FINAL REPORT ON LITHIUM BATTERIES (ULTRALIFE, ANSI 1604) USED IN RESIDENTIAL SMOKE ALARMS DECEMBER 2, 2002

Arthur Lee
Electrical Engineer
Division of Electrical Engineering
Directorate for Engineering Sciences

U.S. CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

U.S. CONSUMER PRODUCT SAFETY COMMISSION

DIRECTORATE FOR ENGINEERING SCIENCES

FINAL REPORT ON

LITHIUM BATTERIES (ULTRALIFE, ANSI 1604)

USED IN RESIDENTIAL SMOKE ALARMS

DECEMBER 2, 2002

Arthur Lee
Electrical Engineer
Division of Electrical Engineering
Directorate for Engineering Sciences

Table of Contents

List of Figures

List of Tables

FINAL REPORT ON LITHIUM BATTERIES (ULTRALIFE, ANSI 1604) USED IN RESIDENTIAL SMOKE ALARMS DECEMBER 2, 2002

INTRODUCTION

This report presents the final results of analyses of lithium batteries used in 10-year smoke alarms as discussed in the U.S. Consumer Product Safety Commission (CPSC) staff report entitled *Preliminary Test Results on Lithium Batteries Used in Residential Smoke Alarms* dated June 28, 2002. This report also includes CPSC staff comments on a report prepared by Ultralife Batteries, Inc., *Report on the Functionality and Use of the Ultralife U9VL-J Battery in Ionization Smoke Alarms,* dated November 6, 2002.

BACKGROUND

The Centers for Disease Control and Prevention (CDC) has programs that fund a number of states to provide smoke alarms to state residents. In a recent 5-year program, CDC required that the funded states install 10-year smoke alarms, unless a special agreement was reached. The funded states and CDC received consumer complaints and/or callbacks to replace the new smoke alarms because of low battery chirping. The CPSC also received several complaints of premature low battery chirping associated with 10-year smoke alarms. Together, CDC and CPSC collected smoke alarms and lithium batteries from the field for testing and analysis.

As reported in *Preliminary Test Results*, 67 lithium batteries were collected from the field. All the batteries collected were associated with reports of premature chirping of 10-year smoke alarms. All the batteries were removable 9-volt lithium batteries (in an ANSI 1604 housing) manufactured by Ultralife Batteries, Inc.

In initial tests of the 67 batteries collected, 47 gave a low-battery indication by causing a test smoke alarm to chirp. Sixteen batteries did not cause a low-battery chirp, and the test smoke alarm sounded normally when the test button was pressed. (Six of the 16 batteries caused a low-battery chirp of the test alarm when they were re-tested nine months later.) Two of the 67 batteries had a no-load reading of 0 volts, and another two either had a damaged terminal or were shorted internally. Table 1 lists the results from the initial tests in the report.

Table 1. Results of Initial Tests as Reported in *Preliminary Test Results*

Batteries	Premature Low Battery Chirping		No Test	TOTAL
	Yes	*No*		
First Tested	47	16	4	67
9-months later	53	10	4	67

The results of the testing and analysis of the collected samples are reported in the CPSC staff report entitled *Preliminary Test Results on Lithium Batteries Used in Residential Smoke Alarms,* dated June 28, 2002. The report concluded that the batteries used in the smoke alarms were causing the smoke alarms to emit a premature low battery warning; the smoke alarm hardware did not appear to be a direct cause. The premature low battery chirping was caused when the smoke alarm placed a load (LED light) on the battery during its routine low-battery test. The no-load, open-circuit voltage of a "bad" battery appeared normal and could only be detected under load. The cause of premature chirping in the smoke alarms appeared to be related to a higher than expected increase in internal resistance in the batteries.

The tested batteries had either a six or a five-digit date code. The six digit date codes represent month/day/year/year/day/month. The five digit date codes represent month/day/year/day/month. Figure 1 shows the translation of the four and five digit date codes. For example, the five-digit date code 00589 can be translated to September 8, 1995. The six-digit date code 010008 can be translated to August 10, 2000.

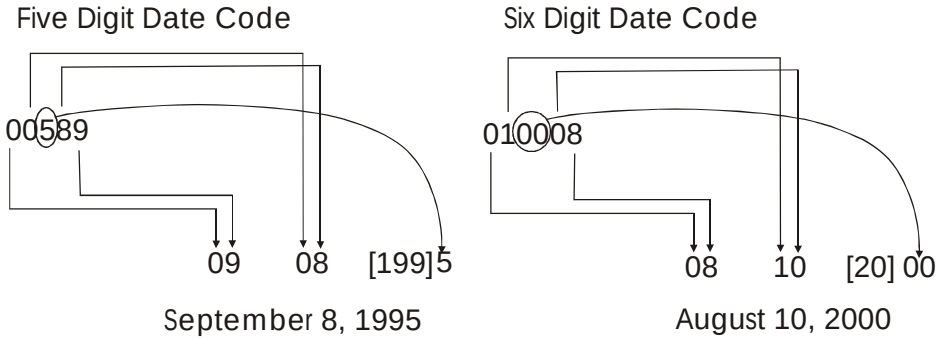


Figure 1. Translation of Date Codes

All of the batteries collected from the field had date codes from May 1995 to August 2000. All but six of the batteries were model U9VL-J; six of the batteries were model BA9VL and had date codes of May 1995, August 1995 or September 1995 as shown in Table 2. The table only displays the month and year of the battery's date code.

