AD NUMBER
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afal ltr, 14 apr 1978

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AFAPL-TR-75-16

LABORATORY SHELF-LIFE TESTS OF PRIMARY RESERVE MAGNESIUM BATTERIES FOR EMISSIVE EXPENDABLE ELECTRONIC COUNTERMEASURE DEVICES

AEROSPACE POWER DIVISION
AIR FORCE AERO PROPULSION LABORATORY

JULY 1975

TECHNICAL REPORT AFAPL-TR-75-16
FINAL REPORT FOR PERIOD APRIL 1971 THROUGH 15 JULY 1974

AIR FORCE AERO PROPULSION LABORATORY
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Presented herein this report are the results of shelf life tests of primary reserve, automatically activated, magnesium anode batteries developed by Eagle-Picher Industries, Inc. under F33615-69-C-1760 for an emissive expendable electronic countermeasure device application. This testing consisted of discharging batteries under simulated anticipated flight test use environment following intervals of storage at various temperatures. The tests were conducted by Messrs. G. H. Miller, C. T. Napier, and W. S. Sexton of the Air Force Aero Propulsion Laboratory under Project 3145 and Task 314522 during the period 1 April 1971 through 15 July 1974.

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This report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFAPL-TR-75-16	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Laboratory Shelf Life Tests of Primary Reserve Magnesium Batteries for Emissive Expendable Electronic Countermeasure Devices		5. TYPE OF REPORT & PERIOD COVERED Final April 71 - 15 July 74
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Gerald H. Miller		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aerospace Power Division (AFAPL/POE-1) Air Force Aero Propulsion Laboratory Wright-Patterson AFB, OH 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task 314522
11. CONTROLLING OFFICE NAME AND ADDRESS Aerospace Power Division (AFAPL/POE-1) Air Force Aero Propulsion Laboratory Wright-Patterson AFB, OH 45433		12. REPORT DATE July 1975
		13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government Agencies Only; Test and Evaluation 6 January 1975). Other requests for this document must be referred to AFAPL/POE, Wright-Patterson Air Force Base, Ohio 45433.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

In-house (AFAPL/POE) laboratory tests of batteries received under Contract F33615-69-C-1760 with Eagle-Picher Industries, Inc.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Magnesium anode, primary reserve batteries, automatically activated aircraft ECM battery, shelf life tests, magnesium anode primary reserve batteries, low temperature automatically activated magnesium batteries

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents results of shelf life testing of automatically activated, magnesium anode batteries developed for aircraft expendable electronics countermeasure (ECM) application. Model LSP2055 batteries stored at 70°F for over 12 months (continuous) demonstrated design service life as did one battery that was desk stored at about 75°F for 45 months. However, Model LSP2055 batteries stored at 130°F for 12 months (continuous) and at 110°F for 12 months (continuous) failed to give minimum service life. These high temperature stored batteries lose water

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) from their electrolyte via evaporation resulting in a too acid electrolyte. Model LSP2021 batteries, similar in most respects to Model LSP2055 batteries, demonstrated their specified discharge life following 6 years desk storage at about 75°F. Although some mechanical causes necessitated some batteries to be manually activated, the general conclusion, based on fresh battery performance and shelf life test results, is that Model LSP2055 battery is a suitable power source for aircraft ECM applications.

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SECTION I
INTRODUCTION

Electronic warfare embraces the development of techniques and devices for countering threat radars. Within this technical field is the development of emissive expendable electronic countermeasures (ECM's) as penetrating aids for aircraft. These aircraft ECM's, sometimes called electronic jammers, are battery powered radio frequency transmitters that deny, confuse, or alter radar information by intentionally interfering with the RF signals.

In June 1969, Eagle-Picher Industries, Inc., under Contract F33615-69-C-1760 began development of an automatically activated battery for a particular jammer application. The resulting nominal 30 volt, 10 cubic inch volume, magnesium anode battery demonstrated the required 10 minutes' active discharge service life over most of the required environmental conditions ranging from -40°F to +125°F and sea level to 40,000 feet altitude. This development effort and the results of testing each of the 75 final design batteries in their fresh (unstored) condition under various loads and environmental combinations is described in the final report under F33615-69-C-1760 (Reference 1). Each of the 25 final design batteries under this contract were shelf-life tested at the Air Force Aero Propulsion Laboratory (AFAPL), and these results are reported herein.

