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RAYTHEON Technical Report

2156
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THERMIONIC CATHODE EVALUATION STUDY

INTERIM REPORT NO. 6

FACILITY FORM 602

N69-21127
(ACCESSION NUMBER)

(THRU)

28
(PAGES)

1
(CODE)

CR# 100447
(NASA CR OR TMX OR AD NUMBER)

09
(CATEGORY)

APR 1969
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MICROWAVE AND POWER TUBE DIVISION

MICROWAVE TUBE OPERATION, WALTHAM, MASS. 02154

RAYTHEON COMPANY
Microwave and Power Tube Division
Waltham, Massachusetts

INTERIM REPORT NO. 6
THERMIONIC CATHODE EVALUATION STUDY

NASA Prime Contract No. NAS7-100
Subcontract No. 951810

October 1 - December 31, 1968

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100

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PT-2156
19 March 1969

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

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ABSTRACT

During the sixth interim period of thermionic-cathode evaluation, diodes using pore-dispenser cathodes have completed at least 10942 hours of life burning and are operating satisfactorily at cathode temperatures of 950°C to 1100°C and at current densities of 0.2A/cm^2 to 1.6A/cm^2.

Diodes using standard barium-strontium oxide cathodes have completed life burning times varying from 7600 to 9720 hours. The diodes are showing cathode emission slump at current densities above 0.15A/cm^2 and cathode temperatures of 825°C to 850°C under T_3 and T_4 operating conditions.

Seven lots of diodes (28 total) were constructed and tested for cathode emission with three different nickel cathode alloys with oxide and coated-particle coating according to the specifications under Modification No. 1 of the program.

The diodes showed low and slumping thermionic emission levels attributable to cathode coating peeling in the case of the oxide cathode and sintered coating in the case of the coated-particle cathode.

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1.0 INTRODUCTION

The materials and Techniques Group of Raytheon's Microwave and Power Tube Operation is performing a study of the life capabilities of these different types of thermionic emitters for the Jet Propulsion Laboratory, California Institute of Technology.

The life capabilities of the following electron-tube cathodes are being evaluated for a period of two years of life testing.

a. Pore-dispenser cathode

b. Coated-particle cathode.

c. Standard oxide cathode.

During this period of study, the thirty-one diodes using pore-dispenser cathodes and oxide cathodes were continued on life burning. The results are reported in Section 2.0 and 3.0.

The diodes constructed with three different nickel cathode alloys are reported in Section 4.0.

2.0 LIFE BURNING AND TESTING OF PORE-DISPENSER CATHODES

The test diodes, constructed with pore-dispenser cathodes and operating under T_1, T_2, and T_3 life-test conditions have completed 11046 hours as of the end of the sixth interim period of study.

The test diodes under T_4 conditions have completed 10943 hours of life burning. The life test results are shown in Tables 1(T_1), 2(T_2), 3(T_3), and 4(T_4).

The last three sets of readings for each diode are the readings taken at the end of the months of October, November, and December, 1968.

As noted in the tables, at each interval of life burning the diodes are tested for cathode current at constant anode voltage and cathode temperature. The cathode current is also recorded for ± 20% of the specified anode voltage.

The diodes are removed from the life-test rack and are read for dip temperature at the specified operating current and for current at 95% of the dip temperature according to the procedure described in the first interim report, Thermiomic Cathode Evaluation Study, January 1 - June 30, 1967.

Figures 1 through 4 are included in this interim report to give a clearer picture of the overall changes in operating current levels for the pore-dispenser cathodes at T_1, T_2, T_3, and T_4 conditions for the 11046 hours of life burning under constant temperature and plate voltage conditions.

TABLE I

LIFE TEST RESULTS

PORE - DISPENSER CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T °C	Ip @ 95[illegible]
T1-950°C, 0.2 A/cm²	M1 Ef = 9.0V	0	10.0	39V	8.4 - 12.0	880	8.80
		2688	11.0		8.9 - 13.2	891	8.00
		8693	11.0		9.0 - 12.9	904	8.57
		9463	10.9		8.9 - 12.9	881	8.69
		10258	11.0		9.0 - 13.1	901	8.50
		11046	11.0		9.0 - 13.1	891	8.69
	M4 Ef = 9.0V	0	10.0	26V	8.3 - 12.5	888	8.81
		2688	10.0		8.4 - 12.2	906	[illegible]25
		8693	9.9		8.4 - 12.0	896	[illegible]11
		9463	9.8		8.1 - 11.5	900	8.25
		10258	9.9		8.2 - 11.8	901	7.88
		11046	9.9		8.2 - 11.9	904	7.87
T1-950°C, 0.4 A/cm²	M2 Ef = 9.0V	0	20.0	49V	15.1 - 27.3	916	19.3
		2688	21.2		16.1 - 25.9	896	17.5
		8693	20.0		15.9 - 23.2	893	17.3
		9463	20.0		15.6 - 23.7	897	16.6
		10258	20.1		15.8 - 24.4	890	17.5
		11046	20.1		16.0 - 23.9	895	17.6
	M3 Ef = 9.0V	0	20.0	35V	16.5 - 27.0	897	15.0
		2688	20.7		16.2 - 25.2	907	16.6
		8693	20.0		15.8 - 23.4	919	15.8
		9463	20.8		16.8 - 24.3	904	16.5
		10258	20.4		16.0 - 24.3	893	16.6
		11046	20.2		16.0 - 23.9	880	17.6

TABLE 2

LIFE TEST RESULTS
PORE - DISPENSER CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T °C	Ip @ 95% I
T2 - 985°C 0.4A/cm²	M7 Ef = 9.0V	0	20.0	34.5V	16.8 - 27.5	899	19.3
		2688	20.0		15.8 - 24.4	957	16.6
		8693	23.9		18.8 - 29.9	957	16.3
		9463	23.9		18.8 - 29.9	943	17.5
		10258	23.9		18.8 - 29.9	951	17.9
		11046	23.9		18.8 - 29.9	945	17.5
	M9 Ef = 9.0V	0	20.0	40V	14.6 - 28.5	910	18.8
		2688	22.5		15.9 - 29.1	935	17.7
		8693	21.5		15.8 - 27.2	941	17.5
		9463	21.8		15.6 - 27.9	943	18.0
		10258	21.8		15.6 - 27.9	948	17.3
		11046	21.8		15.6 - 27.8	941	17.1
T2 - 985°C 0.8A/cm²	M11 Ef = 9.0V	0	40.0	65V	32.0 - 49.5	964	28.0
		2688	37.5		30.8 - 45.8	979	30.3
		8693	34.[illegible]		28.4 - 41.2	970	31.6
		9463	32.7		27.4 - 37.3	985	24.8
		10258	35.8		29.7 - 41.8	985	28.8
		11046	35.5		29.7 - 41.2	946	35.0
	M12 Ef = 9.0V	0	40.0	54V	31.0 - 50.0	913	38.0
		2688	37.0		29.2 - 45.0	957	32.0
		8693	32.1		25.9 - 37.3	951	31.6
		9463	32.1		25.9 - 37.3	946	32.5
		10258	32.0		25.8 - 37.3	938	32.5
		11046	33.8		27.2 - 39.9	910	34.5

