2

BEDFORD ENGINEERING CORP.

(NASA-CR-120291) PHOTOMULTIPLIER TUBE RELIABILITY STUDY FOR THE HEAO PROGRAM (Bedford Engineering Corp., Mass.) ~~65~~ 73 p HC $6.25 CSCL 09A

N74-27684

Unclas G3/09 16967

[redacted]

BEDFORD, MASSACHUSETTS

ALEXANDRIA, VIRGINIA

13

Report
on
Photomultiplier Tube Reliability Study
for
The HEAO Program

January, 1974

Contract No. NAS8-28265

Prepared for: George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

By: Carl Richardson
Bedford Engineering Corporation
P. O. Box 252
Bedford, Massachusetts 01730

TABLE OF CONTENTS

2<

1. INTRODUCTION

This report contains the results of a Photomultiplier Tube Reliability Study performed under Contract No. NAS8-28265. The purpose of the study was to provide reliability information on the Photomultiplier Tubes required for the HEAO Program and to produce specifications for their qualification and procurement. A general specification covering both ruggedized glass and stacked-metal-to-ceramic PMT's and slash sheet specifications for the individual types were to be prepared.

As originally planned, the HEAO-A experiments would have required more than 240 Photomultipliers and HEAO-B experiments would have required at least 358. Only a very few of these requirements could be met with PMT's that had already been qualified for use in space application. Furthermore, it was anticipated that at least three different manufacturers would be involved in fulfilling the requirement. The general specification was intended to provide a series of tests to help insure operational reliability in the applications and to permit comparison of performance of similar PMT types from various manufacturers.

The plan outlined for the study was as follows:

A. Contact each of the HEAO experimenters and determine their particular requirements.

B. Contact the anticipated suppliers (EMR, RCA, and Varian) to review reliability histories and the design and manufacturing techniques of PMT's of the same types or classes required.

C. Contact previous users of PMT's of the same type or class required for HEAO to obtain any pertinent reliability information that might be available.

D. Prepare a draft of a general procurement specification for the HEAO PMT's.

E. Prepare slash sheet specifications for the individual PMT's.

By the time that the first draft of the general specification had been submitted and was being discussed, the program was changed to the point where only about 40 PMT's would be required for HEAO-A. On the basis of this limited requirement it was decided that it would not be practical to attempt to implement the specification. Since completely satisfactory designs still did not exist for the remaining requirements, the scope of our contract was changed to cover some testing of the prototype 3-inch and 5-inch stacked-metal-to-ceramic PMT's.

The results of the tests are included in the report. The tubes involved were:

1	RCA	C31027	Purchased under the contract
1	Varian	21J19-12	Purchased under the contract
1	Varian	21J11-12	Provided by M.I.T.
2	Varian	21J19-12	Provided by M.I.T.
1	RCA	C31027	Provided by M.I.T.
1	RCA	5-inch Eng. Model	Provided by M.I.T.
1	RCA	5-inch Prototype K0124	Provided by M.I.T.

Some test results on seven RCA C31047 stacked-metal-to-ceramic 3-inch tubes purchased during the fall of 1973 for use on another contract are also included.

On the basis of the test results it appears that the RCA Prototype No. K0124 can fulfill the present HEAO-A performance requirements for 5-inch PMT's. This Photomultiplier has much better spatial uniformity than the earlier designs that were tested and the fatigue characteristics appear to be suitable. There was a wide variation in the fatigue characteristics of the Varian PMT's and none of the 5-inch units were really suitable.

On the basis of information obtained during the study we feel that more attention should have been given initially to the possibility of obtaining ruggedized versions of some of the high performance glass Photomultiplier Tubes. The EMI 9712 NB is a ruggedized version of such a tube and might well withstand the stresses produced during launch. The primary advantage to this approach, if it is feasible, is that the dynodes can be activated in a more uniform and predictable manner. The importance of this will be discussed below. A second and not in significant advantage where large quanities are involved is that the cost would be less than for either the stacked-metal-to-ceramic or fused-glass-to-metal structures. The origin of these structures stems from Photomultiplier developments for the oil well logging field where the mechanical and temperature stresses are much more severe than in the HEAO applications.

There are at least two important reasons for having the dynodes uniformly and predictable activated for most of the HEAO applications. These are the higher multiplier gain and the improvement in fatigue characteristics. In the stacked-ceramic PMT's the gain of the higher order dynodes decreases due to the fact that there is less cesium deposited. This is caused by the fact that the cesium reaching these dynodes must migrate or pass through the open spaces in the lower order dynodes. Since PMT fatigue, or loss of anode sensitivity as a function output current level, is thought to be the results of erosion of the cesium from the dynode surfaces, this important characteristic is also affected by the amount and uniformity of the cesium deposited on the higher order dynodes.

2. DISCUSSION

2.1 Original HEAO-A Requirements

The list of Photomultiplier tubes required for the original HEAO-A experiments is shown below. The Photomultipliers being considered at the time the Experimenters were contacted are also indicated.

Experiment	PMT Description	Types under Consideration
A x R - 1	None	
A x R - 2	None	
A x R - 3	48 - 5-inch	RCA C31029 and C31040
		Varian 21-J19-12
	45 - 2-inch	RCA C31057 (Ruggedized 8575)
	2 - 2-inch UV	EMR-541-F-05M-14
	2 - 2-inch	Various EMI and EMR
AGR - 4	22 - 1½-inch	Domed RCA-C70132A
	4 - 3-inch	Varian
	1 - 5-inch	Varian 21J19-12
AGR - 5	12 - 1-inch to 1½-inch	RCA C7151Q
	4 - 5-inch	RCA - Stacked Ceramic
		Varian - Stacked Ceramic
AGR-6	52 - 2-inch	RCA 31057 (Ruggedized 8575)
	8 - 5-inch w/UV windows	RCA C31038A
	16 - 2-inch w/2 nsec rise time	RCA 31057 (Ruggedized 8575)
AGR-7	25 - 5-inch	RCA C31056

2.2 Photomultiplier Status at the Beginning of the Study

At the time original contact was made with the Experimenters, June - August, 1972, the status of the Photomultipliers they were considering was as follows:

A. EMR

The EMR 541F-05M-14 that was being considered for use in AXR-3 is a ruggedized device comprised of a fused envelope containing successive metal rings which serve as both electrical contacts to the secondary emitting dynodes and rugged structural elements. This tube and similar tubes with the same type of construction have been used successfully in numerous space applications. In addition, they had completed an Inspection Plan in accordance with NPC 200-3 for HEAO Photomultiplier Tube Qualification.

Consideration had been given to the possible use of 2-inch EMR Photomultiplier Tubes for the AGR-6 requirement. It had been concluded, however, that a shorter and less expensive PMT, the ruggedized version of the RCA 8575, would be suitable for the application.

B. RCA

Various versions of the RCA stacked-ceramic-to-metal PMT had been used in numerous space applications and there was no question that the structure would withstand the shock and vibration stresses encountered during launch. There was concern however, regarding the detailed performance requirements for some of the HEAO experiments. The AGR-7 experiments had been planned around a PMT designated C 31056 which had still not been produced and the concern in this particular case was the relatively high gain requirements. There was also concern about the spatial uniformity and fatigue characteristics of the

PMT's required for AXR-3 and AGR-5 experiments.

A prototype of a ruggedized version of the 8575 had been constructed and it has successfully passed the shock and vibration requirements outlined in a specification by GSFC. It appeared as though this PMT could be sold for less than $600 and would fulfill the 2-inch requirements for both AXR-3 and AGR-7.

The 1½-inch domed C70312 had been used in previous space applications without any reported difficulty. A quanity of 16 of the C7151Q's had also been used in the OGO-5 experiment without any difficulty being encountered. These C7151Q's had been selected out of a batch of 40 after they had been aged and tested according to a procedure developed by Dr. A. Sheepmächer at Lyden University. Dr. Sheepmächer reported that at least 24 of the aged tubes would have been acceptable.

C. <u>Varian</u>

Varian had produced about 200 of their 1-inch and 2-inch stacked-metal-to-ceramic tubes. They had started a total of only five 5-inch tubes and three of these had been scrapped during the manufacturing process. One of the two useable tubes had been shipped to NRL and the other to UCSD. They accepted an order under this study contract for a 21J19-12 for delivery in December of 1972.

The Varian PMT Product Manager at the time of survey, Mr. R. Goehner, was convinced that he had optimized the design of the electron optics for 3-inch and 5-inch PMT's and could meet the spatial uniformity requirements. He was concerned, however, about the fatigue requirements being discussed by MIT and NRL. Varian was in the process of preparing a proposal for some quanity of 3-inch and 5-inch tubes for UCSD.

2.3 Reliability Histories and Outlook

Both EMR and RCA provided pertinent lists of names of previous users of their Photomultiplier. These lists and the responses we received to our inquiries are outlined below:

A. EMR

Customer	Experimenter	Tube Type	Program
JHU/APL	F. Shenkel	541N	SAS
JHU	Prof. W. Fortre	UV MPT's	Apollo & Rockets
GSFC	W. Hibbard	541N	SSS
GSFC	Dr. Kupperian	UV MPT's	OAO
	Mr. L. Dunkelman	UV MPT's	OAO
Dudley Obs.	Dr. J. Weinberg	541E's	Sky Lab
Harvard Univ.	Dr. E. Reeves	UV MPT's	OAO
Kollsman	L. Siefert	541D's	OAO
Princeton Univ.	E. Wilson	541D	OAO
GSFC	Dr. D. Heath	541D	OGO
JPL	Dr. Scott	541D	Apollo

Representatives of most of the experimenters were contacted by telephone. There were no reports of in flight failures or serious changes in performance characteristics. We also contacted the Harshaw Chemical Co.

regarding approximately two hundred 2-inch PMT's that were used in ruggedized portable instruments during 1971. Harshaw reported that to their knowledge no failures had occurred.

The only note of caution expressed by any of the users contacted, JPL, had to do with the "potting" of the tubes. EMR recommends that they supply PMT's with the dynode dividers attached and potted. Where this is not feasible, EMR will recommend the potting material and techniques which should be used.

Our conclusion based on the history of high reliability and two visits to the EMR facility in Princeton, N.J. is that they do an outstanding job of producing the Photomultiplier Tubes which they supply. HEAO-A experimenters who had considered EMR PMT's and decided against using them had done so on the basis of their longer length and higher cost, relative to RCA's ruggedized 8575.

B. RCA

Customer	Experimenter	Tube Type	Program
Univ. of Chicago	J. Jezewski	C70102E	Pioneer
GSFC	K. Frost	C70132B	OSO-H
UCSD	Dr. L. Peterson	C70132B	OSO
Univ. of N.H.	Dr. E. Chupp	C70132B	OSO
Univ. of N.H.	Dr. E. Chupp	C31012	OSO
JPL	Dr. A. Metzger	C70114M	Apollo
JPL	Dr. A. Metzger	C31009	Apollo
GSFC	Dr. R. Ross	C7151Q	SAS-B

Customer	Experimenter	Tube Type	Program
GSFC	Dr. R. Ross	C31029	SAS-B
GSFC	Dr. R. Hartman	C7151Q	SAS-B
Univ. of Minn.	Dr. R.J. Bingham	C31009C	Pioneer
LRL(LLL)	Dr. A. Toor	C31027	Thor Launched Stellar X-ray Experiment

Only one catastrophic failure of a stacked-metal-to-ceramic PMT was reported to have occurred in an experiment. This was a C31027 which failed due to an internal high voltage breakdown in the LRL Thor Launched Stellar X-ray Experiment. The University of New Hampshire had also experienced some unexpected fatigue effects in a C31012 used in their OSO experiment.

We had experienced outgasing in four C 31009's purchased for used at Bedford Engineering during 1971. JPL reported the same difficulty with C 31009's purchased for the Apollo program about the same time. This difficulty was traced to a deficiency in one of the processing procedures and replacement units have shown no sign of the problem after almost 3 years.

There was also one reported loss of a 7151 Q PMT. This was due to a cracked face plate in SAS-B during 1969.

There were no reported failures of the domed 1½-inch C 70132 series, the C 70114M or the C 70102E.

RCA's test results on the prototype

of the ruggedized 8575 is the only information we have on these new tubes. We understand that two units now designated C31057 were delivered to GSFC. The 8575 itself, however, has an excellent performance history and was used in some rocket borne experiments by Dr. Price of GSFC without any difficulty. Therefore, there is no reason to believe that the C31057 will not be suitable for application such as HEAO.

Our impression of RCA was that they are the best qualified of the manufacturers in terms of experience and resources to produce the ruggedized 3-inch and 5-inch PMT's being considered for the HEAO program. We believe that this confidence was justified on the basis of the 5-inch prototype which they finally delivered to MIT. We do believe, however, that there have been enough questions about and changes in their processing procedures to justify full scale qualification testing, with of course the possible exception of shock and vibration, before they are used in costly space experiments.

C. Varian

There is essentially no reliability history on the Varian 3-inch and 5-inch Photomultiplier tubes.

Our impression at the time that we visited their facility was that they had the basic capability to produce their products, but needed more experience to work out the normal production problems. We do not know if they have tried to maintain this capability in light of the greatly reduced requirements.

As mentioned earlier, the spatial resolution on their PMT's was quite good. The fatigue characteristics, however, were different from unit to unit and not suitable for some of the applications. Varian was concerned about the prospect of having their tubes operated at anode currents as high as 10 microamperes, so the test results are not really surprising.

