NEW NiCd BATTERY STANDARD AND GUIDE

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I think this is a fitting paper to end up today's session on NiCd cells and NiCd battery performance data.

One of the functions that Aerospace Corporation has is to examine the entire industry and examine what's been going on and interface with the various industry organizations and try and distill out of it some general practices, and this is what we have attempted to do.

(Figure 29-1)

We're basically working with two kinds of documents. The first one is military standards and specifications. These provide a formal listing of good practices through an iterative process dealing with people in the industry.

Another purpose is to provide a compliance document for imposing requirements in procurements. Normally these documents do not contain design data. It's usually not the place of a military standard or spec to contain design data. This is usually left for handbooks.

It also provides a technical basis for procurement. It provides a nominal requirement. It's a basis for discussion and negotiations. Any of these documents is always open for negotiation.

(Figure 29-2)

Internal to the Space Division, which is part of the Air Force, there is a new series of documents which are going to be called Program Engineering Technical Guides. These will be used by the various program office individuals and Air Force individuals to gain some general background of the industry practices and various tradeoffs on what might be controversial areas.

The basic difference between a guide and mil spec is a specification is a mandatory document whereas the guide will be informational and primarily a tutorial document. These are strictly going to be in-house documents. They are presented as part of a series. The initial group consists of five documents. And what I have done is I have solicited about 30 inputs from various people throughout the industry on three drafts of this document.

I'm sorry I couldn't get around to all of you, but I just took a selected list of various different government agencies and suppliers.

The Program Engineering Technical Guide is less formal. It's a more dynamic document. It doesn't go through a formal release cycle. It will also allow for divergence of opinions. There will be controversy presented in the documents. It will document engineering or technical data that exists in the industry, and it can also act as a design handbook.

Hopefully it will provide a consistent technical approach. And it will be useful for evaluating diversity of opinions. As some of you are well aware, there are lots of opinions on things like reconditioning, what temperature to operate a battery, different voltage curves, different techniques.

At present there are five guides being prepared. One deals with propulsion system pressurants. Another one deals with vehicle instrumentation during acoustic tests. Another one deals with retest requirements. Another one deals with verifying redundant capabilities in space. And the fifth one deals with use of NiCd batteries during systems tests.

(Figure 29-3)

First I'd like to go over -- incidentally, Gerry Halpert leaned on me. I had 22 vugraphs, and he twisted my arm to cut out about two-thirds of them. So hopefully we'll finish right on time. The remaining 16 viewgraphs will be contained in the proceedings for completeness.

First I'd like to go over the main points of the nickel-cadmium battery usage practices for space vehicles. This will be published as Mil Standard 1578; the nominal release date is 27 July '82. It's currently in the release cycle being published somewhere or other in the vast bureaucracy. Eventually it will be available to the public.

It will establish requirements, and these are based on experience and successful practices, much of the material we've seen here today.

Compliance with the document will help assure proper performance for NiCds during space missions. The compliance with handling procedures should go quite a ways to minimizing degradation. And one thing that it will hopefully do, it will define terminology to be used.

As most of you are aware, there are a lot of confusing and ambiguous terms, like capacity, and this will just provide a definition. It may help eliminate some ambiguities.

(Figure 29-4)

The Program Engineering Technical Guides title is "Use of Rechargeable NiCd Flight Batteries During Space Vehicle Testing." It has three major sections. The first one is a survey of practices that are current in the industry, a discussion of current usage, and it makes recommendations.

(Figure 29-5)

These are the results of a survey of a total of 28 spacecraft systems use broken down in terms of no use, thermal vacuum only, and all systems testing. The majority of people do not use the flight batteries for other than flight. They acceptance test the batteries, they acceptance test the cells first, and then they put the batteries in storage, reconditioning them periodically and reconditioning them just before putting them on the flight vehicle.

Generally the older programs used flight batteries for all systems testing. The trend in most of the newer programs is to minimize use of the designated flight batteries.