Table 2. Battery Dates and Models of the Initial 67 Batteries Collected and Tested.

Battery Date	Model	First Tested			9-Months Later		
		Premature Low Chirping			*Premature Low Chirping*		
		yes	no	no test	yes	no	no test
May-95	BA9VL	1	1		2	0	
August-95	BA9VL	1	1		2	0	
September-95	BA9VL	2			2		
September-96	U9VL-J			1			1
October-98	U9VL-J	3			3		
November-98	U9VL-J	20	3	3	23		3
December-98	U9VL-J	9			9		
February-99	U9VL-J	10	2		11	1	
July-99	U9VL-J	1			1		
July-00	U9VL-J		2			2	
August-00	U9VL-J		7			7	
Subtotal		47	16	4	53	10	4
TOTAL		67			67		

An additional 11 batteries were collected from the field by CPSC investigators after the study began and were not included in the initial report. All 11 batteries had the date code of February 1999. These 11 batteries caused a low-battery chirp when installed in the test smoke alarm. The batteries had a no-load voltage between 9.96 and 10.02 volts. Previous test characteristics and results would indicate that these batteries also exhibited internal impedance that was higher than normal.

The data presented below will not include the six samples with model BA9VL because of the age of the batteries and the unknown advertised life of the batteries when used in a residential smoke alarm.

DISCUSSION

Initial tests included 57 batteries, in which 43 batteries indicated a low battery chirp when installed in a test smoke alarm, as shown in Table 3 column *First Tested*.

A second set of tests was conducted on 68 batteries, which included the initial 57 batteries plus the additional 11 collected after the study began, as shown in Table 3 column *Second Round of Testing*. During this set of tests, 58 batteries caused a low-battery chirp when installed in the test smoke alarm. In the re-test of the initial 57 batteries, 6 additional batteries indicated premature low-battery chirping.

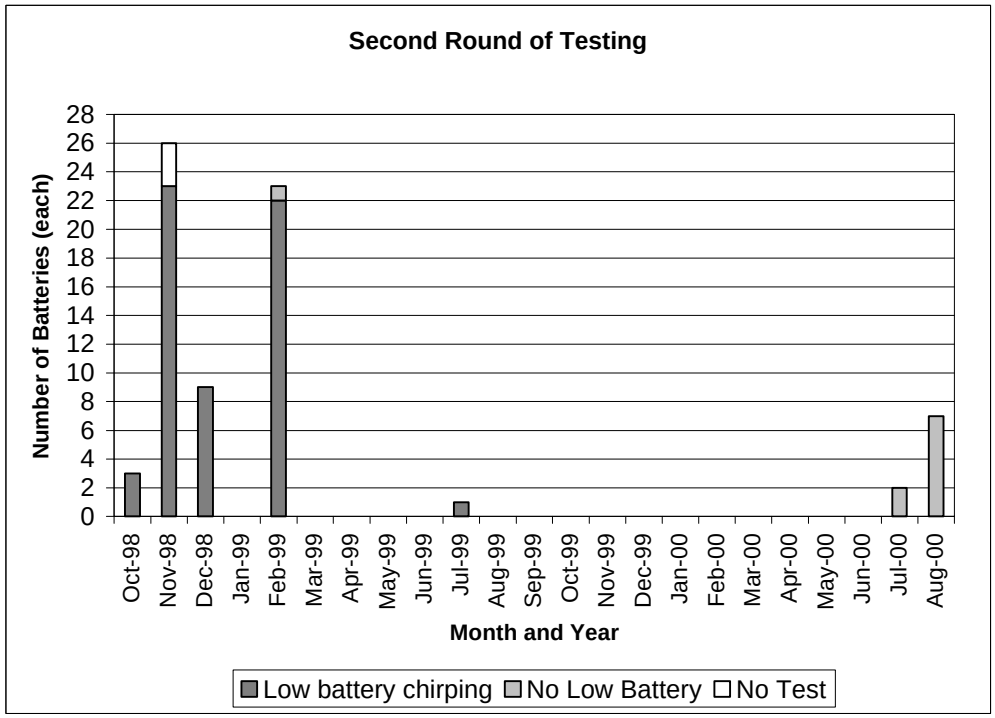
Table 4 shows the date codes of the batteries during this second round of tests, including the four batteries that were not tested. (For simplicity, the one no-test battery with date code September 1996 is not shown in the table.)

Table 3. Battery Dates and Models of the U9VL-J Batteries Collected and Tested.