TABLE 3

LIFE TEST RESULTS
PORE - DISPENSER CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T°C	Ip @ 95%T
T3 - 1035°C $0.6 A/cm^2$	M13 Ef = 11.0V	0	30.0	45V	22.5 - 38.5	965	29.2
		2688	30.0		23.9 - 39.8	961	26.4
		8693	32.2		24.6 - 41.0	1001	25.8
		9463	32.0		22.5 - 41.0	983	26.2
		10258	32.1		24.4 - 40.3	985	27.2
		11046	32.2		24.2 - 40.1	972	24.2
	M18 Ef = 11.0V	0	30.0	48.5V	21.5 - 38.0	949	29.2
		2688	30.0		23.0 - 37.8	1003	25.6
		8693	32.0		24.9 - 40.0	1001	25.0
		9463	33.7		24.4 - 40.0	1005	25.4
		10258	31.7		25.1 - 41.1	1008	26.0
		11046	31.7		24.7 - 40.0	1020	25.4
T3 - 1035°C $1.2 A/cm^2$	M17 Ef = 11.0V	0	60.0	90V	45.0 - 78.5	993	55.5
		2688	61.2		47.8 - 77.4	1020	51.6
		8693	62.2		49.1 - 75.8	1035	51.6
		9463	63.9		49.9 - 77.0	1035	51.8
		10258	63.8		51.7 - 79.9	1035	52.0
		11046	63.2		51.2 - 78.8	1024	51.2
	M14 Ef = 11.0V	0	60.0	98V	44.5 - 69.0	995	56.0
		2688	54.9		41.2 - 70.2	977	55.2
		8693	53.8		40.2 - 67.9	980	55.2
		9463	54.8		47.5 - 68.9	990	57.4
		10258	55.0		41.2 - 70.4	980	56.0
		11046	53.7		40.1 - 68.4	999	54.8

TABLE 4
LIFE TEST RESULTS
PORE - DISPENSER CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T°C	Ip @ 95% 1
T4 - 1100°C 0.8A/cm^2	M21 Ef = 11.0V	0	40.0	57V	23.0 - 52.0	957	37.6
		2521	46.4		28.8 - 59.5	1055	34.6
		8580	51.8		31.4 - 64.0	1042	32.5
		9350	51.0		31.2 - 64.0	1035	29.6
		10145	50.9		31.4 - 63.8	1044	33.5
		10943	50.2		31.0 - 63.0	1048	29.0
	M23 Ef = 11.0V	0	40.0	73V	24.0 - 51.0	997	38.0
		2521	37.2		23.9 - 45.8	1079	31.0
		8580	35.9		23.9 - 42.3	1100	25.0
		9350	32.1		29.4 - 50.0	1100	20.2
		10145	40.7		27.5 - 47.2	1100	30.0
		10943	37.0		24.8 - 46.2	1100	29.0
T4 - 1100°C 1.6A/cm^2	M22 Ef = 11.0V	0	80.0	106V	59.0 - 100.0	1039	73.0
		2521	86.5		71.7 - 110.0	1051	66.0
		8580	86.9		74.2 - 110.0	1100	62.0
		9350	85.4		73.7 - 110.0	1100	64.2
		10145	86.4		74.0 - 110.0	1100	65.4
		10943	86.3		74.1 - 110.0	1100	63.0