2.4 Test Procedures

Due to the fact that most of the Photomultiplier Tubes for the HEAO program were to be used in experiments involving scintillation (or Cerenkov) counting, an attempt was made in the preparation of the draft of the general specification to simplify the normal PMT testing procedures. Depending on the details of the particular counting experiment, the following parameters are important in varying degrees:

A. Transfer Function

(the amount of charge delivered to the anode for a given size burst, "scintillation", of photons delivered to the photo cathode)

B. Energy Resolution

(scintillation spectrometer applications)

C. Noise Pulse Spectrum and Intensity

D. Spatial Uniformity

All of the above parameters are directly relevant to scintillation counting. The other approach to PMT performance testing and one often seen in manufacturers' literature derives from the earlier use of PMT's as sensitive detectors of more or less continuous light beams that are incident on the photo cathode. Thus, instead of the transfer function as defined above, one sees instead a "luminous sensitivity" as being so many amperes per lumen. High values of what is referred to as "cathode efficiency" are looked at as indicating good energy resolution performance (good photo electron statistics), especially when coupled with good photo cathode uniformity. Low "dark currents" are required for good resolution at low "scintillation" energy.

The measurements would have been made as follows:

<u>Transfer Function</u>

We proposed to express the transfer function in units of pico coulombs per Mev with the PMT high voltage setting in parenthesis. The light source (pulser) would consist of a good quality 3/4-inch diameter by 3/4-inch high NaI(Tl) scintillation crystal mounted with a diffuse reflector in an aluminum can and a 0.3 microcurie Cs^{137} source (filtered by 0.2-inch lucite) is attached. See Figure in the general specification.

The measurement is made with the scintillation crystal located on the axis of the tube and coupled with Nujol or similar coupling material. The average charge per 662 Kev scintillation delivered from the anode can best be measured with a multichannel analyzer; however, an oscilloscope may be used. A convenient way of calibrating the output is by injecting 10-11 coulomb pulses by means of a 10 pF capacitor and a 1 volt square wave.

With this test source approximately 13,240 photons are produced per scintillation (total energy peak, assuming 20 photons produced per Kev). Using the published data for the RCA C31029 PMT, an average of 3,575 photo electrons would be produced (photo cathode efficiency = 27%). This is a charge of 5.72 x 10-16 coulombs, which when multiplied by 3.5×10^4 (PMT current amplification at 1,200 volts) yields 2 x 10-11 coulombs (0.4 volts for a 50 pF input capacitance). Thus, the transfer function as defined above would be:

30.2(1,200) pC/Mev

It is expected that light pulsers made up in this way will have some variation from unit to unit. However, the major reason for doing this test is to detect changes that may occur in the tube during the environmental phases of the testing.

Energy Resolution

The set-up for measuring the energy resolution performance of the PMT is the same as for measuring the transfer function except that a 0.3 microcurie Am^{241} source is substituted for the Cs^{137} line. Specifically the width of the spectral lines at these lower energies is very dependent on the photo cathode efficiency. By using small source sizes we are illuminating only a small part of the photo cathode and photo cathode uniformity does not contribute to braodening the resolution.

The full width at 1/2 maximum is measured for the Am 59.5 Kev photo peak and the result expressed as a percentage of the total energy. A multichannel analyzer is necessary for this measurement.

Noise Pulse Spectrum

Using the same set-up as above, the multichannel analyzer is calibrated so that each channel corresponds to 0.2 Kev. A tube pulse noise spectrum is then run for at least 10 minutes. Usually in the literature such curves are plotted against what are called photo electron equivalents. By doing it this way, plotting against Kev of input energy, the results are directly relevant to seeing what the noise is likely to be at a particular input energy. We are especially interested in seeing how the pulse noise intensity above an equivalent input of a few Kev behaves as a function of some of the environmental testing. The results may be diagnostic for gassy tubes. This test is quite a bit different than just measuring the anode dark current since almost all of the contributions to the anode dark current are the thermal electrons from the photo cathode and the first few dynodes and the contribution of the higher energy bursts of photo electrons cannot be seen in the dark current measurement.

Spatial Uniformity

Using the transfer function measurement setup the light source is moved about the photo cathode until the maximum and minimum values of the transfer function are found. The difference between these values, divided by the on-axis transfer function, times 100, is the spatial uniformity (%). As an alternative the light source can be moved to certain specified positions and a map of the photo cathode uniformity obtained. (An alternate light source for this measurement was produced by Harshaw for Dr. Sheepmächer at MIT. It is a ¼-inch diameter NaI(Tl) crystal with an Am^{241} pulser built in.)

On the basis of the small number of PMT's required for the scaled down HEAO program, we do not believe any savings could be anticipated as a result of using these simplified procedures. If the full program should be revised at some later date, however, we still feel that they would be worthwhile.

3. TEST RESULTS

3.1 Spatial Uniformity

The relative pulse height was measured with a light pulser located at seven different points on the fact of the 3-inch PMT's and 19 points on the 5-inch units. Plots of the results of the measurements on the various PMT's acquired under the HEAO program are shown on the following pages. In addition to these plots, the results of measurements on the seven C31047's purchased for another contract are summarized below.

Serial No.	Uniformity (1)	Resolution (2)	Gain (3)
K 0099	20%	8.2%	0.97 (0.5)
K 0106	24% (19%)	10.2%	1.4 (1.1)
K 0108	30% (25%)	(4)	
K 0109	19%	8.2%	1.2 (0.7)
K 0111	14%	8.2%	2.65 (1.9)
K 0112	24% (13%)	10.9%	1.2 (0.8)
K 0116	24% (19%)	10.8%	1.25 (0.6)

Notes:
(1) Measurements were made with M.I.T.'s ¼-inch Am^{241} pulser. The number in ( ) is the uniformity if the worst of the seven measurements is deleted.
(2) 3-inch diameter x 5-inch length NaI(Tl) crystal; 8uc Cs^{137} on axis at 10 Cm.
(3) RCA's reported amps per Lumen (Blue) at 1,500 volts. The number in ( ) is relative (K · Q/E) at 1,000 volts.
(4) Unstable gain.

3.2 Fatigue Properties

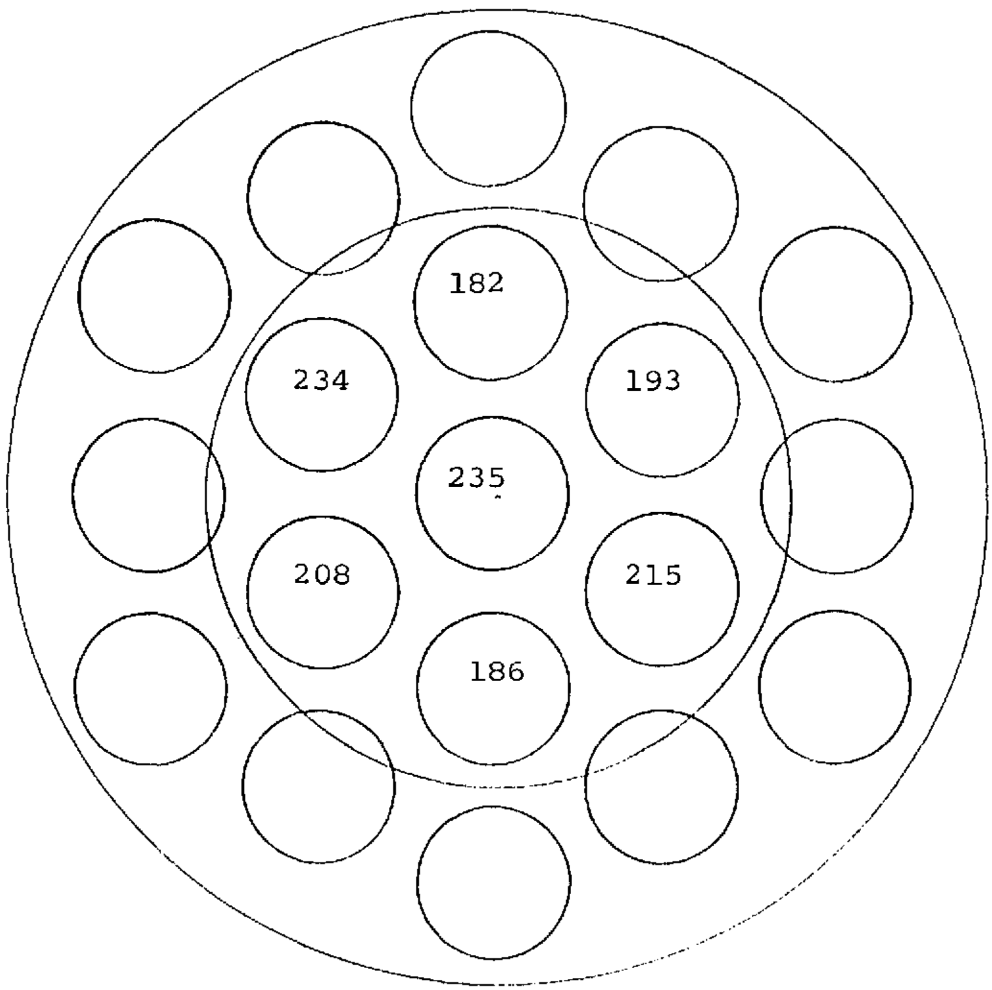
A NaI(Tl) crystal was used as the source of light for the fatigue measurements. The source was

100 millicuries of Gd^{153}. Measurements were made on the PMT's listed below and the results are plotted on the following pages.

Varian:	21J19-12	S.N. 262
	21J19-12	S.N. 271
RCA:	C31027	S.N. 0149
	5-inch Engineering Model	S.N. K 0105
	5-inch Prototype	S.N. K 0124

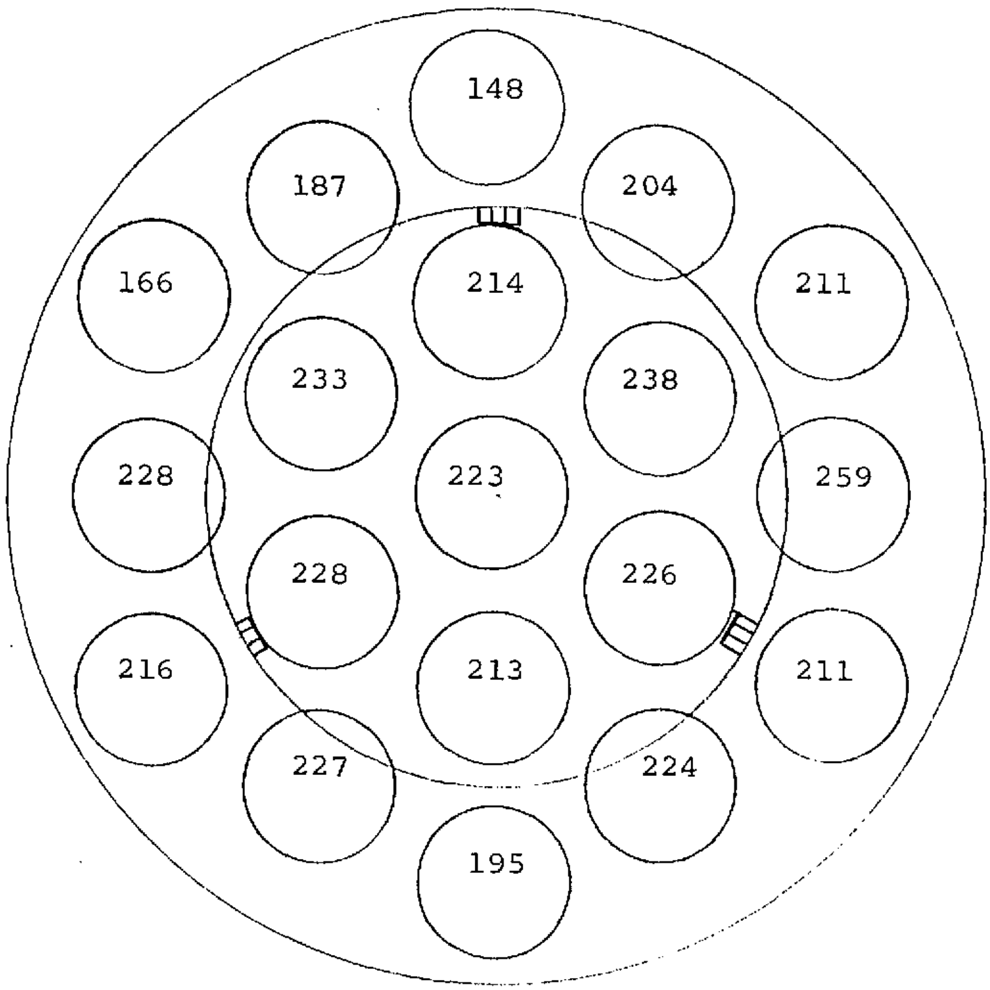
The Varian 3-inch 21J11-12, S.N. 336, was also fatigue tested, but the results were not plotted. They were similiar to those of the first phase of the RCA K 0124.

