STUDY AND DEVELOPMENT OF THE STERILIZABLE GEIGER-MULLER TUBE

APRIL 1966

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CONTRACT No. 951240

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FINAL REPORT

STUDY AND DEVELOPMENT OF THE STERILIZABLE GEIGER-MULLER TUBES

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I. ABSTRACT

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During the development of the sterilizable Geiger-Muller tubes, it was noticed that a number of the thin mica end window tubes, Type 6226, exhibited a downward change in starting voltage. This occurred most often during the dry heat sterilization cycles.

The drop in starting voltage was believed attributable to a slow chemical reaction between the chlorine content of the filling gas mixture and the base material of the cathode. It was further believed that by cladding the cathode surfaces with a protective coating of resistant metal this difficulty could be eliminated.

A thorough investigation of plating and processing techniques was made in order to obtain clad cathode surfaces which were both mechanically and microscopically perfect and which would provide protection of the cathode base material.

AUTHOR

II. INTRODUCTION AND TARGET REQUIREMENTS

This report covers work accomplished by EON Corporation, 175 Pearl Street, Brooklyn, New York, on the study and development of the sterilizable Geiger-Muller Tubes (Contract JPL No. 951240) for the Jet Propulsion Laboratory, Pasadena, California, under the cognizance of the JPL Project Monitor, Robert A. Wengert.

The objectives of this program were:

1. To conduct a study and develop techniques to optimize the conditions of the internal surfaces of sterilizable Geiger-Muller tubes which were developed by the EON Corporation under JPL Contract No. 950681, so as to resist the corrosive action of the halogen quenching gas mixture.
2. To study and determine the optimum composition of the mixture of gases which make up the gas fill of the tubes.
3. To evaluate the effect on the reliability of the tubes resulting from the development effort.

All tubes must satisfy the requirements as specified in JPL Statement of Work SW-3171A, Sterilizable Geiger-Muller Tubes, dated 23 January 1964. These requirements comprise the electrical characteristics, the ability to be sterilized, the ruggedness of the tubes and the physical dimensions. The required target specifications have been reproduced in Appendix A.

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III. METHOD OF APPROACH

To achieve optimum electrical and operational characteristics in a halogen quenched Geiger-Muller tube certain precautions in the manufacturing process must be observed to prevent chemical combination of the halogen gas (which in most cases is chlorine) with the metal parts used in the construction of Geiger-Muller tubes.

It should be remembered that chlorine is chemically an extremely active material. Copper, iron, lead, nickel, platinum, silver, steel and tantalum are chemically resistant to dry chlorine only at temperatures below 230° F. Titanium reacts spontaneously with anhydrous chlorine at room temperature. Platinum is suitable for temperatures up to 500° F in dry chlorine. Chromium reacts with chlorine at 600° C to form chromium chloride ($CrCl_2$). To prevent and/or minimize the effects of this reaction, Geiger-Muller tube cathodes (especially when the tubes are used for operation at higher than room temperatures) are plated on the inside with one and sometimes two noble metals which are not readily attacked by the halogen gas. The stainless steel cathodes are, after chemical cleaning and vacuum firing, generally plated first with rhodium. On top of this material, a coating of platinum is then deposited. Rhodium is used because of the difficulty in plating platinum directly onto the steel alloy surface, which

in this case is a 446 alloy (72% Fe, 28% Cr). Platinum also increases the sensitivity of the Geiger-Muller tube because of its high absorption coefficient.

In spite of these precautions, some of the tubes continued to exhibit a drop in starting voltage while others remained perfectly stable. This can be explained by the fact that the plating is often porous thus permitting the chlorine to penetrate the plating and to attack the base material, or that appreciable sections of steel remain unplated thus presenting unprotected areas of steel which can react with the halogen gas.

The original concept with regard to plating of the electrodes has been, that because the surface area of the cathode is so great as compared to that of the anode, only the cathode required plating. Some results, however, indicated that the anode too may require plating in order to make it resistant to the corrosive action of the halogen gases. The anode presents a number of unusual problems because of its small diameter. Plating of the anode becomes very critical because it can provide a source of minute irregularities which will seriously affect the magnitude of the electric gradient at its surface. . Microscopic irregularities will for example immediately give rise to field emission, causing a steep plateau and possibly continuous discharge. This is one of the reasons why in the past the anode was simply passivated using concentrated sulphuric

acid plus a suitable inhibitor. The passivation process is one in which fractured crystals of iron are etched out leaving a smooth surface of chromium. Chromium is one of the metals which has great resistance to corrosion by the halogens. Test results indicated that we did not have a homogeneous chromium surface and we therefore had to resort to plating. After plating the anode had to be carefully polished to provide a uniformly smooth and continuous plated surface.

Other metallic elements in the tube also had to be considered. One of these is the stainless steel anode support. This support is the part to which the anode wire is mechanically attached and which is also fabricated from the same iron-chromium alloy as the cathode and anode because of the requirements for equal thermal expansion. Unless this same alloy is utilized it would not be possible to fabricate the ceramic to metal seal which can be operated over the required temperature range. The anode support is usually larger than the anode itself. However, a microscopic point on the anode support could again result in creating a large and undesirable gradient in this region.