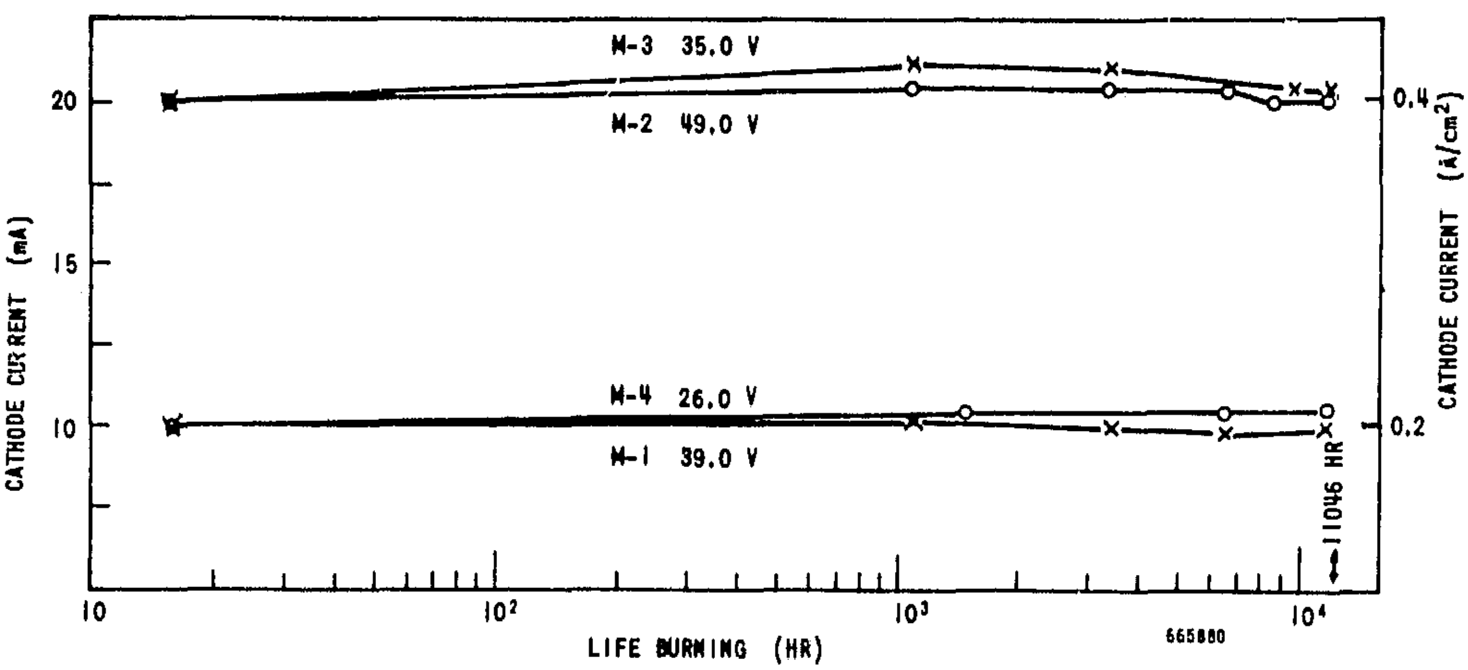

Figure 1. Pore-dispenser Cathode - T1 = 950°C_{BR}

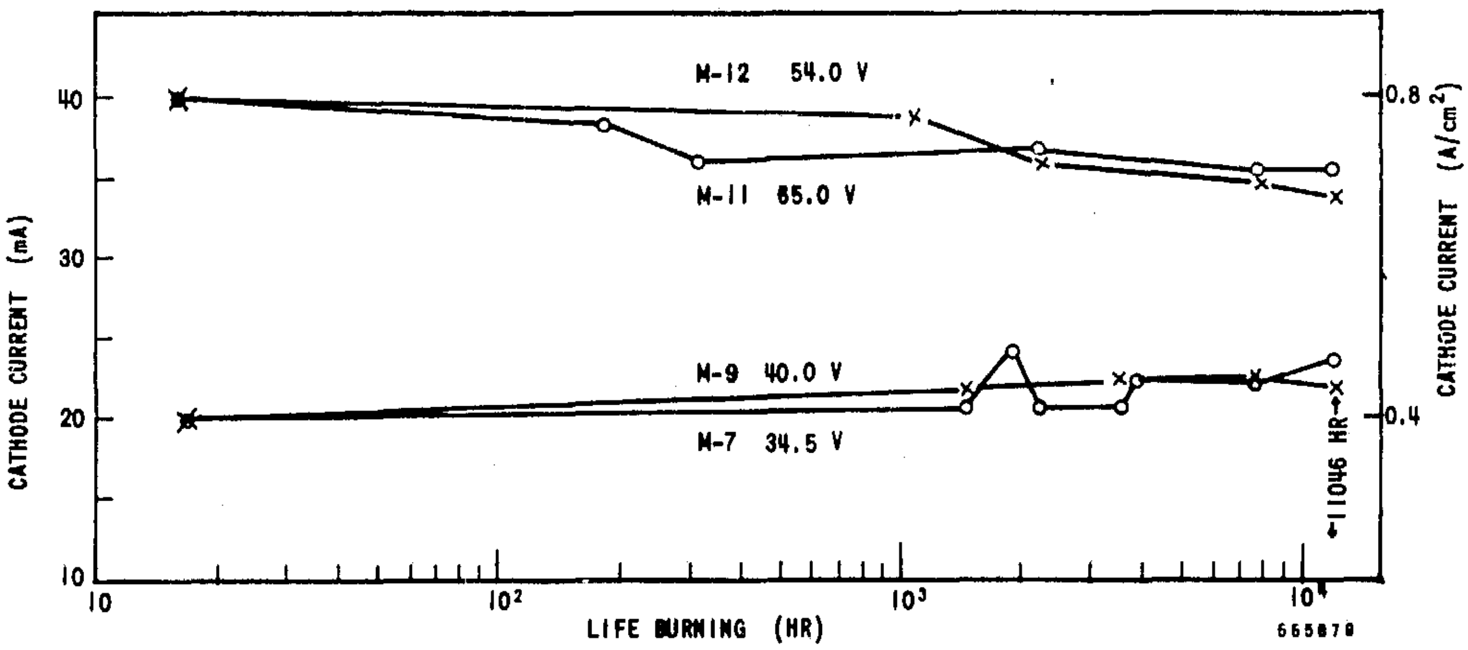

Figure 2. Pore-dispenser Cathode - T2 = 985°C_{BR}

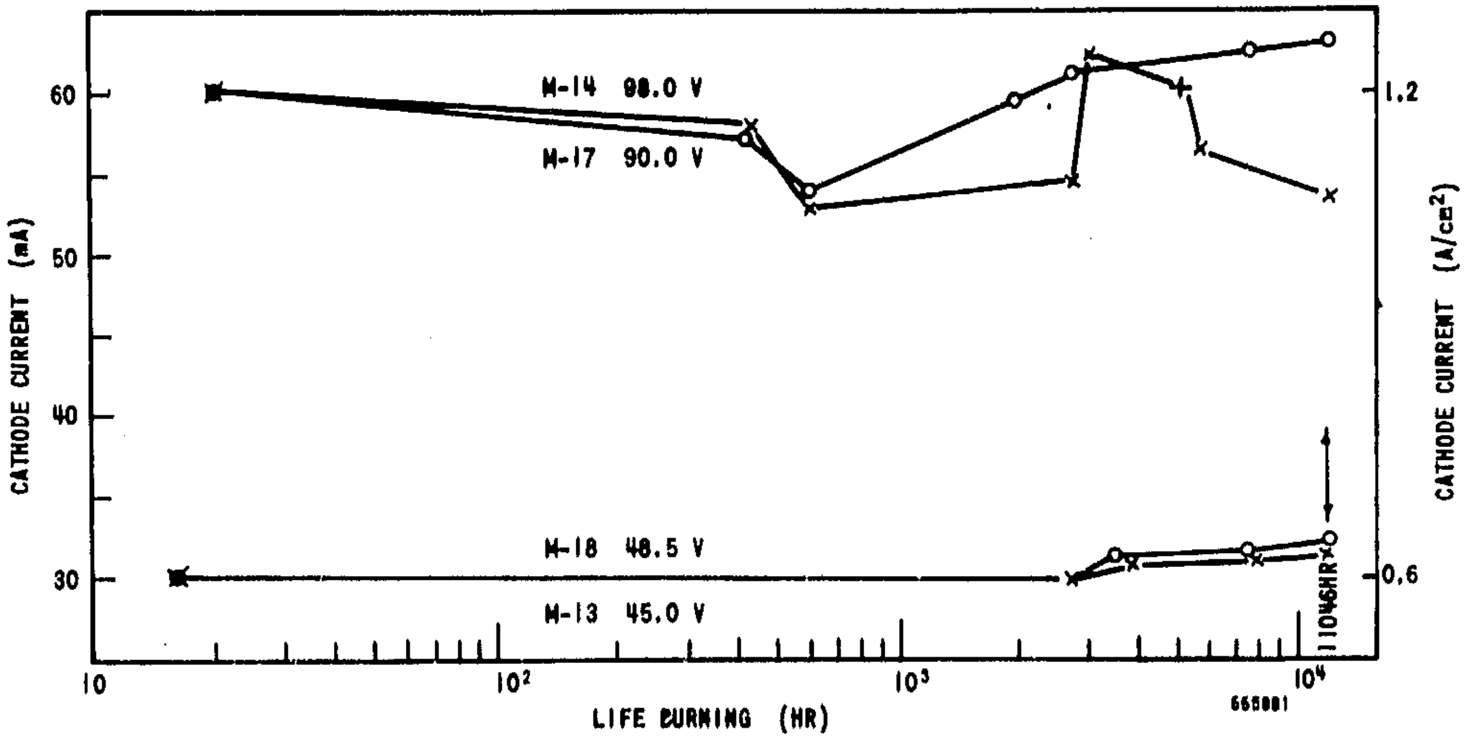

Figure 3. Pore-dispenser Cathode - T3 = 1035° C_{BR}

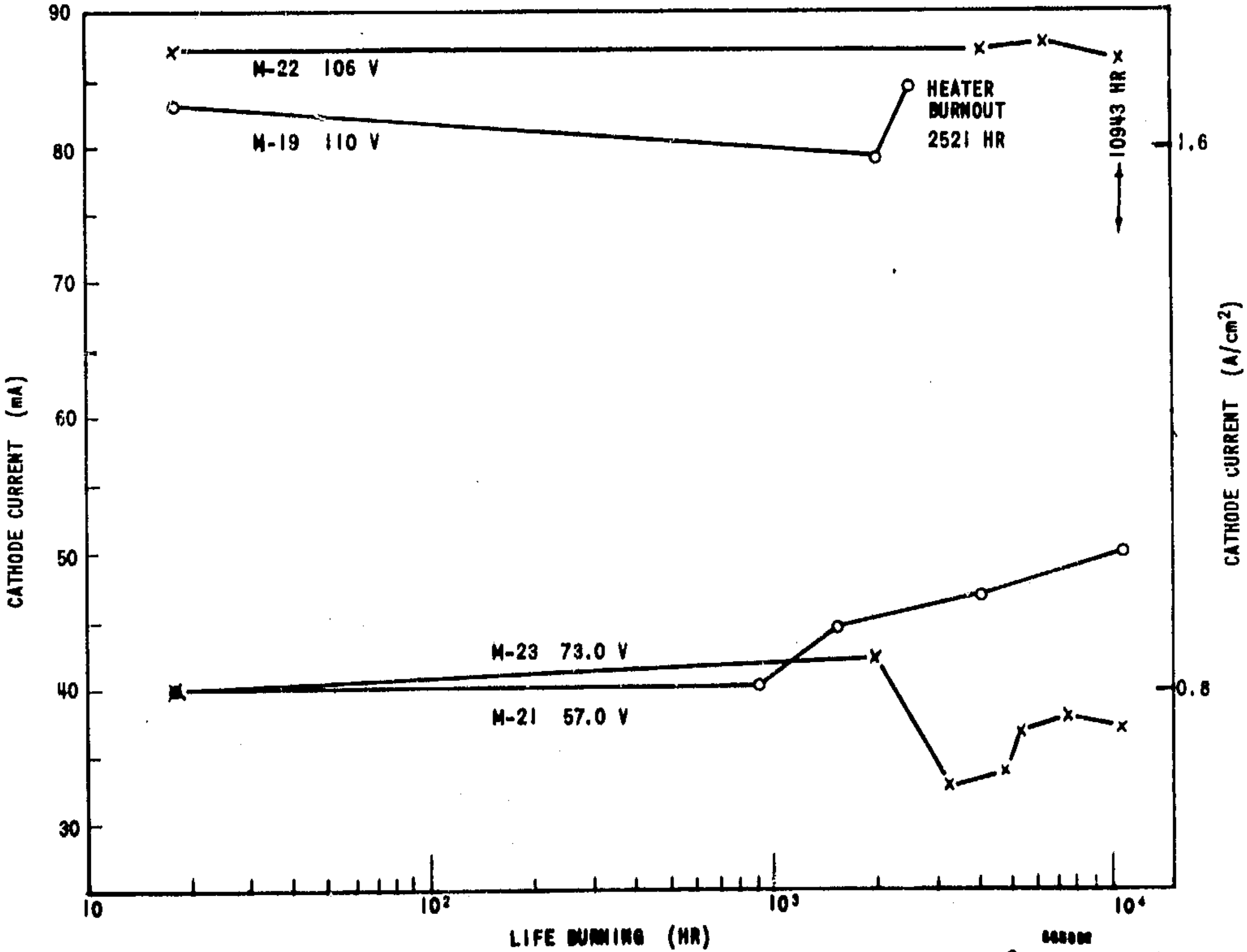

Figure 4. Pore-dispenser Cathode - T4 = 1100°C_{BR}

The diodes operating under T_1 conditions (950°C, 0.2 and 0.4A/cm^2) have not shown any significant changes in life burning conditions or in the test conditions.

The diodes operating under T_2 conditions (985°C, 0.4A/cm^2) have not shown any changes in characteristics up to 11046 hours of life burning. The diodes operating under T_2 conditions (985°C, 0.8A/cm^2) have shown a slump of 12.4 and 15.5% up to this point in life burning.

One diode (1035°C, 1.2A/cm^2) under T_3 conditions has shown a 10.5% slump in cathode current in 11046 hours. The other three diodes under T_3 conditions have not shown any significant changes in operating or test characteristics.

The diodes operating under T_4 conditions (1100°C, 0.8 and 1.6A/cm^2) have not shown any significant changes in cathode current for 10943 hours of life burning.

In summary, it can be said that the pore-dispenser cathodes have been operating satisfactorily up to 10943 hours of life-burning from 950°C to 1100°C with the cathode current varying from 0.2A/cm^2 to 1.6A/cm^2.