Reference 1. E.P. Broglio, A Low Temperature Miniature Automatically Activated Magnesium Battery, AFAPL-TR-71-25, April 1971.

SECTION II
OBJECTIVE

The test objective is to determine the active discharge service life capabilities of primary reserve, automatically activated, magnesium anode battery, Eagle-Picher Industries Model LSP 2055, under simulated aircraft ECM use environment following storage at various temperatures for a given duration.

SECTION III
SUMMARY OF RESULTS

The ability of Model LSP2055 and similar Model LSP2021 batteries to perform in terms of activation, load voltage rise time, and active discharge life when discharged into a 30-ohm load while at -10°F and 20,000 feet altitude following storage at temperatures of 130°F, 110°F, and 70°F for 12 months and longer is summarized.

1. ACTIVATION

Battery Model LSP2055-S/N 222 failed by electrolyte leakage before storage, thus was not assigned to storage. Twenty-three of the total 24 stored model LSP2055 batteries successfully activated (19 automatically and 4 manually assisted). Stored battery S/N 208 could not be activated. Three of the manually assisted activated batteries and battery S/N 208 were stored at 130°F for 12 continuous months. The other manually assisted activated battery was desk stored for 45 months. Both of the Model LSP2021 batteries successfully activated, one automatically, the other manually assisted, following over 72 months' desk storage.

2. LOAD VOLTAGE RISE TIME

Nineteen of the total 23 activated Model LSP2055 batteries reached or exceeded 24 volts' load voltage within 10 seconds. Battery S/N 203 stored at 130°F for 12 months and battery S/N 249 stored at 70°F for 12 months reached 23.5 volts in 10 seconds. Battery S/N 207 stored at 130°F for 12 months took 4 minutes to reach 24 volts' load voltage while battery S/N 239 stored at 70°F for 12 months reached 24 volts' load voltage in 15 seconds. Both of the Model LSP 2021 batteries met their specified 20 volts in 10 seconds.

3. ACTIVE DISCHARGE LIFE

Only seven of the total 24 stored Model LSP2055 batteries met the 10 minutes above 24 volts' service life requirement (none of the 7 batteries stored at 130°F for 12 months, none of the 7 batteries stored at 110°F for 12 months, 6 of 9 batteries stored at 70°F for 12 months, and 1 of 1 desk stored for 45 months gave the required service life). Both of the Model LSP2021 batteries desk stored for over 72 months met their specified life.

4. BATTERY FAILURE MODES

Only 7 of the total 25 model LSP 2055 batteries were operationally acceptable. Eleven of the 18 failed batteries did so for reason of not operating for the minimum of 10 minutes above 24 volts. These 11 battery failures are related directly to high temperature storage. The other seven failed batteries consisted of 1 battery leaking electrolyte, 1 battery not able to activate, 4 batteries requiring manual assistance to activate, and 1 battery having excessively long voltage rise time. These seven battery failures are mechanical in nature and not necessarily related to the storage temperature.

SECTION IV
CONCLUSIONS

The major conclusions, with no statistical claims attached, of this test program involving Model LSP2055 and similar Model LSP2021 batteries discharged into 30 ohm load at -10°F and 20,000 feet altitude following storage are:

1. High temperature storage degrades battery operating life, e.g.,
   a. 7 of 7 Model LSP2055 batteries stored at 130°F for 12 months continuously gave about 50% of the required 10 minutes' discharge life;
   b. 7 of 7 Model LSP2055 batteries stored at 110°F for 12 months continuously gave about 90% of the required 10 minutes' discharge life;

2. Room ambient temperature storage of about 75°F does not affect battery discharge life, e.g.,
   a. 6 of 9 Model LSP2055 batteries stored at 70°F for 12 months continuously exceeded 10 minutes' discharge life;
   b. 1 of 1 Model LSP2055 battery desk stored at room ambient temperature for 45 months exceeded 10 minutes discharge life;
   c. 2 of 2 Model LSP2021 batteries desk stored at room ambient temperature for over 72 months gave their design operating life.