Battery Date	Model	First Tested			Second Round of Testing [1]		
		Premature Low Chirping			*Premature Low Chirping*		
		yes	no	no test	yes	no	no test
September-96	U9VL-J			1			1
October-98	U9VL-J	3			3		
November-98	U9VL-J	20	3	3	23		3
December-98	U9VL-J	9			9		
February-99	U9VL-J	10	2		22	1	
July-99	U9VL-J	1			1		
July-00	U9VL-J		2			2	
August-00	U9VL-J		7			7	
Subtotal		43	14	4	58	10	4
Tested Total		57			68		
TOTAL		61			72		

1. Includes the additional 11 batteries collected and the retest (9-months later) of the initial batteries

Table 4. Battery Dates that Failed During Second-Round Tests
(72 Batteries[2] including the additional 11 Batteries and the no-test batteries)



2. Does not show no-test battery sample from September 1996.

ULTRALIFE ANALYSIS

Ultralife Batteries, Inc. reviewed the CPSC staff report and provided comment in their report entitled *Report on the Functionality and Use of the Ultralife U9VL-J Battery in Ionization Smoke Alarms*, dated November 6, 2002 (see Appendix A). This report states that the cause for the failures in the Ultralife batteries was a result of the "grease sealing process in which grease is applied to the outside of sealed plastic housing which contains the three cells of the battery." The manufacturer stated that the problem was isolated to the timeframe August 1998 to May 1999. During this period, the grease sealing process that was used in the manufacturing process allowed external moisture to enter the batteries, which would affect [increase] the internal resistance over time.

Ultralife conducted a performance analysis of the battery life based on the current drain characteristics of a smoke alarm and determined that, in the absence of the problem identified, the battery is capable of providing a service life of 10 or more years in a typical ionization smoke alarm.

CPSC Staff Comments on the Ultralife Analysis

Fifty-seven of the 58 batteries collected by CPSC and CDC that were associated with a premature low-battery chirping have date codes that are within the nine-month period (August 1998 to May 1999) that the manufacturer identified as related to a problem with the grease sealing process. Only one sample with date code July 1999 was outside the nine-month timeframe. There have been no additional reports of premature low-battery chirping in 10-year smoke alarms received by CPSC or CDC staff.

Ultralife calculated the approximate life of a lithium battery in a smoke alarm application (*Section 6 – Smoke Alarm and Battery Characteristics*). In their report, the table entitled *Smoke Alarm Drain Rate Measurements and Battery Capacity Consumption* lists the minimum, average, and maximum measured values of current and duration of current drain when installed in an ionization smoke alarm. Table 5 below repeats the data from the Ultralife report. The table shows the calculated approximate life (years) of a battery when used in an ionization smoke alarm.

The calculated life of a lithium battery as presented in Table 5 under the column "Actual Measured Values Maximum" does not represent the worst case scenario, nor does the Ultralife report claim it does. To calculate the worst case scenario from the data presented in the table, values for the maximum current used by the smoke alarm and the minimum interval for battery condition check would be used. Table 6 below shows the calculated value for the life of a battery under the worst case conditions presented in the data from Table 5. The table also shows the calculated life to one decimal point for minimum, average, maximum, and worst case values. Under these worst case conditions, the calculated approximate life of a battery is 10.7 years, or 10 years and 36 weeks.

Table 5. Smoke Alarm Drain Rate Measurements and Battery Capacity Consumption
(Data from the Ultralife Report)

Current Drain Characteristics	**Actual Measured Values Minimum**	**Actual Measured Values Average**	**Actual Measured Values Maximum**
Quiescent Current (uA)	4.1	4.7	5.2
Battery Condition Check			
Pulse Load (mA)	10.4	11.9	13.3
Duration (ms)	5.5	7.5	9.4
Interval (second)	22.0	29.5	37.0
Weekly Test			
Pulse Duration (mA)	11.3	11.3	11.3
Duration (second)	3.0	3.0	3.0
Total Capacity Consumption			
Weekly (mAh/wk)	1.2	1.3	1.5
Annual (mAh/yr)	63.4	67.6	78
Calculated approximate battery life using a battery capacity of 1000 mAh (yrs)	16	14	12

Table 6. "Worst Case" Scenario
(Using the Data from the Ultralife Report)

Current Drain Characteristics	**Actual Values Minimum**	**Actual Values Average**	**Actual Values Maximum**	**Worst Case Values**
Quiescent Current (uA)	4.1	4.7	**5.2**	**5.2**
Battery Condition Check				
Pulse Load (mA)	10.4	11.9	**13.3**	**13.3**
Duration (ms)	5.5	7.5	**9.4**	**9.4**
Interval (second)	**22.0**	29.5	37.0	**22.0**
Weekly Test				
Pulse Duration (mA)	11.3	11.3	11.3	**11.3**
Duration (second)	3.0	3.0	3.0	**3.0**
Total Capacity Consumption				
Week Quiescent Current (mAh/wk)	0.69	0.79	0.87	0.84
Week Battery Condition (mAh/wk)	0.44	0.51	0.57	0.95
Week Weekly Test (mAh/wk)	0.01	0.01	0.01	0.01
Total Weekly (mAh/wk)	1.2	1.3	1.5	**1.8**
Annual (mAh/yr)	63.4	67.6	78	**93.6**
Calculated approximate battery life using a battery capacity of 1000 mAh (yrs)	15.7	14.8	12.8	**10.7**

Note – The totals may not correspond to values listed due to rounding errors

The Underwriters Laboratories Inc. (UL) voluntary standard for residential smoke alarms is *UL 217 – Single and Multiple Station Smoke Alarms*. The fifth edition, dated February 21, 1997, *Section 63 – Battery Test* states, "it [smoke alarm] shall provide power to the unit under intended ambient conditions for at least 1 year in the standby condition, including novelty and weekly alarm testing, and then operate the alarm for a minimum of 4 minutes of alarm, followed by 7 days trouble signal." The standard does not evaluate battery performance for smoke alarms with long-life batteries (in excess of one year).