Another problem to be considered is the degree of oxidation of the base material.

In general when a tube is plated the plating is applied to the base metal which has not been purposely oxidized. A slightly oxidized

stainless steel surface has the proper work function for optimum operation of Geiger-Muller tubes utilizing the noble gas plus halogen admixtures. However, it is this same oxidation which very often prevents proper adherence of the plating to the base material.

To summarize, it was proposed to make a very thorough investigation of all the factors which contribute to the problem of creating plated surfaces which are both mechanically and microscopically perfect using base materials which are presently available and plating materials which are known to be resistant to the corrosive action of the chlorine gas admixture.

The tube type to be used for these investigations was Tube Type 6226. This type was developed by the EON Corporation for the JPL Contract No. JPL-CPFF-950681. (Fig. 1)

Tube Type 5112R which was also developed for the JPL Contract, did not exhibit any problems. It is believed that the 5112R did not exhibit the change in starting voltage because of its smaller surface to volume ratio. This seems apparent from the following computation:

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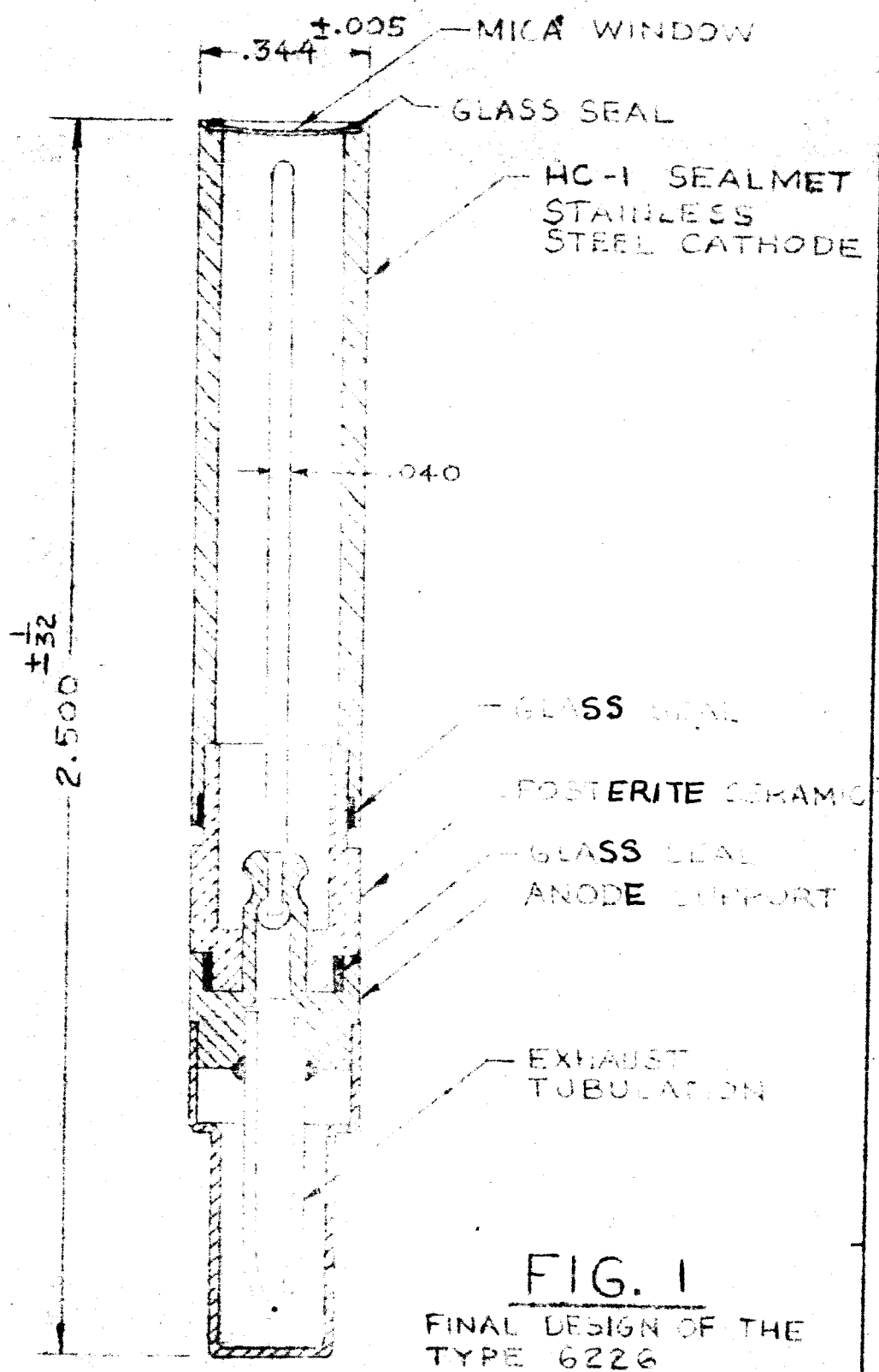

FIG. 1

FINAL DESIGN OF THE TYPE 6226 STERILIZABLE GM DETECTOR.

