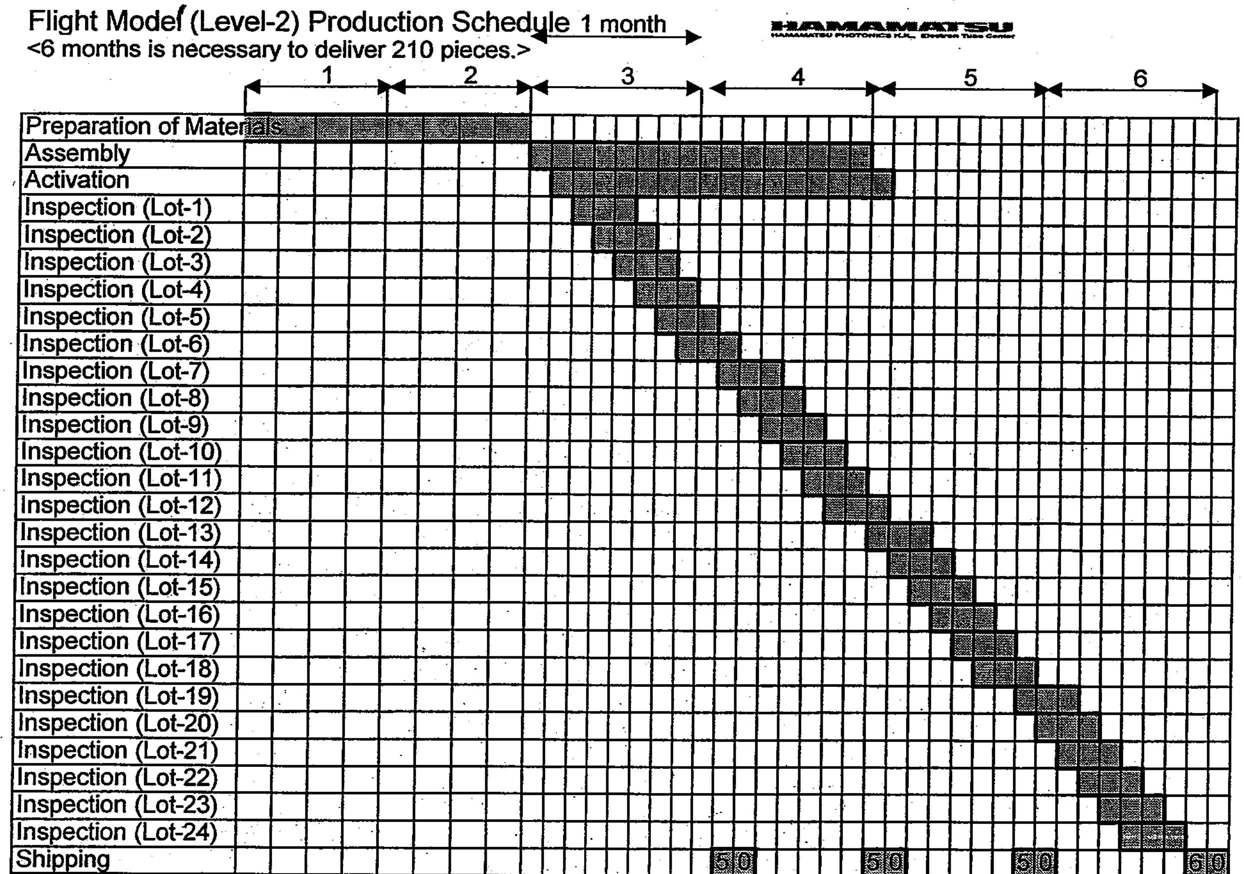
<6 months is necessary to deliver 210 pieces.>



(Inspection Lot is 10 pieces each.)