3.0 LIFE BURNING AND TESTING OF OXIDE-COATED CATHODES

The test diodes with oxide-coated cathodes under T_1 and T_2 conditions have completed 7600 hours of life burning.

The test diodes with oxide-coated cathodes under T_3 and T_4 conditions have completed 9720 hours of life burning.

The life-test results are shown in Tables 5(T_1), 6(T_2), 7(T_3), and 8(T_4). Figures 5 through 8 are also included for the purpose of showing the changes in operating current levels under the specified conditions as noted in the figures.

The diodes operating under T_1 conditions (1800°C, 0.075 A/cm^2 and 0.15 A/cm^2) have shown a change in cathode operating current from 8.8 to 25.0%.

The diodes operating under T_2 conditions (825°C, 0.15 A/cm^2 and 0.30 A/cm^2) are showing a slump in cathode current of 0 to 29.6%. It should also be noted that the dip temperatures have risen to 825°C (operating temperature).

The diodes operating at T_3 conditions (825°C, 0.225 A/cm^2 and 0.45 A/cm^2) are showing cathode current slumps from 17.0% to 69.4%. The dip temperature is also up to 825°C (operating temperature).

The diodes under T_4 conditions (850°C, 0.3 A/cm^2 and 0.6 A/cm^2) are showing cathode current slumps from 24% to 52%. The dip temperature is also up to 850°C.

An analysis of the test results shows the diodes with oxide-coated cathodes to be slumping at current densities above 0.15 A/cm^2 as the current density or temperature is increased.

