GEPP-TM-1093
UC-706

Pinellas Plant

U.S. Department of Energy

Technical Memorandum

MC2736 Lot 9 Daily Lot Sample Failures

R. A. Pike
Product Engineer
Product Engineering

March 4, 1991

The Pinellas Plant is operated for the U. S. Department of Energy by GE Neutron Devices under Contract No. DE-AC04-76DP00656.

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Under Contract No. DE-AC04-76DP00656

By GE Neutron Devices
P. O. Box 2908
Largo, FL 34649-2908

ABSTRACT

Two Daily Lot Sample (DLS) failures occurred in Lot 9 of the MC2736 battery. The first DLS failed to reach the required voltage. X-rays were carefully reviewed for evidence of any condition which would impact battery performance. It was concluded that Serial No. 4422 failed because of oversized header potting. When the normal stack force used for closure welding was applied, it forced the header potting into the insulation sleeve. As a result, no pressure was applied to the cell stack. Because this condition could be detected on the standard battery x-rays, all x-rays for this lot were reviewed. No other batteries were found which showed any evidence of this problem.

The second DLS failure produced no voltage when tested. Upon examination, the primer was found not to have ignited. Extensive investigation failed to determine the cause of the primer failure. The lot was accepted based on performance data from this and previous lots. This primer failure was shown to have no impact on the overall system reliability.

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INTRODUCTION

Two Daily Lot Sample (DLS) failures occurred in Lot 9 of the MC2736 battery, both during the first week of August 1990. The first failure was a battery which never reached the required voltage of 8.2 V. This battery came up slowly to its peak voltage of 7.8 V and had a long life above 5.0 V (a monitored performance parameter), but never reached required voltage. The second DLS failure produced no voltage upon testing. This report provides a summary of the actions taken to determine the cause of each failure. The steps which will be taken to prevent these problems from occurring again are briefly described.

BACKGROUND

Lot 9 of the MC2736 was fabricated at Eagle-Picher Industries (EPI) in Joplin, Missouri. At the time of these two DLS failures, this lot was slightly over half complete. The contract required construction of 600 batteries in order to deliver 350 War Reserve (WR) units. At the time the build was stopped due to the two failures, 305 units had been built, with 212 batteries set to be shipped as WR. The other 93 batteries were preproduction units, material evaluation units, daily lot samples, and rejects.

ANALYSIS AND DISCUSSION

FIRST DAILY LOT SAMPLE FAILURE

The first DLS failure was Serial No. 4422. The Visicorder* trace for this battery revealed a slow rise with a smooth curve showing no noise. The final inspection x-ray showed some inconsistencies, but did not appear initially to suggest performance problems. Al Jacobson, Sandia National Laboratories-Albuquerque (SNL), and Dave Pattison, EPI, traveled to GEND on August 3, 1990, to postmortem Serial No. 4422. Two batteries which were destructively-tested successfully were also shipped to GEND for comparison (Serial No. 4408, tested cold and Serial No. 4409, tested hot). The functional performance of both of these batteries exceeded the requirements of the product specification.

After the failure, the tester load was verified to be correct. Prior to cutting open Serial No. 4422, the x-rays were carefully reviewed for evidence of any condition which would impact battery performance. It had previously been noted that a gap was visible between the two heat pellets in each pair of heat pellets, one pair at each end of the stack assembly. Further, a gap was visible between the potted header and the stack assembly. Additional review led to the observation that the header was welded resting further above the case than normal. These observations suggested that the battery was not closed properly. An x-ray of Serial No. 4422 is shown in Figure 1. For comparison purposes, an x-ray of a normal battery (Serial No. 4586) is shown in Figure 2.

The overall height of each battery from the header surface to the bottom of the case (excluding the primer holder) was measured. The averages of three readings for each battery were as follows: Serial No. 4422 - 0.593″, Serial No. 4408 - 0.584″, and Serial No. 4409 - 0.585″. This 0.008″ to 0.009″ difference was further indication that Serial No. 4422 was not properly closed.

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*Trademark, Honeywell Inc.

All three batteries were cut open and carefully disassembled. The test failure, Serial No. 4422, exhibited larger than normal areas of unreacted calcium on the bimetal. However, the cause of its poor performance was noted by the observance of the header potting appearing to be oval shaped. Measurements of the largest potting width yielded the following dimensions: 0.896″, 0.887″, 0.906″, and 0.901″. The drawing (No. 290424-200) calls for a potting diameter of 0.875″ ± .002″. For the inner diameter of the insulator sleeve placed into the case, the specification was 0.888″ +.004″/-.000″ (Drawing No. 290417-200).

Accurate measurements of the insulator sleeve after firing the battery are difficult; heat from the cells melts grooves into the inside diameter. Measurements taken, allowing for the inside grooves, confirmed that the inside diameter of the insulator sleeve met the drawing requirements. A potting diameter larger than 0.892″ would not fit into the insulator sleeve. With the potting dimensions as large as 0.906″, the closure force would have forced the header potting into the insulator sleeve, and no force would have been applied to the cell stack. This would explain the appearance of the lines indicating gaps between the heat pellets in x-rays of this battery.