Am^{241} Pulser
ES-354 (M.I.T.)
1000 Volts
8/11/73



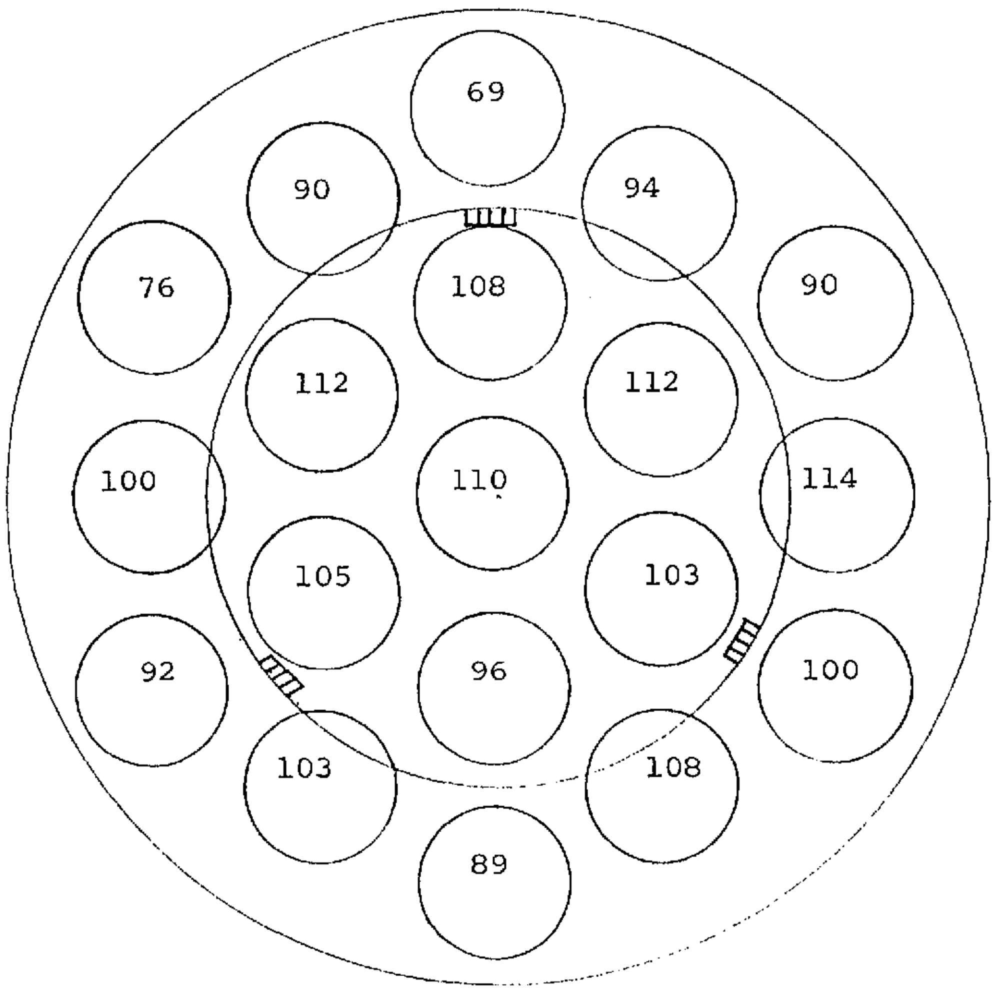
Relative Pulse Height
Varian 21J11-12 S.N. 336

Am^{241} Pulser
ES-354 (M.I.T.)
1200 Volts
8/11/73



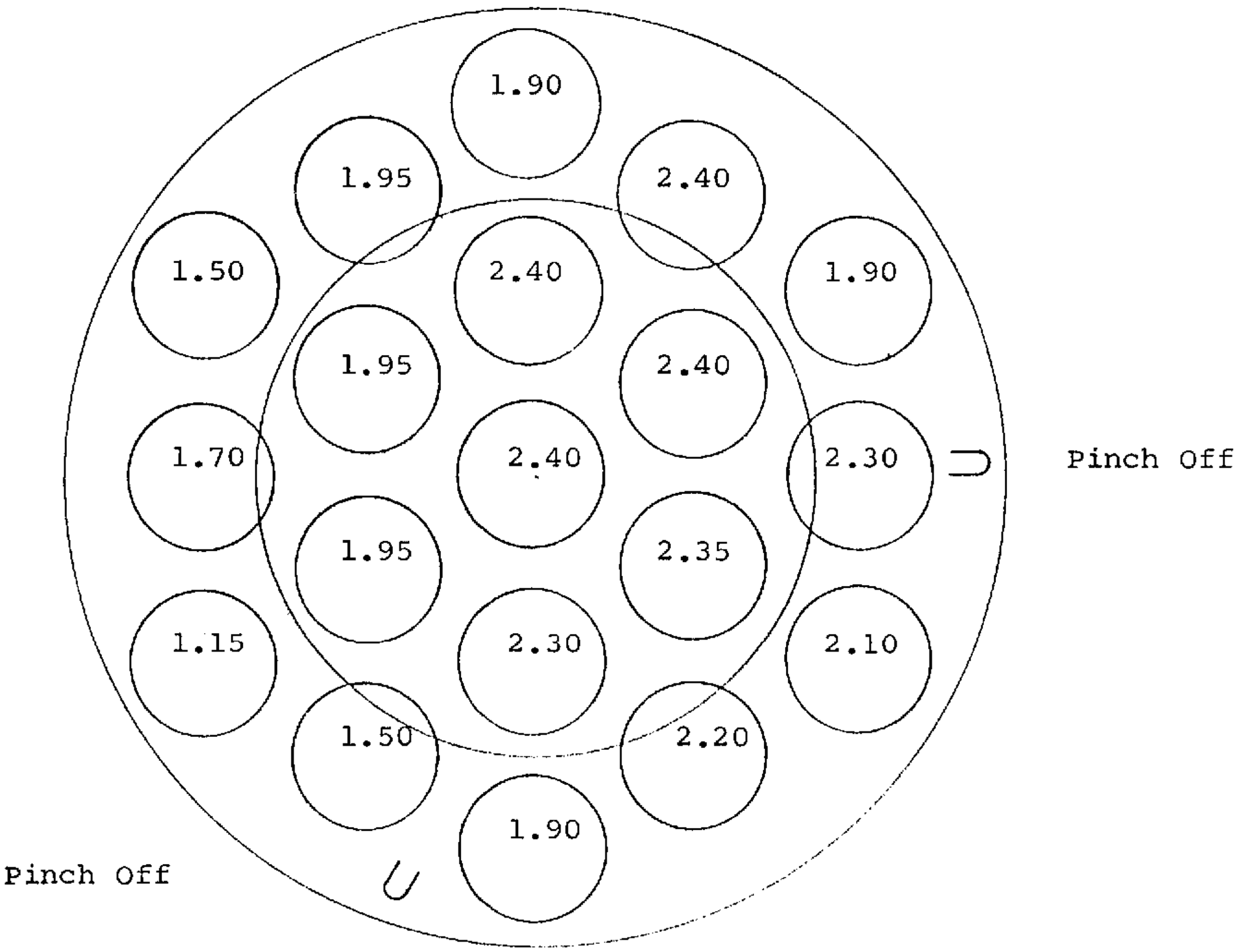
Relative Pulse Height
Varian 21J19-12 S.N. 199

Am^{241} Pulser
ES-354 (M.I.T.)
1000 Volts
8/11/73



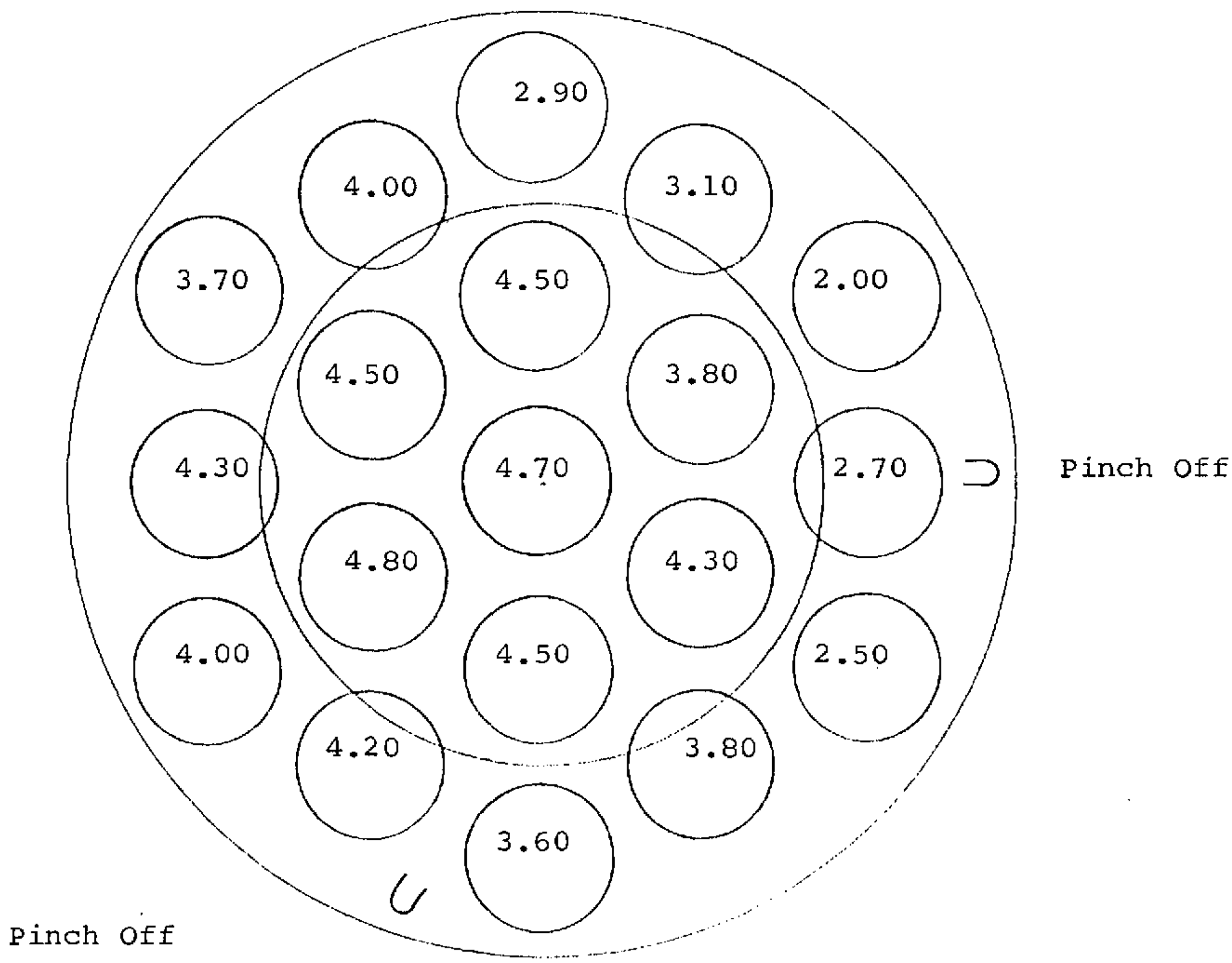
Relative Pulse Height
Varian 21J19-12 S.N. 271

1¼" $C_sI(Na)$
Bi^{207}, 570 Kev
1200 Volts
11/14/72



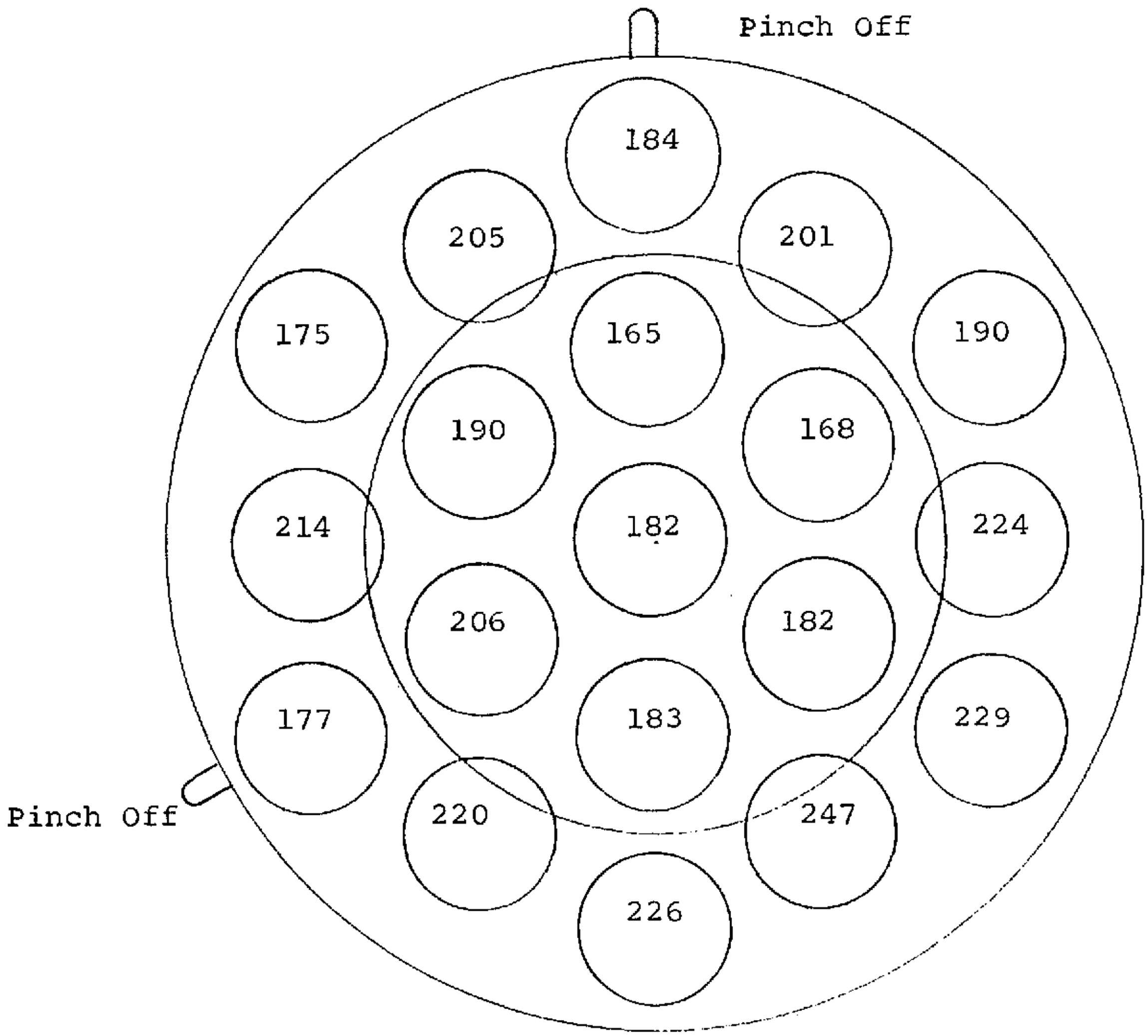
Relative Pulse Height
RCA C31027 #V0149 purchased for Contract