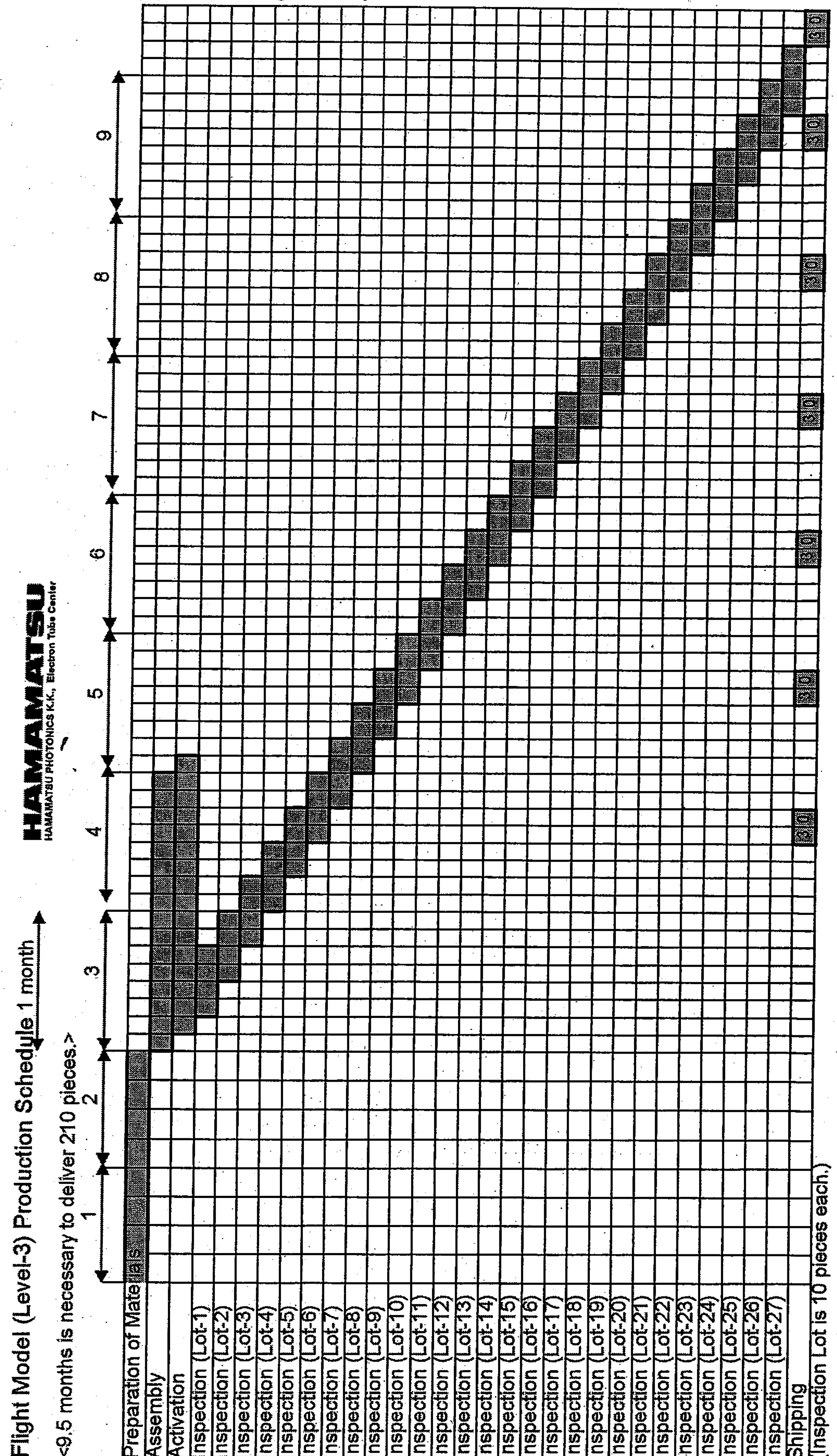
Flight Model (Level-2) Production Schedule

<6 months is necessary to deliver 210 pieces.>



(Inspection Lot is 10 pieces each.)

Table 6-F: *Flight Model Level 3 Testing Delivery Schedule*



7. Price Quotation & Warranty

Hamamatsu's Firm Fixed Priced quotation for the NASA GLAST ACD photomultipliers described in this proposal is given in Table 7-A. Form 1449 is also included to show EIN and Cage Code with signature.

Terms: Net 30 days. FOB destination: Nasa Goddard, Greenbelt, MD All goods are manufactured in Japan.

This price quotation/proposal is valid for 30 days from date of submission. In accordance with FAR 52.217.6 and the RFQ5-09742, Nasa will have the following Options:

- **Option 1:** Within 45 days after delivery of the Basic Contract Qty 10 Qualification units, Nasa Goddard may place order for Qty 40 Engineering Models at the price specified in Table 7-A.
- **Option 2:** Within 45 days after delivery of the Option 1 Engineering Models Nasa Goddard will have option to place order for Qty 210 Flight Models at the price specified in Table 7-A.