Prior to identifying the probable cause of this failure, Sam Mack (EPI) suggested that the closure force on Serial No. 4422 might have been less than required. Serial No. 4411 was closed with a stack force in the 50- to 100-lb range. (Due to gauge limitations, accurate readings cannot be made at pressures lower than approximately 100 lbs.) This reduced stack force battery was functionally tested and performed normally. To test the validity of this hypothesis as the cause of failure for Serial No. 4422, a MC2736 battery was welded closed with as little stack force as possible (nearly zero). This battery (Serial No. 4647) was measured for overall height in the same manner as the previous three batteries. The average of three measurements was 0.596″, similar to the height of the failed unit (Serial No. 4422 - 0.593″). Serial No. 4647 passed the MC2736 functional test requirements, but showed a reduced level of performance similar to the failed unit. Peak voltage was only 9.0 V; detailed test data is given in Table 1. The Visicorder trace for Serial No. 4647 was smooth, with a long life above 5.0 V, similar to the trace observed with Serial No. 4422. A review of the x-rays for Lot 9 revealed that other batteries exhibited faint lines between the upper and lower pairs of heat pellets. Two of these batteries, Serial Nos. 4620 and 4621, which appeared to have the darkest lines, easily passed functional testing. This test data is also shown in Table 1. X-rays of Serial Nos. 4647 and 4620 are shown in Figures 3 and 4, respectively.

Based on the data from these tests and measurements, it was concluded that Serial No. 4422 failed because of the oversized header potting. This condition may have been caused by inadequate trimming of the sprue from the potting. The result was oval-shaped potting, with the largest dimension being greater than the inside diameter of the inner Vespel* insulation sleeve. Thus, when the normal stack force used for closure welding was applied, it forced the header potting into the insulation sleeve. As a result, no pressure was applied to the cell stack. Further information on this investigation is detailed in a SNL memorandum dated August 8, 1990 (see Appendix A).

*Trademark, E.I. du Pont de Nemours & Co., Inc.

To prevent the reoccurrence of any similar problems, the remaining potted header assemblies were screened for potting diameter. Also, based on the x-ray data gathered in this study, all x-rays for MC2736 Lot 9 were screened for separations in the two pairs of heat pellets located on each end of the cell stack. This condition was seen on the x-rays as dark visible lines between the two end pairs of heat pellets. Gaps between the header potting and the top heat pellet and the positioning of the header in the case were other conditions searched for in the x-rays which might signal a stack force problem. The x-rays for Serial No. 4647 (near zero closure force - unacceptable), Serial No. 4411 (reduced closure force - marginal), and for all the standard closure batteries, such as Serial Nos. 4620 and 4621, (standard closure - fully acceptable) were used as comparison standards. Upon screening, no other batteries were found which showed any evidence of this condition.

Table 1. Functional Test Results for Special Test MC2736 Batteries

Serial No.	Temp. (C°)	Peak Voltage (V)	Rise to 5.0 V (msec)	Rise to 8.2 V (msec)	Life > 5.0 V (sec)	Life > 8.2 V (sec)	Volts @ 0.3 sec	Volts @ 0.35 sec
4410	-25	10.3	130	172	0.59	0.30	10.1	9.7
4411	-25	10.3	140	175	0.60	0.25	9.9	9.4
4413	-25	10.6	130	175	0.48	0.28	10.3	9.8
4414	-25	10.4	130	175	0.83	0.24	10.1	9.4
4422	-25	7.8	150	--	1.20	0.00	7.6	7.7
4445	-25	11.2	120	148	0.86	0.33	10.9	10.5
4476	-25	10.6	140	175	0.97	0.27	10.4	9.9
4477	-25	10.9	130	155	0.46	0.33	10.5	10.3
4487	-54	10.5	150	190	0.49	0.23	10.2	9.5
4488	-54	11.1	148	175	0.96	0.23	10.4	9.4
4492	-54	11.1	130	170	0.41	0.24	10.5	9.7
4566	-25	11.2	123	145	0.91	0.39	10.9	10.7
4620	-25	10.6	140	168	0.62	0.35	10.4	9.9
4621	-25	10.4	140	175	0.46	0.30	10.2	9.8
4647	-25	9.0	150	205	1.10	0.33	9.0	8.9
4676	-25	11.2	126	155	1.02	0.31	11.0	10.6