1¼" $C_sI(Na)$
Bi^{207}, 570 Kev
1200 Volts
10-16-72



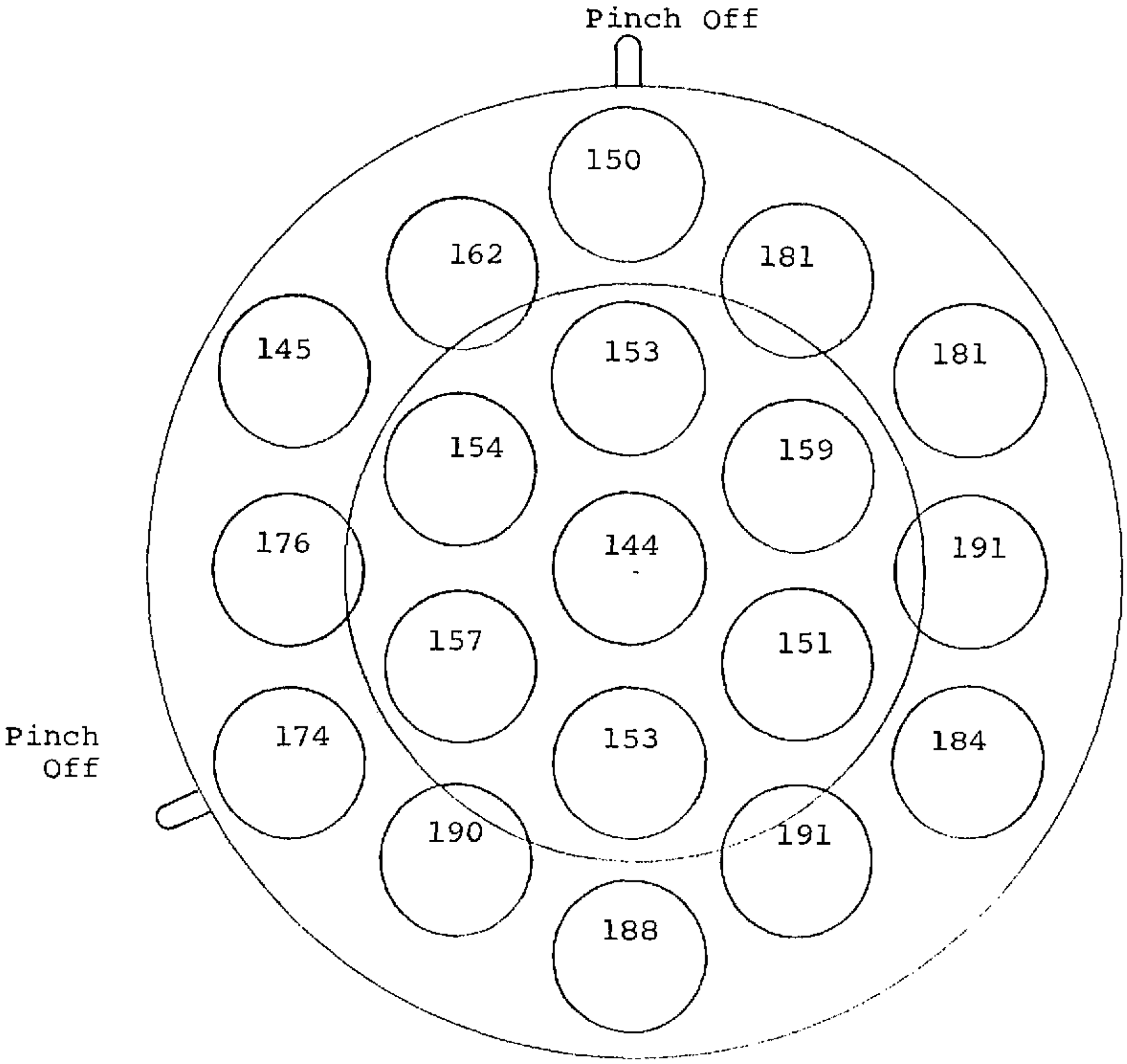
Relative Pulse Height
RCA C31027 on loan to M.I.T.

Am^{241} Pulser
ES-354 (M.I.T)
1000 Volts
8/18/73

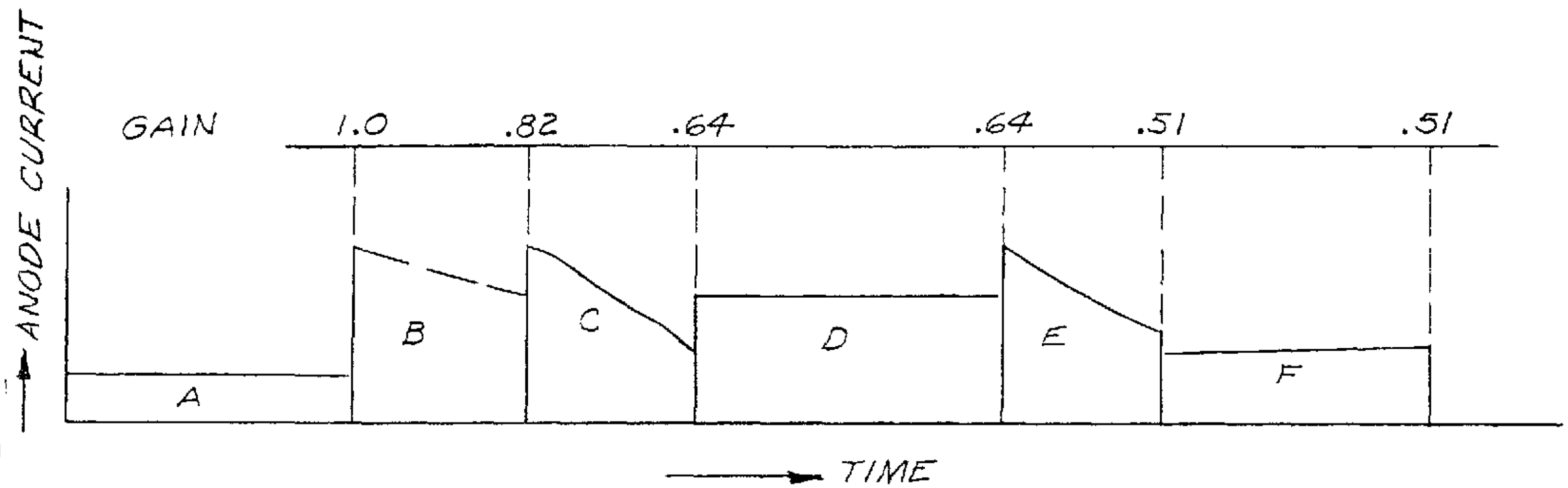


Relative Pulse Height
RCA 5" Engineering Model S.N. K0105

Am^{241} Pulser
ES-354 (M.I.T.)
1000 Volts
10/20/73



Relative Pulse Height
RCA 5" Prototype S.N. K0124



A. BURN IN, 18 HOURS AT 0.1 μA

B. FATIGUE, 2 HOURS AT 1 μA

C. FATIGUE, 2 HOURS AT APPROXIMATELY 10 μA

D. RECOVERY, NO RECOVERY AFTER 18 HOURS

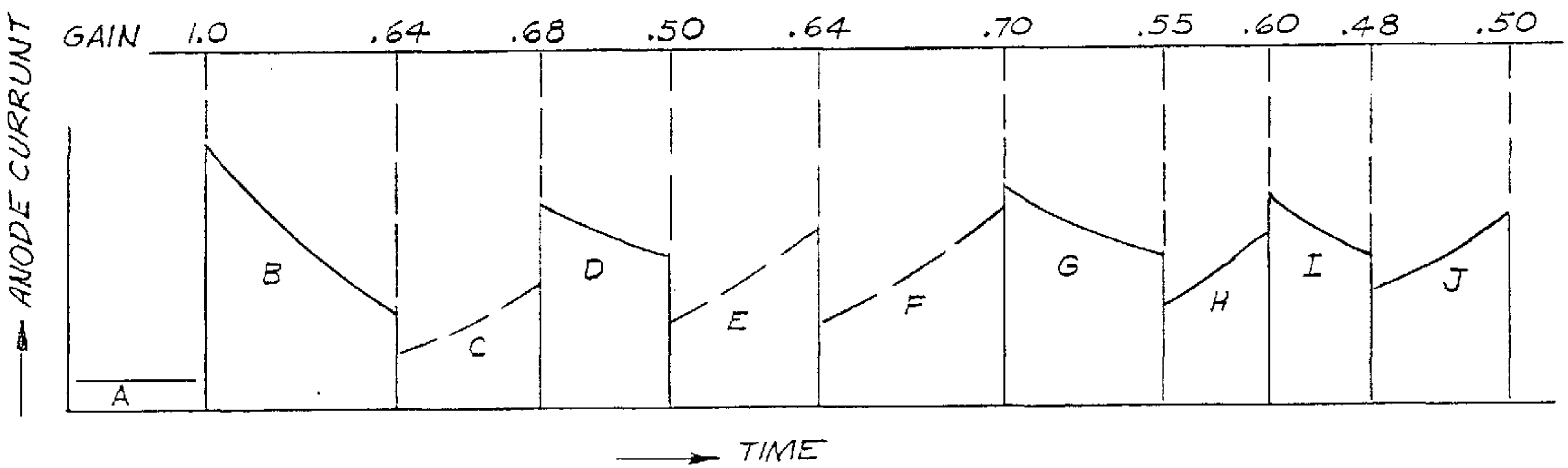
E. FATIGUE, 4 HOURS AT APPROXIMATELY 10 μA

F. RECOVERY, NO RECOVERY AFTER 2.5 DAYS

TOTAL FATIGUE OF
APPROXIMATELY 62 μA HOURS

FATIGUE MEASUREMENTS

VARIAC 21J19-12 S.N. 262



A. BURN IN, 100 HOURS AT APPROXIMATELY 150 nA

B. FATIGUE, 50 HOURS AT 1 μA

C. RECOVERY, 12 HOURS AT APPROXIMATELY 0.1 μA

D. FATIGUE, 6 HOURS AT 10 μA

E. RECOVERY, 12 HOURS

F. RECOVERY, 45 HOURS

G. FATIGUE, 6.1 HOURS AT 10 μA

H. RECOVERY, 3 DAYS

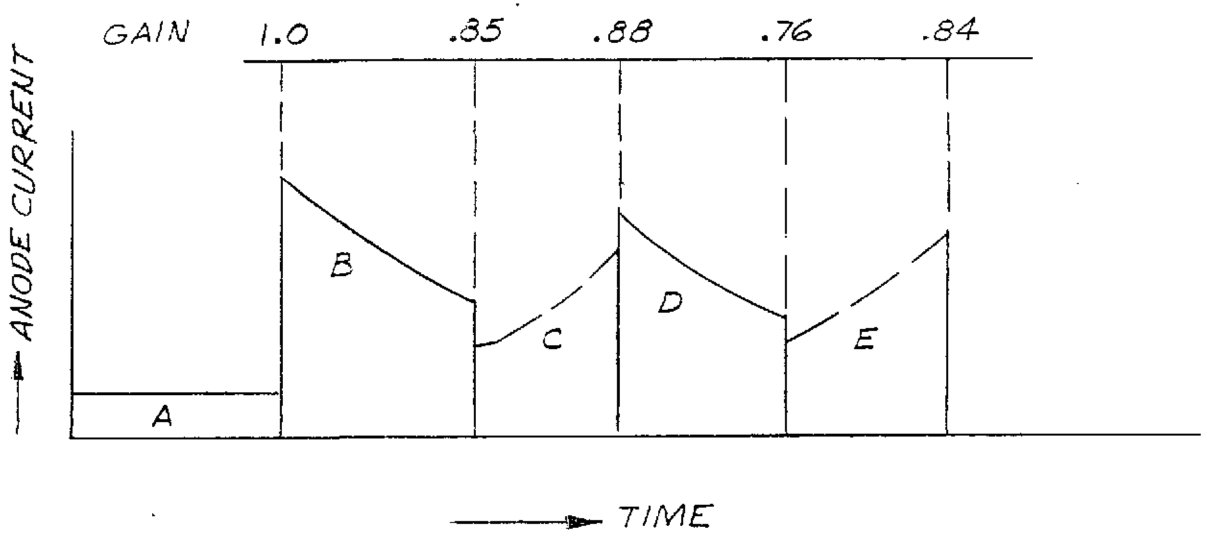
I. FATIGUE, 10.7 HOURS AT 10 μA

J. RECOVERY, 2 DAYS

TOTAL FATIGUE OF APPROXIMATELY 227 μA HOURS

FATIGUE MEASUREMENTS

VARIAC 21J19-12 S.N. 271



A. BURN IN, 21 HOURS AT APPROXIMATELY 160 nA

B. FATIGUE, 6 HOURS AT APPROXIMATELY 10 μA

C. RECOVERY, 12 HOURS

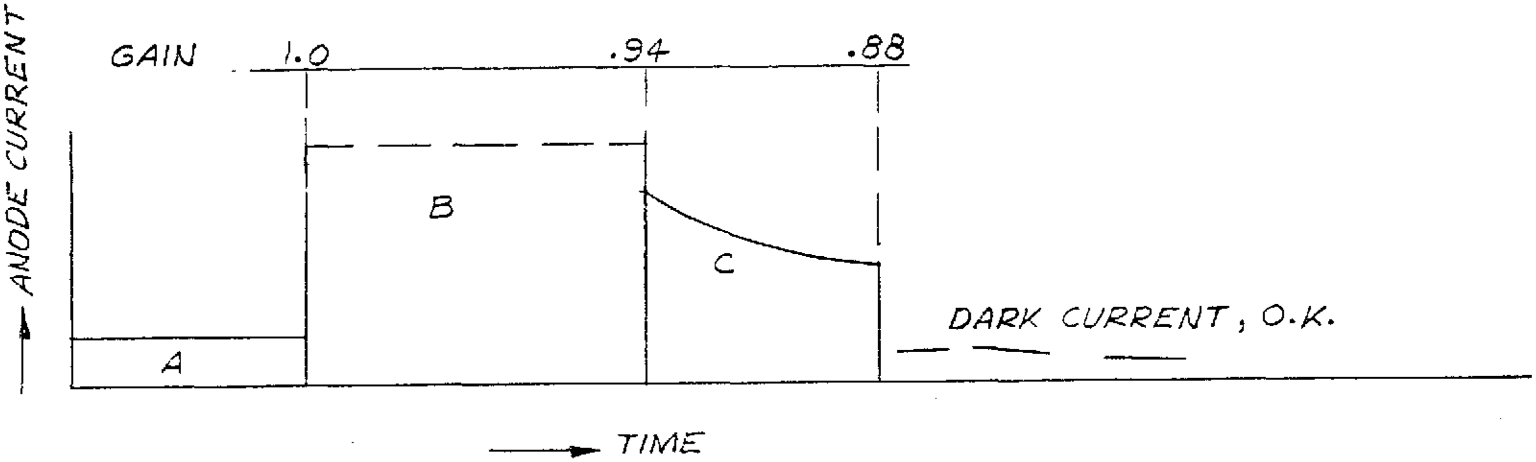
D. FATIGUE, 6 HOURS AT APPROXIMATELY 10 μA