Item	Qty	Unit Price	Comments
Basic Contract Qual units			
R4443 Q-2	10	$1,600.00	Qualification Units Tested to Level-2
Option 1 Engineering Models			
R4443 E-1	40	$1,165.00	Engineering Models Tested to Level-1
R4443 E-2	40	$1,450.00	Engineering Models Tested to Level-2
R4443 E-3	40	$1,640.00	Engineering Models Tested to Level-3
Option 2 Flight Models			
R4443 F-1	210	$1,000.00	Flight Models Tested to Level-1
R4443 F-2	210	$1,225.00	Flight Models Tested to Level-2
R4443 F-3	210	$1,350.00	Flight Models Tested to Level-3

Table 7-A: *Pricing for R4443*

Signature _Andrew W. Allen_ 10/8/01
Andrew W. Allen Sales Engineer

Warranty:

All Hamamatsu photomultiplier tubes and related products are warranted to the original purchaser for a period of 12 months following the date of shipment. The warranty is limited to repair or replacement of any defective material due to defects in workmanship or materials used in manufacture.
A: Any claim for damage of shipment must be made directly to the delivering carrier within five days.
B: Customers must inspect and test all detectors within 30 days after shipment.
C: No credit will be issued for broken detectors unless in the opinion of Hamamatsu the damage is due to a bulb crack or a crack in a graded seal traceable to a manufacturing defect.
D: No credit will be issued for any detector which in the judgment of Hamamatsu has been damaged, abused, modified or whose serial number or type number have been obliterated or defaced.
E: No detectors will be accepted for return unless permission has been obtained from Hamamatsu in writing, the shipment has been returned prepaid and insured, the detectors are packed in their original box and accompanied by the original data sheet furnished to the customer with the tube, and a full written explanation of the reason for rejection of each detector.
F: When products are used at a condition which exceeds the specified maximum ratings or which could hardly be anticipated, Hamamatsu will not be the guarantor of the products.

SOLICITATION/CONTRACT/ORDER FOR COMMERCIAL ITEMS

OFFEROR TO COMPLETE BLOCKS 12, 17, 23, 24, & 30

1. REQUISITION NO.

PAGE 1 OF

2. CONTRACT NO.

3. AWARD/EFFECTIVE DATE

4. ORDER NO.

5. SOLICITATION NO. RFQ5-09742 Amend #3

6. SOLICITATION ISSUE DATE

7. FOR SOLICITATION INFORMATION CALL ▶ a. NAME

b. TELEPHONE NO. *(No collect calls)*

8. OFFER DUE DATE/LOCAL TIME

9. ISSUED BY CODE

10. THIS ACQUISITION IS

☐ UNRESTRICTED

☐ SET ASIDE: % FOR

☐ SMALL BUSINESS

☐ SMALL DISADV. BUSINESS

☐ 8(A)

SIC:

SIZE STD:

11. DELIVERY FOR FOB DESTINATION UNLESS BLOCK IS MARKED

☐ SEE SCHEDULE

12. DISCOUNT TERMS

☐ 13a. THIS CONTRACT IS A RATED ORDER UNDER DPAS

13b. RATING

14. METHOD OF SOLICITATION ☐ RFQ ☐ IFB

15. DELIVER TO CODE

16. ADMINISTERED BY CODE

17a. CONTRACTOR/OFFEROR CODE FACILITY CODE

Hamamatsu Corporation
360 Foothill Rd
Bridgewater, NJ 08807
Cage Code 0JXJ4 TIN13-2638233
TELEPHONE NO. 908-231-0960

18a. PAYMENT WILL BE MADE BY CODE

☐ 17b. CHECK IF REMITTANCE IS DIFFERENT AND PUT SUCH ADDRESS IN OFFER

18b. SUBMIT INVOICES TO ADDRESS SHOWN IN BLOCK 18a UNLESS BLOCK BELOW IS CHECKED ☐ SEE ADDENDUM

19. ITEM NO.	20. SCHEDULE OF SUPPLIES/SERVICES	21. QUANTITY	22. UNIT	23. UNIT PRICE	24. AMOUNT
1	GLAST ACD Qualificiation Units	10		See Table 7-A for Pricing details Page 29 of proposal	
2	Option 1 Engineering Models	40			
3	Option 2 Flight Models	210			