CPSC staff calculated the approximate life of a battery (using the worst case conditions in Table 6) and included the UL 217 requirements of 4 minutes of alarm and 7 days of trouble signal, as well as weekly testing and battery condition check (see Table 7). The additional requirements of UL 217 reduce battery life in the worst case scenario by 21 weeks – from 10 years 36 weeks to 10 years 15 weeks.

Table 7. "Worst Case" Scenario Using the Data from the Ultralife Report and UL 217 Performance Requirements

Current Drain Characteristics	**Values Minimum**	**Values Average**	**Values Maximum**	**Worst Case**	**Worst Case and UL 217**
Quiescent Current (uA)	4.1	4.7	5.2	5.2	5.2
Battery Condition Check					
Pulse Load (mA)	10.4	11.9	13.3	13.3	13.3
Duration (ms)	5.5	7.5	9.4	9.4	9.4
Interval (second)	22.0	29.5	37.0	22.0	22.0
Weekly Test					
Pulse Load (mA)	11.3	11.3	11.3	11.3	11.3
Duration (second)	3.0	3.0	3.0	3.0	3.0
Total Capacity Consumption					
Total Weekly (mAh/wk)	1.2	1.3	1.5	1.8	1.8
Annual (mAh/yr)	63.4	67.6	78	93.6	93.6
			Battery Usage (mAh)		
			First 10 Years		936
			UL 217		
			4 minutes of alarm		0.8*
			7 days of trouble		36**
			TOTAL Battery Usage (mAh)		972.8
			Remainder using a battery capacity of 1000 mAh (mAh)		27.2
			Remaining weeks		15
Calculated approximate battery life using a battery capacity of 1000 mAh (years and weeks)	15 yrs 36 wks	14 yrs 42 wks	12 yrs 42 wks	10 yrs 36 wks	**10 yrs 15 wks**

* 4 minutes of alarm – calculated from "weekly test" of 11.3 mA for 4 minutes

**7 days of trouble – calculated from one week of quiescent current, battery condition check, and horn (chirping). Horn chirping – current 11.3 mA, duration [estimated] 400 milliseconds, and interval 22 seconds.

Note – The totals may not correspond to values listed due to rounding errors

CPSC Staff Calculated Battery Life in a Smoke Alarm

The test smoke alarm mentioned in the CPSC staff report entitled, *Preliminary Test Results on Lithium Batteries Used in Residential Smoke Alarms* was used to measure the current and duration of a "good" lithium U9VL-J battery. Table 8 lists the values for the quiescent, battery check, and weekly alarm testing. Three measurements were taken and averaged.

Table 8. CPSC Staff Actual Current and Duration Measurements

Current Drain Characteristics	**Measurement 1**	**Measurement 2**	**Measurement 3**	**Average**
Quiescent Current (uA)	5	5	5	5
Battery Condition Check				
Pulse Load (mA)	12.00	12.80	12.80	12.5
Duration (ms)	11.44	11.52	11.44	11.5
Interval (second)	41.35	41.70	41.53	41.5
Weekly Test				
1-second cycle				
LED Load (mA)	11.3	11.3	11.3	11.3
LED Duration (ms)	11.5	11.5	11.5	11.5
Horn Load (mA)	24	23.2	28	25.1
Horn Duration (ms)	512	512	512	512
Quiescent Current (uA)	5	5	5	5
Quiescent Duration (ms)	476.5	476.5	476.5	476.5
LED (mAh)	3.99E-5	3.99E-5	3.99E-5	3.99E-5
Horn (mAh)	3.41E-3	3.30E-3	3.98E-3	3.57E-3
Quiescent (mAh)	6.62E-7	6.62E-7	6.62E-7	6.62E-7
3-seconds (3 cycles)				
Total (mAh)	1.04E-3	1.00E-3	1.21E-3	1.08E-3
Total Capacity Consumption				
Week Quiescent Current (mAh/wk)	0.84	0.84	0.84	0.84
Week Battery Condition (mAh/wk)	0.56	0.59	0.59	0.58
Week Weekly Test (mAh/wk)	0.01	0.01	0.01	0.01
Total Weekly (mAh/wk)	1.41	1.44	1.44	1.43
Annual (mAh/yr)	73.3	74.9	74.9	74.4
Calculated approximate battery life using a battery capacity of 1000 mAh (yrs)				**13.4**

Note – The totals may not correspond to values listed due to rounding errors

The quiescent current is an estimated measurement due to the limits of the instrumentation. Therefore, 5uA was used for all three measurements.