E. RECOVERY, 1 DAY

TOTAL FATIGUE OF
APPROXIMATELY 120 μA HOURS

FATIGUE MEASUREMENTS

RCA C31027 S.N. 0149



A. BURN IN, 17 HOURS

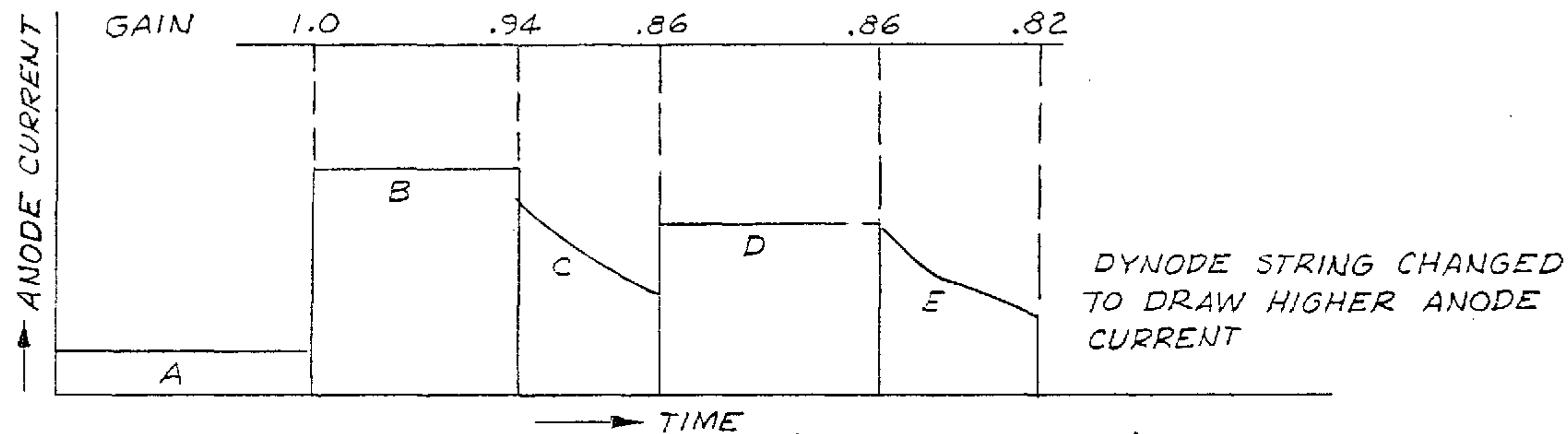
B. FATIGUE, 22 HOURS AT APPROXIMATELY 10 μA

C. RECOVERY, 40 HOURS

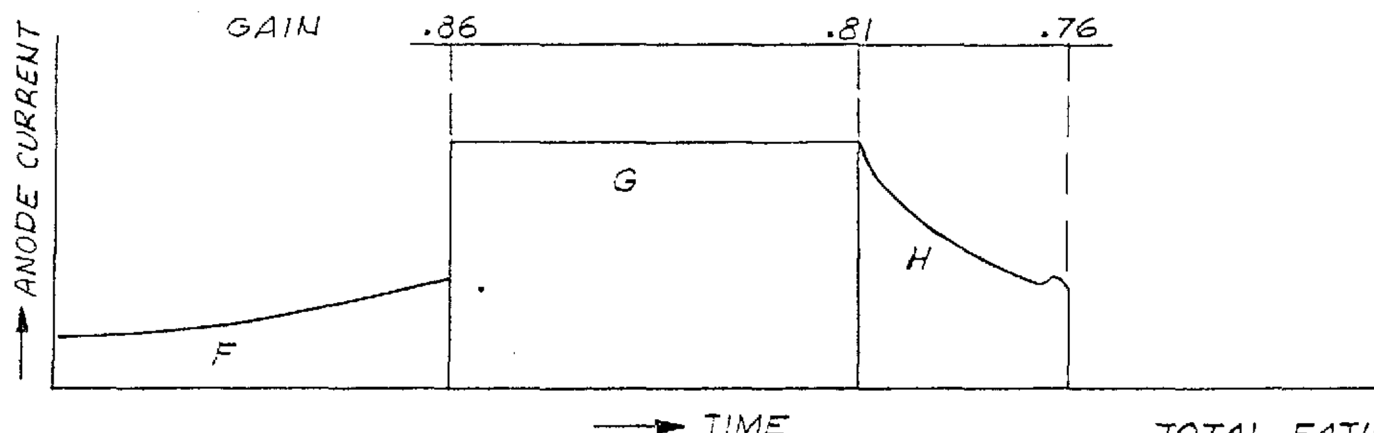
TOTAL FATIGUE OF
APPROXIMATELY 220 μA HOURS

FATIGUE MEASUREMENTS

RCA 5" ENGINEERING MODEL S.N. K0105



A. BURN IN, 29 HOURS AT APPROXIMATELY 1 μA (INCREASE IN GAIN)
B. FATIGUE, 12 HOURS AT APPROXIMATELY 9 μA
C. RECOVERY, 12 HOURS
D. FATIGUE, 10 HOURS AT APPROXIMATELY 10 μA
E. RECOVERY, 8 HOURS



TOTAL FATIGUE OF APPROXIMATELY 680 μA HOURS

F. BURN IN, 2 HOURS
G. FATIGUE, 22 HOURS AT APPROXIMATELY 20 μA
H. RECOVERY, 18 HOURS

FATIGUE MEASUREMENTS

RCA 5" PROTOTYPE S.N. K0124

APPENDIX A

(Preliminary)

Photomultiplier Tubes,

Specification for Procurement and Screening

For

HEAO Program

1. SCOPE

1.1 Scope - This specification establishes the requirements for photomultiplier tubes (PMT) to be met in the selection of the manufacturer, qualification, acceptance, screening, and receiving inspection of devices for space applications.

1.2 Objective - The objective of this document is to delineate the source approval, qualification, screening, and receiving inspection requirements to enhance the procurement of consistently high quality reliable PMT's which will improve the possibility of mission success.

1.3 Classification - PMT's procured to this document shall be classified as either Class I (stacked ceramic) or Class II (glass), relative to the ruggedization of the PMT construction, based on the device's ability to withstand the environmental conditions as defined in paragraph and substantiated by qualification testing.

2. APPLICABLE DOCUMENTS

2.1 Documents - The following documents form a part of this specification to the extent referenced herein. Unless otherwise indicated, the issue and revision if effect on the date of invitation for bids or request for proposals shall apply.

SPECIFICATIONS

National Aeronautics and Space Administration

S-320-G-1	General Environmental Test Specification for Spacecraft and Components
MIL-E-1G	Electron Tubes, General Specification For

STANDARDS

Military

MIL-STD-810B	Environmental Test Methods
MIL-STD-1311A	Test Methods for Electron Tubes

PUBLICATIONS

National Aeronautics and Space Administration

NHB 5300.4(1B)	Quality Program Provisions for Aeronautical and Space System Contractors
NHB 5300.4(1C)	Inspection System Provisions for Aeronautical and Space System Materials, Parts, Components, and Services

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General - PMTs supplied in accordance with this document must be procured from a manufacturer that has met the source approval requirements, be of a design type that has passed the qualification requirements and meet the acceptance, screening and receiving inspection requirements, as specified in this document and the specific slash sheet for that tube.

3.2 Slash Sheets - The slash sheet for each specific PMT shall specify the following detail requirements:

- Part Number and Class
- Dimensional Outline Diagram
- Electrical Connection Diagram
- Window Style and Material
- Photocathode Material
- Dynode Style and Material
- Number of Stages
- Characteristics (Response and Electrical)
- Maximum Ratings
- Electrical Acceptance Tests (with limit requirements)

3.3 Source Approval - To become an approved source for photomultiplier tubes, each manufacturer must meet the supplier capability survey requirements and have manufactured PMTs that have passed the qualification tests. The manufacturer must comply with the supplier survey findings and recommendations prior to the commencement of qualification testing. All PMT manufacturers who have the capability to consistently manufacture devices which can meet the requirements of this document shall be given the opportunity to become an approved PMT source.

3.3.1 Supplier Capability Survey - The supplier capability survey shall be administered by MSFC. The facility which is to be surveyed shall be open for visits by MSFC Technical representatives. The survey shall consist of a documentation and plant survey during which the management team and policies, personnel utilization and training, process documentation and controls, manufacturing techniques, PMT design, quality assurance provisions and facility requirements deemed necessary to consistently manufacture PMTs with the specified characteristics shall be reviewed.

3.4 PMT Qualification - PMTs manufactured by an approved source that have successfully completed qualification test requirements of Table 1 are qualified. Qualification shall be by PMT type, class, style and size. The cost of qualification shall be at the expense of the manufacturer. Construction analysis samples of the PMTs shall be furnished to MSFC at no cost.

3.4.1 Samples - The samples selected for qualification testing shall be representative of the manufacturer's normal production. The samples must have successfully met the requirements of the inspection acceptance and screening tests prior to commencement of qualification testing.

3.4.1.1 Numbers of Samples - The groups of samples designated A and B in Table 1 shall consist of the following numbers of PMTs:

(a) Group A shall contain four (4) samples

(b) Group B shall contain two (2) samples

3.4.1.2 Types of Samples - A group of samples of each basic type of PMT for which the manufacturer is seeking qualification shall be tested. The results of these tests can be used to qualify similar PMT for which there are no basic differences. Basic differences for the purposes of this section are the type of envelope construction, the type of dynode structure, and the nominal PMT size. PMT's of diameter two (2) inches or smaller may be considered similar. PMT's of diameter from two (2) to four (4) inches may be considered similar, and PMT's of diameter four (4) inches or larger may be considered similar insofar as size is considered. Refer to Section 1.3 for other classification criteria.

3.4.1.3 Qualification - Qualification is disallowed for any group in which any one sample fails to meet any specification requirement or fails to pass any test as itemized in Table 1, but may be allowed under extenuating circumstances subject to review by MSFC, particularly if a tube is accidentally caused to fail (due to some stress other than those prescribed) prior to completion of the life test. The group may nevertheless be qualified based upon the remaining samples provided that the eliminated tube was not known to be defective prior to the accidental failure. Following qualification of a PMT type as specified herein, other similar types shall be qualified by similarity of class, type of structure, and size as outlined above. However, MSFC reserves the right to refuse qualification of any type not actually tested.

3.4.2 Qualification Test Data - One reproducible qualification test report containing all the qualification test data required by this document shall be submitted to MSFC upon completion of qualification testing. The report shall contain all environments and parameter test data and a summary of the test results, showing number of failures in each qualification test group, and indicating the parameter or parameters failed by each device. The report shall be signed by the manufacturer's quality control manager and by the MSFC designated representative. Qualification of the manufacturer shall be withheld until this qualification test report is received, evaluated, and approved by MSFC.

3.4.3 <u>Failure Analysis Report</u> - If a failure occurs during qualification, a complete failure analysis report shall be prepared. The report shall include the procedure used to perform the analysis. After completion of qualification testing, one copy of all reports concerning failures that occurred during qualification testing shall be submitted to MSFC.

3.4.4 <u>Loss of Qualification</u> - Manufacturers can loose their qualified status on the PMT QPL by notification from MSFC. The notification shall state the reason for the change in qualification status. Justifications for removal are:

(a) The device does not meet the requirements of the applicable specification.

(b) The manufacturer has failed to comply with the data and report submission requirements of the applicable specification.

(c) The manufacturer has discontinued production of the product or has changed its design, material, or manufacturing process.

(d) The manufacturer has violated the quality and reliability assurance requirements specified herein and in the applicable specification.

3.4.5 Reinstatement or Appeal of Loss of Qualification - Suppliers who have lost qualification to supply photomultipliers to MSFC for any of the above reasons, may have qualification reinstated after all surveys, tests, studies, and measurements of the original qualification (to the extent specified by the qualifying activity) are repeated and successfully completed. The supplier will present to the qualifying activity written evidence in defense of any changes he considers essential to the reliability or quality of the devices, or which are necessary in manufacturing.

3.5 Markings - All photomultipliers shall be marked in a legible and permanent manner on the base, envelope, or shell as specified herein. If any additional marking is used, it shall in no way intefere with the marking required herein and shall be completely separated therefrom.