(Attach Additional Sheets as Necessary)

25. ACCOUNTING AND APPROPRIATION DATA

26. TOTAL AWARD AMOUNT *(For Govt. Use Only)*

☐ 27a. SOLICITATION INCORPORATES BY REFERENCE FAR 52.212-1, 52.212-4. FAR 52.212-3 AND 52.212-5 ARE ATTACHED. ADDENDA ☐ ARE ☐ ARE NOT ATTACHED.

☐ 27b. CONTRACT/PURCHASE ORDER INCORPORATES BY REFERENCE FAR 52.212-4. FAR 52.212-5 IS ATTACHED. ADDENDA ☐ ARE ☐ ARE NOT ATTACHED.

28. ☐ CONTRACTOR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ____ COPIES TO ISSUING OFFICE. CONTRACTOR AGREES TO FURNISH AND DELIVER ALL ITEMS SET FORTH OR OTHERWISE IDENTIFIED ABOVE AND ON ANY ADDITIONAL SHEETS SUBJECT TO THE TERMS AND CONDITIONS SPECIFIED HEREIN.

29. ☐ AWARD OF CONTRACT: REFERENCE ____________ OFFER DATED ____________. YOUR OFFER ON SOLICITATION (BLOCK 5), INCLUDING ANY ADDITIONS OR CHANGES WHICH ARE SET FORTH HEREIN, IS ACCEPTED AS TO ITEMS:

30a. SIGNATURE OF OFFEROR/CONTRACTOR

Andrew Allen

31a. UNITED STATES OF AMERICA *(SIGNATURE OF CONTRACTING OFFICER)*

30b. NAME AND TITLE OF SIGNER *(TYPE OR PRINT)*

Andrew Allen Sales Engineer

30c. DATE SIGNED 10/8/01

31b. NAME OF CONTRACTING OFFICER *(TYPE OR PRINT)*

31c. DATE SIGNED

32a. QUANTITY IN COLUMN 21 HAS BEEN

☐ RECEIVED ☐ INSPECTED ☐ ACCEPTED, AND CONFORMS TO THE CONTRACT, EXCEPT AS NOTED

33. SHIP NUMBER

☐ PARTIAL

34. VOUCHER NUMBER

35. AMOUNT VERIFIED CORRECT FOR

36. PAYMENT ☐ COMPLETE ☐ PARTIAL ☐

37. CHECK NUMBER

32b. SIGNATURE OF AUTHORIZED GOVT REPRESENTATIVE

32c. DATE

38. S/R ACCOUNT NO.

39. S/R VOUCHER NO.

40. PAID BY

42a. RECEIVED BY *(Print)*

41a. I CERTIFY THIS ACCOUNT IS CORRECT AND PROPER FOR PAYMENT

41b. SIGNATURE AND TITLE OF CERTIFYING OFFICER

41c. DATE

42b. RECEIVED AT *(Location)*

42c. DATE REC'D *(YY/MM/DD)*

42d. TOTAL CONTAINERS

8. Past Performance and References

Hamamatsu Photonics has been a world leader in the development and manufacture of Photomultiplier Tubes for over 40 years. A brief history of the company and summary of present facilities is shown in the attached brochure[3] *Photon is Our Business --Corporate Outline* dated July 2001. A summary of the different divisions and corporate research projects for Hamamatsu is detailed in the attached brochure[4] *Photon is Our Business—A brief look at the Company.*

Hamamatsu has successfully completed a number of PMT projects for space applications. Table 8-A shows a summary of these projects. In particular, the SOHO & EVRIS Missions for France used the R4444-03 ½" PMT (essentially identical in construction to the proposed R4443 for GLAST ACD). All the projects in Table 8-A have been successfully completed with quantity and delivery dates as indicated.