5112R	6226
Length: 2-15/16"	Length: 1-1/4"
I.D.: 0.726"	I.D.: 0.250"
Area: 6,695 square inches	Area: 0.981 square inches
Volume: 1.215 cubic in.	Volume: 0.061 cubic in.
$\frac{\text{Surface Area}}{\text{Volume}} = 5.5$	$\frac{\text{Surface Area}}{\text{Volume}} = 16$

Thus, the surface area to volume ratio of the Tube Type 6226 is approximately three times as great as the surface area to volume ratio for the tube type 5112R.

Tube Type 6226 utilizes a stainless steel cathode, a Fosterite ceramic insulator, a stainless steel anode and anode support and a thin mica end window with a stainless steel strongback. Since the tubes used for this contract were intended for dry heat sterilization cycles only, the strongbacks which were used on tubes in the previous contract because of the requirement for gas sterilization in partial vacuum and vacuum storage were omitted. Otherwise the construction of these tubes and gas fills are substantially the same as arrived at when the sterilizable version of this tube type was developed. Gas compositions were however varied during the development stages of the task to study the effects of variation in composition.

It was initially intended to start the investigation with five lots consisting of twenty (20) tubes each.

One lot to be plated with rhodium only, another lot with rhodium on top of which a thin layer of platinum was to be deposited. The balance of the cathodes to be chromium plated. A number of chromium plated cathodes to be fired in wet hydrogen to obtain a very hard and stable chromic oxide.

Some of the oxidized and non-oxidized chromium plated cathodes to be plated with a thin layer of platinum. An adequate number to be evaluated without platinum plating. All internal members were to be chromium plated. The filling gas mixture to be used was to be substantially the same as arrived at when the sterilizable tube was developed. The lot which shows the best performance would then be chosen for further investigation of the optimum gas mixture.

After consultation with JPL engineers, it was agreed to drop further investigation of the rhodium and rhodium-platinum cathodes because some work on these combinations had already been done during the previous contract.

The decision to use chromium as plating material for the cathode and anode was arrived at from a study of the special properties which are exhibited by chromium and are not possessed by any other suitable materials. The most important of these properties are hardness, adhesion and corrosion

resistance. The corrosion resistance is equal or even superior under most conditions to that of such noble metals as gold and platinum. The corrosion resistance of chromium is due to its capacity to become and remain passive, a characteristic that chromium has in much greater degree than other metals. For the development and maintenance of the passive condition, exposure in oxidizing atmospheres is necessary. In fact the commonly accepted explanation of the passivity of chromium is the existence of a protective layer of chromium oxides. For each application, the most desirable thickness of the chromium plating has to be determined empirically. If high corrosion resistance is required, relatively heavy deposits of chromium are required. Platinum and/or lead anodes which are insoluble in chromic acid solutions are almost always used in chromium plating from chromic acid baths. The use of lead anodes is generally preferred. The film of lead peroxide which forms on these anodes during use causes the chromium to be reoxidized continuously to chromic acid. Anodes of chemical lead can be used, but as compared with lead alloy anodes, they are much more readily attacked by the solution and cause the formation of excessive amounts of lead chromate sludge. It is important to use thick enough anodes to conduct the high currents required for chromium plating. Anodes that are too thin will overheat in use and tend to corrode and warp excessively during plating. Lead anodes used in chromium plating cannot have too heavy or irregular a coating of lead

peroxide on them or the current distribution may be affected. It is customary to clean the anodes regularly. This cleaning is done by acid dips and scratch brushing, but is difficult and frequently not all the semi insulating coating is removed.

A high degree of adhesion of chromium to steel is the normal result of plating in a hot chromic acid bath, but can best be assured by electrolytic cleaning or etching of the steel surface before chromium plating. A satisfactory etch is obtained by treatment of steel parts to be plated (as anode) at 6 volts for about a minute in chromic acid solution or in the plating bath. Anodic etching in sulfuric acid at about 25° C for about one minute gives the highest adhesion. Similar results can also be obtained by electropolishing of the parts before plating.

IV. TECHNICAL DIFFICULTIES ENCOUNTERED

The following problems in the plating studies were encountered:

1. Obtaining the right amount of chromium deposit on the internal cathode surface.
2. Obtaining a uniform and smooth deposit.
3. Obtaining the right oxidation of the chromium plate.
4. Depositing a thin layer of platinum on top of the chromium plate.

Some difficulties were encountered when plating the inside of the cathodes with chromium. It was found that the plating was spotty on some cathodes and formed little globules and heavy concentration of chromium on others, leaving large areas unplated. When the plating fixture was inspected, it was noticed that the lead wire anodes had deformed. The outside diameters were no longer uniform and the surface of the anode wires was pitted and covered with a heavy layer of lead chromate sludge. The reason for this difficulty was that the anodes were made of chemical lead and were too thin. Because the wire diameter was too small the anodes overheated during the process of plating, corroded and warped excessively, thus affecting the uniform current distribution.