3. Model LSP2055 and Model LSP2021 batteries appear capable of withstanding more than 5 years room ambient (~75°F) storage and yet activate and operate per their design specifications. The observed nonsuccessful automatic activations appear mechanically correctable.

4. A general conclusion based on fresh battery performance (Reference 1) and the shelf life test results reported herein is that magnesium anode battery Model LSP2055 battery is a suitable power source for aircraft ECM applications, while, however, acknowledging that important considerations yet remain such as proper interfacing of the battery with particular ECM device hardware and confirming battery reliability and safety.

SECTION V
RECOMMENDATION

It is recommended that magnesium anode battery Model LSP2055 be considered a candidate power source for aircraft ECM applications wherein:

1. Only moderate levels of source power is required (e.g., nominal 24 volts and 1 ampere for 10 minutes or 0.5 amperes for 20 minutes).
2. The operating environment for the power source ranges from -40°F to 75°F and up to 40,000 feet.
3. The withstanding environment for the power source ranges from -65°F to +165°F and up to 80,000 feet and long term (>5 years) storage at controlled temperatures (≤75°F).
4. A battery volume of 10 cubic inches is tolerable.
5. A low cost battery is essential (Model LSP2055 battery produced in quantities of 40 batteries/day is estimated using 1971 materials and labor rates to cost $17.49 each).

SECTION VI
PREVIOUS BATTERY DEVELOPMENT PROGRAM

1. ECM DEVICE VIEWPOINT

Power sources for aircraft expendable ECM's should, from an ECM device point of view:

1. Physically fit into existing dispenser packages.
2. Operate generally (i.e., provide the proper current at voltage for the specified time duration and under given environmental contributions).
3. Operate after unattended storage of 3 years or longer.
4. Be reliable and safe.
5. Be available in large quantities at low cost (<$25.00).

2. ECM BATTERY VIEWPOINT

Translating the ECM device constraints into criteria for selecting candidate electrochemical systems says that the electrochemical system must:

1. Have current density and voltage characteristics to operate the device.
2. Have specific energy density (watt-hour/cubic inch) capability to fit into the given volume.
3. Be capable of yielding the current, voltage, and watt-hour/cubic inch characteristics over wide environmental conditions.
4. Be insensitive to long-term unattended storage.
5. Be simple in design with nonhazardous components and materials.
6. Be suitable for large quantity production by more than one supplier.

3. BATTERY DEVELOPMENT F33615-69-C-1760

The development effort by Eagle-Picher Industries under F33615-69-C-1760 was to provide a battery capable of fitting into any of three different dispensers and supply a minimum 300 watt-minute capacity.

Some of the leading device requirements and details about the selected electrochemical system, and features of the final design battery of this development effort are summarized in Table 1.

Figures 1 and 2 are photographs of the final design, Model LSP2055 battery. Its operating logic, component drawings, and large quantity production unit cost estimates are detailed in the referenced final report (Reference 1). The electrical performance capabilities of the Model LSP2055 battery as determined by Eagle-Picher Industries tests of 75 each fresh (unstored) batteries under various loads at 40,000 feet altitude is summarized in Table 2.