Table 8-A: *Reference List for Hamamatsu PMT's in Space projects*

Project Name	Agency / Country	PMT number	Qty	Delivery Schedule	Contact Information
AMS	INFN Bologna / Italy	R5900 (1"Metal Package PMT)	500	July 96 to Nov 96	Dr.Palmonari
	TELEOMNI / Taiwan		150	May 97 to June 97	Dr.Laurenti
SAX	LABEN / Italy	R5015 (3"PS-PMT) <*Note 1>	Qual 1	May 92 to Aug 92	Mr.Latza
			FLT 6		Dr.Dobler
	ESTEC / Netherlands	R5118 (3"MA-PMT) <*Note 2>	Qual 1	Aug 92 to Feb 93	
			FLT 5		
SOHO (GOLF Project)	CEA SACLAY / France	R4444-02 (1/2"PMT)	Qual 7	Oct 90 to Jan 92	Mr.R.Duc
			Flt 23		Mr. D.Krakowski
EVRIS Mission	OBS De Meudon / France	R4444-03 (1/2"PMT)	Qual 3	Oct 91 to Jan 92	Mr.Epstein
			Flt 7		

Note 1 : PS-PMT => Position Sensitive PMT
Note 2 : MA-PMT => Multi Anode PMT

Approximate value for SOHO contract was $200,000
Approximate value for EVRIS contract was $150,000

Contact Details related to Table 8-A:

- Gerard Epstein, Observatoire de Meudon
  5 PLACE JULES JANSSEN 92195 MEUDON PRINCIPAL CEDEX, FRANCE
  tel: +33.1.45.07.77.22 fax:+33.1.45.07.28.06 e-mail: gerard.epstein@obspm.fr

- Federico Palmonari, INFN Bologna , V.LE.B Pichat 6/2 Bologna, BO 40126 Italy
  Tel 051 209 5143 Fax 051 2095040 email: palmonari@bo.infn.it

- Giuliano Laurenti , INFN Bologna V.LE.B Pichat 6/2 Bologna, BO 40126 Italy
  Tel 051 6305263

- Franco Cervelli, INFN PISA
  VIA Vecchia Livonese 1291 S. Piero A Grado PI 56010 Italy
  050 880241 email: cervelli@pi.infn.it

- Rene Duc, CEA-CEN Saclay DSM/DAPNIA
  91191 GIF Sur Yvette Cedex
  ph: 01.69.08.55.03 email: rene.duc@cea.fr

Hamamatsu expects to be awarded contract for PMT's for the Messenger Spacecraft Mission this month. This contract will include qualification and flight models for ruggedized versions of ½" diameter head on PMT's models R759, R1080, R1081. These PMT's have similar construction to the proposed R4443, but incorporate Cs-Te photocathodes with Quartz windows. The R1081 was successfully flown on the Cassini (1998) and Snoe(1999) missions.

- Messenger Spacecraft UV Spectrometer, U. of Colorado LASP
  R759, R1080, R1081 ½" ruggedized PMT's Qualification and Flight Units
  Contact: Ginger Drake, U. of Colorado
  Ph: 303-492-5899 email:drakev@spot.colorado.edu

Hamamatsu has been involved in many ground based high energy physics projects over the years involving large number of photomultiplier tubes. Below is a partial list of some relevant completed projects that demonstrate Hamamatsu's ability to provide high quality PMT's in large quantity to meet critical applications for high energy physics experiments.

- KTev at Fermilab
  2300 pcs of R5364 (3/4" dia) and 1000 pcs R5330(1.5" dia)
  Contact Dr. Katsushi Arisaka, UCLA
  Ph: 310-825-4925 Email: arisaka@physics.ucla.edu

- Wipple Gamma Ray Telescope
  300 pcs R1398 (1-1/8" dia)
  Contact: Dr. John Finley, Purdue University
  Ph: 317-494-5048

- CDF Upgrade at Fermilab
  2100 pcs of R4124 (3/4" dia)
  Contact: Dr. Jim Freeman

9. Document References

Copies of the relavant referencesa are included with proposal.

1) Hamamatsu PMT Handbook *Photomultiplier Tubes—Basics and Applications,* 2nd Edition, Hamamatsu 1999

2) Hamamatsu *Ruggedized High Temperature Photomultiplier Tubes* Catalog, Feb 1999

3) Brochure: *Photon is Our Business* -- Corporate Outline, Hamamatsu, July 2001

4) Brochure: *Photon is Our Business* -- A Brief Look at the Company, Hamamatsu, July 2001