To correct this, a mold was made which permitted us to make heavier anodes using commercially available lead instead of chemical lead. The results showed a considerable improvement in plating uniformity.

It was found that the right thickness of the plating and the degree of oxidation were of imperative importance. Chromium deposits are generally quite good regardless of moderate variations in the conditions of the plating as long as satisfactory thickness is applied for the intended use. Too heavy a plating would form blisters and flake off in the following heat treatment while too thin a coating would not give enough protection to the cathode material against the corrosive action of the halogen gas. Chromium plating normally has a very thin oxide film on its surface. The plating remains bright at temperatures up to 260° C. On prolonged heating of chromium plate to temperatures of the order of 315° C in air, the oxide film thickens and darkens. At higher temperatures, temper colors are produced and a green-bluish oxide layer is finally formed. This green-bluish oxide layer represents a very stable, hard and corrosive resistant chromic oxide.

Tubes made with cathodes having this oxide showed excellent results after undergoing three dry heat sterilization cycles.

It was originally intended to obtain this oxide by firing the cathodes in wet hydrogen. A number of cathodes were fired for 20 minutes

at 1000° C in wet hydrogen. These cathodes were then fired in vacuum to free them of any occluded hydrogen. The tubes which were made using these cathodes showed very poor results. All tubes showed a considerable rise in starting voltage which increased with each dry heat sterilization cycle. This resulted in a shift of the plateau in the direction of increasing voltage. This could only be explained by the fact that the cathodes were not degassed at high enough temperature after the firing in hydrogen. Some of the occluded gas was released during the operation of the tubes, thus increasing the gas pressure, contaminating the filling gas, raising the starting voltage and shifting the plateau towards higher voltage.

A number of cathodes which were oxidized in wet hydrogen were then vacuum fired at a higher temperature. These cathodes could not be used because of the blistering and peeling of the plating. In the meantime it was found that some partly assembled tubes with chromium plated cathodes when left for some time on the shelf in air indicated a change in the color of the oxide to the desired degree.

Because of the difficulties encountered with tubes the cathodes of which were oxidized in wet hydrogen, the firing in hydrogen was discontinued.

The amount of chromium plating weight was arrived at by depositing different amounts of chromium on stainless steel strips and then oxidizing the plated strips in air in an oven at 580° C for several hours. The strips

were then left for approximately two weeks on shelf exposed to air. The strips having a thin chromium plate hardly exhibited a change in the oxide color. With increasing plating weight the change in color became visible. The strips with a plating weight between 56 and 62 mg/cm^2 showed after two weeks on the shelf the distinctive colors. The strips which had a plating weight of more than 70 mg/cm^2 showed peeling of the plating when oxidized and were therefore discarded.

We were not successful in our efforts to deposit a layer of platinum on chromium plated cathodes, some of which were oxidized, and some of which were not.

Whenever it is desired to deposit another metal on chromium, special precautions are necessary, owing to the passive surface condition of the chromium. This condition may be overcome by dipping the chromium surface in strong hydrochloric or other strong acid until the chromium starts to etch and hydrogen is briskly evolved. Quick rinsing and plating should result in an adherent electro deposit of almost any metal. This procedure suffers from the disadvantage that etching may remove more chromium than is permissible, or result in greater dulling and roughening of the surface than is desired. In such cases, the chromium may be activated without etching by cathodic cleaning in alkali,

followed by a short dip in mild acid such as sulfuric at about 25° C.

Both methods were tried unsuccessfully. The chromium plated surface either did not accept any plating at all or the platinum plating peeled off immediately.

Several rare metal and plating consultants have been consulted on this subject. According to the information received, it is almost impossible to deposit any metal on a chromium surface because of the chromium oxide which forms, the moment the chromium plated surface is removed from the plating bath.

All parts, after having been received from the machine shop were degreased, ultrasonically cleaned and vacuum fired. The cathodes were weighed on a chemical balance and placed in the plating fixture. The plating fixture accepted 6 cathodes for simultaneous plating. Special care had to be taken to center the lead anodes within the cathodes. The fixture was then lowered into the glass beaker containing the chromium plating solution. The cathodes were then anodically cleaned for 10 to 20 seconds at 4 to 6 volts. After the cleaning process, the polarity was reversed making the tubing the cathode. The plating process took about 90 minutes. Towards the end of this period, one cathode was removed from the fixture, washed thoroughly in distilled water, dried in acetone and weighed. If the weight of the plating was within the predetermined value of between

50 and 60 mg/cm^2, the remaining cathodes were removed from the plating jig, washed, dried and weighed to determine the weight of the plating on each cathode. The cathodes having a plating weight which was below or above the specified value were rejected. The plating on these cathodes was stripped by immersion in 30% hydrochloric acid. After all the chromium was removed, the cathodes were thoroughly washed, dried and weighed again and then replated by the same procedure as outlined above.