Figure 1. Model LSP2055 Battery

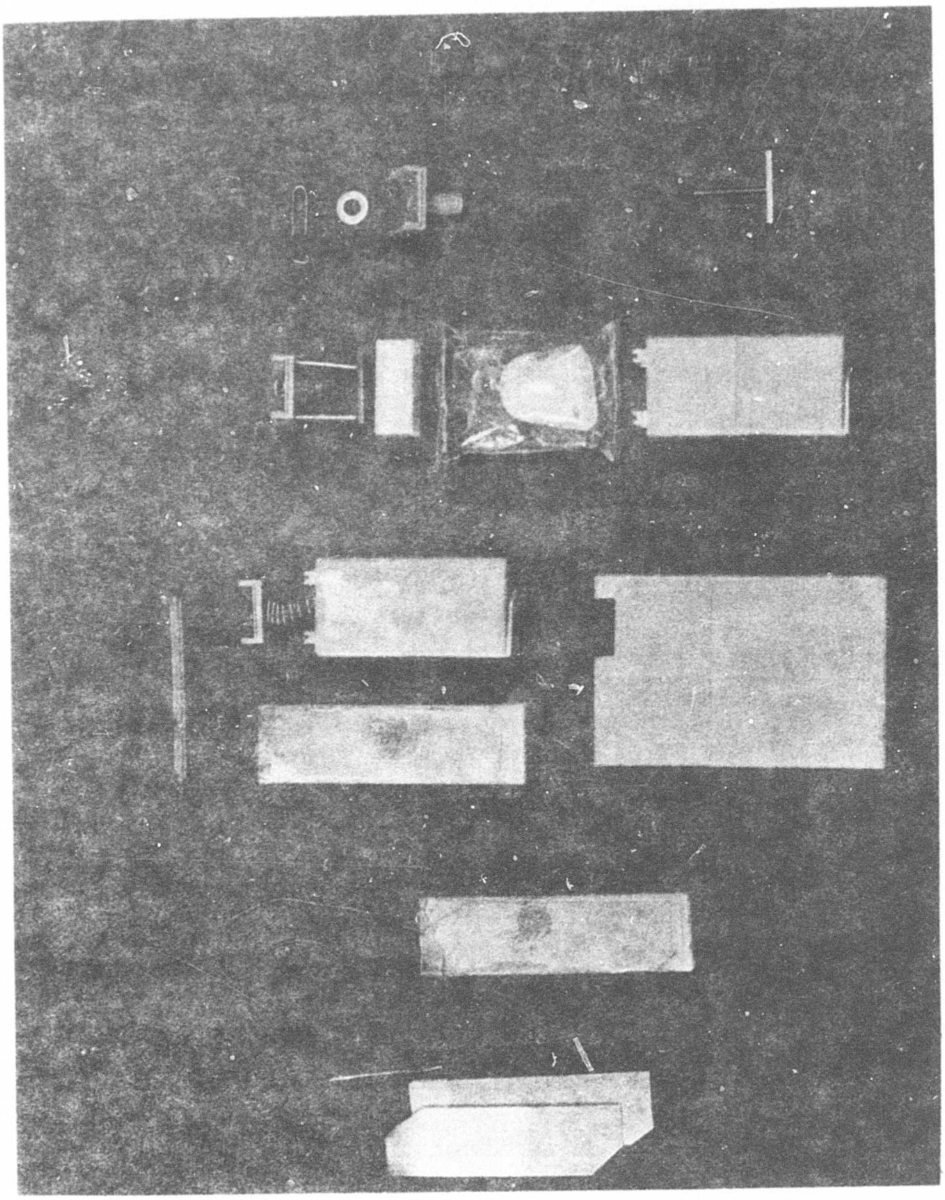


Figure 2. Model LSP2055 Battery Details

TABLE 1

MODEL LSP2055 BATTERY DESIGN REQUIREMENTS AND FEATURES

JAMMER REQUIREMENTS	ELECTROCHEMICAL SYSTEM	BATTERY MODEL LSP2055
<u>Service</u>	<u>System</u> $HgO-MnO_2/HCLO_4-Mg(ClO_4)_2-H_2O/Mg$	16 cell/battery
10 minutes above 24 volts into 30 ohm load over environment of -40°F to +125°F from sea level to 40,000 feet altitude	<u>Positive Plate</u> 1/cell 0.023 x 3.25 x .94 (inches) 2 grams/cell: HgO 42%; MnO_2 42%; Ag_2O_2 4%; Black Carbon 10%; Fiber 0.5%; Binder 1.5%	$30v^{+2}_{-6}$, 300 watt-minutes 2.61 l x 0.96 w x 4.0 h (inches) 10 cubic inch volume 160 grams weight Lanyard release - spring piston activated
<u>Size & Shape</u> 10 cubic inch volume and fit into any of the following dispensers 2.935 x 1.935 x 4.935 (inches) 2.935 x 0.935 x 9.567 (inches) 2.687 dia. x 6.562 h+ (inches)	<u>Negative Plate</u> 2/cell 0.005 x 1.375 x 4.50 (inches) 1.1 grams/cell pure magnesium	
<u>Activation</u> 10 seconds to voltage and current via auto activation	<u>Separator</u> 0.004 x 3.37 x 2.0 (inches) hemp paper	
	<u>Electrolyte</u> 2 mil/cell: $HClO_4$ 17%; $Mg(ClO_4)_2$ 19%; Water 65%	
	Theoretical Capacity 31 ampere-minutes (based on positive plates)	
	Required Capacity 10 ampere-minutes	