The battery condition check produced a repeatable pulse width and current draw. Figure 2a and 2b shows the LED pulse signal and the current draw, respectively. The current was measured 4 ms after the negative slope of the LED pulse.

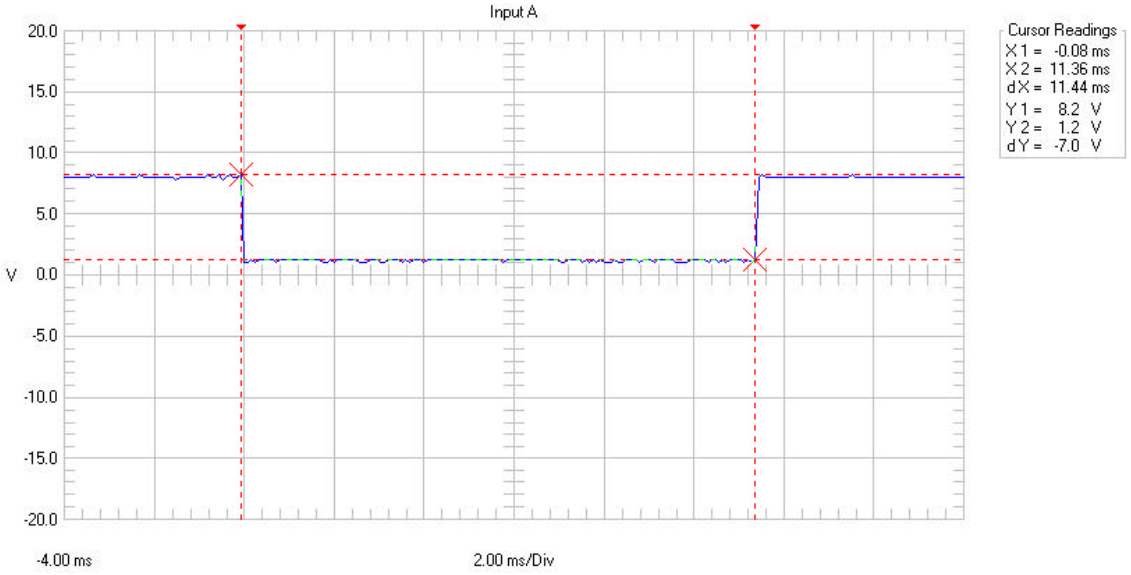


Figure 2a. LED Pulse Width

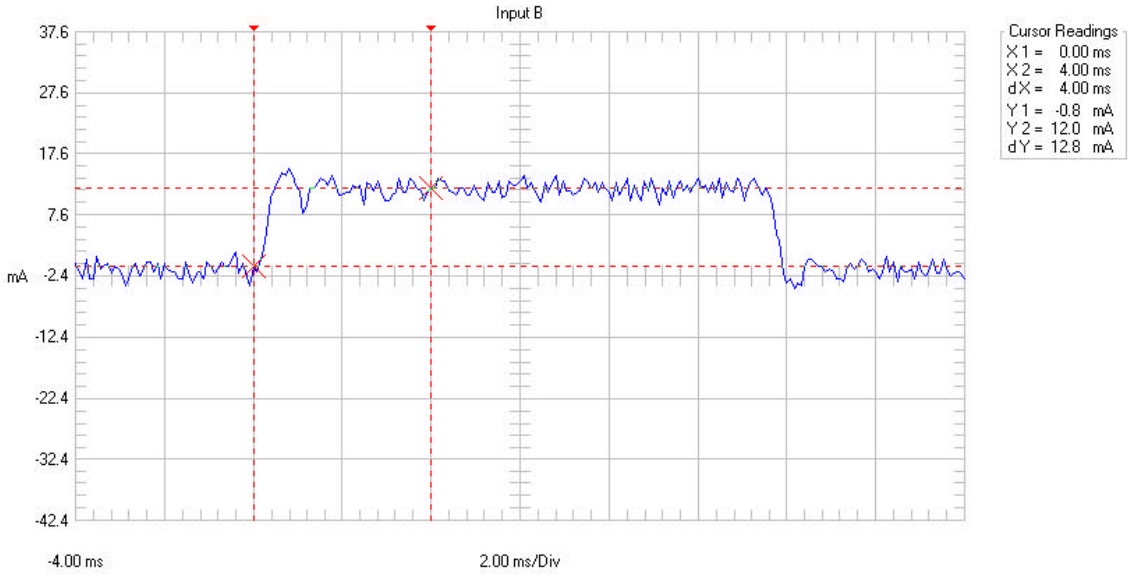


Figure 2b. LED Current Draw

The total weekly test was calculated for a 3s period (3 cycles). The number was calculated from standby (quiescent), LED flashing (battery check), and the horn sounding. When the smoke alarm was tested, the LED light blinked approximately every second (one cycle). When tested, the smoke alarm outputs a temporal three pattern of three horn sounds followed by no sound, then again by three horn sounds. The horn duration was approximately 0.5 second and drew approximately 25 mA current while sounding as shown in Figure 3b.