The composition of the plating solution and plating conditions were as follows:

55 oz/gal (413 gr/lt) chromic acid

12 gr/lt sodium sulfate

Current Density: 2 amp/sq. in. of surface area

Anodes: Lead alloy

V. TEST RESULTS AND EVALUATION SUMMARIES

The test results are tabulated and enclosed in Appendix B.

The test data contains the counting rates at three points on the plateau; the relative plateau slope and the background count. All counts were taken for a period of three minutes. The data reported are the average counting rates, i.e. $\frac{\text{The counts accumulated in three minute period}}{3}$

The tubes were tested for their electrical characteristics after exhaust processing and then subjected to three dry heat sterilization cycles. Electrical tests were also performed after each dry heat sterilization cycle. The tubes were not subjected to either gas sterilization or environmental tests because it was shown by the work done under JPL Contract No. 950681 that this tube construction will satisfy the gas sterilization and all environmental test requirements.

Most tubes showed only insignificant changes in plateau slope, counting rate and background counts. On many tubes an improvement in plateau slope with each dry heat sterilization cycle can be noticed. Some tubes (these were the tube with the cathodes which were oxidized in wet hydrogen) show high plateaus to start with and a deterioration of the plateau slope with each

dry heat sterilization cycle. This was due, as mentioned in the previous section to some hydrogen being released by the cathode during the dry heat sterilization cycles. On a few of the tabulated tubes the background readings were higher than specified. A microscopic inspection of the inside surface of other tubes having higher background counts revealed the presence of pin hole like depressions and grooves which were not deep enough to cause leaks but which certainly contributed to higher background counts and shrinkage during the exhaust process due to discharge. Some cathodes were sent out for honing of the inside surfaces but the test results of these were still not satisfactory.

The following tubes were fabricated with cathodes which had been oxidized in wet hydrogen

3451

3460

3463

3467

3489

3499

3504

3507

3522

3532

3554

All other tubes were fabricated with cathodes oxidized in air:

1957	3494	3534
3094	3495	3544
3142	3497	3545
3165	3502	3550
3225	3512	3563
3397	3518	3594
3455	3524	3600
3471	3528	3643
3491	3529	

VI. CONCLUSIONS

The results which are shown in Appendix B are typical of results obtained from many tubes which were fabricated.

The best tubes were obtained by chromium plating of all internal parts as described in Section IV. These tubes in general meet all of the requirements and showed no dropping of starting voltages as was evident on tubes made during the previous contract. The starting voltages have been observed over a period of 2 to 4 months.

Although the target requirements of this program have been met, we have a number of recommendations to make which we believe worth consideration by JPL in furthering this particular program.

A number of these recommendations are important from the point of view of being able to extend their results to other detectors of the same general design but which have other configurations. e.g. the EON pancake type detector which bears a rather large and thin mica or metal window and which has an extremely low background, as well as other types of halogen quenched detectors which are suitable for space probe work.

RECOMMENDATION NO. 1

Some work was done in which the internal surfaces of the detectors

were honed. Our initial results were extremely disappointing. However we believe that this work should be carried forward, and that honing should be explored for the virgin surfaces themselves, and subsequently after plating. The importance of honing is that it may be possible to accept a wider range of finish in the original tubing and wire. At present it is very difficult to repeatedly get material which meets our desired requirements for finish. If the honing technique could be made to work, we would be able to accept materials which presently must be rejected. However, what is more important is that the honing process would cause greater control during processing and provide for greater reliability and yield.

RECOMMENDATION NO. 2

The chromium technology should be carried further to determine how the specific oxides can be formed at will and without resorting to a shelf aging process as was utilized here.

A further investigation should be made to determine specifically which of the oxides of chromium provides the best surface, and work done to produce that specific oxide to the possible exclusion of the others.

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RECOMMENDATION NO. 3

A larger number of tubes should be fabricated using the most recent techniques so that better statistics can be obtained.

RECOMMENDATION NO. 4

The samples which have already been fabricated should be monitored for at least 6 to 12 months more. During this time, these tubes should be operated on an active type of life test, and an equal number should be set aside for shelf life test. In this way it should again be possible to extract information which will be more meaningful than that obtained from the very limited life tests already performed.

APPENDIX A

TARGET SPECIFICATIONS

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APPENDIX A

TARGET SPECIFICATION

TUBE TYPE 6226:

A. PHYSICAL REQUIREMENTS

Diameter	0.344" nom.
Length	2" max.
Window Thickness	1.0 - 1.5 mg/cm^2

B. ELECTRICAL CHARACTERISTIC REQUIREMENTS

Operating Voltage	800 V max.
Plateau Length	75 V min.
Plateau Slope	5%/100 V max.
Dead Time	50 usec max.
Background due to cosmic rays at sea level	5c/min. max.

C. STERILIZATION REQUIREMENTS

1. DRY HEAT: Three cycles - 36 hours each at 145° ± 2° C in a dry nitrogen atmosphere. After each high temperature run, the tube shall be allowed to stabilize at room temperature.