(a) Permanent-marking requirements - The following information, as applicable, shall be marked on the tube, as specified in (b).

(1) Part number as specified in 3.5.1

(2) Qualification code

(3) Serial number

(b) Permanent-marking methods - The information specified in 3.5(a) shall be applied to the tube by a process, such as grit blasting, etching, baked-enamel silk screening, permanent adhesive decals or labels, or any other method that will assure permanence equal to the methods specified above. The method shall be permanent to the degree that removal of the information can only be accomplished by deliberate mutilation of the marking, or destruction of the tube.

(c) Secondary marking requirements - Required information, other than that specified in (a) shall be marked on the tube as specified in (b) or by any other method that will assure legibility after prolonged used of the tube.

(d) Manufacturer's Identification - The tube shall be marked with the name, initials, or trademark, of only the bonafide tube manufacturer who has contracted under this specification to supply directly either the Government agencies or their equipment manufacturers with tubes, and at whose plants or establishments the specification tests have been performed and inspection made upon such tubes contracted to be supplied. The marking shall not detract from the tube designation.

3.5.1 Part Number - The type number shall be the alphanumeric characters as specified herein.

(a) The first digit shall designate the type of construction as indicated below:

The numeral one (1) denotes a stacked ceramic structure (higher level of mechanical vibration tests).

The numeral two (2) denotes a ruggedized glass envelope construction (lower level of mechanical vibration tests).

(b) The second set of digits shall be the nominal tube diamenter (size), as indicated below:

NUMBER	SIZE (in inches)
05	1/2
07	3/4
10	1
11	1 1/8
15	1 1/2
20	2
30	3
50	5

(c) The following letter shall indicate the cathode material, as indicated below:

LETTER	CATHODE MATERIAL
A	Ag-O-CS
B	Cs_3Sb
C	Multialkali or Trialkali
D	Bialkali
E	Extended Red Multi-Alkali (ERMA)
F	Ag-O-Rb
G	All others

(d) The next letter shall designate the style of window - (A) Plano-Plano, (B) Plano-Concave and (C) Convex-Concave.

(e) The final two numbers shall indicate the number of stages the particular device has. For stages that number less than ten, the numeral shall be preceded by a zero.

EXAMPLE:

1-50-D-A-10

A stacked ceramic, 5 inches in diameter, bi-alkali cathode, plano-plano face plate, and 10 stages of amplification.

4. QUALITY ASSURANCE PROVISIONS

4.1 Quality Inspection System - The supplier is responsible for the performance of all inspection requirements as specified herein except receiving inspection. The supplier may utilize his own or any other inspection or quality control plan as required by the applicable NASA Publication NHB 5300.4(1B) and NHB 5300.4(1C) as referenced in the contract. Unless otherwise specified, the inspection plan as required by NASA Publication NHB 5300.4(1C) shall be submitted for review with the supplier's bid or proposal. Inspection and test records shall be kept complete and upon request made available to the procuring activity or its designated representative in accordance with NASA Publication NHB 5300.4(1B), NHB 5300.4(1C) or other provisions of the contract or procurement document. The procuring activity, or its designated representative, reserves the right to perform any or all of the inspections set forth in this specification to insure that the end item conforms to the prescribed requirements.

4.1.1 Test Classification - Tests will be classified by the following:

Title	Description
Qualification	These tests are performed to insure the reliability of PMT design, and integrity of manufacturing processes for units to be used under severe operating conditions.

Title	Description
Acceptance	These tests are performed to insure that tubes of a qualified lot will satisfactorily perform in operation.
Screening	These tests are performed to eliminate tubes which might otherwise fail prematurely in use, and to stabilize the operating characteristics of all others.
Receiving	These tests are performed to verify after delivery that the tubes will function as specified.

4.2 Qualification Tests - The required number of samples of each class and type of PMT being qualified shall be subjected to the tests listed in Table 1. The testing shall be performed in facilities acceptable to MSFC. Any failures during qualification shall be reported to MSFC, a failure analysis conducted and a report submitted. Manufacturers whose type and classes of PMT's have successfully completed all the requirements shall be approved to supply those devices to the requirements of this specification.

4.3 Acceptance Tests - Each PMT supplied in accordance with the requirements of this document shall pass the electrical tests required by the appropriate slash sheet. Any PMT that fails to pass the requirements shall be rejected. The tests shall be performed by a laboratory that is acceptable to MSFC.

4.4 <u>Screening</u> - Each PMT supplied in accordance with the requirements of this document shall pass the screening tests listed in Table 2. Any PMT failing to meet the requirements shall be rejected. The tests shall be performed by a laboratory that is acceptable to MSFC.

QUALIFICATION TEST SCHEDULE

Test	Method Class 1	Class 2
Visual Examination	4.6.1	4.6.1
X-Ray	4.6.2	4.6.2
Dark Current	4.8.1	4.8.1
Spectral Response	4.8.2	4.8.2
Noise	4.8.3	4.8.3
Spatial Uniformity	4.8.4	4.8.4
Gamma Ray Energy Resolution	4.8.5	4.8.5
Saturation	4.8.6	4.8.6
Pulse Saturation	4.8.7	4.8.7
Transfer Function	4.8.8 or 4.8.9	4.8.8 or 4.8.9
Rise and Transit Times	4.8.10	4.8.10
Stability	4.8.11	4.8.11
Mean Gain Deviation	4.8.12	4.8.12
Vibration	4.7.1.1	4.7.1.2
Transfer Function	4.8.8 or 4.8.9	4.8.8 or 4.8.9
Shock	4.7.3.1	4.7.3.2
Transfer Function	4.8.8 or 4.8.9	4.8.8 or 4.8.9
Acceleration	4.7.5.1	4.7.5.2
Transfer Function	4.8.8 or 4.8.9	4.8.8 or 4.8.9
Temperature Cycling	4.7.7	4.7.7
X-Ray	4.6.2	4.6.2
Dark Current	4.8.1	4.8.1
Noise	4.8.3	4.8.3
Spatial Uniformity	4.8.4	4.8.4
Gamma Ray Energy Resolution	4.8.5	4.8.5
Saturation	4.8.6	4.8.6
Pulse Saturation	4.8.7	4.8.7
Transfer Function	4.8.8 or 4.8.9	4.8.8 or 4.8.9

Table 1

Rise and Transit Times	4.8.10	4.8.10
Stability	4.8.11	4.8.11
Mean Gain Deviation	4.8.12	4.8.12
Life Test	4.8.13	4.8.13
Dark Current	4.8.1	4.8.1
Noise	4.8.3	4.8.3
Spatial Uniformity	4.8.4	4.8.4
Gamma Ray Energy Resolution	4.8.5	4.8.5
Transfer Function	4.8.8 or 4.8.9	4.8.8 or 4.8.9

Table 1

SCREENING TESTS

Test	Method
Fatigue	4.9.1
Ageing	4.9.2
Turn On Characteristics	4.9.3
After Pulse	4.9.4

Table 2

4.5 Receiving Inspection - The purchaser shall perform on all PMT inspections and tests listed in Table 3 as the minimum receiving inspection. Additional tests can be performed at the option of purchaser provided that the tests are not detrimental to the PMT. Any PMT that fails to pass the requirements shall be rejected and MSFC notified.

RECEIVING INSPECTION

Data Pack Review	Method
Visual Examination	4.6.1
Dark Current	4.8.1
Noise	4.8.3
Transfer Function	4.8.8 or 4.8.9

Table 3

4.6 Inspection

4.6.1 Visual Examination - Each PMT shall be inspected to insure freedom from defects in workmanship, design, physical dimensions, loose particles, marking, materials, manufacturing processes, tests and handling. The face plate shall be free from air bubbles, flaws, nicks or scratches and shall be the specified type of glass.

4.6.2 X-Ray - Each PMT shall be radiographed as specified herein, unless otherwise indicated.

4.6.2.1 Mounting - Any suitable mounting fixture may be used provided that it does not interfere with the x-ray beam, either between the source and the PMT or between the PMT and the film holder. Whenever possible the film holder should be supported flat on the worktable, the PMT should be set on the film holder, and the x-ray source should be positioned above the PMT at a convenient distance great enough to minimize divergent distortion of the image.

4.6.2.2 Views - Each PMT shall be radiographed in each of three orthogonal planes as follows:

(a) with the PMT axis of symmetry parallel to the film plan and with the dynodes perpendicular to the film plane

(b) with the PMT axis of symmetry and the dynodes parallel to the film plane

(c) with the PMT axis of symmetry Perpendicular to the film plane, with the cathode end of the PMT as close as possible to the film.

4.6.2.3 Film Identification - Each film made of the devices shall be identified with the following information:

(a) Manufacturer's name

(b) Serial numbers

(c) X-ray laboratory name

4.7 Environmental Tests

4.7.1 Vibration, Qualification

4.7.1.1 Class I - PMTs being qualified to Class I requirements shall be subjected to sinusoidal vibration in each of the X, Y and Z axes as shown in the appropriate slash sheet. The vibration cycle for each axis shall have a duration of 5 ± 1/2 minutes during which the frequency shall be varied logarithmically from 50 ± 5 to 2000 ± 100 and back to 50 ± 5 hertz at a level of 60 ± 3 g's.

4.7.1.2 Class II - PMTs being qualified to Class II requirements shall be subjected to sinusoidal vibration in each of the X, Y and Z axes as shown in the appropriate slash sheet. The vibration cycle for each axis shall have a deviation of 5 ± 1/2 minutes during which the frequency shall be varied logarithmically from 50 $\pm$ 5 to 3000 $\pm$ 100 and back to 50 $\pm$ 5 hertz at a level of 20 $\pm$ 2 g's.

4.7.2 Vibration, Acceptance

4.7.2.1 Class I - PMTs being acceptance tested as Class I devices shall be subjected to Random and Sinusoidal vibration in each of the X, Y and Z axes as shown in the appropriate slash sheet. The vibration cycle for each axis shall have a duration of 5 $\pm$ 1/2 minutes during which the frequency shall be varied logarithmically from 50 $\pm$ 5 to 3000 $\pm$ 100 and back to 50 $\pm$ 5 hertz at a level of 30 $\pm$ 3 g's.

4.7.2.2 Class II - PMTs being acceptance tested as Class II devices shall be subjected to sinusoidal vibration in each of the X, Y and Z axes as shown in the appropriate slash sheet. The vibration cycle for each axis shall have a duration of 5 $\pm$ 1/2 minutes during which the frequency shall be varied logarithmically from 50 $\pm$ 5 to 3000 $\pm$ 100 and back to 50 $\pm$ 5 hertz at a level of 10 $\pm$ 2 g's.

4.7.3 Shock, Qualification

4.7.3.1 Class I - Each PMT of Class I shall be subjected to three half-wave sinusoidal shock pulses in each direction of the X, Y and Z axes, with each impact having a peak acceleration of 150 $\pm$ 15 g and a time duration of 11 ± 1 milliseconds. There will be a total of 18 impacts.

4.7.3.2 Class II - Each PMT shall be subjected to three half-wave sinusoidal shock pulses in each direction of the X, Y and Z axes, with each impact having a peak acceleration of 30 ± 3 g and a time duration of 11 ± milliseconds. There will be a total of 18 impacts.

4.7.4 Shock, Acceptance

4.7.4.1 Class I - Each Class I PMT shall be subjected to one half-wave sinudoidal shock pulses in each direction of the X, Y and Z axes, with each impact having a peak acceleration of 50 ± 5 g and a time duration of 11 ± 1 milliseconds. There shall be a total of 6 impacts.

4.7.4.2 Class II - Each Class II PMT shall be subjected to one half-wave sinusoidal shock pulses in each direction of the X, Y and Z axes, with each impact having a peak acceleration of 15 ± 1.5 g and a time duration of 11 ± 1 milliseconds. There shall be a total of 6 impacts.

4.7.5 Acceleration, Qualification

4.7.5.1 Class I - PMTs being qualified to Class I requirement shall be subjected for one minute to constant acceleration level of 150 ± 10 g's in both the positive and negative directions of each of the X, Y and Z axes as shown in the appropriate slash sheet.

4.7.5.2 Class II - PMTs being qualified to Class II requirement shall be subjected for one minute to constant acceleration level of 100 $\pm$ 10 g's in both the positive and negative directions of each of the X, Y and Z axes as shown in the appropriate slash sheet.

4.7.6 Acceleration, Acceptance

4.7.6.1 Class I - PMTs being acceptance tested as Class I devices shall be subjected for one minute to constant acceleration level of 75 $\pm$ 10 g's in both the positive and negative directions of each of the X, Y, and Z axes as shown in the appropriate slash sheet.

4.7.6.2 Class II - PMTs being acceptance tested as Class II devices shall be subjected for one minute to constant acceleration level of 50 $\pm$ 10 g's in both the positive and negative directions of each of the X, Y and Z axes as shown in the appropriate slash sheets.

4.7.7 Temperature Cycling Qualification - Class I and Class II PMT's being qualified shall be subjected to 5 temperature cycles from 100 $\pm$ 5° C to -55 $\pm$ 5° C. The tubes shall be maintained at each temperature extreme long enough to stabilize but not less than 1 hour. Temperature changes may be gradual; or, the manufacturer may place the tubes directly in a chamber at the high or low temperature and after stabilization transfer them to the other chamber either directly or after allowing them to stabilize at room temperature.

4.7.8 Temperature Cycling Acceptance - Class I and II PMT's being acceptance tested shall be subjected to one temperature cycle from room temperature to 100 $\pm$ 5° C to -55 $\pm$ 5° C and back to room temperature. The tubes shall be maintained at each temperature extreme long enough to stabilize but not less than 1 hour. Temperature changes may be gradual, or, the manufacturer may place the tubes directly in a changer at the high or low temperature and after stabilization transfer them to the other chamber either directly or after allowing them to stabilize at room temperature.