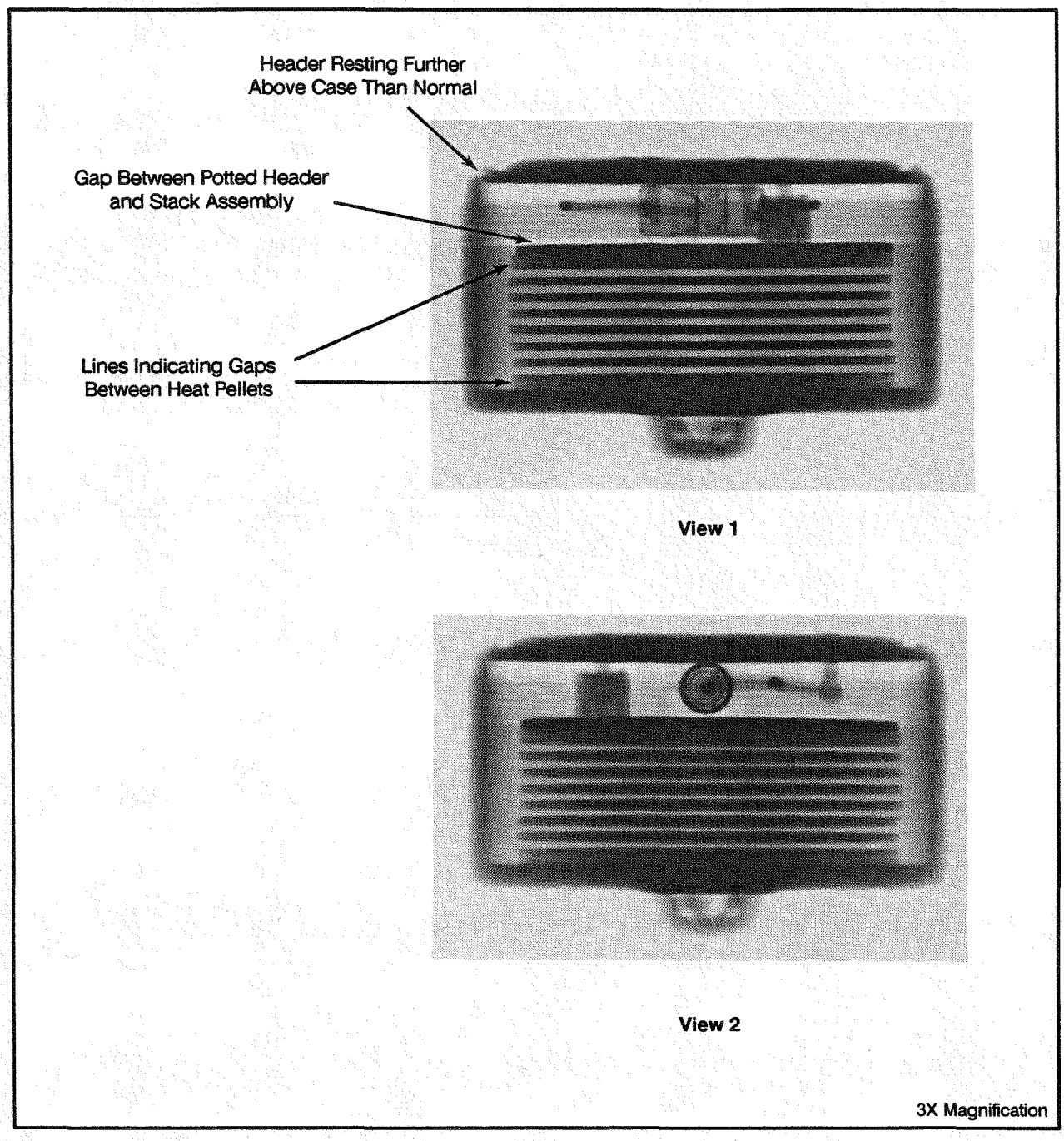
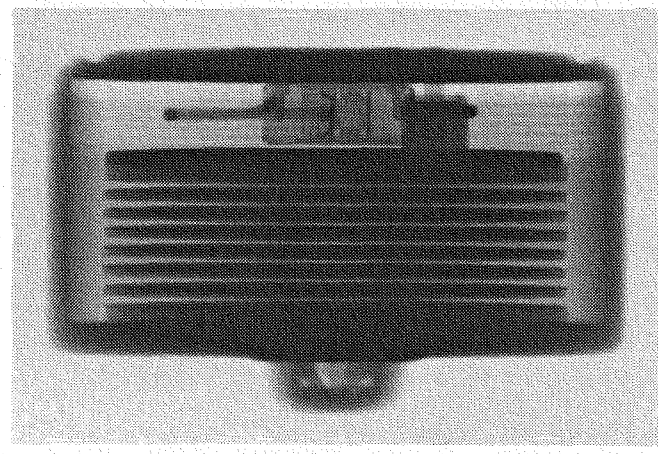
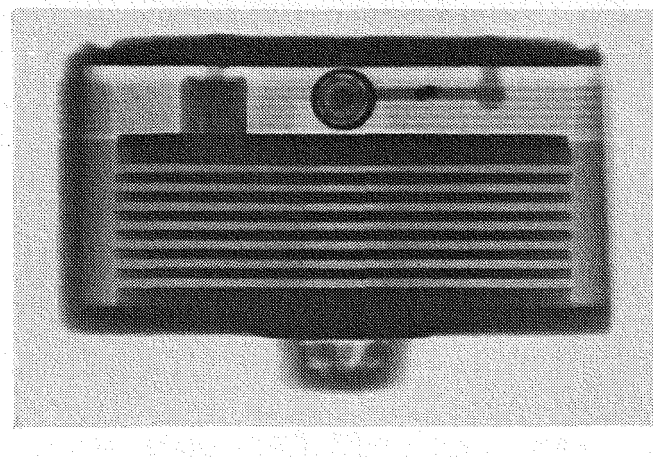