TABLE 2

FRESH BATTERY PERFORMANCE

LOAD	MINUTES LIFE ABOVE 24 VOLTS AT TEMPERATURE AND 40,000 FEET ALTITUDE				
	-40°F	0°F	35°F	75°F	125°F
30 ohms	16.2	13.7	11.5	9.5	4.0
45 ohms	22.7	21.0	17.7	13.5	7.7
60 ohms	25.2	27.7	23.2	17.5	10.1

SECTION VII
THIS TEST PROGRAM

1. AS-RECEIVED BATTERIES

Each of the 25 Model LSP2055 batteries, manufactured in October 1970, received at AFAPL on 18 February 1971, were inspected and weighed on 4 March 1971, and weighed about 160 grams, with no physical or electrical abnormalities observed.

2. ASSIGNED TO STORAGE

On 19 April 1971, the batteries were assigned to storage groups per Table 3. Battery S/N 222 was leaking electrolyte and thus not assigned. Also, assigned to storage were two Eagle-Picher Model LSP2021 batteries. These batteries (model LSP2021) are primary-reserve automatically activated, magnesium anode batteries, similar in most respects to Model LSP2055 batteries and also designed for an aircraft ECM application.

TABLE 3
STORAGE GROUP ASSIGNMENT

Group A	Group B	Group C	Group D
12 mo at 130°F	12 mo at 110°F	12 mo at 70°F	>3 years desk storage
S/N 202	S/N 210	S/N 232	S/N 244
203	213	234	LSP2021 - S/N 821
204	214	237	LSP2021 - S/N 6
206	218	240	
207	220	241	
208	222*	243	
209	227	239	
	228	247	
		249	

* Leaking, not assigned

3. DISCHARGE SERVICE TEST ROUTINE

The discharge service test routine consisted of soaking individual batteries for 25 minutes duration at -10°F and 20,000 feet altitude, then activating and discharging the battery into a 30-ohm load while at -10°F and 20,000 feet altitude. This service test routine simulates a flight test environment for aircraft ECM's, wherein, shortly after aircraft takeoff the ECM's are dispensed at 20,000 feet altitude and their (ECM's) operation monitored. This routine was selected because it seems to be more severe on battery activation and operation than is soaking the battery for several hours at -10°F or lower temperature even though this latter environment more closely simulates mission condition.

4. DISCHARGE SERVICE TEST RESULTS

Each battery was weighed when removed from storage. The before-storage and after-storage weight measurements are given in Table 4. Recall, all of the Model LSP2055 batteries were manufactured in October 1970, thus, were 6 calendar months old when assigned to storage. The results of service test discharging the batteries following storage is summarized in Table 5 and discussed next.

A. Group A (12 months at 130°F)

Each of the seven batteries stored at 130°F for 12 continuous months lost about 12 grams or 8% of their before-storage weight. This weight loss is thought to be water from the electrolyte, evaporating through the polyethelene bag holding the electrolyte and the plastic case enclosing the electrolyte bag. Of the 7 batteries, 3 automatically activated, 3 required manual pull of stuck-keeper clips to activate, and 1 battery could not be activated. Of these 6 activated batteries, 5 were near or above 24 volts within 10 seconds, with battery S/N 207 taking 4 minutes to reach 24 volts' load voltage. None of the 6 activated batteries met the 10 minutes above 24 volts' life requirement.

