

NASA/MARSHALL'S LITHIUM BATTERY APPLICATIONS

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(Figure 1-37)

This first chart consists of items I will cover in my presentation today. I gave you a presentation about 2 years ago on the NASA/Marshall battery applications, different battery applications. Today I am going to expand a little bit on what I gave previously.

The items will be a brief summary of the applications, general battery description, and in particular, I will discuss a particular battery, the IECM battery, design and construction details, thermal vacuum test, projection tests, and acceptance tests.

(Figure 1-38)

The second chart lists the various program applications. In most cases, these batteries are being flown on the SRB, an external tank. In particular, the SRB has one range safety battery. The external tank has two range safety batteries. So, there are four on each flight.

Also, in the SRB on the frustum, there are two frustum location "A" batteries. The IECM experiment will fly in Earth orbit, the same for the TCSE. IECM formation has induced environmental contamination monitors.

TCSE is an experiment thermal controlled services. Generally, all these batteries are lithium carbon monofluoride types rated 18 ampere-hours and have 13 cells in each housing.

In all cases, with the exception of the IECM battery, a NylaFil composition of fiberglass and nylon housing is utilized. Aluminum housing is used for the IECM batteries. All qualification tests each of these batteries have been completed.

(Figure 1-39)

Turning specifically to the IECM battery, I have shown a top view of the battery, looking down from the top. You will note that the cells are viewed looking down from horizontal. On the far end up there is an open cavity of space there, and the vents are facing in that direction.

There is a safety protection on the end of the vents to keep anything out of it. This area in here is what I am referring to as being an open area. And on this end we have it vented, as you will see later on another figure there, just where that vent is.

Between each of these rows is an aluminum fan that comes up through here and that way. This one here comes down, up this way here. That is welded to this side and to this side.

Down here is a thermostat.

(Figure 1-40)

This one shows the battery looking from the side. As you see, the cells are stacked on top of each other. This area here is the void area I mentioned. Here is a fuse and here is a connector.

This is a pressurizing valve and cover seal.

(Figure 1-41)

This is a view looking at the end. Here is the crosshatch. You will see that the aluminum fans are designed to carry the heat to the outside housing. These fans come down and are welded to the base of the battery. The cells are against the aluminum fan. They also have an insulated thermal trip over the cells and over the wire there to protect them.

There again you see the fuse, the connector on this end here. This part in here is the relief part, right in here. That is a protection cover over there to keep anything from getting into it.

From this lower point back, all of this area is potted with a wax to aid in thermal control.

(Figure 1-42)

Here is a simplified schematic of the battery. As you see, there is the fuse. Seeing these with the cells and a thermostat there protect against all the temperatures.

Also, there are two thermistors used in this experiment. These thermistors are routed to the experiment electronics package. At the present time, they are not utilized to turn off the experiment, but they could be turned off. This thermostat is set to open at $175 \pm 5^\circ \text{ F}$.

(Figure 1-43)

On this chart I have listed some of the thermal vacuum tests that we have drawn on the battery. There are two series of tests. Certain ones are going to be done at the plant and others are done at Marshall on full battery.

In addition to the thermal vacuum test, of course, we are going to chart vibration tests. These tests are basically the same. There is a little difference in the test. For example, on the vendor test the vacuum is 1×10^{-4} torr. On the Marshall test it is 1×10^{-6} .

The side temperatures are slightly different; the cold plates are slightly different. The load currents that we run are slightly different.

You will note that in each case, it started out as a higher current and dropped off. The higher current is used for 5 to 15 minutes, 15 minutes over there and 5 minutes here, and has dropped down. Using it at the lower test, it will run 3 to 4 hours apiece.

A single battery goes through a cold test and a high-temperature test. As I pointed out, the thermostat is designed to open at $175 \pm 5^\circ\text{F}$, so 180°F is maximum.

(Figure 1-44)

As part of the acceptance test on the batteries, there is a cell block test which is used to measure capacity, using a cell out of a particular block from which the battery is from. The minimum is 18 ampere-hours.

There is a cell impedance test performed, also a dielectric strength insulation and resistance test, thermistor test, pin case voltage test, dimensional check, battery seal, and battery case seal. This consists of pressurizing the housing to 12 psig and holding that. The case should hold that pressure for 5 minutes without a drop in pressure in tests of 0.1 psig.

The final battery case seal consists of putting the battery in 160°F thermal vacuum chamber for 4 hours. There is to be no wax leak when the battery is turned on its side.