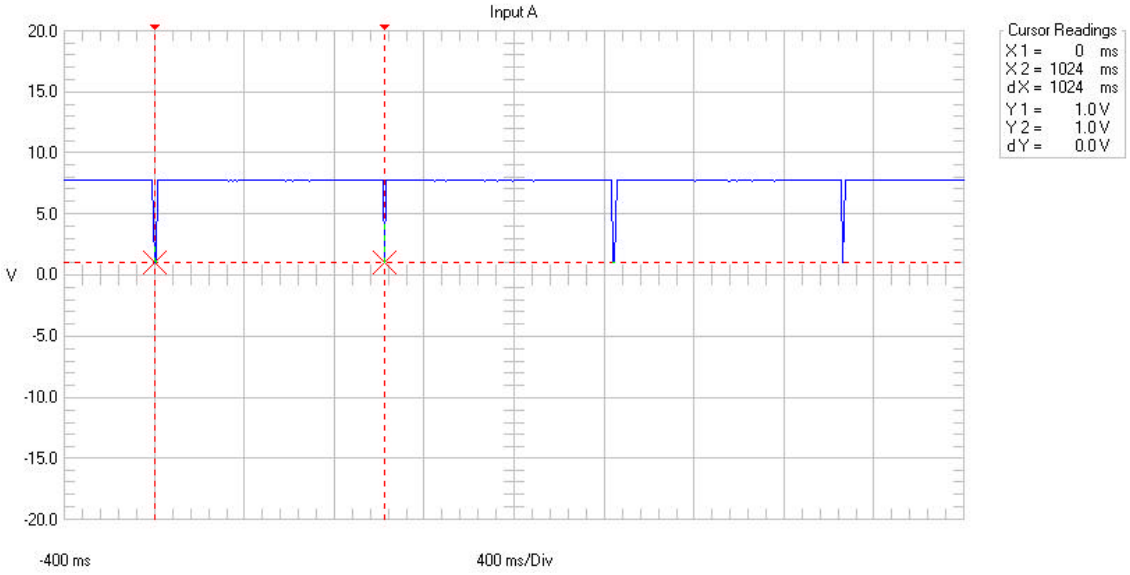


Figure 3a. LED Cycle during Weekly Test

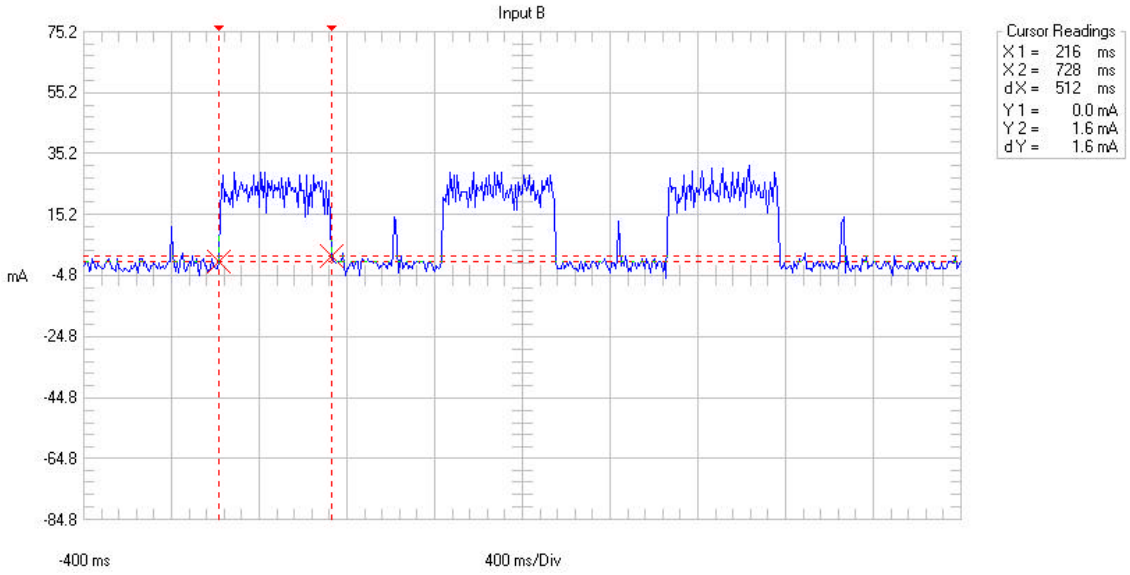


Figure 3b. Horn Duration and Current Draw during Weekly Test

The calculated battery life, using 1000 mAh battery capacity, was approximately 13.4 years for the smoke alarm used in the test. The variable that has the most significant effect on the battery life in a smoke alarm appears to be the battery condition check. The current draw, duration, and interval for battery condition check all have an influence on the battery life for a smoke alarm.

CONCLUSIONS

Ultralife Batteries, Inc. reviewed the CPSC staff report *Preliminary Test Results on Lithium Batteries Used in Residential Smoke Alarms* dated June 28, 2002. They provided comments in a report entitled *Report on the Functionality and Use of the Ultralife U9VL-J Battery in Ionization Smoke Alarms* dated November 6, 2002. Ultralife attributed the cause of the premature battery failures to a manufacturing problem during the grease sealing process; this problem was isolated to the period August 1998 to May 1999. CPSC staff review of the data gives support to the findings that the problem is limited to a specific timeframe, as stated in the Ultralife report. In addition, using the data presented in the Ultralife report, CPSC staff calculations indicate that, under worst case conditions, the lithium battery U9VL-J should last 10 years or more in an ionization smoke alarm.

