NASA Technical Memorandum 81441



# THERMIONIC CATHODE LIFE TEST STUDIES

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Prepared for the
1980 Tri-Services Cathode Workshop
sponsored by the Department of the Air Force
New York, New York, April 15-17, 1980

# THERMIONIC CATHODE LIFE TEST STUDIES

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## SUMMARY

A NASA-Lewis Research Center Program for life testing commercial, high-current density impregnated tungsten cathodes has been in progress since 1971. This report is an update of this program first presented at the Cathode Workshop in Washington in 1978. B-type cathodes, operated at a current density of $2A/cm^2$ and a cathode temperature of $1100^oC$, have now been run satisfactorily for more than four years. M-cathode, at the same current density but at an operating temperature of only $1010^oC$, have been tested for more than three years. The M-cathodes show no degradation in current over their present operating life whereas the current from the B-cathodes degrade about 6% after four years of operation.

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## DISCUSSION

At the Cathode Workshop held in Washington, D.C. in February, 1978, life test data on impregnated tungsten cathodes were first presented.[1] The present report is an update of this information which is part of a NASA-Lewis Research Center program for life testing commercial, high-current density impregnated tungsten cathodes, in progress since 1971. The program was sponsored by the Lewis Research Center and contracted to Watkins-Johnson Company of Palo Alto, California. The objectives of this continuing program are: 1) to demonstrate the ability of specific cathode types to produce current densities of $2A/cm^2$ over a minimum design life of 20,000 hours of continuous operation without failure and 2) to competitively evaluate the performance of different cathode types by endurance testing, while operating under identical electrical, geometrical and vacuum conditions that realistically duplicate the operating conditions present in a transmitter tube. To accomplish the latter objective, a cathode life test tube was designed which is essentially the same as a high power microwave tube.[2] The only difference between the cathode life test unit and a high power microwave tube is that the former uses a solid metal drift tube in place of the rf interaction circuit employed in the latter.

Five different cathode types have been evaluated on this program. They are the "B", "S", "Tungstate," "M" and Litton type "B" cathode. The "B" type is an impregnated tungsten cathode originally developed by Philip Metalonics.[3,4] Its distinguishing features are that it uses a 5:3:2 ($BaO:CaO:Al_2O_3$) impregnant mixture and the density of the porous tungsten base is about 80%. The "S" cathode is an impregnated tungsten cathode manufactured by Semicon Associates.[5] Its unique features are that it employs a 4:1:1 ($BaO:CaO:Al_2O_3$) impregnant mixture with a porous tungsten base density of about 82%. The "Tungstate"

cathode is a type developed at General Electric Company[6,7] and consists of a mixture of approximately 90% tungsten, 9% tungstate compound $Ba_5Sr\ (WO_6)_2$ and 1% $ZrH_2$, which is pressed and sintered into a matrix at high temperature. The "M" cathode was originally developed by Philips,[8] as a standard impregnated "B" type cathode with a sputter deposited coating of Osmium and Ruthenium. As a result, the work function of the surface is lowered so that operation at lower temperatures is possible. The Litton type "B" cathode uses the 5:3:2 ($BaO:CaO:Al_2O_3$) impregnant mix and was fabricated by Litton for the CTS 200 watt 12.2 GHz tube program. They were installed on life test in the period 1975-1976, a time corresponding to the CTS satellite launch period.

Life test data on the first four cathode types, covering the period up to the early part of 1978, have been published.[2] They showed the Tungstate cathodes failed within 7000 hours and the "S" cathodes were all removed from test after about 20,000 hours or less. The "B" and "M" cathode types were still running satisfactorily after about 30,000 hours and 20,000 hours respectively. "B" and "M" type cathodes have continued to be tested and the results as of December 1979 are illustrated in Fig. 1. The older "S" type information is included in the figure. The "B" type cathode has been run for more than 40,000 hours and shows steady degradation. It is down 6% whereas we have set 10% as the failure point. The "M" cathode has been tested for 30,000 hours and still shows no degradation. The unusual feature of the "M" cathode data is the fact that initially its performance seems to improve with time. This was characteristic of all the "M" cathodes tested. All the other cathode types which have been tested showed degradation with time.