At Marshall, an outgas and leak test was also performed on the battery. This test is 158°F , 48 hours at 1×10^{-6} torr. There is no wax leak within outgas specifications.

From the typical data that we picked up on some of our test batteries, the seals number 7, 8, 9, and 10, the cell block tests range from about 20 to about 23 1/2. The voltage was a little higher at the beginning of the test. At the 158 to 160°F temperature following this test, there is a matter of open circuit voltage.

(Figure 1-45)

Following all of these individual battery evaluation tests, we performed several systems tests in which the batteries were installed on an actual flight IECM package and were installed in the thermal vacuum. They are old batteries on the IECM, and they all figured through the isolating valve to a common bus.

The test setup was such that the systems had capability of running some items from ground power with the battery turned off. One of our batteries saw something like 15 cycles ranging from 0 to 70°C , estimated 300 to 400 hours under 70°C . There was a hold somewhere on the order of 10 to 24 hours. In some cases that elevator jumped.

On the first systems test, the total output recorded was 42 ampere-hours. With four batteries on board, the total capacity was 72 ampere-hours.

It was somewhat surprising that the capacity was so low. But, in going back and looking at the records, it was determined that there were some periods of time when they were performing ground tests or ground trials, the batteries were actually on low.

So, we probably don't know exactly what the total capacity was on a good many batteries. It was supposed to have been off. We know it was much higher than the 42 ampere-hours. That is just what was observed. So when the batteries are turned off now, they are off.

The second test was done a little later and was still in the same category 0 to 70°C. The capacity was 66.43 ampere-hours, about 10-percent total capacity there. We expected to get some reduction in capacity due to the high temperature and the higher discharge rate. So that was considered and checked for.

The system itself, maximum experiment, uses something like about 55 ampere-hours.

In each of these tests, two of the batteries were discharged completely. Those two that discharged did vent. There was no indication or institution of any high temperature. No knowledge of this venting was revealed until the batteries were removed from the system and the cover was removed.

The other two batteries on each of the two systems had residual capacities left in them. There was no cell venting in the case of either of the two batteries with residual capacity.

We have yet to evaluate the amount of capacities left on the systems test.

DISCUSSION

HESS: Two questions: What were the discharge rates on these systems tests?

PASCHAL: Systems tests with about 0.8 of an ampere-hour per battery.

HESS: What were the stoichiometric proportions of the lithium?

PASCHAL: I can't answer that. I don't have that figure with me.

BENNETT: Can you tell me what the weight of the battery system was?

PASCHAL: About 12-1/2 to 13 pounds.

It was caused to be a little heavy. It was necessary to put wax in it in order to get the long, 3- to 4-hour usage.

GROSS: Several questions. First, the cells did vent under full discharge? I presume this is unacceptable. Is this correct?

PASCHAL: The two that were discharged on the systems test did vent.

GROSS: Yes. My question is, do you consider this unacceptable and therefore you will do something in the program to correct the design so that won't happen in the future? Or, do you consider this satisfactory?

PASCHAL: At this particular point in time we do not contemplate doing anything.

The reason we don't is that this venting occurred at what appeared to be without any generation of heat at a point when the batteries were pretty well impinging. It was not known that it did not vent gas out of the battery housing. So, there was no contamination.

Incidentally, this experiment is an IECM, Inducement Environmental Contamination Monitoring, and it is extremely important that we not vent outside the housing. Actually, the housing will vent at about 52 psig.

GROSS: My second question was regarding voltage.

When you operate over a large temperature range of approximately 170 or 180°F down to 32 degrees, as I understand the ranges from the chart, there would be a very large voltage change just due to the very thermodynamic behavior of the system. And second, this is, of course, aggravated by a range of discharge currents.

So, my question is, what voltage range did you experience on the system, and, secondly, what if anything was done in the design to minimize the voltage?

PASCHAL: The voltage was between 26 and 32 volts, which were the requirements set up on the system. I haven't looked at all of the data, but as far as I can recall, they are all within the range of 26 to 32 volts. The colder temperatures results in colder voltage there until you got real high. Temperatures on the battery started coming free, and then, of course, the voltage dropped. The systems tests terminated around 26 volts.

GROSS: That is one of the important problems with this system in a lot of applications. And it is worth looking at closely.

OTZINGER: Last year, during the lithium session, we had people from NASA Headquarters, discussing safety requirements. One of the things they pointed out was that for vehicles leaving KSC — and I believe this being shuttle as well — the design will have to be submitted to the safety group at KSC for their approval.

Has this been done and has this battery been approved for flight?