Figure 1. X-ray of Failed MC2736 Battery, Serial No. 4422



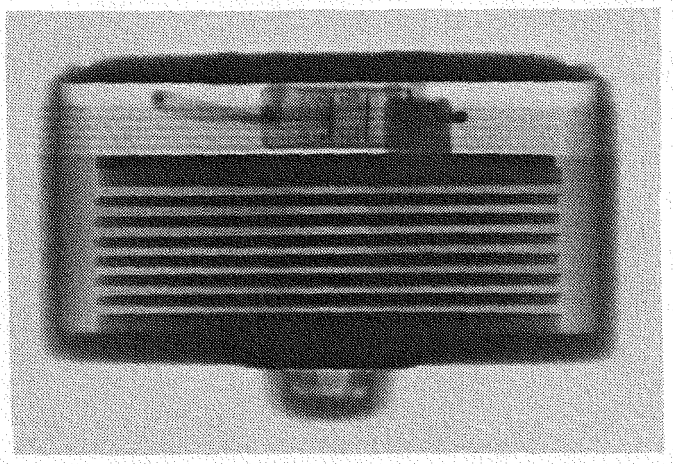
View 1



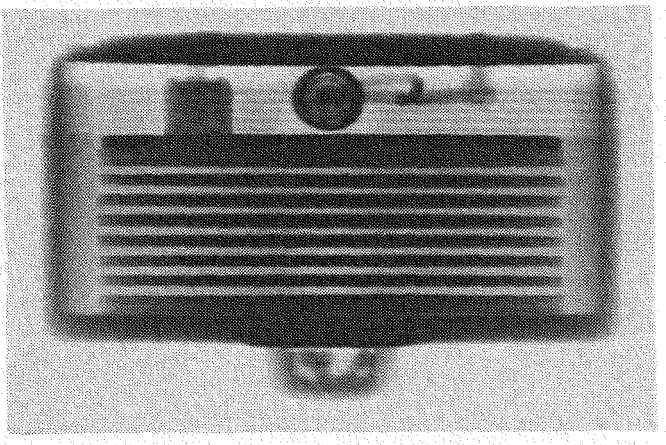
View 2

3X Magnification

Figure 2. X-ray of Normal MC2736 Battery, Serial No. 4586



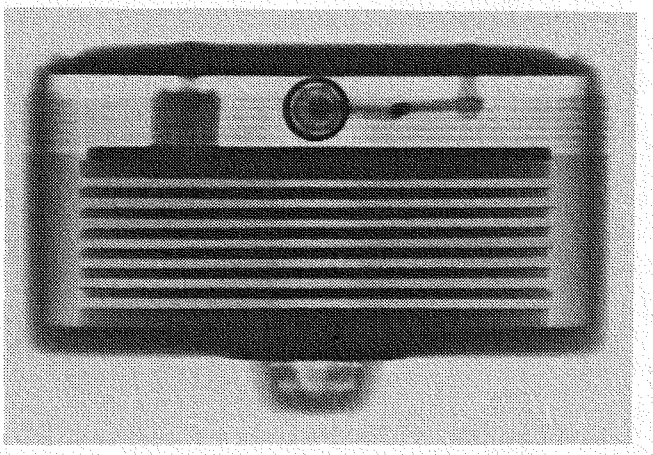
View 1



View 2

3X Magnification

Figure 3. X-ray of MC2736 Battery, Serial No. 4647, Intentionally Welded Closed Using No Stack Force



View 2

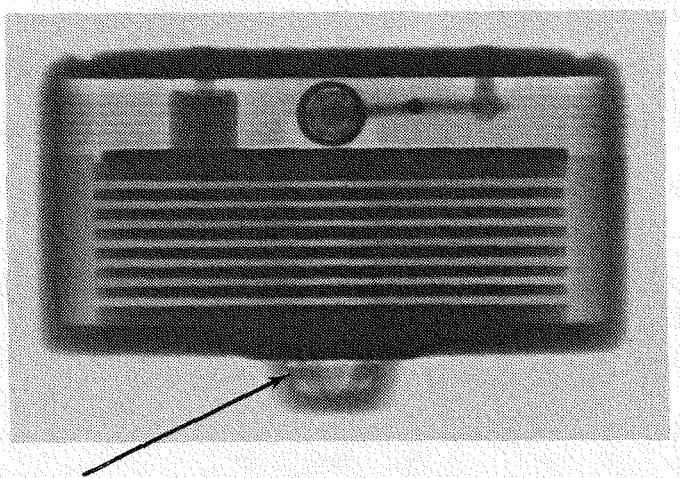
3X Magnification

Figure 4. X-ray of MC2736 Battery, Serial No. 4620, Exhibiting Faint Lines Between Heat Pellets

SECOND DAILY LOT SAMPLE FAILURE

Later in the first week of August, a second daily lot sample failure occurred. This test unit, Serial No. 4590, produced no voltage when functionally tested. The tester was checked to ensure that it was working properly. The normal dent in the base of the primer was noted, indicating that the primer had been struck by the firing pin. The primer used in the MC2736 thermal battery is the WW42C1, supplied by EG&G Mound. The temperature monitor did not trip, indicating that the battery did not fire.

The postmortem for this failure was conducted at EPI. [Further information on the postmortem is given in a SNL memorandum dated August 16, 1990 (see Appendix B)]. First, the failed unit was visually examined. It was noted that the primer had been struck by the firing pin, and this produced a dent that appeared normal but slightly off center. Other daily lot samples were found which had primers with dents that were off center, so this did not appear to be an unusual occurrence. Review of the x-ray for this battery showed the primer to be slightly tilted within the primer holder (see Figure 5); other battery x-rays showed the same condition. Plans were made to screen some of the primers before their insertion into the primer holders to determine if the primer case had been cut squarely.



Tilted Primer in Primer Holder **View 2**

3X Magnification

Figure 5. X-ray of MC2736 Battery, Serial No. 4590, Showing Tilted Primer

Next, dimensional measurements were made of this battery. The width of the threads on the outer diameter of the battery were found to be approximately 0.140″, with the case drawing (No. 290422-200) specifying 0.110″ ± .010″. In addition, the distance from the bottom of the case, excluding the primer holder, to the bottom thread was measured to be about 0.376″, while the drawing gives the allowable range as 0.382″ to 0.402″. The height of the primer holder was found to be within dimensional tolerance. No other dimensions were found to deviate from drawing requirements. The test fixture, which simulates the next assembly, was measured to determine if the above drawing dimension deviations would create problems when functionally testing the battery. The fixture was found to be able to easily accommodate these battery deviations while continuing to allow the battery to bottom in the test fixture.