TABLE 5
LIFE TEST RESULTS
OXIDE - COATED CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T°C	Ip @ 95% T
T1 - 800°C 0.075A/cm^2	0-32 Ef = 8.0V	0 1371 5238 6018 6813 7600	6.0 6.0 5.1 5.1 5.2 5.2	19.5V	4.7 - 7.9 4.9 - 7.4 4.2 - 6.1 4.2 - 6.0 4.2 - 6.0 4.2 - 6.0	722 666 693 742 740 732	4.13 5.14 5.19 5.06 5.11 4.95
	0-35 Ef = 8.0V	0 1371 5238 6018 6813 7600	8.0 7.8 7.1 7.0 7.0 7.0	18.5V	7.1 - 9.7 7.2 - 8.9 7.4 - 8.0 6.8 - 7.0 6.8 - 7.0 6.8 - 8.0	750 740 774 780 802 780	4.13 5.14 4.88 4.76 4.69 4.88
T1 - 800°C 0.15A/cm^2	0-39 Ef = 8.0V	0 1371 5238 6018 6813 7600	12.0 11.8 11.8 12.1 9.0 9.0	36V	9.0 - 15.1 8.9 - 14.3 8.9 - 14.4 9.6 - 14.4 6.4 - 11.2 6.4 - 10.9	655 680 692 726 755 714	10.9 10.5 10.3 9.8 10.1 10.2
	0-40 Ef = 8.0V	0 1371 5238 6018 6813 7600	12.0 12.0 10.3 10.1 10.2 10.0	29V	9.6 - 14.7 9.9 - 14.1 8.9 - 12.2 8.2 - 11.9 8.3 - 12.2 8.4 - 12.0	769 703 743 761 775 757	9.3 10.1 9.1 10.2 9.4 9.75

TABLE 6
LIFE TEST RESULTS
OXIDE - COATED CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T°C	Ip @ 95% I
T2 - 825°C 0.15A/cm²	0-38 Ef = 8.0V	0	12.0	29V	9.3 - 15.2	741	11.0
		1371	11.0		8.0 - 13.0	804	10.2
		5238	9.9		8.0 - 11.4	825	8.7
		6018	9.0		7.4 - 10.6	825	8.5
		6813	10.0		8.2 - 11.7	825	8.1
		7600	14.2		12.1 - 15.8	825	9.7
	0-41 Ef = 8.0V	0	12.0	34V	9.1 - 14.7	727	10.8
		1371	12.0		9.3 - 14.9	758	10.8
		5238	11.0		8.5 - 13.2	825	10.1
		6018	9.8		7.5 - 12.0	825	9.5
		6813	9.9		7.8 - 12.0	825	9.5
		7600	10.0		7.9 - 12.1	825	9.0
T2 - 825°C 0.30A/cm²	0-33 Ef = 8.0V	0	24.0	45V	19.0 - 30.4	787	21.0
		1371	20.9		16.2 - 25.4	825	20.8
		5238	19.2		15.0 - 23.0	825	18.0
		6018	18.3		14.2 - 22.1	825	19.5
		6813	17.8		14.0 - 21.0	825	17.4
		7600	16.9		13.7 - 20.2	825	17.2
	0-37 Ef = 8.0V	0	24.0	56V	19.1 - 30.7	735	22.6
		1371	21.0		17.0 - 24.7	825	18.0
		5328	20.0		16.5 - 23.5	825	19.1
		6018	20.0		16.7 - 23.4	825	18.0
		6813	20.0		16.8 - 23.4	825	18.9
		7600	20.0		16.9 - 23.3	825	20.1

TABLE 7

LIFE TEST RESULTS

OXIDE - COATED CATHODE

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T°C	Ip @ 95% I
T3 - 825°C 0.225A/cm^2	0-11 Ef = 8.0V	0	18.0	31V	14.0 - 22.2	779	16.4
		3439	11.0		9.0 - 12.4	825	11.6
		7368	10.4		8.9 - 12.4	825	12.4
		8138	10.4		8.4 - 12.4	825	12.4
		8933	10.4		8.6 - 12.4	825	14.1
		9720	10.0		8.4 - 12.0	825	12.6
	0-15 Ef = 8.0V	0	18.0	28V	13.9 - 23.5	769	16.6
		3439	14.2		11.3 - 18.0	825	13.5
		7368	13.4		10.7 - 15.9	825	10.8
		8138	15.7		11.8 - 19.8	825	10.7
		8933	12.8		10.3 - 15.0	825	7.3
		9720	12.4		10.2 - 15.0	825	11.9
T3 - 825°C 0.45A/cm^2	0-7 Ef = 8.0V	0	36.0	34V	28.0 - 45.5	783	33.5
		3439	20.0		17.0 - 22.4	825	32.8
		7368	18.6		16.3 - 21.9	825	28.4
		8138	18.4		16.3 - 21.8	825	22.5
		8933	11.0		10.9 - 14.3	825	28.1
		9720	11.0		10.9 - 14.3	825	22.5
	0-14 Ef = 8.0V	0	36.0	67V	28.0 - 44.5	768	31.7
		3439	35.4		27.0 - 46.2	825	29.3
		7368	33.0		26.9 - 44.2	825	24.8
		8138	30.5		24.7 - 43.9	825	24.1
		8933	31.0		24.8 - 44.3	825	21.4
		9720	29.8		24.2 - 42.5	825	28.4

TABLE 8
LIFE TEST RESULTS
OXIDE - COATED CATHODES

Test	Diode	Hours	Ip (ma)	Volts	Ip + 20% V	Dip T°C	Ip @ 95% I
T4 - 850°C	0-21	0	24.0	39V	18.2 - 29.0	774	21.6
0.3A/cm²	Ef = 8.0V	3439	15.0		12.2 - 19.8	850	18.3
		7368	13.5		10.9 - 17.4	850	16.9
		8138	13.9		10.9 - 16.3	850	16.4
		8933- -	-Diode Failed-		- -Loose Anode		
	0-22	0	24.0	46V	19.7 - 28.0	775	18.2
	Ef = 8.0V	3439	15.8		13.1 - 21.2	.850	19.3
		7368	11.7		10.0 - 13.1	850	13.5
		8138	11.8		10.0 - 13.1	850	13.8
		8933	11.5		10.0 - 13.0	850	13.1
		9720	11.5		9.9 - 12.3	850	8.2
T4 - 850°C	0-19	0	48.0	57.5V	35.0 - 59.3	796	42.0
0.6A/cm²	Ef = 8.0V	3439	41.9		31.4 - 64.5	850	36.0
		7368	42.2		32.2 - 55.8	850	35.1
		8138	39.2		30.9 - 53.8	850	34.2
		8933	37.4		29.3 - 52.2	850	27.4
		9720	36.5		29.3 - 51.8	850	28.5
	0-20	0	48.0	70V	36.8 - 60.0	769	42.6
	Ef = 8.0V	3439	41.4		32.0 - 55.3	850	37.5
		7368	35.8		26.9 - 44.9	850	31.2
		8138	31.9		25.8 - 42.7	850	31.2
		8933	32.5		26.0 - 40.0	850	23.7
		9720	28.3		23.1 - 36.4	850	24.2