Fig. 2 illustrates the reproducability of the data obtained from the

"B" cathodes designated "P", tested on this program. The "S" and "M" curves of Fig. 1 are shown in this figure for reference. Cathode P-4 and P-6 have been operated for more than four years. Cathode P-7 failed in about three years. Cathode P-5 was operating satisfactorily for more than three years life when an accident occurred and the tube containing this cathode developed a vacuum leak. It is very encouraging to note that, even though the number of samples were limited to four, individual results are well correlated with each other and are different than those obtained for the "S" and "M" cathodes.

Fig. 3 illustrates the data obtained on the Litton "B" type cathodes, designated L. Included in the figure are the "M", "B" and "S" cathode curves of Fig. 1. The life test studies are continuing on these cathodes and the results correlate quite well with the "B" type cathode data; an indication that the impregnant mix does control the life characteristics of the tungsten impregnated cathode.

The most interesting data in this series are those for the "M" type cathodes. Fig. 4 illustrate the data obtained on the four "M" cathodes tested. Initially they all showed an increase in emission as is illustrated in the figure. To obtain a better understanding of what this means, it is necessary to describe the procedure used for setting the parameters initially in the experiment. After activation and initial processing the anode voltage on the cathode life test vehicle is adjusted (approximately 10 kV) to give a space charge limited anode current of 0.620 A. With a cathode area of 0.31 $cm^2$, this corresponds to 2A/$cm^2$. The tube is then put on life test and the current at this initial anode voltage is measured as a function of time. All the other cathodes showed steady degradation but the M-cathodes all showed an increase in current. This is an unexpected phenomenon because the current is adjusted to be space charge limited. Since anode voltage and geometrical spacing remain

constant with time during life, the only other possible variable is surface area of emission or surface coverage of active material. One possible explanation for the phenomenon is that with M-cathodes the surface coverage of active material (Ba on Os or some compound formation between Os and Ba), responsible for copious emission, increases early in life with stabilization taking place in about 5,000 hours. In the case of the "B" and "S" type cathodes a similar explanation[2] has been offered to explain the reverse effect of decreasing current with time by assuming the partial monolayer coverage decreases with time.

## REFERENCES


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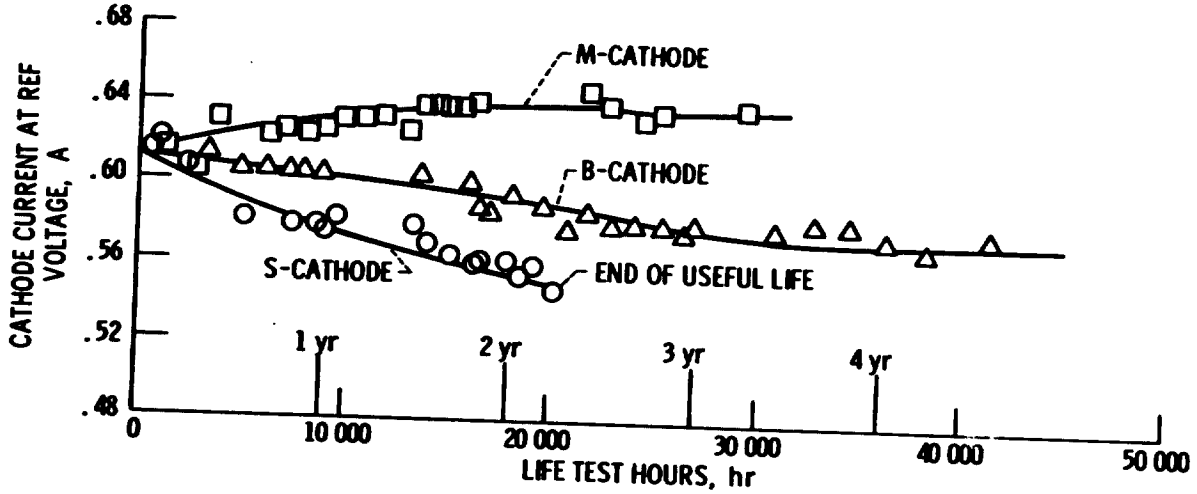


Figure 1. - Cathode current at fixed anode reference voltage versus time for the "S," "B," and "M" cathodes.