(Figure 29-6)

In going through this survey there were a number of reasons which were presented by enough people to give some repetition. The reasons given for the use of flight batteries in systems testing were the collection of base line data: in actual vehicle environment where you've got the actual leads, you've got the actual connections, it gives you a chance to do a full up test.

In many vehicles the battery is an intimate part of the thermal subsystem, and if the battery is a part of it this is the one chance you really have for checking out that thermal interface.

A number of people said it gave them an opportunity to discover early failures by actually using the flight batteries. I'd like to point out, though, that there's a clear tradeoff between life and testing.

And a couple of people -- particularly on commercial programs -- said that the use of the flight batteries or a single set of flight batteries is a low cost option. In commercial systems this is a major consideration. However in many military systems this is really not a consideration. Life and performance are the critical parameters.

(Figure 29-7)

The reasons given against the use of flight batteries in system tests were that secondary batteries do have a limited life, and what we would like to do is maximize the on-orbit life. Jim Dunlop said he thinks that if you use the batteries on the ground you're going to lose as much as a year in orbit. Probably a good number.

Of course another very important point is the only environment where there is a simulation of space is during a thermal vacuum test, and in the survey a large number of people said the only test they did use the actual flight batteries, the designated flight batteries, was during thermal vacuum.

Of course the other reason, or major reason, against is the batteries could be damaged in test. Most of you are familiar with the horror stories of the test area and junction boxes and the various holds and whatever that go on during vehicle testing, particularly on the first vehicle in a series. So you've got to trade off the handling and the installation problems with the data that you're going to gain.

Finally, perhaps one of the strongest reasons is battery related data can be collected in subsystem testing where you actually do have access to the battery with hard wired connectors as opposed to, on a spacecraft, where you're counting on telemetry through some kind of a data acquisition system. This is much, much safer from a battery standpoint. And in most cases use of the engineering test models will give you all the test data that you need. There's really no need to use flight batteries.

(Figure 29-8)

The Program Engineering Technical Guide ends up with three basic recommendations:

The first one is not to use batteries designated for flight during vehicle systems testing except to provide absolutely necessary data.

The second is using space quality batteries for vehicle systems testing. This could be engineering models, it could be qual. models, it could be any other battery but not the actual designated flight batteries. They could be flight type, flight quality or flight configuration. Each different organization uses different words for the same thing.

And the final recommendation is install flight batteries at the last practicable time prior to launch. If possible install them at the launch pad, if you have the facilities. If not, install them just before shipping.

Any questions?

DISCUSSION

HENDEE (Telesat Canada): The result of all these wise comments is Floyd's comment to me in the hall that I wasn't giving everybody enough static again this year.

I'd like to make two comments:

First of all, it's my old one, that once again I'd like to say that limiting cost is rather selfish. Let's give Jim Dunlop 100 percent error in his calculations. Let's say it's only six months that you will degrade -- you will lose six months of performance at a cost of around -- what? -- let's say 80 million projected over an eight year period. That's amortizing it off at about ten million a year; in half a year it's worth five million dollars. I'm quite sure GE would like to sell us a five million dollar battery for test purposes. It's stupid.

MILDEN: Well, the funny thing is in some of the older programs when you're dealing with program office people get very adamant when you talk about -- you know, my God, you could extend the thing so many months if you'd only give us $100,000. You've been there.

HENDEE: Oh, I know I've been there. We're flying a couple of them too.

MILDEN: Yes.

HENDEE: The other thing is you made a comment there -- and validly so -- install flight batteries at the last practical time prior to launch. In my rather disorganized paper of a couple of years ago I showed that also activation date had a large effect on my end result. And I can quite readily envision people buying a lot of cells, or several lots of cells, for the systems testing and flight, putting the flight aside. I say you're also probably going to be giving up something doing it that way.

My recommendation is that you probably at least activate your batteries at the latest possible time so that you can verify that they're good batteries, have a fall-back, et cetera, and then install them on the satellite.

MILDEN: Among the 15 or so viewgraphs that Gerry twisted my arm over, one of them says there's a three year maximum activation time at time of launch, preferably two years.

HENDEE: Yes, preferably as little as possible.