2. GAS: 32 hours at 110° ± 10° F in a gas mixture consisting of 12% ethylene oxide and 88% Freon 12 by weight.

Relative humidity shall be between 35 - 90%.

D. ENVIRONMENTAL REQUIREMENTS:

1. STATIC ACCELERATION

± 190 g for 20 minutes in each of 3 orthogonal directions.

2. VIBRATION

Sinusoidal vibration swept at 1/2 octave/min. as follows:

a)	± 0.5" constant displacement	5 - 17 cps
b)	5 g rms	17 - 50 cps
c)	15 g rms	50 -100 cps
d)	35g rms	100-2000 cps
e)	wide band noise -25g rms for 9 minutes	15 - 2000 cps

3. SHOCK

(5 blows in each direction along each of three axes)

a) ± 200 g terminal peak sawtooth - 0.5ms rise time

b) ± 150g terminal peak sawtooth - 5.0 ms rise time

c) ± 1000 g terminal peak sawtooth - 3.0 ms rise time

4. THERMAL

a) 12 days in vacuum at 75° C

b) 4 days in vacuum at -10° C

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APPENDIX B

TEST RESULTS

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TUBE TYPE 6226

TUBE #	PLATEAU POINTS - CPM			R.P.S. % / 100v.	BACK GROUND c/m	TEST	DATE
	700 v.	~~750 v.~~	800 v.				
3518	5929	6065	6057	2·1	7		10.28
	5932	6197	6210	4·5	6	1. DRY HEAT	11.1
	6204	6310	6242	0.6	5	2. DRY HEAT	11.5
	6084	6095	6169	1·4	4	3. DRY HEAT	11.27
3471	6044	6160	6254	3·4	15		10.28
	6083	6136	6294	3·4	17	1.D.H	11.1
	6254	6327	6425	2·7	12	2.D.H	11.5
	6077	6186	6144	1·1	19	3.D.H	11.27
3455	6137	6134	6344	3·9	10		10.28
	6010	6178	6249	3·4	7	1.D.H	11.1
	6237	6318	6303	1·5	5	2.D.H	11.5
	6061	6140	6267	3·3	7	3.D.H.	11.27
3529	6025	6227	6200	2·8	13		10.28
	5894	5974	6142	4·1	10	1.D.H	11.1
	6018	6270	6307	4·6	8	2.D.H	11.5
	6101	6065	6289	3·1	10	3.D.H	11.27

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TUBE TYPE 6226

TUBE #	PLATEAU POINTS - CPM			R.P.S. % /100V.	BACK GROUND c/m	TEST	DATE
	700v.	750v.	800v.				
3497	6037	6205	6780	12	5		10.28
	6101	6143	6537	7.1	3	1. DRY HEAT	11.1
	6402	6445	6660	4.0	3	2. DRY HEAT	11.5
	6007	6106	6356	5.7	8	3. DRY HEAT	11.27
3495	6156	6189	6207	0.8	9		10.28
	6030	6090	6198	2.8	3	1 D.H	11.1
	6175	6270	6464	4.6	5	2. D.H	11.5
	6146	6186	6404	4.2	5	3. D.H	11.27
3494	5986	6237	6480	3.1	23		10.28
	6032	6123	6175	2.3	22	1. D.H	11.1
	6255	6289	6407	2.4	18	2. D.H	11.5
	6067	6235	6242	2.8	25	3. D.H	11.27
3512	5919	6142	6326	6.7	12		10.28
	5956	6034	6264	5.1	7	1. D.H	11.1
	6272	6387	6425	2.4	7	2. D.H	11.5
	6024	6062	6199	2.9	4	3. D.H	11.27

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TUBE TYPE 6226

TUBE #	PLATEAU POINTS - CPM			R.P.S. %/100v.	BACK GROUND c/m	TEST	DATE
	700v.	750v.	800v.				
3503	5616	5865	5937	5·5	6		2.7.66
	5224	5862	5840	10·5	4	1. DRY HEAT	2.9
	5458	5780	5901	7·7	4	2. DRY HEAT	2.11
	5688	5873	6009	5·5	5	3. DRY HEAT	2.16
3468	5483	5716	5930	7·8	8		2.7.66
	5604	6049	6098	7·7	10	1 DH	2.9
	5648	5927	6029	6·4	6	2 DH	2.11
	5636	5989	6047	6·9	9	3 DH	2.16
3465	5659	5950	6036	6·3	1		2.7.66
	5461	5939	6077	10·4	2	1 DH	2.9
	5376	5929	5889	8·6	2	2 DH	2.11
	5354	5899	5970	10·4	1	3 DH	2.16
1695	6701	6729	7019	4·7	35		2.7.66
	6906	6989	7167	3·8	30	1 DH	2.9
	6991	7011	7180	2·7	34	2 DH	2.11
	6845	6971	7004	2·3	34	3 DH	2.16