In summary, CPSC staff noted the following:

- The failed batteries were limited to a specific timeframe.
  - Fifty-seven of the 58 batteries collected by CPSC and CDC that were associated with premature low-battery chirping of smoke alarms were within the timeframe associated with a manufacturing problem reported by the manufacturer.
  - Only one battery collected and tested associated with premature low-battery chirping was outside the specified timeframe.
  - CPSC and CDC have not received any additional reports of smoke alarms exhibiting premature low-battery chirping.

- The approximate life of the Ultralife lithium battery model U9VL-J, as calculated by Ultralife and based on actual measured values in an ionization smoke alarm, should be 10 years or more in a residential ionization smoke alarm.
  - In a "worst case" scenario, using the data from the Ultralife report, CPSC staff calculated the life of a battery in a smoke alarm to be approximately 10 years and 36 weeks.
  - Including the UL 217 requirement of 4 minutes of alarm and 7 days of trouble signal following the advertised life of the battery reduces the life of the battery by 21 weeks (from 10 years 36 weeks to 10 years 15 weeks, using the worst case conditions).
  - *UL 217 – Single and Multiple Station Smoke Alarms* does not evaluate battery performance for smoke alarms with long-life batteries (in excess of one year).

- The values (current and duration of current drain) presented in the Ultralife report in the table titled *Smoke Alarm Drain Rate Measurements and Battery Capacity Consumption* were not investigated by CPSC staff for representation of all or general residential smoke alarms using long-life batteries. However, the values appear to be reasonable.
- CPSC staff calculated the life of a U9VL-J lithium battery to last approximately 13.4 years, using the test smoke alarm described in the CPSC staff report, *Preliminary Test Results on Lithium Batteries Used in Residential Smoke Alarms* dated June 28, 2002.
- The battery life in a smoke alarm is very dependent on the current draw, duration, and interval during the battery condition check.

Appendix A

Report on
the Functionality and Use of the
Ultralife U9VL-J Battery
in Ionization Smoke Alarms

November 6, 2002.

Andrew Naukam
Vice President Research & Development

Ultralife Batteries, Inc.

Total Pages 6

Contents

REPORT ON
THE FUNCTIONALITY AND USE OF THE ULTRALIFE U9VL-J BATTERY IN IONIZATION SMOKE ALARMS

November 6, 2002

Andrew Naukam
Vice President Research & Development

Ultralife Batteries, Inc. • 2000 Technology Parkway • Newark, NY 14513 • 315-332-7100 • Fax: 315-331-7800
www.ultralifebatteries.com

Contents

1) Executive Summary

(a) The Ultralife Batteries Model U9VL-J 9-volt lithium battery is recognized under the Component Recognition Program of Underwriters Laboratories (UL) standard UL1642.

(b) The batteries/smoke alarms returned to the CPSC were not operating normally. These batteries were returned due to an impedance problem, which was caused by an isolated and particular grease sealing process in the course of the batteries' manufacture, which may be exacerbated by storage conditions. Further, this may result in low battery alarm conditions in only certain applications. The impedance problem was corrected as a result of Ultralife using new grease in the manufacturing process.

(c) The battery, in the absence of the problem identified in paragraph (b), is appropriate for use in long-life smoke alarms.

2) CPSC Report

In the CPSC report *Preliminary Test Results on Lithium Batteries Used in Residential Smoke Alarms, dated June 28, 2002*, and in discussions between Ultralife and CPSC, it has been stated that low battery signals in collected field units were caused by failures of the lithium batteries used in the alarms. Further, CPSC staff recommends that performance requirements be developed to ensure that long-life (10-year) smoke alarms perform as claimed by the manufacturer. Additionally CPSC looks to encourage smoke alarm manufacturers to ensure that the batteries they use meet the 10-year specification.

3) Historical Perspective

The Ultralife Batteries Model U9VL-J 9-volt lithium battery is designed for 10-year operation in specific ionization smoke alarms, and is recognized under the Component Recognition Program of Underwriters Laboratories, per UL standard 1642.

Typical smoke alarms are designed, tested and certified per Underwriters Laboratories (UL) standard UL217, *Single and Multiple Station Smoke Alarms*. This industry standard specifies the waiver forms for the calculation of the current drains required to operate the alarms. Ultralife uses this information and actual current drain measurements for the determination of service life of the U9VL-J battery in alarms.

Since 1992, Ultralife has sold approximately 23 million U9VL-J batteries, which were distributed and are in use worldwide in smoke alarms, security systems, medical devices and many other electronic products.

Over the last several years various smoke alarm manufactures have made and sold millions of smoke alarms that have been supplied with U9VL-J batteries, and these units were widely distributed in the U.S. as well as other locations throughout the world.

4) Discussion of Problem Cause

Some of the batteries supplied during the timeframe noted in the CPSC report had a battery impedance problem. This problem was related to a grease sealing process in which grease is applied to the outside of a sealed plastic housing which contains the three cells of the battery. The battery is then encased in an aluminum can, which is crimped in place.