Gerry, you shouldn't have done that. You see, I took up the time anyway.

MILDEN: Also, in terms of the activation, what a lot of programs where you've got several vehicles will do is they'll give the cell vendor the order and they'll release the procurement in staged fashion so that you get them activated at the latest possible point.

FORD (Goddard): I guess I have a little bit different perspective on that activation date than you do. I think I heard somebody talk about this afternoon batteries had been activated 38 months or something before launch. I think once you get over the hurdle of this problem we're talking about in terms of use in integration, certainly that becomes another factor. But until we get program managers off their adamant positions, as you mentioned, and get them to recognize that they are taking -- and I think Jim is being conservative at one year -- I think for every hour they're on the spacecraft before launch it's at least two hours you're going to lose in orbit. That's our experience.

There's things that go on during this integration period that are not common to NiCd cells in a space environment. And I think if you go back to the OAO life test that was run and reported over a period of five years here, we saw degradation mechanisms in what we refer to as intermittent years that don't show up under cycling. So, you know, I don't think there's any question. And your program manager, your old program is very right -- people, the older they get the harder they are to change. Just remember that.

STEINHAUER (Hughes): My recommendation is that the customer, the end user, if he wants to system test batteries, bring money. I think they can go on at the Cape or the launch site. There's one thing -- And I think all portions of the test programs at the system level can be accommodated with test batteries with one possible exception: The availability of dynamic balancing facilities at the launch site and the utilization of those facilities at the Cape. It may be difficult. Those batteries may be needed just before it leaves the manufacturer to get proper balancing.

MILDEN: That's an interesting point. Hopefully these documents will be used by -- Well, Floyd's comment is really to the wrong group. I mean we're all convinced here that you've got to minimize battery use and you've got to do all these good things.

By providing some kind of a standard document hopefully you can go back to your management and say, 'Hey, guys, here's a document we can argue from.'

HENDEE (Telesat Canada): I'd like to back up Floyd just — I'm close, I'm in between the two of you guys. I saw about a one-to-one degradation; if you got them two years in advance, knock two years off the end.

DUNLOP (COMSAT): Other people responded to that question here besides me, I'm sure.

One comment: One thing you might want to add, if you're going to have batteries around for two years or three years, you might also add how you're going to store those batteries if you're not going to put them in the spacecraft. And I'm sure that's something that a lot of people are working on right now.

MILDEN: Minus ten to plus five degrees C.

DUNLOP: That's in your --

MILDEN: Yes.

DUNLOP: Okay.

KASTEN: Since I was the one that presented the 38 month battery that we launched, we went through an exercise, I guess it was about a year ago, where we were coming up and launching a vehicle that our batteries were really getting old. They were all 38 months and older on most of them. And we did go through quite an exercise with our customer and we did finally make some program changes. We ended up ordering five new batteries from GE -- we gave Helmut some more business -- for replacement batteries for our vehicles that -- we're scheduled to launch one in December '81 and that's going to have newer batteries on.

We've also compromised in our test flow. We are now putting the batteries on just prior to thermal vac, which should cut down the test time to about five months. But we're also finding out that when we're producing -- If you'll recall, one year in '78 we launched four vehicles. During that time our test people were very busy. Things were going through the test flow very rapidly. When they don't get very busy this test time tends to stretch out, especially at the beginning. You're always waiting for that one last box. And so what you plan on nine months ends up to be 18 months; plus either the launch vehicle isn't ready or something else.

So usually after thermal vac in our experience things are flowing fairly fast. So we have compromised in installing our batteries just prior to thermal vac, mainly, again, because of some of the reasons you mentioned: our thermal people like to see those batteries on the vehicle and balancing and all of that stuff.

The other thing, when we store our batteries now we kind of caved in to people on the other side of town, and we are shorting them.

One thing I guess you have to watch out for when you store the batteries, though, is to make sure you don't end up storing them at the temperature that your thermal switches are closed at because then you can end up damaging -- or ending up with a permanent set in your thermal switches if you do have thermal switches on the batteries. That's something to consider.