PASCHAL: We have received several preliminary approvals of the system. Final approval has not been given at this time. We are in the process of discussing it with JSC. Most likely, we will want to run some supplemental tests over what we have done. But, to answer your question, it has been submitted to JSC. Final approval has not been received.

HALPERT: Is there a lot qualification? In other words, have you put separate ones aside that are going to fly, or are they going to fly new ones all over again?

PASCHAL: There is a qualification for the batteries, particular battery design. We have qualified a certain number of batteries for the design of the system. Then, of course, we run through the check, including the precase venting test and the high-temperature thermal vacuum at both Marshall and at the vendor's plant. All of that constitutes an acceptance of each specific battery.

HALPERT: But you are going to buy a new lot for the actual mission?

PASCHAL: Well, yes. There is a new lot for each — for several batteries. This group that I showed you had several lots involved.

ORGANIZATION: EC12	MARSHALL SPACE FLIGHT CENTER MSFC LITHIUM BATTERY APPLICATIONS	NAME I. E. PASCHAL DATE NOVEMBER 1979
<p>1. SUMMARY OF MSFC APPLICATIONS</p> <p>2. GENERAL BATTERY DESCRIPTION</p> <p>3. IECM BATTERY</p> <ul style="list-style-type: none"> o DESIGN & CONSTRUCTION DETAILS o THERMAL VACUUM TESTS o BATTERY ACCEPTANCE TESTS o SYSTEMS TESTS 		

Figure 1-37

ORGANIZATION: EC12	MARSHALL SPACE FLIGHT CENTER MSFC LITHIUM BATTERY APPLICATIONS	NAME I. E. PASCHAL DATE NOVEMBER 1979												
<p><u>SUMMARY OF MSFC APPLICATIONS</u></p> <table border="0"> <thead> <tr> <th><u>PROGRAM</u></th> <th><u>FUNCTION</u></th> </tr> </thead> <tbody> <tr> <td>SRB</td> <td>FRUSTIUM LOCATION AIDS (FLA)</td> </tr> <tr> <td>SRB</td> <td>RANGE SAFETY</td> </tr> <tr> <td>ET</td> <td>RANGE SAFETY</td> </tr> <tr> <td>IECM</td> <td>PAYLOAD EXPERIMENT POWER</td> </tr> <tr> <td>TCSE</td> <td>PAYLOAD EXPERIMENT POWER</td> </tr> </tbody> </table> <p><u>GENERAL BATTERY DESCRIPTION</u> - ALL APPLICATIONS</p> <p>BATTERY TYPE: 13 - 18 AH LI/CF CELLS</p> <p>VENDOR: EAGLE PICHER</p> <p>HOUSINGS:</p> <p>FLA, RSS, TCSE: G4/45 NYLAFIL</p> <p>IECM: ALUMINUM</p> <p>QUALIFICATION STATUS: COMPLETE</p>			<u>PROGRAM</u>	<u>FUNCTION</u>	SRB	FRUSTIUM LOCATION AIDS (FLA)	SRB	RANGE SAFETY	ET	RANGE SAFETY	IECM	PAYLOAD EXPERIMENT POWER	TCSE	PAYLOAD EXPERIMENT POWER
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Figure 1-38