Continuing this investigation, Serial No. 4590 was cut open and examined. The heat pellets were unlit, the cells unreacted, and the primer did not fire. The primer was examined under magnification. Other than a small drop of red lacquer on one side of the inside of the case, no other imperfections or abnormalities were noted. In comparison, primers awaiting insertion into battery cases were also visually examined. The anvil appeared to be off center or tilted in one-third to one-half of the more than 120 primers that were reviewed.

After examining the components of Serial No. 4590, the header was welded to the case/primer assembly, which was empty except for the Vespel sleeve. Unfortunately, the welding was done with a hand-held welder, and this procedure heated the case/primer assembly considerably. As a result, the primer may have been damaged. This unit was shipped to SNL for further evaluation of the primer. Using various chemical analysis techniques, it was determined that the pyrotechnic powder in this primer did not contain the proper amount of tetracene. The pyrotechnic powder in the WW42C1 primer normally contains 5 weight % tetracene, a chemical which enhances the explosiveness of the powder. It is possible that the welding operation heated the primer sufficiently to volatilize this material.

About one month later, after gathering and reviewing the chemical analysis data from the Serial No. 4590 primer, two more samples were shipped to SNL. In an attempt to duplicate the condition in which Serial No. 4590 was received by SNL, a header was welded using the same hand-held welder as before to a case/primer assembly with a Vespel sleeve inside the case. This operation was performed to duplicate as closely as possible the processing of Serial No. 4590 prior to shipment. The purpose of preparing this sample was to determine if the welding operation performed on Serial No. 4590 was the reason that little tetracene was found in the pyrotechnic powder. The second sample was simply a primer randomly selected from the stock available for this battery lot. This sample was examined to establish the composition of the primers used in this battery lot and whether this composition met specifications. At this time, no results are available for these two samples.

Based on the observations to this point, three possible factors were identified for testing which may have caused or contributed to the failure of this battery to fire. First, the case dimensions deviated from the drawing dimensions in the two places noted above. It was felt that this may have prevented the battery from bottoming out in the test fixture. Any additional distance from the firing pin might lessen the pin's impact. Prior to the removal of Serial No. 4590, an x-ray was taken of the battery/test assembly combination with the battery failure in place. This revealed a 0.005″ to 0.006″ gap between the bottom of the battery and its normal placement in the fixture. Yet the dimensions of the test fixture, which simulates the next assembly, should be able to compensate for the case dimension deviations. Second, the dent made by the firing pin on the primer of Serial No. 4590 was off center. The test fixture was examined and was found to allow the battery position within the fixture to be very operator dependent due to the large tolerances and small diameters of the mounting pins. Third, primers cocked or tilted within the primer holder were identified as a potential source of problems in firing the primer.

Testing was conducted in an attempt to determine the sensitivity of the primers to the presence of the above three conditions. The first two conditions identified above could be tested by altering the positioning within the test fixture. The battery screws into the test fixture using 1.0-56 fine threads; a complete turn of the battery equates to a travel distance of 0.018″ along a path parallel to the axis of the battery case. Backing the battery off some multiple or fraction of turns would control the distance from the bottomed-out position in the test fixture. By holding the battery off to one side while tightening it in the test fixture, the firing pin can be made to strike the primer off center. After reviewing the battery x-rays, several batteries were selected with the largest degree of tilt of the primer within the primer holder cavity. These batteries were chosen to evaluate this condition as a factor that might contribute to the failure of the primer to fire. The test conditions of the batteries fired to evaluate the primer failure are given in Table 2.

Table 2. Test Conditions for Units Used in Second Failure Evaluation*

Serial No.	Misaligned Primer	Firing Pin Strike Off Center	Number of Turns Backed Off
4410	-	-	1/2
4411	-	X	-
4413	X	X	1/2
4414	X	X	1
4445	-	-	2
4476	X	-	-
4477	X	X	-
4487**	X	-	-
4488**	X	-	-
4492**	X	X	1/2
4566	X	X	2

*All units were tested at low temperature, -25°C, except where noted.
**Tested at -54°C

As can be seen from the performance data in Table 1, all batteries tested in attempts to duplicate the primer failure met the performance requirements of the MC2736 product specification. None of the three factors tested caused the primers to fail, whether tested individually or in combination. In addition, Serial Nos. 4487, 4488, and 4492 were tested at -54°C to assess the sensitivity of the primer powder to temperature. As an aside, the thermal monitors on each of these three units operated properly at this low temperature. In the past, problems have been encountered with the operation of this monitor at -54°C. These units also successfully completed performance testing.

Additional dimensional checks were made to determine the conformance of the battery components to the drawing specifications and the importance of conformance. All of the battery cases in stock at the time (202) were screened for primer holder depth and found to meet drawing requirements. Measurements were also made on primers in stock at both EPI and GEND.

Ten primers randomly selected at EPI were measured on an optical comparator. None of these primers had been subjected to the sizing operation in which the primers are forced through a tube which makes out-of-round cases round. The axes of the cylindrical primer cases were found to be perpendicular to the base in all cases. However, the sides of the cases were shorter at some points than at others. In other words, the open end of the case did not form a plane that was parallel to the base. As a measure of the proper alignment of the anvil in the case, the differences in protrusion of the anvil legs were measured on these ten samples. The difference in anvil leg protrusion can be defined as the vertical distance from the tip of the least protruding leg to the tip of the most protruding leg. Seven of ten were found to be level, with two showing a difference of 0.001" and one with a difference of 0.0065".

The primer with the 0.0065″ difference in primer leg protrusion also failed the specification for primer height (0.114″ to 0.116″) by measuring 0.118″. This primer was built into a battery and tested at -25°C with the primer being struck off center. This battery satisfactorily passed functional testing. Another 29 primers were randomly selected from EPI stock. These units, which had also not been sized, were measured for overall height and anvil protrusion. All met the specification for primer height. Five of the 29 exhibited differences in the protrusion of the anvil's legs; the maximum was measured to be 0.0012″.