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TUBE TYPE 6226

TUBE #	PLATEAU POINTS - CPM 700v.	750v.	800v.	R.P.S. % /100v.	BACK GROUND c/m	TEST	DATE
3532	5126	5750	5995	15.1	31		2.21
	5251	5838	6124	15.0	28	1. DRY HEAT	2.25
	5519	5961	6206	11.5	30	2. DRY HEAT	3.2
	5799	6283	6316	8.3	29	3. DRY HEAT	3.4
3463	5426	5859	6056	10.8	8		2.21
	5592	5885	6164	9.8	4	1 DH	2.25
	5662	6270	6052	6.2	5	2 DH	3.2
	5610	6235	6289	10.9		3 DH	3.4
3544	7737	7982	8336	7.5	9		2.21
	7921	7959	8219	3.8	6	1 DH	2.25
	7835	8022	8287	5.6	6	2 DH	3.2
	7841	7869	8309	6.0	6	3 DH	3.4
3450	5719	5989	6268	9.2	13		2.21
	5643	5930	6207	9.5	14	1 DH	2.25
	5829	6145	6148	5.2	10	2 DH	3.2
	5849	5899	6202	6.0	10	3 DH	3.4

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TUBE #	PLATEAU POINTS - CPM			R.P.S. % /100v.	BACK GROUND c/m	TEST	DATE
	700v.	750v.	800v.				
3545	5955	6189	6224	4.3	4		10.28
	6028	5998	6237	3.5	7	1. DRY HEAT	11.1
	6138	6126	6260	2.0	4	2. DRY HEAT	11.5
	6062	6270	6164	1.6	4	3. DRY HEAT	11.27
1957	6184	6308	6424	3.8	7		10.28
	6357	6434	6589	3.6	9	1.D.A	11.1
	6409	6584	6679	4.1	6	2.D.A	11.5
	6501	6606	6923	6.2	7	3.D.A	11.27

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TUBE #	PLATEAU POINTS - CPM 700v.	750v.	800v.	R.P.S. % /100v.	BACK GROUND c/m	TEST	DATE
3571	5770	6178	6118	5.6	4		2.7.66
	5829	5952	6062	3.9	11	1. DRY HEAT	2.9
	5799	6082	6294	8.1	3	2. DRY HEAT	2.11
	5900	5839	6119	3.8	2	3. DRY HEAT	2.16
3459	5672	6053	6169	8.2	2		2.7.66
	5942	6123	6232	4.7	3	1.DH	2.9
	6062	6130	6389	5.3	2	2.DH	2.11
	6146	6252	6538	6.3	3	3 DH	2.16
3583	5358	5868	6251	15.2	7		2.7.66
	6109	6454	6582	2.7	5	1 D.H	2.9
	6184	6305	6524	7.0	5	2.DH	2.11
	6160	6350	6432	4.3	5	3.DH	2.16
3581	5520	5865	6005	8.3	1		2.7.66
	5924	6204	6249	5.2	2	1 D.H	2.9
	6076	6280	6503	6.8	2	2.DH	2.11
	5859	5984	6395	9.0	1	3 DH	2.16

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TUBE #	PLATEAU POINTS - CPM 700 v.	750 v.	800 v	R.P.S. % 00 v.	BACK GROUND c/m	TEST	DATE
3563	5306	5610	6165	15·3	5		2·21
	5568	5849	5885	5·4	5	1. DRY HEAT	2·25
	5566	5735	5872	5·7	5	2. DRY HEAT	3.2
	5585	5699	5929	6·1	7	3. DRY HEAT	3.4
3594	5520	5751	5889	6·4	2		2·21
	5547	5773	5885	5·9	6	1 D4	2·25
	5490	5643	5915	7·5	5	2 D4	3.2
	5449	5671	5799	6·2	1	3 D4	3.4
3600	5299	5526	5731	7·8	2		2·21
	5642	5788	6072	7·5	4	1 D4	2.25
	5577	5643	5822	4·0	4	2 D4	3·2
	5606	5701	5825	3·8	3	3 D4	3·4

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TUBE #	PLATEAU POINTS - CPM 700 v.	750 v.	800 v.	R.P.S. % / 100 v.	BACK GROUND c/m	TEST	DATE
3504	5455	6040	6290	13.8	.3		2.21
	5671	6156	6360	11.2	.2	1. DRY HEAT	2.25
	6091	6555	6414	4.9	4	2. DRY HEAT	3.2
	6188	6611	6690	7.6	3	3. DRY HEAT	3.4
3467	5680	5899	6164	8.2	4		2.21
	5719	5937	6119	6.8	4	1 DH	2.25
	5616	5931	6101	8.2	2	2 DH	3.2
	5763	6044	6264	8.3		3 DH	3.4
3451	5536	5853	6184	11.1	8		2.21
	5932	6029	6195	3.9	6	1 DH	2.25
	5922	6105	6297	6.1	6	2 DH	3.2
	5905	6055	6506	9.9	6	3 DH	3.4
3643	5450	5563	5822	6.7	6		2.21
	5769	6020	6064	4.9	6	1 DH	2.25
	5755	5825	5863	1.9	6	2 DH	3.2
	5744	5845	6022	4.1	5	3 DH	3.4