B. Group B (12 months at 110°F)

Each of the 7 batteries stored at 110°F for 12 continuous months lost about 9 grams or 5.5% of their before-storage weight. This

TABLE 4

BATTERY WEIGHT DATA

Group	S/N	As-Received Weight (grams)	Before Discharge Weight (grams)	Weight Change (grams)	Weight Change (%)	Storage Environment
	202	162.354	149.606	-12.748	-7.85	
	203	158.535	146.141	-12.394	-7.81	
	204	158.414	145.594	-12.820	-8.09	12 months
A	206	158.962	145.507	-13.455	-8.46	at 130°F
	207	159.655	146.132	-13.523	-8.47	
	208	163.269	147.815	-15.454	-9.46	
	209	157.157	144.550	-12.607	-8.02	
	210	162.556	153.318	- 9.238	-5.68	
	213	157.213	147.776	- 9.437	-6.00	
	214	162.979	153.450	- 9.529	-5.84	
B	218	157.085	147.935	- 9.150	-5.82	12 months
	220	158.739	149.828	- 8.911	-5.61	at 110°F
	227	156.396	147.831	- 8.565	-5.47	
	228	158.748	151.276	- 7.472	-4.70	
	232	160.750	160.886	+ 0.136		
	234	158.821	158.994	+ 0.136		
	237	158.397	158.378	- 0.019		
	239	156.129	-	-		12 months
C	240	158.848	159.129	+ 0.281		at 70°F
	241	160.719	160.740	+ 0.021		
	243	159.136	159.722	+ 0.586		
	247	161.320	160.433	- 0.887		
	249	156.765	-	-		
	244	159.851	159.200	- 0.651		>3 years
	2021-6	-	92.0	-	-	desk storage
D	2021-821	-	91.6	-	-	

TABLE 5

30-OHM DISCHARGE SERVICE TEST RESULTS

Storage	S/N	Discharge date	Service Test environment	Activation auto	Activation manual	Load Voltage 5 sec.	Load Voltage 10 sec.	Minutes To 24v.	Minutes To 20v.	Remarks
Group A (12 mo. at 130°F)	202	21Apr72	-10°F, 20K altitude	X		25	27.5	5.5	6.21	
	203				X	22.5	23.5	4.19	5.74	
	204			X		26	27.5	5.8	7.5	
	206			X		12.5	24	4.9	5.75	
	207				X	0	0	2.4	3.6	
	208			-	-	0	0	0	0	Did not activate
	209				X	21.5	24	5.27	5.91	
Group B (12 mo. at 110°F)	210	24Apr72		X		35	30	9.6	9.87	
	213			X		31	32	7.55	9.5	
	214			X		34	32	9.6	10.58	
	218			X		26.5	32	9.0	10.27	
	220			X		24.5	30	9.3	11.0	
	227			X		33	31.5	7.5	9.2	
	228			X		33	31	8.0	11.27	
Group C (12 mo. at 70°F)	232	21Apr72		X		31.5	31.0	15.8	17.14	
	234	"		X		32	32	15.4	16.75	
	237	"		X		27	27.5	7.7	9.84	
	239	15Mar72		X		1	13	8.0	11.0	
	240	24Apr72		X		30	31	11.5	13.4	
	241	"		X		31.5	30	12.2	14.55	
	243	"		X		30.5	30.5	13.65	15.47	
	247	"		X		30	31.5	15.97	17.4	
	249	14Mar72		X		16	23.5	0.2	0.2	
Group D >3 yr. desk storage	244	1Jul74			X	33	32.5	17.6	18.7	See Text
	(2021)-6	"			X	-	-	-	-	See Text
	2021-821	"		X		-	-	-	-	

weight loss is also attributed to evaporation of water from the electrolyte Each of the 7 batteries activated automatically and exceeded 24 volts' load voltage within 10 seconds, but none of the batteries gave 10 minutes' life above 24 volts even though they did operate longer than did the Group A batteries. As per Table 5, load voltage of 35 volts was measured within seconds after activation into the 30-ohm load.

C. Group C (12 months at 70°F)

As per Table 4 weight measurements, less than 1 gram weight change was measured for batteries stored at 70°F for 12 continuous months. Each battery automatically activated and was near to or above 24 volts within 10 seconds, excepting battery S/N 239, which took 15 seconds to reach 24 volts' load voltage. Six of the total 9 batteries met the 10 minutes above the 24 volts' life requirement. Battery S/N 249 essentially had zero capacity above 24 volts, whereas the other two failed batteries did give over 7 minutes' life above 24 volts.