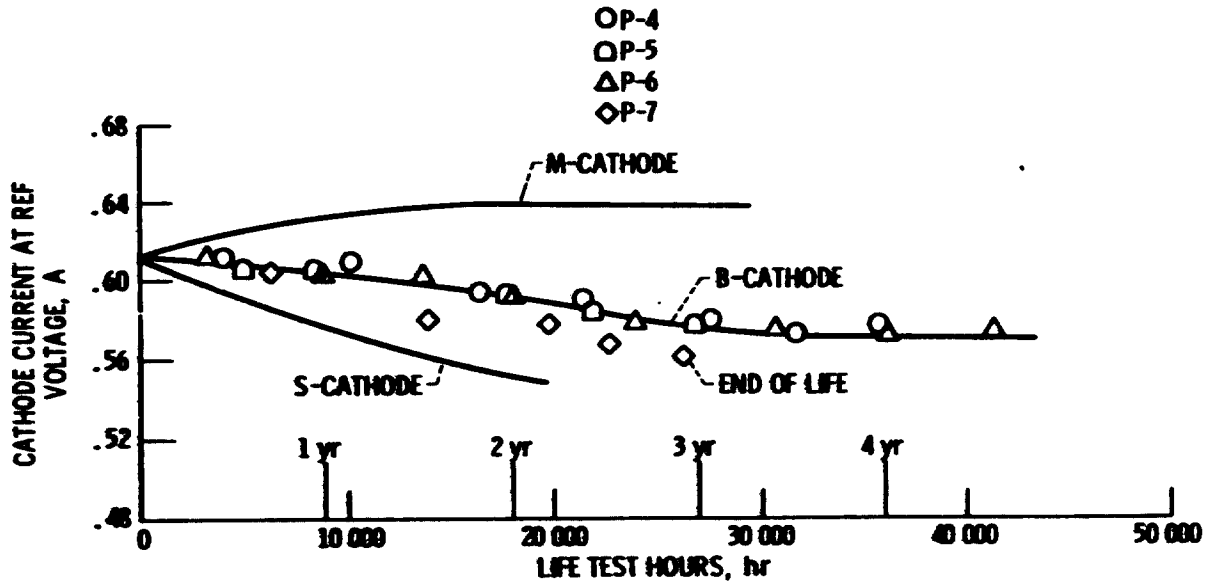


Figure 2. - Cathode current at fixed anode reference voltage versus time for four "B" type cathodes.