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TUBE #	PLATEAU POINTS - CPM 700v.	750v.	800v	R.P.S. %/100v.	BACK GROUND c/m	TEST	DATE
3094	5975	6034	6198	3.6	11		6.30
	5784	5931	6109	3.7	11	1. DRY HEAT	7.6
	5861	5970	6061	3.3	11	2. DRY HEAT	7.12
	5640	5809	5824	3.1	9	3. DRY HEAT	8.2
3165	5877	6035	6146	2.8	2		6.30
	5600	5853	5888	4.8	2	1 Dry Heat	7.6
	5970	6014	6071	1.6	1	2 Dry Heat	7.12
	5840	5912	5980	6.6	1	3 Dry Heat	8.2
3225	5887	6047	6199	3.5	2		6.30
	5724	5873	5912	3.2	2	1 Dry Heat	7.6
	5821	6037	6052	4.3	1	2 Dry Heat	7.12
	5745	5902	5939	1.6	2	3 Dry Heat	8.2
3142	5825	6048	6091	4.1	-		6.30
	5730	6010	6051	5.3	3	1 Dry Heat	7.6
	5917	6071	6116	5.0	4	2 Dry Heat	7.12
	5721	5887	6011	4.9	2	3 Dry Heat	8.2

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TUBE #	PLATEAU POINTS - CPM 700	750	800	R.P.S. % /100v.	BACK GROUND c/m	TEST	DATE
3397	5621	5865	5923	5.0	2		6.30
	5420	5791	6099	11.6	2	1. DRY HEAT	7.6
	5124	5992	6177	7.5	2.	2. DRY HEAT	7.12
	5562	5722	6039	8.3	2	3. DRY HEAT	8.2

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TUBE #	PLATEAU POINTS - CPM			R.P.S. % / 100V.	BACK GROUND c/m	TEST	DATE
	700	750	800				
3524	5769	5870	6050	4·8	1		8.30
	5743	5994	6152	8·2	3	1. DRY HEAT	9.1
	5661	6007	6164	8·4	2	2. DRY HEAT	9.7
	5708	5911	6044	5·7	1	3. DRY HEAT	9.10
3550	5580	5829	5966	6·6	2		8.30
	5817	6040	6250	7·2	1	1.D.H.	9.1
	5670	5909	6074	7·2	1	2.D.H	9.7
	5607	6032	6101	8·2	2	3.D.H.	9.10
3534	5538	5771	6280	12·8	0		8.30
	5436	6001	6201	12·7	0	1.D.H	9.1
	5721	6029	6131	6·8	1	2.D.H	9.7
	5533	5838	6009	8·1	0	3.D.H	9.10
3489	5746	5952	6249	8·5	2		8.30
	5511	6082	6100	9·7	2	1.D.H.	9.1
	5199	6038	6055	14·2	1	2.D.H.	9.7
	4710	5590	5912	21·5	2	3.D.H	9.10

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	700 v.	750 v.	800 v.				
3522	5356	5704	5825	8·2	3		8.30
	5099	5762	6045	16·4	2	1. DRY HEAT	9.1
	4189	5280	5833	31·0	3	2. DRY HEAT	9.7
	4428	5397	5748	24·5	3	3. DRY HEAT	9.10
3499	5745	5955	5904	2·7	3		5.30
	5611	5984	6113	8·4	6	1 D.H	9.1
	5003	5675	6141	19·8	5	2 D.H	9.7
	4730	5704	5959	21·5	5	3 D.H	9.10
3554	5741	6060	6651	15·0	0		5.30
	5094	6064	6088	16·4	1	1 D.H	9.1
	5780	6023	6081	9·6	1	2 D.H	9.7
	5604	5897	6014	7·0	0	3 D.H	9.10
3507	5637	5964	6072	7·3	2		5.30
	5321	5974	6120	13·4	2	1 D.H	9.1
	5446	6008	6215	12·8	3	2 D.H	9.7
	5342	5997	6248	15·1	2	3 D.H	9.10

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	700v.	750v.	800v.				
3460	5691	5805	5915	3.9	1		8.30
	4971	5962	6170	19.8	1	1. DRY HEAT	9.1
	4522	5002	5926	28.0	1	2. DRY HEAT	9.7
	4626	5574	5839	21.7	1	3. DRY HEAT	9.10
3491	5432	5815	5963	9.5	4		8.30
	5563	5961	6117	9.3	2	1.D.H	9.1
	5749	5930	6137	6.4	2	2 D H	9.7
	5830	6018	6016	3.1	3	3 D H	9.10
3528	5689	5770	6093	7.0	1		8.30
	5753	6118	6234	7.9	1	1.D H	9.1
	5590	6005	6170	9.7	2	2 D.H	9.7
	5588	5957	6046	7.7	1	3.D.H	9.10
3502	5724	6026	6310	9.7	0		8.30
	5657	5991	6155	8.3	2	1.D H	9.1
	5834	6004	6084	4.2	1	2 D.H	9.7
	5811	5986	6224	6.9	1	3.D.H	9.10