DUNLOP (COMSAT): I really can't resist this. There was one other comment I made to you in that letter regarding nickel hydrogen batteries, and I think the comment was that in the nickel-cadmium battery the major problem is temperature - or one of the problems was temperature and an uncontrolled temperature and a degradation of separator material. The nickel hydrogen battery, the types of separator materials that are typically used are really rather insensitive to temperature and there's a good likelihood that with the nickel hydrogen battery you wouldn't have - you could go back to the original old program office idea of using that battery through all the spacecraft integration testing.

MILDEN: Well, Jim, what I did as a result of your letter and about three others, all of whom are nickel hydrogen users, was to add the works "nickel-cadmium" to the title of the program guide. We've got to make room for new technology.

Mil Stds/Specs

- FORMAL LISTING OF GOOD PRACTICES
- COMPLIANCE DOCUMENT FOR IMPOSING REQUIREMENTS
- NORMALLY DOES NOT CONTAIN DESIGN DATA
- PROVIDES TECHNICAL BASIS FOR PROCUREMENT

Figure 29-1

Program Engineering Technical Guide

- IN-HOUSE DOCUMENTS
- LESS FORMAL - MORE DYNAMIC
- DOCUMENTS ENGINEERING OR TECHNICAL DATA
- CAN INCLUDE DESIGN HANDBOOK INFORMATION
- PROVIDES A CONSISTENT TECHNICAL APPROACH

Figure 29-2

Nickel-Cadmium Battery Usage Practices for Space Vehicles

- ESTABLISHES REQUIREMENTS
- COMPLIANCE HELPS ASSURE PROPER PERFORMANCE FOR NiCds DURING SPACE MISSIONS
- COMPLIANCE WITH HANDLING PROCEDURES WILL MINIMIZE DEGRADATION
- DEFINES TERMINOLOGY TO BE USED

Figure 29-3

Use of Rechargeable Flight Batteries During Space Vehicle Testing

- SURVEY OF PRACTICES
- DISCUSSION OF USAGE
- RECOMMENDATIONS

Figure 29-4

Survey of Practices
USE OF FLIGHT BATTERIES DURING SYSTEMS TESTS

USE OF FLIGHT BATTERIES DURING SYSTEMS TESTS

	ALL PROGRAMS	MILITARY
NO USE	13	5
THERMAL VACUUM ONLY	7	5
ALL SYSTEMS TESTING	8	3
	28	13

- OLDER PROGRAMS USED FLIGHT BATTERIES FOR ALL SYSTEMS TESTS
- TREND IS TO MINIMIZE USE OF FLIGHT BATTERIES

Figure 29-5

Survey of Practices

REASONS GIVEN FOR USE OF FLIGHT BATTERIES IN SYSTEMS TESTS:

- COLLECTION OF BASELINE DATA IN ACTUAL VEHICLE ENVIRONMENT
- VALIDATION OF THERMAL INTERFACE
- DISCOVERY OF EARLY FAILURES BY USING FLIGHT BATTERIES
- USE OF SAME BATTERIES IS A LOW COST OPTION

Figure 29-6

Survey of Practices

REASONS GIVEN AGAINST USE OF FLIGHT BATTERIES IN SYSTEMS TESTS:

- SECONDARY BATTERIES HAVE A LIMITED LIFE
- ONLY THERMAL VACUUM TEST ENVIRONMENT IS SIMILAR TO SPACE
- BATTERIES MAY BE DAMAGED IN TEST
- BATTERY RELATED DATA CAN BE COLLECTED IN SUBSYSTEM TESTING

Figure 29-7

Recommendations

- DO NOT USE BATTERIES DESIGNATED FOR FLIGHT DURING VEHICLE SYSTEMS TESTING EXCEPT TO PROVIDE NECESSARY DATA
- USE SPACE QUALITY BATTERIES FOR VEHICLE SYSTEMS TESTING
- INSTALL FLIGHT BATTERIES AT LAST PRACTICABLE TIME PRIOR TO LAUNCH