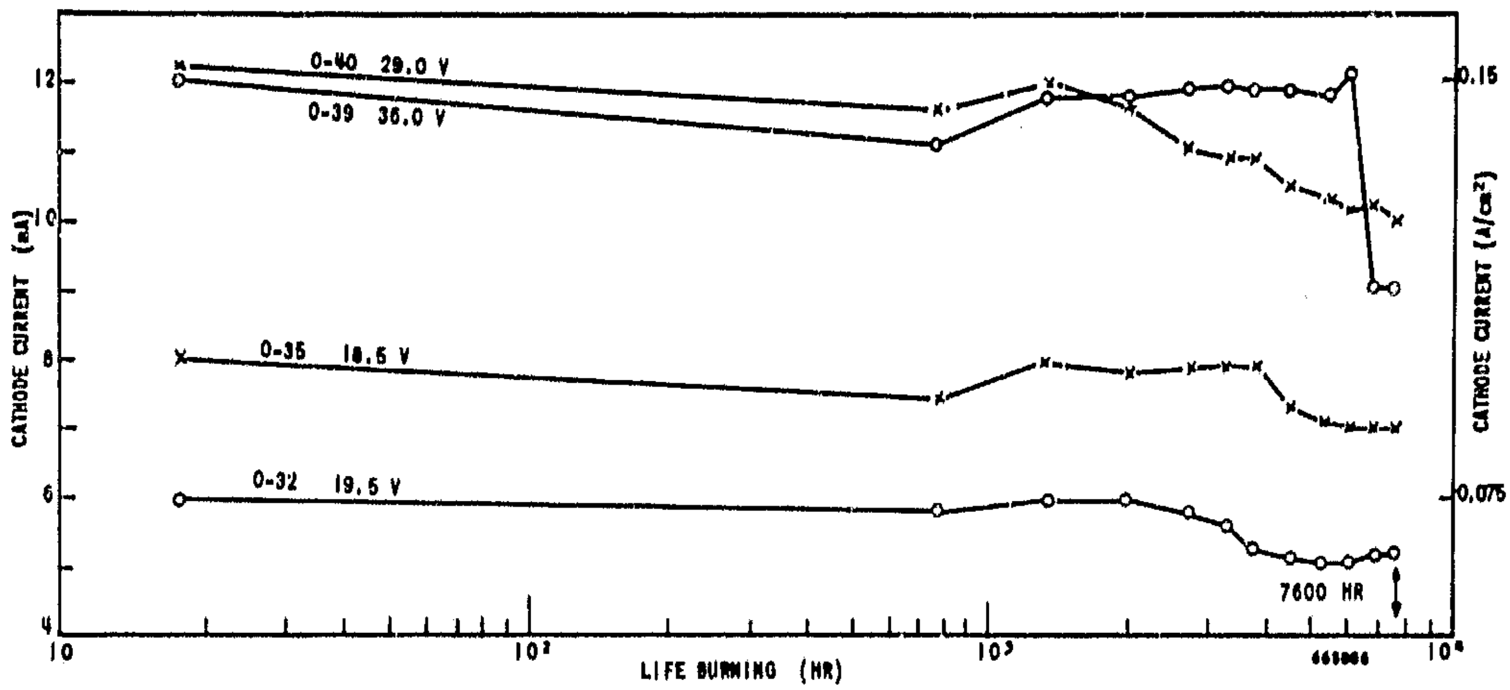

Figure 5. Standard Oxide Cathode - T1 = 800°C$_{BR}$

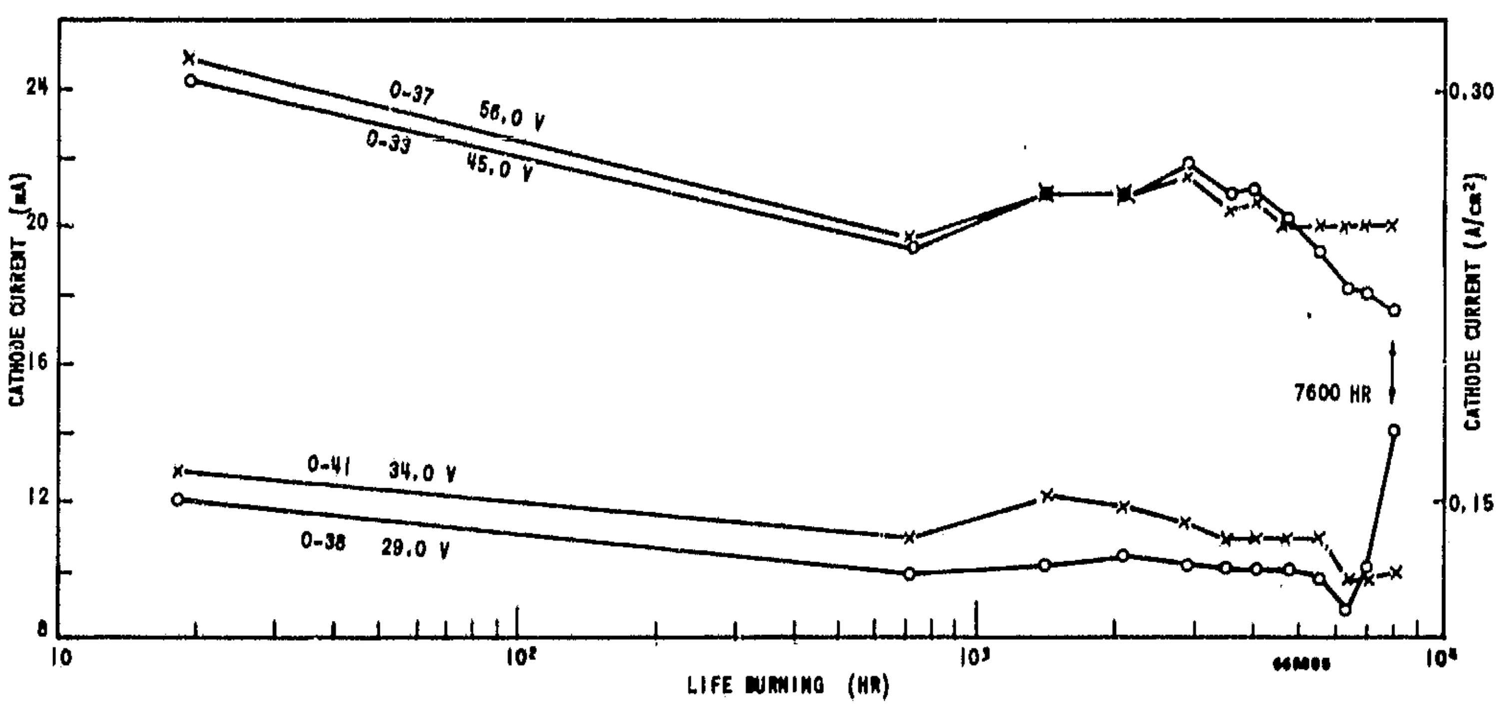

Figure 6. Standard Oxide Cathode - T2 = 825°C$_{BR}$

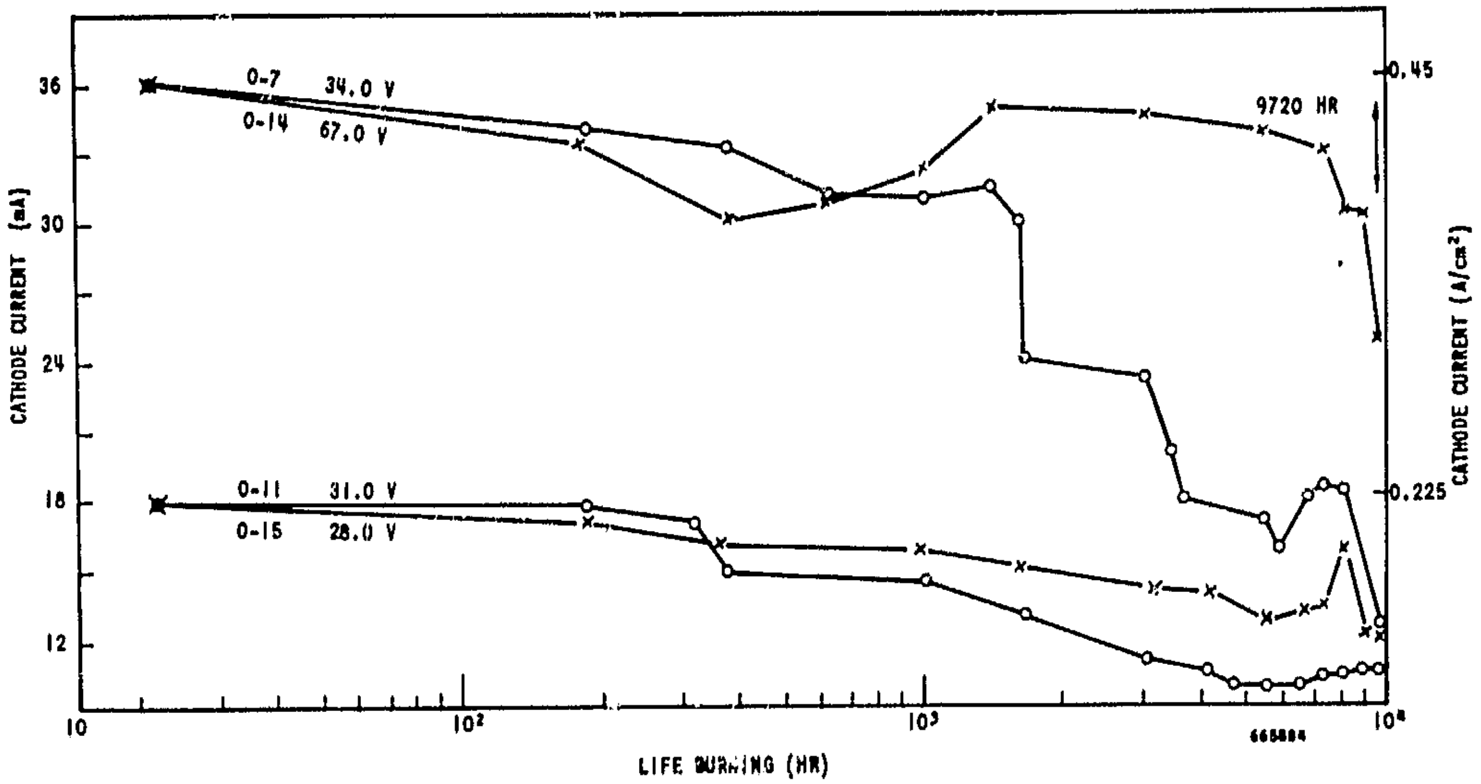

Figure 7. Standard Oxide Cathode - T3 = 825°C_{BR}

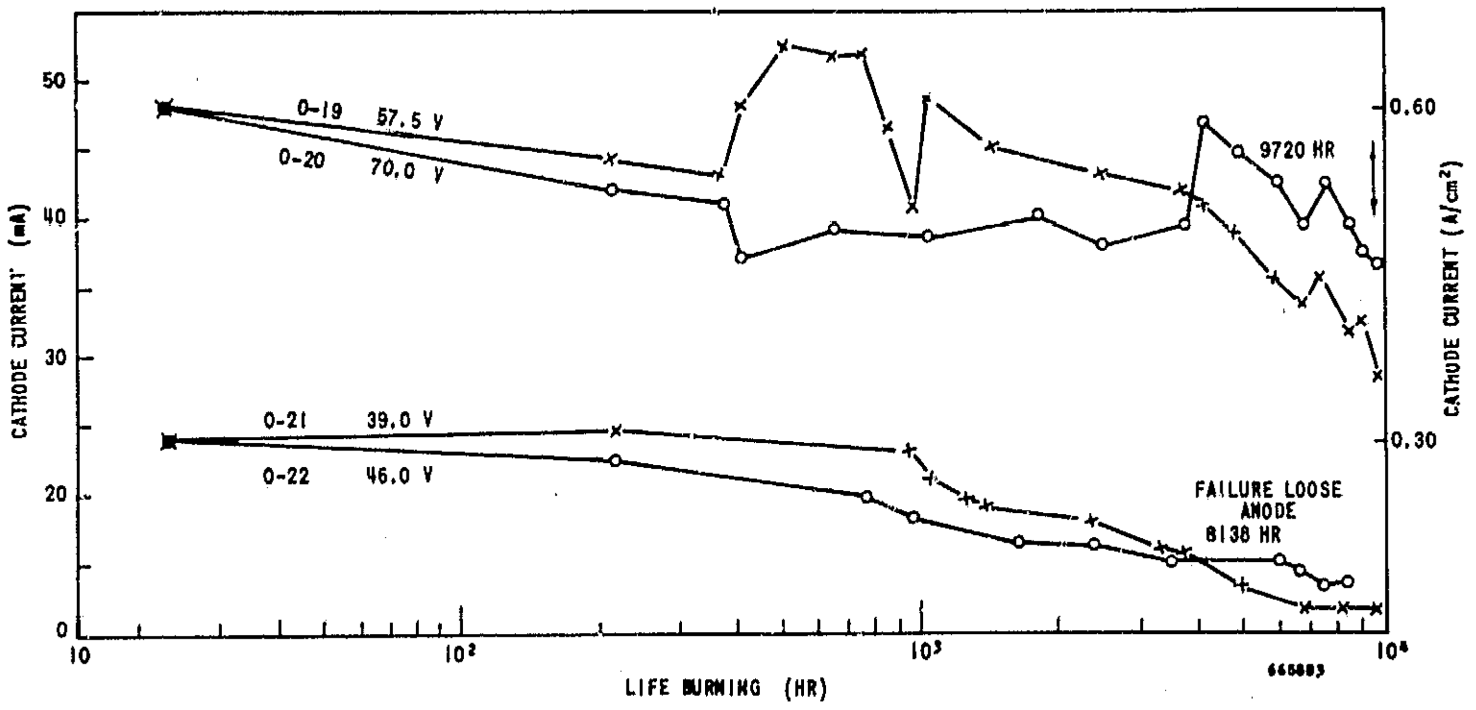

Figure 8. Standard Oxide Cathode - T4 = 850°C_{BR}

4.0 BEHAVIOR OF OXIDE-COATED AND COATED-PARTICLE CATHODES WITH THREE DIFFERENT CATHODE ALLOYS

The diodes, which were constructed with three different cathodes according to the specification described in Table 9, Life Test Procedures, Modification No.1, were exhaust processed, aged for stabilization, and pretested for life burning during this sixth interim period of study.

Interim Report No. 5, Thermionic Cathode Study, July 1 - September 30, 1968, describes in detail the fabrication of the cathodes and the construction of the diodes.

The diodes were exhausted on a double vacuum bakeout system in groups of four diodes. A total of seven exhaust loads were run on the system.

The seven lots of diodes contained the cathodes as described in Table 10.

TABLE 9
LIFE TEST PROCEDURES
MODIFICATION NO. 1

CATHODE	LIFE TEST TEMP.	REQ'D UNITS	CURRENT DENSITY ma/cm^2
	T_2	1	150
Oxide Cathode	T_2	1	300
Using 220 Alloy	T_3	1	225
Nickel Base	T_3	1	450
(4 Units)			
Oxide Cathode	T_2	1	150
Using Cathalloy	T_2	1	300
A-33 Nickel Base	T_3	1	225
(4 Units)	T_3	1	450
Oxide Cathode	T_2	1	150
Using 0.1% Zr in	T_2	1	300
Ni-pure Nickel Base	T_3	1	225
(4 Units)	T_3	1	450
Coated Particle	T_2	1	275
Cathode Using Cath-	T_2	1	550
alloy A-33 Nickel Base	T_3	1	415
(4 Units)	T_3	1	830
Coated Particle	T_2	1	275
Cathode Using 0.1%	T_2	1	550
Zr in Ni-pure Nickel Base	T_3	1	415
(4 Units)	T_3	1	830

TABLE 10

CATHODE DESCRIPTION - DIODE LOTS

DIODE LOT NO.	CATHODE	COATING
1	0.1% Zr in Ni-pure Nickel Alloy	Oxide-coating C51-3