During a specific timeframe the Ultralife battery grease sealing process that was used in the manufacturing of batteries left the possibility of moisture ingress into the battery under certain conditions.

This manufacturing problem was an isolated occurrence over a short period of time – a nine-month period from August 1998 to May 1999. The result of this problem left the possibility of an increased rate of moisture ingress into the battery, which affected the batteries' internal impedance.

Dependent on exposure to specific storage conditions and also on the certain application of use, some batteries could exhibit an early high impedance characteristic and potentially premature low battery alarms. To correct this problem Ultralife implemented a change to a new grease to ensure that the condition mentioned above did not exist going forward.

The low-battery alarm chirping problem referred to in the CPSC report was a result of the battery impedance growing to high levels under relatively short periods of time. The impedance growth caused reduced operating voltage of the battery, which in turn caused the premature low battery alarm condition.

5) Problem Described in CPSC report has Assignable Cause

The performance issue stated in the CPSC report was caused by the battery grease-sealing process problem described in paragraph (4) above, which has been resolved.

6) Smoke Alarm and Battery Characteristics

Prior to supplying U9VL-J batteries to smoke alarm manufactures, Ultralife conducted a performance analysis of the battery life based on typical alarm current drain characteristics and determined that the battery would last for a period of at least 10 years in a typical ionization smoke alarm. In an ongoing effort to better understand the battery performance capability in smoke alarms, Ultralife continues to undertake studies to reaffirm previous calculations and conclusions as well test the latest revision smoke alarms and batteries.

Smoke Alarm Discussion

The following chart compares typical smoke alarm electrical drain characteristics and actual measured values obtained by measuring the electrical operating characteristics of ionization smoke alarms.

Smoke Alarm Drain Rate Measurements and Battery Capacity Consumption

Current Drain Characteristics		Actual Measured Values Minimum	Actual Measured Values Average	Actual Measured Values Maximum
Quiescent Current (uA)		4.1	4.7	5.2
Battery Condition Check				
	Pulse Load (mA)	10.4	11.9	13.3
	Duration (millisecond)	5.5	7.5	9.4
	Interval (second)	22.0	29.5	37.0
	No. per hour	NA	NA	NA
	No. per year	NA	NA	NA
Weekly Test				
	Pulse Load (mA)	11.3	11.3	11.3
	Duration (second)	3.0	3.0	3.0
Hush Feature				
	Pulse Load (mA)	NA	NA	NA
	Duration (hrs)	NA	NA	NA
	TOTAL Weekly Capacity Consumption (mAh/wk)	1.2	1.3	1.5
	TOTAL Annual Capacity Consumption (mAh/yr)	62.4	67.6	78
	Available Battery Capacity (mAmph)	1000	1000	1000
	Calculated Approximate Battery Life (yrs)	16	14	12

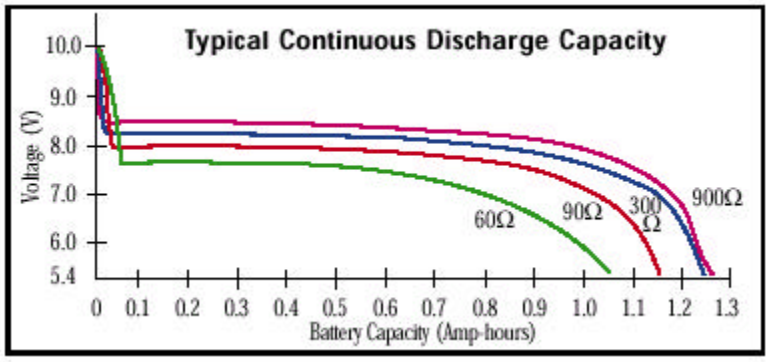
Chart Interpretation

For example, using the maximum measured value of 1.5 mAh per week, and multiplying it times 52 weeks per year gives 78 mAh per year of capacity consumption. Dividing the available battery capacity of 1000 mAh by the annual capacity consumption gives the approximate battery life in years.

Ultralife Model U9VL-J Battery Discussion

The capacity rating of the battery per the Ultralife Technical Data sheet is 1,200 mAh at 900 Ohms (approximately 9 mA) at room temperature to 5.4 volts cutoff. The following graph displaying typical room temperature performance, is taken from the data sheet.

Ultralife U9VL-J Battery Capacity



The capacity rating of the battery at a cutoff voltage for smoke alarms is approximately 1,000 mAh at 900 Ohms (approximately 9 mA) at room temperature to 7.8 volts cutoff.

Therefore, the battery capacity of 1,000 mAh should be divided by the annual capacity consumption of a smoke alarm in mAh. Typical smoke alarm maximum actual consumption is approximately 78 mAh per year.

From this, an Ultralife U9VL-J battery can provide a service life in excess of 10 years under normal use conditions.

7) Conclusion

The battery, in the absence of the problem identified in paragraph (4), is capable of providing a service life of 10 or more years.

Andrew Naukam
Vice President Research & Development
Ultralife Batteries, Inc.