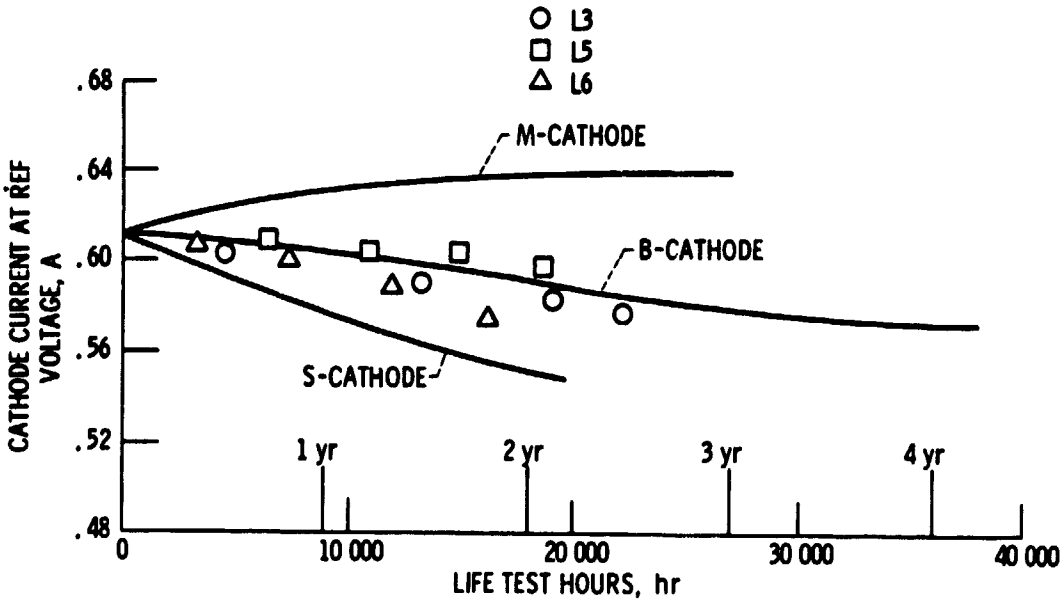


Figure 3. - Cathode current at fixed anode reference voltage versus time for three Litton type "B" cathodes.

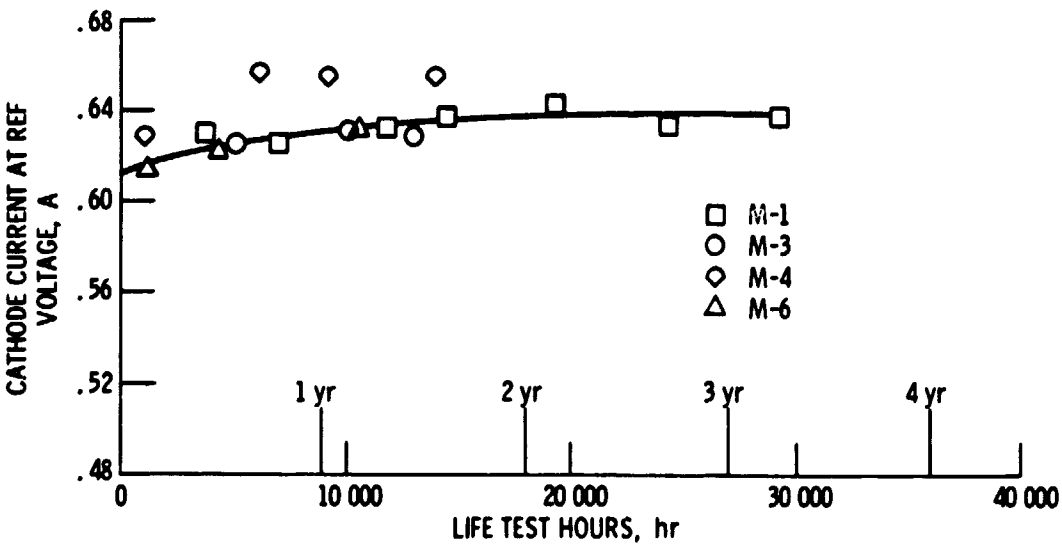


Figure 4. - Cathode current at fixed anode reference voltage versus time for four "M" type cathodes.

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| NASA TM-81441 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| THERMIONIC CATHODE LIFE TEST STUDIES | 6. Performing Organization Code |

| 7. Author(s) | 8. Performing Organization Report No |
|---|---|
| Ralph Forman and Paul Elmer | E-317 |
| | 10. Work Unit No. |

| 9. Performing Organization Name and Address | 11. Contract or Grant No. |
|---|---|
| National Aeronautics and Space Administration<br>Lewis Research Center<br>Cleveland, Ohio 44135 | |

| 12. Sponsoring Agency Name and Address | 13. Type of Report and Period Covered |
|---|---|
| National Aeronautics and Space Administration<br>Washington, D.C. 20546 | Technical Memorandum |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes

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| 17. Key Words (Suggested by Author(s)) | 18. Distribution Statement |
|---|---|
| Traveling wave tubes<br>Cathodes<br>Life tests | Unclassified - unlimited<br>STAR Category 33 |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price* |
|---|---|---|---|
| Unclassified | Unclassified | | |

* For sale by the National Technical Information Service Springfield Virginia 22161