Figure 29-8

Battery Storage and Handling

- >45 DAYS, STORE
  - DISCHARGED
  - SHORTED
  - -10° TO +5°C
- CONDITIONING AFTER STORAGE
  - C/20 FOR 40 ± 4 HRS AT 22° ± 3°C
  - C/2 TO 1.0V/CELL, AVERAGE
  - 1Ω RESISTOR ACROSS EACH CELL FOR ≥16 HRS

Figure 29-9

Battery Storage and Handling

- CONTINUOUS TRICKLE CHARGE
  - BATTERY TO BE AT ≤27°C
- OPEN CIRCUIT PERIODS
  - MINIMIZE NUMBER
  - MINIMAL DURATION, ≤96 HRS
- RECONDITIONING
  - EVERY 45 ± 3 DAYS IN USE
  - WITHIN 30 DAYS OF LAUNCH

Figure 29-11

Battery Storage and Handling

- SHIPPING
  - DISCHARGED AND SHORTED, EACH CELL OR AT BATTERY CONNECTOR
  - ON OR OFF S/C; -15° TO +30°C
  - 30°C EXPOSURE MINIMAL ≤10 DAYS, ≤4 HRS PER DAY

Figure 29-10

Battery Storage and Handling

- TRACEABILITY FROM ASSEMBLY TO LAUNCH
- CELLS ACTIVATED > THREE YEARS ARE NONFLIGHT

Figure 29-12

On Orbit Operations

- CHARGE CONTROL BASED UPON DEVELOPMENT TESTING
- MINIMAL HIGH RATE OVERCHARGING
- TRICKLE CHARGE TO AVOID STAND LOSSES

Figure 29-13

On Orbit Operations

- RECONDITIONING
  - GEO, PRIOR TO EACH ECLIPSE SEASON
  - MEO, VARIABLE PERIODIC BASIS
  - LEO, MAY NOT BE POSSIBLE
- DoD AND CYCLE LIMITS
  - TO BE BASED UPON GERMANE DATA
  - 5° ± 5°C; MINIMAL EXCURSIONS

Figure 29-14

On Orbit Operations

- OVERTEMPERATURE BACK-UP PROTECTION
  - ≤32°C
  - SWITCHING TO REDUCE OR TERMINATE CHARGING
- BATTERY ISOLATION
  - CHARGE CIRCUITS
  - LOAD

Figure 29-15

On Orbit Operations

- DATA
  - BATTERY AND INDIVIDUAL CELL VOLTAGE
  - BATTERY CURRENT
  - BATTERY TEMPERATURE

Figure 29-16

Development Testing

- NOMINAL AND FAILURE MODE CASES
- FOR EACH APPLICATION OF A NEW BATTERY DESIGN
- FOR EACH NEW APPLICATION OF AN EXISTING DESIGN
- FOR EACH NEW SUPPLIER OF AN EXISTING DESIGN

Figure 29-17

Development Testing/Charge Control

- MINIMUM CHARGE RATE AND RECHARGE RATIO TO MAINTAIN RATED CAPACITY THROUGHOUT THE MISSION
- PARAMETER CHARACTERIZATION
  - ΔV
  - ΔI
  - ΔT
- DESIGN MUST ADDRESS CONTINGENCIES

Figure 29-18

Development Testing/Charge Control

- EXCLUDED AS PRIMARY METHOD
  - THIRD ELECTRODE CELLS
  - COULOMBMETER CELLS
  - SINGLE TEMPERATURE SET POINT

Figure 29-19

Development Testing/Life

- ACCEPTANCE TESTED FLIGHT-TYPE BATTERIES
- ELECTRICAL AND ENVIRONMENTAL CONDITIONS EXPECTED DURING S/C OPERATION
- THERMAL PROFILE CHARACTERIZATION
- REAL TIME (no acceleration)

Figure 29-20

Development Testing/Thermal Vacuum

- FLIGHT-TYPE BATTERIES
- THERMAL CYCLE TEMPERATURE MONITORING
- BATTERY HEAT TRANSFER VALIDATION

Figure 29-21