D. Group D (>3 years desk storage)

Battery Model LSP2055 S/N 244 lost less than 1 gram weight while being desk stored for about 45 months (October 1970 to 1 July 1974). Automatic activation of S/N 244 was not successful, because the keeper clip was stuck. Upon manually assisted activation, battery S/N 244 exceeded 24 volts' load voltage within 5 seconds and remained above 24 volts for 17.6 minutes. The other model batteries, Model LSP 2021 S/N's 6 and 821, appeared to have no significant weight change during their desk-stored life of 73 and 74 months, respectively. (LSP 2021-S/N 6 and S/N 821 were manufactured May 1968 and June 1968, respectively. Both LSP 2021 S/N 6 and S/N 821 activated, but S/N 6 required manual pull of its stuck keeper clip. Both batteries performed nearly alike, i.e., they reached 20 volts within 5 seconds after activation into a 30-ohm load while under the service test routine of -10°F and 20,000 feet altitude, and they gave 15 minutes' service above 15 volts, 22 minutes above 13 volts, and over 30 minutes above 10 volts. This activation, voltage-time response, operating life, and capacity, meets the design requirements and shows no degradation as a result of over 5 years' storage at room ambient.

5. INFLUENCE OF STORAGE TEMPERATURE ON BATTERY FAILURE

A. A battery power source for ECM devices is considered failed if it does not operate the device because it (battery) didn't activate or reach proper load voltage, or if it does not operate for the minimum required duration. Failure to activate is an absolute failure for there is no chance of operating the ECM. Failure to achieve proper load voltage in the given time may be critical if voltage rise time greatly exceeds 10 seconds (e.g., minutes). Lastly, if active discharge service life is much less than the minimum 10 minutes the ECM may be functionally ineffective.

B. The mode of failure for the 25 each Model LSP 2055 batteries is given in Table 6 in terms of failure to operate (Type A failure) and failure to operate 10 minutes (Type B failure). Regarding Type A failure (i.e., failure to operate), battery S/N's 222 and 208 are absolute failures for they possibly cannot operate the ECM. Storage at 130°F for 12 continuous months may have contributed to battery S/N 208's failed activation system. Storage temperature is not, however, thought to be the cause of the 4 batteries' needing manual assistance to activate because, as per Table 6, batteries stored at 130°F and at 70°F had stuck keeper clips, and this problem appears to be purely mechanical. The greater than 10 seconds' voltage rise time may be due to combined mechanical and electrochemical faults in the activation sequence and not necessarily influences of storage temperature; as per Table 6, batteries stored at 130°F and 70°F exhibited long voltage rise times. Regarding type B failure (i.e., failure to operate 10 minutes), storage temperature indeed influences battery operating life, since all of the batteries stored at 110°F and 130°F failed to give 10 minutes' service life, whereas batteries stored at 70°F did demonstrate 10 minutes' life. Notice in Table 7 that Group A batteries stored 130°F for 12 continuous months gave about half the required service life, Group B batteries stored at 110°F for 12 continuous months gave about 90% of the required life, and almost all of the Group C batteries stored at 70°F for 12 continuous months exceeded the life requirement, as did Group D battery S/N 244 desk stored for 45 months. The weight data of Table 4 shows

TABLE 6
MODEL LSP2055 BATTERY FAILURE MODES

Group	Failure Type A				Failure Type B
	Leaker	Did Not Activate	Manual Activate	>10 Sec. Rise Time	<10 Minutes Service Life
Group A (12 mo. at 130°F)	222	208	203 207 209	203 207	202 203 204 206 207 209
Group B (12 mo. at 110°F)					210 213 124 218 220 227 228
Group C (12 mo. at 70°F)				239 249	237 239 249
Group D (>3 yrs. desk stored)			244 (2021)-S/N6		