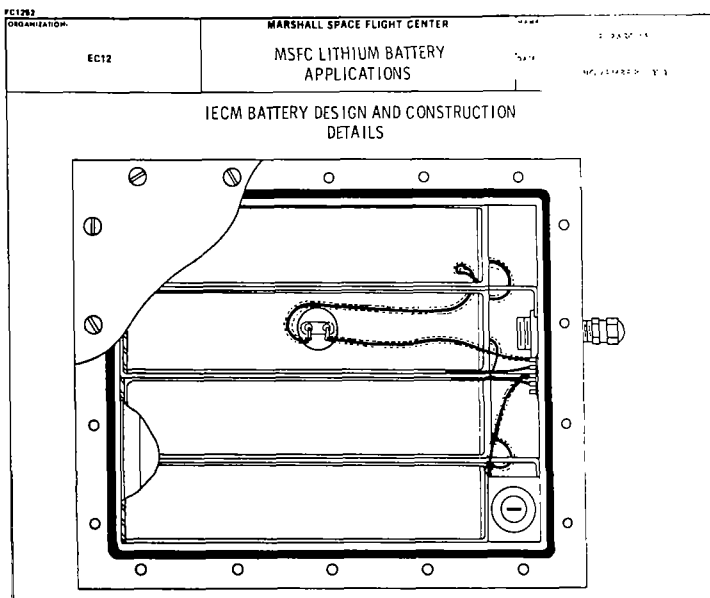


Figure 1-39

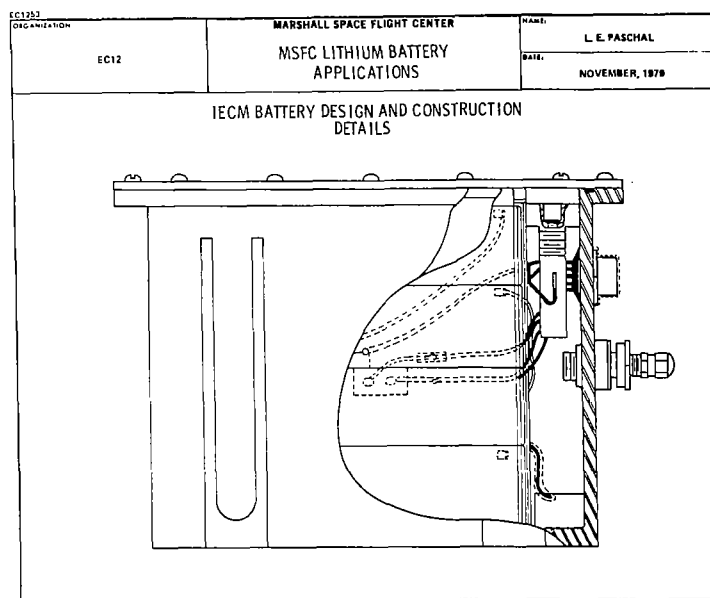


Figure 1-40

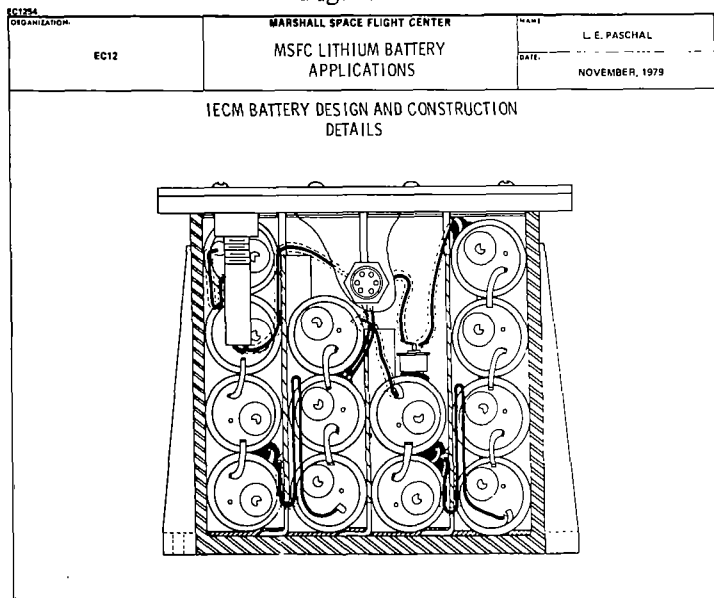


Figure 1-41

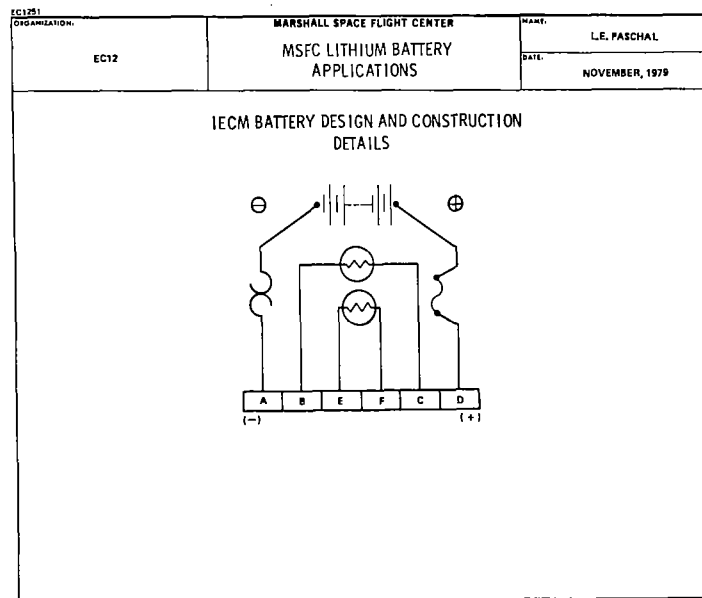


Figure 1-42

ORGANIZATION: EC12	MARSHALL SPACE FLIGHT CENTER MSFC LITHIUM BATTERY APPLICATIONS	NAME: L. E. PASCHAL DATE: NOVEMBER 1979
<u>THERMAL VACUUM TESTS</u>		
<u>VENDOR TESTS</u>		<u>MSFC TESTS</u>
1 X 10 ⁻⁴ TORR SHROUD -300°F MOUNTING: CELL HORIZONTAL		1 X 10 ⁻⁶ TORR MOUNTING: CELL HORIZONTAL & VERTICAL
<u>COLD TEMP. - COLD PLATE</u> 32° +5°F -0		<u>COLD TEMP. - COLD PLATE</u> 20°F ±5°F
2.3 AMPS - 5 MIN. 1.6 AMPS - 4 HRS. - 50 MIN. 1.5 AMPS - 1 HR.		1.72 AMPS - 15 MIN. 1.3 AMPS - 1 HR. - 45 MIN. 1.2 AMPS - 3 HRS.
AMBIENT TEMP. & PRESSURE 1.4 AMPS - 1 HR.		
<u>HIGH TEMP. - COLD PLATE</u> 100° +0°F -5		<u>HIGH TEMP. - COLD PLATE</u> 104°F ± 2°F
2.3 AMPS - 5 MIN. 1.6 AMPS - 4 HRS. - 50 MIN. 1.5 AMPS - 1 HR.		1.2 AMPS - 1 HR. 1.72 AMPS - 15 MIN. 1.3 AMPS - 1 HR. - 45 MIN. 1.2 AMPS - 3 HRS.
AMBIENT TEMP. & PRESSURE 1.4 AMPS - 1 HR.		AMBIENT TEMP. 1.2 AMPS - 1 HR.
MAX. BATTERY TEMP. 180°F		

Figure 1-43

ORGANIZATION: EC 12	MARSHALL SPACE FLIGHT CENTER MSFC LITHIUM BATTERY APPLICATIONS	NAME: L. E. PASCHAL DATE: NOVEMBER 1979		
<u>ACCEPTANCE TESTS</u>				
CELL BLOCK CAPACITY		>18 AH		