A random selection of 30 primers from GEND stock was also measured for overall height and difference in anvil protrusion. Eleven of these units had a difference in leg protrusion greater than 0.002″. Eight units failed the height specification; all the failures exceeded the upper limit of 0.116″. In addition, only two of these were not included in the first group of eleven. The largest difference in leg protrusion was found to be 0.0041″; the largest height measured was 0.1175″.

Three primers were selected and had varying amounts of Loctite* adhesive applied to the inside of the primer over the anvil. The Loctite was allowed to dry overnight. Without building these primers into batteries, the primers were fired successfully.

Since the cause of the primer failure could not be determined, the data for this and previous MC2736 thermal battery lots, using the same percussion primer, was analyzed statistically. The total failure probability for the MC2736 was calculated to be less than 0.007. Since the MC2736 is used redundantly in Joint Test Assembly (JTA) systems, the assessed failure probability of this component will have no significant effect on system reliability. The basis for acceptance of Lot 9, despite this unexplained lot sample failure, is spelled out in much greater detail in a memo from D. L. Wright to A. K. Jacobson, "MC2736 Thermal Battery Reliability," dated September 5, 1990. A copy of this memo is included in Appendix C. Wright recommended "... that Lot 9 production and testing be continued at the planned rate and Lot 9 be accepted for WR, assuming no further failures, based on the history of the MC2736." As no further failures were encountered, Lot 9 of the MC2736 thermal battery was accepted for WR.

SUMMARY AND CONCLUSIONS

The first daily lot sample failure encountered, Serial No. 4422, failed to reach the required voltage of 8.2 V. This unit peaked at 7.8 V and had a long life above 5.0 V. After analyzing this battery, it was determined that oversized potting on the header was forced into the insulation sleeve, resulting in no stack force being applied to the battery stack. Because this failure mechanism could be detected on standard battery x-rays, all x-rays for this lot were reviewed. No other batteries were found which showed any evidence of this problem.

The second daily lot sample failure, Serial No. 4590, produced no voltage when tested. Upon examination, the primer was found to have failed to ignite. Extensive investigation was unable to determine the cause of the primer failure. The lot was accepted based on performance data from this and previous lots. This primer failure was shown to have no impact on the overall system reliability.

*Trademark, Loctite Corp.

ACKNOWLEDGMENTS

The work covered within this report involved the efforts of many people. Al Jacobson (SNL) brought his years of battery experience to bear on these two failures. Many of the key ideas and observations were his. Dave Pattison (EPI) was responsible for coordinating the activities at his location. His efforts were greatly appreciated. Thanks to Sam Mack, Dan Sgro, and Don Hardy (GEND) for helping to provide new ideas and critical discussion of these and other problems.

APPENDIX A

SANDIA NATIONAL LABORATORIES–ALBUQUERQUE MEMORANDUM, "MC2736 LOT SAMPLE FAILURE POSTMORTEM"

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: August 8, 1990

to: R. P. Clark, 2522

from: A. K. Jacobson, 2522

subject: MC2736 Lot Sample Failure Postmortem

An MC2736 thermal battery, Lot 9 daily lot sample S/N 4422, failed rise time and peak voltage at -25°C. The MC2736 is manufactured at Eagle-Picher. A postmortem was conducted at GENDD on August 3, 1990.

Participating:

Dave Pattison	EP
Rick Pike	GE
Dan Sgro	GE
Al Jacobson	SNL

The postmortem plan was to:

First review the data.

Review the xrays of the failed unit and others built the same day.

Make mechanical measurements of the failed unit and others built the same day.

Disassemble the failed unit and two others which had functioned normally.

Photograph all parts.

DATA

The rise time to 5 volts was 150 ms as compared to 110 to 120 ms for normal units. The requirement is 200 ms to 5.0 volts and 300 ms to 8.2 volts. The battery voltage peaked at 7.5 v, thus failing the peak voltage and rise time to 8.2 v. Typically, the peak voltage is 10 to 12 volts at -25°C. The voltage trace was free of noise and also remained above 5.0 volts for 1.2 seconds, which was longer than most MC2736s tested. The percussion

primer appears to have functioned properly as evidenced by the deep dent in the primer cap and the normal start of voltage rise.

XRAYS

There were two things noticeably different about S/N 4422 as compared to other units assembled the same day.

1. The readily identifiable difference was a larger separation between the cell heat pellets. There are seven cells in the MC2736 and even taking into account differences due to parallax, the cells did not appear to be stacked as tight.

2. Dan Sgro noted that the header was not seated as far into the case. The normal closing force is 225 +/- 25 lbs.

   EP has assembled and tested one battery, S/N 4411, at 75 +/- 25 lbs. When tested at -25°C, the battery functioned normally. The xray of S/N 4411 looked the same as other normally function units.

MECHANICAL MEASUREMENTS

The overall height was recorded for S/N 4422 (failed) and two normal units.

S/N 4422	.5928 inches
S/N 4408	.5839
S/N 4409	.5847

The xray and the difference of 8.9 mils in height suggest that the failed unit, S/N 4422, had not been closed properly.