2	A-33 Ni Alloy	CPC coating
3	A-33 Ni Alloy	Oxide coating C51-3
4	0.1% Zr in Ni-pure Nickel Alloy	CPC coating
5	220 Ni Alloy	Oxide coating C51-3
6	220 Ni Alloy	Oxide coating C51-3
7	220 Ni Alloy	Oxide coating C51-3

The exhaust system used to process the diodes consisted of a Vac-ion pumping system (125 l/s) for internal pumping of the vehicles and a vacuum bakeout oven backed by an oil-diffusion pump capable of 1×10^{-6} Torr pressure at 400 l/s.

The diodes were exhaust processed as follows:

a. Bakeout diodes at 450°C for 24 hours under double vacuum conditions (P at end of cycle = 1×10^{-6} Torr).

b. Heat anode to 900°C for 1 minute. ($P < 1 \times 10^{-7}$ Torr).

c. Heat cathode to 1000°C, maintaining pressure $< 1 \times 10^{-7}$ (20 - 30 minutes).

d. Hold at 1000°C for 5 minutes ($P = 3 \times 10^{-8}$ Torr).

e. Hold cathode at 900°C for 10 minutes ($P = 1 \times 10^{-8}$ Torr).

f. Tip off diode ($P = 1 \times 10^{-9}$ Torr).

g. Flash getter.

h. Attach bakelite base to diode.

The diodes were next aged for periods of 24 - 100 hours at 800 - 825°C cathode temperature and voltage at 50 V dc. The diodes under test showed from 6 - 12 mA of cathode current at 50 V dc. Increases in anode voltage showed little or no increases in cathode current.

Dip tests of the diodes at 800°C and 50 V dc anode voltage showed the diodes to be operating in the temperature-saturated region.

A physical examination after five lots of diodes using oxide-coating (C51-3) showed the coating to be very thin and peeling from the nickel-alloy base metal.

An examination of the coated-particle cathodes showed the coating to be very thin with slight peeling of the coating.

The tests were discontinued at this time because of the cathode-coating peeling problem.

5.0 PLANS FOR THE SEVENTH INTERIM REPORT

During the next interim period from January 1 to March 31, 1969, the following program will be in effect.