CELL IMPEDANCE		<1.0 OHMS		
DIELECTRIC STRENGTH (500 V, 60 HZ/60 SEC)		<.5 MA		
INSULATION RESISTANCE (100 V DC/2 MIN)		>50 MEGOHMS		
THERMISTOR TESTS		PER CALIB. CURVE		
PIN/CASE VOLTAGE TEST		<250 MV		
DIMENSIONS		PER DRAWINGS		
BATTERY CASE SEAL PRELIM. (12 PSIG)		<.1 PSIG DROP/5 MIN		
FINAL BATTERY CASE SEAL (160°F/4 HRS; 1 X 10 ⁻⁴ TORR)		NO WAX LEAK		
MSFC OUTGAS/LEAK TEST (158°F/48 HRS; 1 X 10 ⁻⁶ TORR)		NO WAX LEAK; WITHIN OUTGAS SPECS.		
<u>VENDOR/MSFC DATA:</u>				
SERIAL NO.	7	8	9	10
CELL BLOCK AH	23/23.5	21.5	21.25/21.5	20.0/20.5
VOLTAGE PRE-OUTGAS	39.0	39.1	38.1	38.3
VOLTAGE POST-OUTGAS	38.2	38.3	37.3	37.2

Figure 1-44

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SYSTEMS TESTS

○ THERMAL VACUUM

- PART OF FULL IECM TEST
- 1 X 10⁻⁶ TORR
- 4 BATTERIES (72 AH TOTAL CAPACITY) ON BUS
- 15 TEMPERATURE CYCLES 0 - 70°C (ESTIMATED 300/400 HRS. UNDER 70°C)
- HOLDING 10 - 24 HOURS

○ TEST 1 RESULTS

- KNOWN DISCHARGE CAPACITY 42.0 AH (20/21 AH AT 70°C)
- UNKNOWN DISCHARGE CAPACITY DUE TO INSTRUMENTATION PROBLEM
- TWO BATTERIES DISCHARGED - CELL VENTING
- RESIDUAL CAPACITY TWO OTHER BATTERIES - NO CELL VENTING

○ TEST 2 RESULTS

- KNOWN CAPACITY DISCHARGE 66.43 AH
- TWO BATTERIES DISCHARGED - CELL VENTING
- TWO BATTERIES - RESIDUAL CAPACITY - NO CELL VENTING