DISASSEMBLY

Three batteries, S/N 4422, S/N 4408, and S/N 4409 were disassembled. S/N 4422 and 4408 had been tested at -25°C. S/N 4409 had been tested at 74°C. Findings were:

1. All bimetal discs were assembled properly.

2. There were seven cells in each battery.

3. All heat pellets had ignited. This was suggested earlier by the long life above 5.0 volts.

4. There were large areas of unreacted calcium on four of the seven anodes in S/N 4422. Since the heat pellets seem to have functioned, the presence of unreacted calcium suggests poor contact.

   S/N 4408 also had some unreacted calcium in the cell next to the primer. This might be expected as there is no insulation at the ends of the cell stack. The other six cells appeared to be normal.

5. The diameter of the encapsulant in the region of the potting sprue was 0.906 inches. The drawing requirement is 0.875 +/- .002. It appears the sprue had not been removed properly.

   The encapsulant is supposed to fit inside the Vespel cup. The cup ID drawing requirement is 0.888 + .004 - .000 inches. The encapsulant would not fit inside the Vespel cup without applying considerable force. There were marks on the inside edge of the cup indicating that perhaps most or all of the 225 lbs closing force was used to force the encapsulant into the cup.

CONCLUSION

Our preliminary conclusion is that the battery was not closed properly, resulting in higher than normal internal stack impedance, causing the lower than normal voltage and consequently failing the rise time.

ACTION

1. Measure the ID of the Vespel cup on S/N 4422 (We had not done this before I left GE).

2. Review all xrays for similar characteristics, i.e., wide cell spacing and poor seating of the header.

3. If units are found in Paragraph 2 above, measure battery length, record and test at -25°C.

4. Screen all encapsulated headers remaining to be assembled.

5. Fabricate and test one or more units with "zero" closing force.

6. Measure battery height as a function of closing force and correlate to functional data, if possible.

I will issue an SIER requesting these measurements and tests be done. I will also contact Don Wright, 7222, and determine from him if a revised sample plan is needed.

AKJ:2522:jan

Copy to:
2520 N. J. Magnani
7222 D. L. Wright
7263 J. N. Middleton
2522 Day File
2522 A. K. Jacobson

APPENDIX B

SANDIA NATIONAL LABORATORIES–ALBUQUERQUE TRIP REPORT, "POSTMORTEM OF MC2736 FAILURES AT EP"

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: August 16, 1990

to: R. P. Clark, 2522

from: A. K. Jacobson, 2522

subject: Postmortem of MC2736 Failures at EP: Trip Report

Ref: Memo, A. K. Jacobson, 2522, to R. P. Clark, 2522, dtd August 8, 1990, subject: MC2736 Lot Sample Failure Postmortem.

The referenced memo reported on a postmortem of a MC2736 thermal battery at GEND. The battery had failed to meet peak voltage and rise time requirements during a daily lot sample test at Eagle-Picher. The memo reported in the conclusion; the battery had not been properly closed at final welding due to a potting sprue not being completely removed which prevented the header from seating properly.

As a continuing part of this investigation, Eagle-Picher has repeated the failure in one of three MC2736 tests. A review of the production x-rays produced two units with what appeared to be extra wide spacing between the cells. S/Ns 4620 and 4621 were tested at -25°C. Both units functioned satisfactorily. A third unit, S/N 4627, was assembled with "zero" stack force and tested at -25°C. The peak voltage was only 9.0 v and the rise time was 200 ms to 5.0 v. The battery met the peak voltage requirement of 8.2 v and the activated life; however, the peak voltage is approximately 2.0 v lower than average for the lot. The activated life was also greater than 1.0 seconds, which was identical to the failed unit. The typical life above 5.0 v is only 90 ms. The slow rise, low voltage, and what for this battery is an abnormally long life, confirms that low or "zero" stack force caused the failure.

PERCUSSION PRIMER FAILURE

A second MC2736 thermal battery failure was experienced at Eagle-Picher on July 3. The initial report stated that the percussion primer in S/N 4590 had failed to initiate. The battery was a daily lot sample being tested at -25°C and did not involve mechanical

environments. The cause for this failure has not been determined. The following potential problems were itemized during the postmortem analysis:

1. A visual examination of the battery did not reveal any obvious problems, except that the firing pin impact on the primer was off center. The depth of dent made by the firing pin was more than adequate to fire the primer. The primer seemed to have been inserted properly. The test fixture and adapter were designed by GEND prior to Lot 8 production after the many problems encountered in Lot 7. The tolerance stack-up between parts is such that the adapter which holds the battery in the firing fixture has some side-to-side movement which results in a random off-center impact of the pin. Examination of other tested batteries which had functioned properly showed the same off-center impact in more than 75 percent of the cases.

   Fifteen each MC2736s tested on the centrifuge using a MC2443 actuator were also examined. The depth of dent in these 15 units is considerably less and in some cases off-center as well. All 15 units function.

2. Eagle-Picher had x-rayed the battery/test adapter assembly prior to removing the battery. The x-ray showed a five to six mil gap between the bottom of the battery and the adapter. The battery is threaded into an adapter which simulates the next assembly for testing. We were not able to determine a cause for the gap. The dimensions of the adapter and the battery are such that the battery should always bottom in the adapter. The only possibility is that dirt in the threads prevented the technician from threading the battery in far enough. The 1.0-56 fine threads are very difficult to keep clean and threading into test adapters and fixtures has always been a problem.

3. Sam Mack, GEND, conducted a mechanical inspection of the battery and found that the threads were 0.025 inches longer than allowed on the drawing and also the boss on the case which houses the primer was 0.002 inches longer than allowed. Neither of these two dimensions could have contributed to the gap discussed above, and also they could not have caused the primer to fail. The firing pin has sufficient

length and travel to overcome these discrepancies. The depth of dent in the primer is confirmation.