4.8 Electrical Tests - Electrical test procedures for PMT's are outlined herein. The individual slash sheets specify the specification limits and which tests are to be performed at each level of inspection outlined in 4.1.1. General requirements applicable to these tests include the following:

(a) aggregate high voltage supply instability with line, load and time shall be less than 0.1%

(b) PMT ambient temperatures shall be within +23 $\pm$ 3° C.

(c) no appreciable radiation shall be permitted to fall on the PMT photosensitive surfaces during a particular test other than those specified in the test specification

(d) tubes will be degaussed

(e) magnetically shielded for the electrical tests

(f) prior to the start of the electrical tests, the PMT shall be operated in the PERFORMANCE TEST CIRCUIT with the operating voltage indicated in the slash sheet with the cathode uniformly illuminated for a period of 48 hours at an ambient temperature of 23 $\pm$ 3° C. The anode current shall be controlled to 2 $\pm$ 0.5 uA throughout this period. Adjustment of the anode current shall be accomplished by control of the incident illumination.

4.8.1 Dark Current - Each PMT shall be tested for dark current characteristics operating in the PERFORMANCE TEST CIRCUIT at the value of high voltage determined as follows. Following the procedures specified in Section 4.8.9 or 4.8.10 as applicable, determine the high voltage required to give the value of the transfer function specified in the slash sheet. Remove all voltage and illumination for at least one (1) hour. Using the ALTERNATE PERFORMANCE TEST CIRCUIT apply voltage and record the anode current for one (1) hour. Measure the maximum current, and the mean current versus time. Note the maximum mean currents during the following time periods:

MMC-1 = maximum mean current during the first 10 minutes

MMC-2 = maximum mean current during the first 30 minutes

MMC-3 = maximum mean current during the second 30 minutes

4.8.1.1 Read and record the dark current between the first and second minute of operation.

4.8.2 Spectral Response - Photocathode spectral response shall be tested to limits specified in the appropriate slash sheet. The test is performed by determining experimentally the following wave lengths using a monochromator with constant output power.

(a) the wavelength giving maximum response, W_m

(b) a shorter wavelength, giving 10% of maximum response, W_s

(c) a longer wavelength, giving 10% of maximum response, W_l

Cathode current shall not exceed the specified value during these measurements; voltage and monochromator light levels will be set at appropriate levels for (a) above, and maintained at these levels for (b) and (c) above.

4.8.3 Noise - Each PMT shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltages as shown in the slash sheet. Adjust the multichannel pulse height analyzer calibration for the value specified in the slash sheet using the Americium-241 source outlined herein and accumulate a spectrum for at least 10 minutes with the scintillator removed and the PMT dark-adapted for at least one hour (this time may include the above calibration time provided that the PMT has not been exposed to light other than the Americium-241 illuminator). Record the channel counts per minute as follows. All values must be less than the limits specified in the slash sheet.

A Channel 1

B Channel 2

C Channel 3

D	Sum, Chan. 4 & 5
E	Sum, Chan. 6 thru 8
F	Sum, Chan. 9 thru 12
G	Sum, Chan. 13 thru 18
H	Sum, Chan. 19 thru 29
I	Sum, Chan. 30 thru 49
J	Total, All Chan. 50

4.8.4 Spatial Uniformity - Each PMT shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltage as shown in the slash sheet. The illuminator specified in 4.8.9 shall be placed at various locations on the photocathode window with an optical coupling substance, as illustrated in Figure 2 herein. Measuring the photopeak pulse height at these several locations, determine the locations of the illuminator which yield the maximum and minimum values. Record the values, the illuminator shall then be placed at each of these locations with optical substance, and the transfer function values TF max and TF min computed as described in Section 4.8.9. The spatial uniformity (%) is given by the computation

$$SU = \frac{(TF\ max)\ minus\ (TF\ min)}{(TF\ nom)}\ (times\ 100\%)$$

4.8.5 Gamma-Ray Energy Resolution - Each PMT shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltages as shown in the slash sheet. The illuminator is specified in 4.8.9, but irradiated with a 0.3 microcurie Americium-241 radioactive source filtered to absorb alpha particles. The output signal must be analyzed with a multichannel pulse height analyzer.

The energy resolution is given by the computation ER = (FWHM — PK) % where FWHM is the full peak width (number of channels) at half the maximum level and PK is the channel number of the 59.9 Kev photopeak.

4.8.6 Saturation - Each PMT shall be tested for linearity of response. The tube shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltages as shown in the slash sheet. The entire photocathode must be illuminated by light from an incandescent lamp in a lamp-house which prevents light from illuminating the tube except that which passes through the blue filter and the removable neutral filter of density one (1). With both filters in place and operating the PMT at the high voltage specified in the slash sheet, increase the illumination gradually until the anode current meter reads one tenth (0.1) microamp. With the same conditions as above, remove the neutral filter and record the anode current. The tube saturation (SAT) is given by the computation.

SAT = (ANODE CURRENT x 10)

4.8.7 Pulse Saturation - Each PMT shall be tested for saturation of response under pulse conditions by comparing the ratio of the amplitudes of the Cs 137 to Am 241 photopeaks at two PMT gain settings. For the first gain setting the tube shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltages as shown in the slash sheet. The Cs 137 illuminator is as specified in 4.8.8 and the Am 241 illuminator as in 4.8.4. The PMT gain is then increased approximately 10 x by increasing the HV exactly 50% and the above ratio redetermined. The pulse saturation "SAT_p(%)" is found by dividing this second ratio by the first and multiplying by 100.

4.8.8 Transfer Function, Pulse - Each PMT shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltages as shown in the slash sheet. The illuminator will be a sodium iodide scintillation crystal 3/4" high packed with diffuse reflector material in an hermetic can, with a UV-transmitting window, and irradiated with a 0.3 uc Cesium-137 radioactive source filtered by 0.2" lucite. The illuminator shall be coupled to the PMT with Nujol (or similar coupling substance) at the center of the photo-cathode. The same illuminator shall be used with any particular PMT each time this test is performed to ensure validity of comparisons of the measurements. The preferred source configuration and crystal are shown in Figure 1 herein. The preamplifier must be calibrated by injecting charge pulses with the test input signal as shown; the output signal must be measured with a pulse height analyzer. The nominal transfer function of the PMT is given by the computation

$$TF(nom) = \frac{PH(PMT) \times C(cal) \times SIG(cal)}{0.662 \times PH(cal)} \text{ pC/Mev}$$

with PH in volts, C in picofarads, SIG in volts.

4.8.9 Transfer Function, DC - Each PMT shall be tested to determine the anode voltage required to obtain the value of transfer function specified in the slash sheet. Calibrate the

UV light source as specified below. Illuminate the photocathode through a mask with a 1.13 inch diameter round hole centered on the PMT axis. Increase the high voltage until the anode current is one tenth (0.1) microampere.

4.8.9.1 Ultraviolet Lamp - The UV lamp for this test must be a low-pressure mercury vapor lamp with a quartz envelope. The lamp must be operated from a DC supply with suitable ballast. A UV filter and a neutral density filter mounted in a suitable lamphouse are required to obtain the specified light power level at the PMT cathode. Using a suitable photometer, adjust for ten (10) picowatts per square centimeter at the cathode, with 10% accuracy traceable to NBS standards.

4.8.10 Rise and Transit Times - For this measurement the tube shall be operated in the PERFORMANCE TEST CIRCUIT with the operating voltages as shown in the slash sheet. The pulsed light source must uniformly illuminate the photocathode. The intensity of the pulsed source is adjusted to be comparable with the Cs 137 illuminator. The anode rise time is defined as the time between occurrence of 10% and 90% of the maximum point of the anode pulse. The electron transit time is the delay between the onset of the light pulse and the time of occurrence of the 50% of maximum point of the anode pulse.

4.8.11 Stability - Each PMT shall be tested for DC drift. The tube shall be operated in the PERFORMANCE TEST CIRCUIT with operating voltages as shown in the slash sheet. The entire photocathode must be illuminated by light from the lamp specified in Figure 4 herein.

(1) Adjust the lamp operating voltage and distance from the PMT to obtain an anode current of one tenth (0.1 microampere).

(2) Rest the PMT for at least sixteen (16) hours with no voltages and no light applied.

(3) Apply high voltage only with no light for one hour.

(4) Apply illumination and record anode current with a strip chart recorder for one (1) hour.

(5) Calculate the following drift ratios:
DR-1 = % drift during first 10 minutes
DR-2 = % drift during first 30 minutes
DR-3 = % drift during second 30 minutes

4.8.12 <u>Mean Gain Deviation</u> - Using the values of the transfer function for any tube determined above, the drift rate is given by the calculation

$$MGD = \frac{TFM-TFI}{N} \times \frac{100}{TFM} \quad (I = 1 \text{ to } I = N)$$

where TFM is the mean transfer function, TFI is the transfer function found from the I-th measurement, and N is the total number of measurements made with that tube.

4.8.13 <u>Life Test</u> - Each PMT shall be operated at voltage and current levels specified in the slash sheet for 1000 hours continuously.

Any convenient light source may be used for cathode illumination provided that at least a major portion of the cathode is illuminated.

4.9 Screening Tests

Note: Failure to pass these stringent test requirements for the HEAO Program does not necessarily preclude the use of the PMT's in other applications.

4.9.1 Fatigue - Each PMT shall be tested to determine the effects of fatigue. The tube shall be operated in the PERFORMANCE TEST CIRCUIT with the operating voltage as shown in the slash sheet. The illumination shall be initially adjusted for the anode current indicated in the slash sheet. The tube shall then be sequentially exposed to light levels 10x, 100x and 200x, the initial value for a minimum of six hours. After each exposure, the tube anode shall be monitored at intervals of 10 minutes or less for a period of four hours prior to the beginning of the subsequent exposure. Tubes which are found not to return to within 5% of the initial anode current value without overshoot shall be rejected.

4.9.2 Ageing - Each PMT shall be aged to insure that there is no unusual drift in its performance. The tube shall be operated in the PERFORMANCE TEST CIRCUIT with the operating voltage as shown in the slash sheet.

4.9.2.1 Initial Tests - After two hours of dark operation at an ambient temperature of 23 $\pm$ 3° C the following tests shall be made and the data recorded:

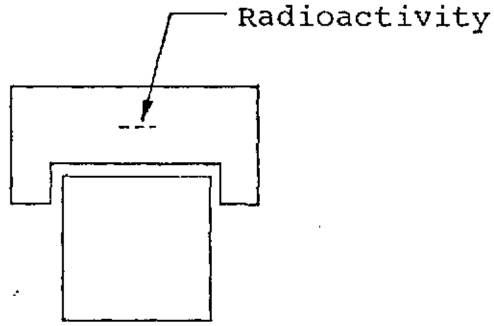
Test	Method
Dark Current	4.8.1
Noise	4.8.3
Gamma Ray Energy Resolution	4.8.5
Transfer Function	4.8.8 or 4.8.9

4.9.2.2 Elevated Temperature - After the tests called for in 4.9.2.1 have been completed, the operating voltage shall be removed and the illumination shall be reduced to zero. The ambient temperature shall then be increased to 45 ± 3° C. After a soak 20 hours at this temperature, the operating voltage shall be re-applied. After two hours of dark operation, the 4.9.2.1 tests will be repeated.

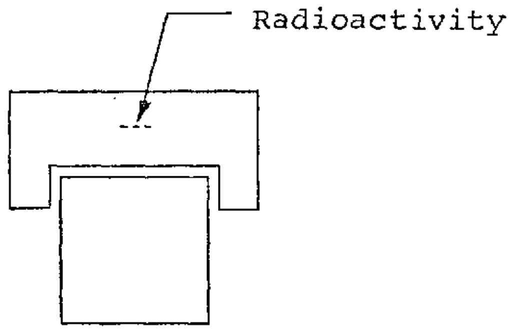
4.9.2.3 Room Temperature - After tests at the elevated temperature have been completed, the operating voltage shall again be removed and the illumination reduced to zero. The ambient temperature shall then be reduced to 23 ± 3° C. After 22 hours at this temperature the operating voltage shall be re-applied. After 2 hours of dark operation, the 4.9.2.1 tests shall be repeated.

4.9.2.4 Repeat Cycling - The ageing and tests in 4.9.2.3 and 4.9.2.2 shall be repeated for a minimum of ten (10) cycles with the test data being recorded for each set of measurements.