a. Continue life testing of pore-dispenser cathodes now on life burning.

b. Continue testing of oxide cathodes now on life burning.

c. Assemble and exhaust new diodes according to Table 9, with elimination of the cathode peeling problem.

d. Start life-burning of 20 diodes according to Table 9.

6.0 CONCLUSIONS AND SUMMARY

The Raytheon Materials and Techniques Group, in conducting a study of the life capabilities of the pore-dispenser cathode and the oxide cathode, has drawn the following conclusions from fifteen months of life burning under the conditions noted in Tables 1 through 8.

a. The pore-dispenser method is suitable for dc operation for at least 10943 hours at current ranges of 0.2 A/cm^2 to 1.6 A/cm^2 and temperatures ranging from 950°C to 1100°C.

b. The standard barium/strontium-oxide cathodes are showing emission slump at current densities above 0.15 A/cm^2 under T_3 and T_4 operating condition from 7600 to 9720 hours. Though the emission level in these diodes is decaying, they should not be counted as failures at this point of life.

c. The diodes constructed with the cathode alloy modifications listed in Table 9 have shown cathode coating peeling in the case of the oxide-coated cathode and very thin coating in the case of the coated-particle cathode. Both these conditions have contributed to low cathode emission and slump.

d. It is postulated that the reason for the cathode peeling in the case of the oxide cathode is the lack of surface roughness which is necessary for physical adhesion of the coating particles to the nickel alloy base. In order to overcome this difficulty, the next lots of diodes with nickel alloy cathodes will have a sintered layer of pure nickel on the cathode base metal to increase adhesion.

e. At this point, the only candidate for satisfying the objective of 1 A/cm^2 is the pore-dispenser cathode.