4. X-rays taken of the failed battery after removal from the adapter showed that the primer was slightly cocked in the primer pocket. The primer anvil was bottomed in the pocket. The primers are screened to a height of .114/.116 inches at Mound. The primer pocket is .109/.111 deep. The primer insertion tooling is designed so that the primer is inserted into the pocket flush with the top giving .002 to .006 inches of reconsolidation of the anvil into the primer pyrotechnic. The firing pin impact distorts the primer case making it difficult to determine if the primer was inserted flush to the top. There was nothing to indicate that the primer was not flush or that the reconsolidation was not satisfactory.

In summary, the three conditions discussed above, if occurring together or in some combination, might cause the primer to fail:

Firing pin impact off center.

Improper assembly of the battery into the test adapter.

Primer inserted cocked.

Insufficient reconsolidation could also be a cause for primer failure; however, the data available did not indicate this condition existed.

A matrix of six tests were conducted to determine the possibility of a failure from the three conditions. Batteries with cocked primers were screened from the lot production. The gap between battery and adapter was simulated by backing the battery out of the adapter one and two full turns. Each turn is equivalent to .018 inches. The off-center condition was accomplished by pushing the battery/adapter assembly to one side of the test fixture. All batteries were tested at -25°C.

All of the batteries tested with the "anomalies"

function normally. In other words we were not able to duplicate the failure.

ACTION ITEMS

The following action items were listed:

GEND is to request Eagle-Picher to screen all of the remaining battery cases for correct primer pocket height.

Eagle-Picher is to test three units with the conditions discussed above at -54°C. The purpose would be to eliminate the possibility of a marginal situation.

SNL, Division 2512, is to dissect the failed primer.

SNL, Division 2522, is to contact Don Wright, 7222, for a direction and a possibility of a larger test sample.

There is the possibility that the WW42C1 percussion primer will not give the desired reliability and that random failures are to be expected.

AKJ:2522:lb

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APPENDIX C

SANDIA NATIONAL LABORATORIES–ALBUQUERQUE MEMORANDUM, "MC2736 THERMAL BATTERY RELIABILITY"

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: September 5, 1990

to: A. K. Jacobson, 2522

from: D. L. Wright, 7222

subject: MC2736 Thermal Battery Reliability

Ref.: Memo, A. K. Jacobson, 2522, to R. P. Clark, 2522, Sbj. Postmortem of MC2736 Failure at EP: Trip Report, dtd. 8/16/90.

The reference documented two problems occurring in the MC2736 Lot 9 production. One output failure was concluded to be due to low closing force caused by part interference. The completed batteries were screened for this problem - none were found. This failure will not be counted in the reliability assessment for the battery since the screening and rework procedures are considered to have been effective in removing this defect. The second Lot 9 problem was due to failure of the primer to activate. No single cause has been found for this failure. The purpose of this memo is to evaluate the effect of this failure to activate on the MC2736 reliability.

The MC2736 is currently used in the W62, W76, W78, and W87 JTA's to activate the main telemetry power supply. The MC2736 is activated by a primer that is initiated by either the MC2443 or MC1996 g-device. Two MC2736's are used in parallel to activate a single JTA power supply. The MC2736 is used in a similar manner for W62 and W87 DoD telemetered flights.

The MC2736 is activated by the output of a WW42C1 primer. This primer has been used in the MC2736 starting with Lot 7, replacing the older M42C primer. There had been one failure of the M42C primer, in the Lot 6 of the MC2736, that was attributed to improper consolidation of the primer when it was inserted into the header. The entire lot was x-ray screened to detect improperly installed primers. There have also been a number of monitor problems with this battery with a new monitor installed beginning with Lot 8. During Lot 8 pilot production, there were several battery failures due to failure of the primer to ignite the heat pellets. In these cases the primer had fired, although the amount of output was unknown. The primer activation system for testing was changed and the heat pellet ignition interface was improved with no further failures occurring. There were no failures during Lot 8 WR production. The Lot 9 primer failure, however, did not fire and is the first recorded failure of

the WW42C1. The Reference describes the investigation that was unable to duplicate the failure or determine the exact cause. The Lot 9 production has been halted.

Since a cause for the Lot 9 primer failure has not been found, the question is this lot acceptable for WR acceptance and how does this failure affect the reliability assessment for the MC2736? There have been approximately 151 MC2736's tested for TMS and Daily Lot Sample in Lots 7 - 9 that used the WW42C1 primer with the one countable failure. This provides a point estimate of 0.005 failure probability for this primer. During the course of preparing for the production of each of these lots, another 307 batteries with the WW42C1 were also fired without a failure. These combined data (1/458) indicate a primer failure probability point estimate of approximately 0.002.

The total failure rate of the MC2736 is the sum of the failure probability of the primer to fire and the failure probability of the battery to be initiated by the primer output and provide the required output. The failure of the battery to activate and provide the required output, given successful primer activation, can be estimated from the entire production history of the MC2736. There have been approximately 544 lot sample and TMS units tested in the 9 lots produced without a battery output failure. These data provide an estimated 0.002 failure probability (0/544 at the 50% confidence level). Thus, the total failure probability for the MC2736 can be calculated to be less than 0.007 (0.002 + 0.005) using the more conservative estimate for WW42C1 primer failure probability. Assuming redundant use of the MC2736 in the JTA systems, this MC2736 assessed failure probability should have no significant effect on the JTA system reliability. I recommend that Lot 9 production and testing be continued at the planned rate and Lot 9 be accepted for WR, assuming no further failures, based on the history of the MC2736.

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