TABLE 7
MODEL LSP2055 BATTERY DISCHARGE SERVICE LIFE

Minutes ≥ 24 Volts	Group A (130°F for 12 mos)	Group B (110°F for 12 mos)	Group C (70°F for 12 mos)	Group D (Desk Storage >3 years)
0-1			249	
1-2				
2-3	207			
3-4				
4-5	203, 206			
5-6	202, 204, 209			
6-7				
7-8		213, 227	237	
8-9		218, 228	239	
9-10	↑ (Unacceptable Life)	210, 214, 220		
10-11	↓ (Acceptable Life)			
11-12			240	
12-13			241	
13-14			243	
14-15				
15-16			232, 234, 247	
16-17				
17-18				244

Group A and Group B batteries lost weight probably in the form of water evaporation from the electrolyte, resulting in a more acid electrolyte, which, in turn, increases internal heating during discharge and shortens discharge life.

C. Notice in Table 6 that battery S/N 249 failed to reach voltage and failed to give 10 minutes' life. Even though this battery failed two criteria it can be considered as failed only once. In practice, battery S/N 249 is considered failed because it took 4 minutes to reach 24 volts load voltage and not because it gave less than 1 minute life above 24 volts. Other batteries of Table 6 also failed several criteria but in Table 8 are considered as failed only once. This Table 8 shows that only 7 of the total 25 batteries are operationally acceptable. Of the 18 failed batteries, 7 batteries failed to operate (Type A failure) and 11 failed to operate (Type B failure) sufficiently long. The Type A failures appear to be mechanically caused, while the Type B failures are due to high temperature storage for 12 continuous months.

TABLE 8

MODEL LSP2055 BATTERY FAILURE SUMMARY

<u>Total Issued</u> ——————→ 25,

minus outright failures: <u>-2</u> { leaker (S/N222) / not activated (S/N208);

Total activated batteries ——————→ 23,

minus manual-assisted activated batteries: <u>-4</u> (S/N's 203, 207, 209, 244);

Total auto-activated batteries ——————→ 19,

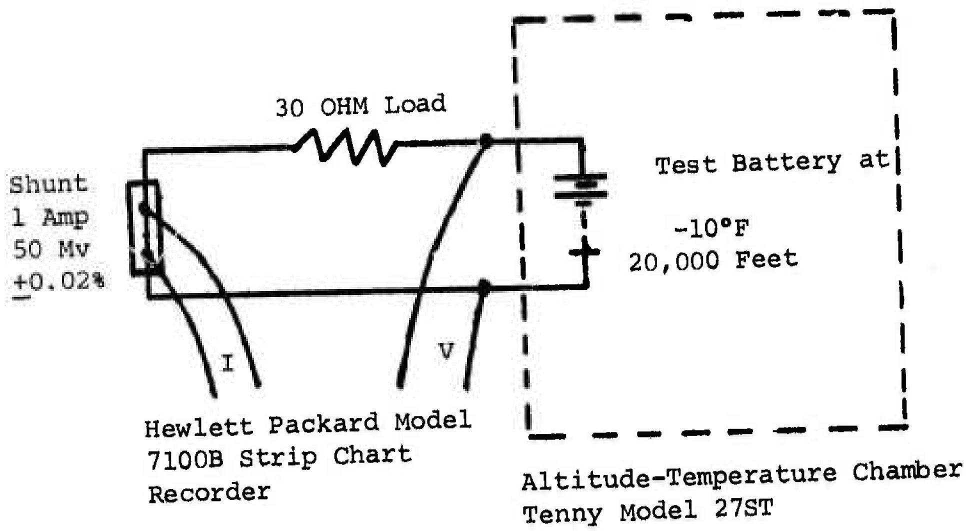
minus >10 sec. voltage response: <u>-1</u> (S/N 249)

Total activated to voltage batteries ——————→ 18

minus <10 minute life: <u>-11</u> (S/N's 202, 204, 206, 210, 213, 214, 218, 220, 227, 228, 237)

<u>TOTAL OPERATIONAL BATTERIES</u> ——————→ 7

APPENDIX



SERVICE TEST DISCHARGE CIRCUIT

Other Instrumentation:

- Weight — Right-A-Weigh, 200 gram capacity, William Ainsworth & Sons

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