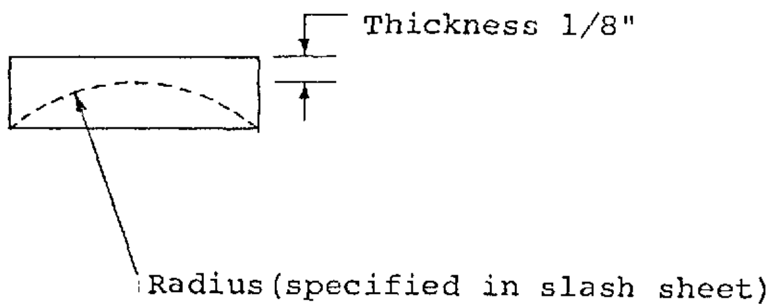
Cs-137
Source



Am-241
Source



Scintillation Crystal



Light Pipe Adapter

Figure 1

ILLUMINATOR CONFIGURATIONS

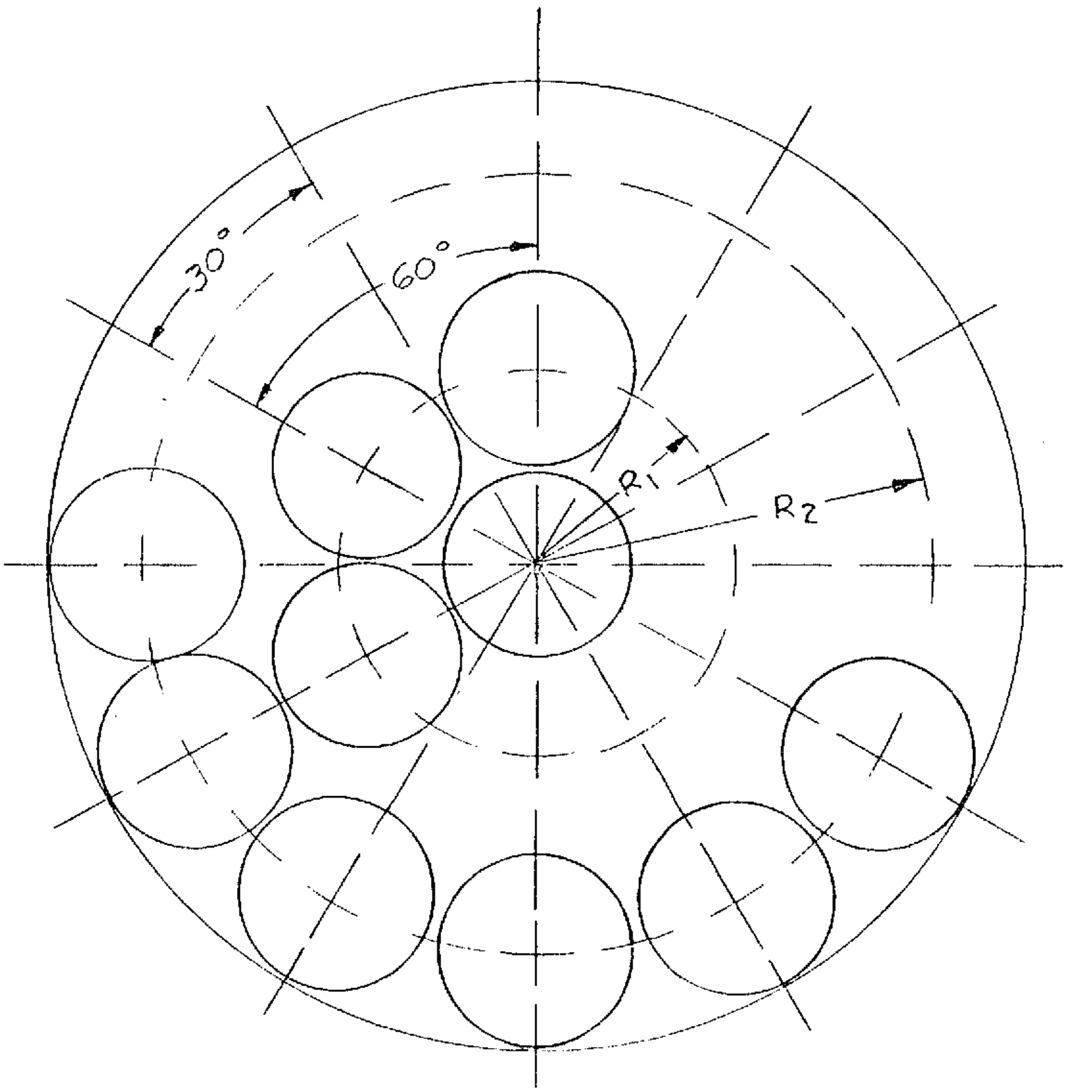
Figure 2: <u>Photocathode Uniformity Mapping</u>

For photocathodes with D≥4" make 19 measurements as shown.

For 2.5" D 4" delete all R_1 measurements and make R_2 measurements every 60° (total of 7 measurements).

For D 2.5" delete all R_1 measurements and make R_2 measurements every 90° (total of 5 measurements).

Sketch orientation of 1st dynode relative to map.



Photocathode Diameter = D

$R_1 = \frac{D-1}{4}$ $\qquad$ $R_2 = \frac{D-1}{2}$

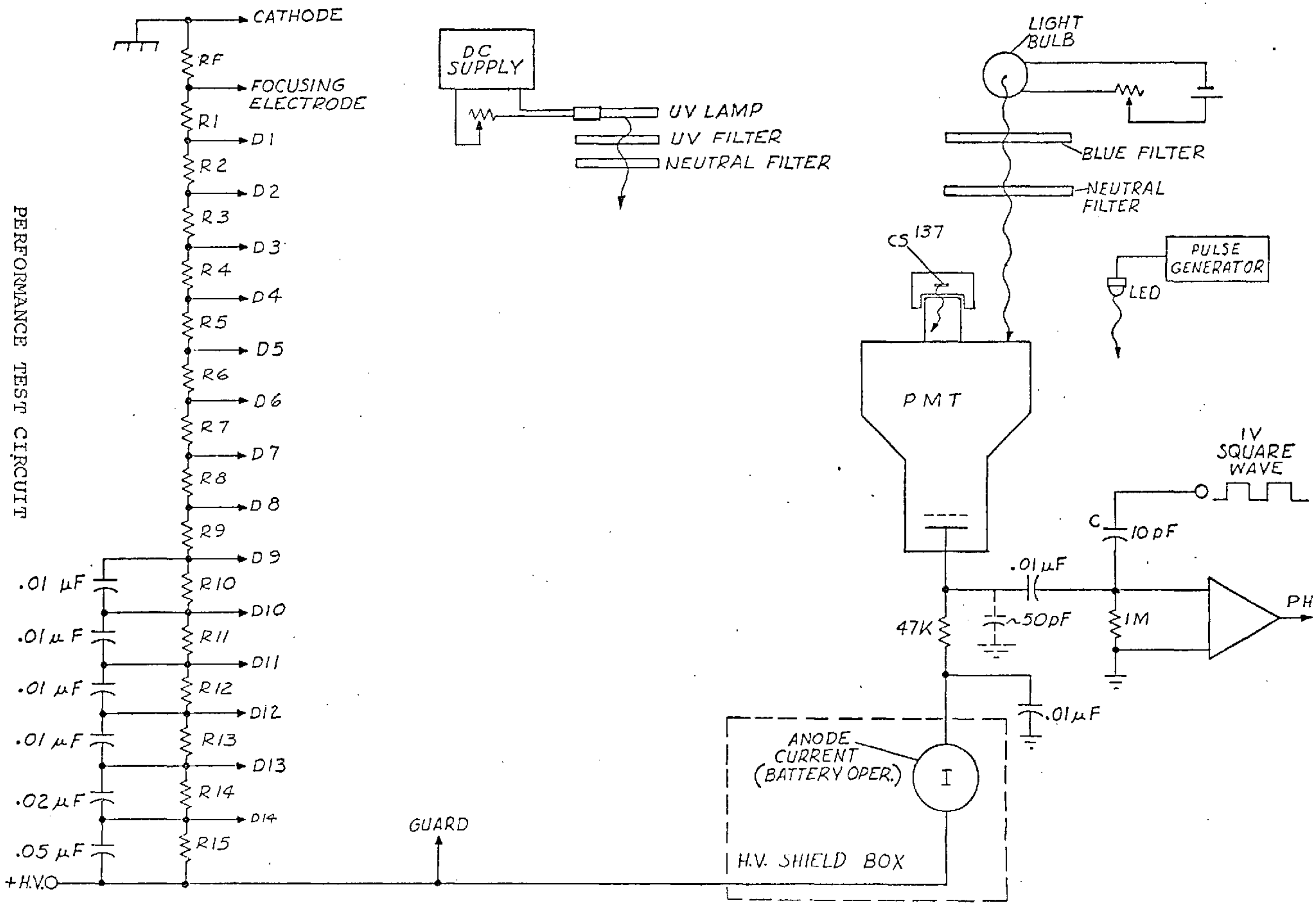
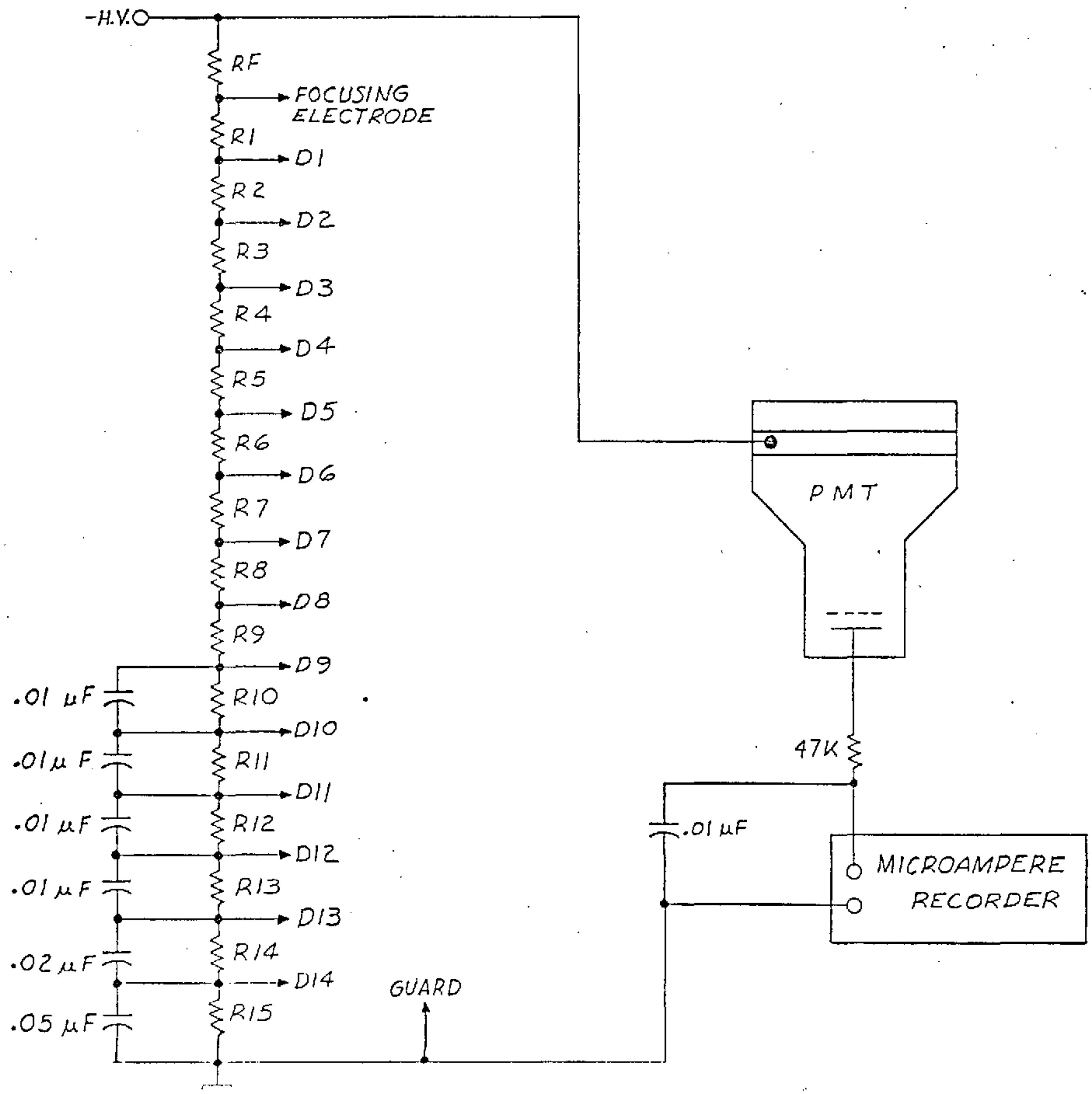


FIGURE 3

PERFORMANCE TEST CIRCUIT



ALTERNATIVE PERFORMANCE TEST CIRCUIT

FIGURE 3A

The slash sheet may require a larger number of cycles.

4.9.2.5 Rejection Criteria - The permissable change in the characteristics tested during the ageing period shall be as specified in the slash sheet.

4.9.3 Turn-on Characteristics

(To be added)

4.9.4 After Pulse

(To be added)

5. PREPARATION FOR DELIVERY

5.1 Packaging - Each PMT shall have a protective face plate attached and then be individually sealed in a poly bag. The bagged tube shall be individually wrapped with opaque film and sealed in a poly bag, or sealed in an opaque poly bag. This shall be labeled and placed in an individual box with at least one (1) inch of packing. These boxes shall be labeled and placed in a carton with at least two (2) inches of packing surrounding the group of boxes. The carton shall be labeled and sealed.

5.2 Labeling - The following labeling system shall be effected for each PMT prior to delivery.

5.2.1 Bag Label - The outer bag shall bear a label containing the information specified in 3.5 (a) and the following cautions: FRAGILE: HANDLE WITH CARE and WARNING: OPEN ONLY IN DARKENED ROOM

5.2.2 Box Label - The box shall be labeled with the information specified in 3.5(a) and the caution FRAGILE: HANDLE WITH CARE...TO BE OPENED ONLY BY AUTHORIZED PERSONNEL

5.2.3 Carton Labels - The carton shall bear at least two obvious labels which clearly indicate that the contents are fragile.

6. NOTES

6.1 Intended Use - This specification covers photomultipliers to be used in space vehicles and intended for space applications on HEAO.

6.2 Ordering Data - Procurement documents should specify the following:

(a) MSFC part number

(b) Title, number, and date of this specification

(c) Title, number and date of Specification Control Drawing

(d) Whether MSFC will require Qualification Tests.

6.3 Qualification - With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable Qualified Parts List whether or not such products have actually been listed by that date. The attention of the suppliers is called to this requirement, and the manufacturers are urged to arrange to have tested for qualification the products that they propose to offer, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility or any obligation whatsoever; and the fact that the Government may have formulated, furnished or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:
NASA - George C. Marshall Space Flight Center

Preparing Activity:
George C. Marshall Space Flight Center