PREFERRED RELIABILITY PRACTICES

BATTERY SELECTION PRACTICE FOR AEROSPACE POWER SYSTEMS

Practice:

When selecting batteries for space flight applications, the following requirements should be considered: ampere-hour capacity, rechargeability, depth of discharge (DOD), lifetime, temperature environments, ruggedness, and weight. Many batteries have been qualified and used for space flight, enhancing the ease of selecting the right battery.

Benefits:

Selection of the optimum battery for space flight applications results in a safe, effective, efficient, and economical power storage capability. The optimum battery also enhances launch operations, minimizes impacts to resources, supports contingency operations, and meets demand loads.

Programs That Certified Usage:

Space Shuttle Solid Rocket Booster (SRB); Space Shuttle External Tank (ET); Materials Experiment Assembly (MEA); Inertial Upper Stage (IUS); Tethered Satellite System (TSS); Transfer Orbit Stage (TOS); Saturn IB Launch Vehicle; Saturn V Launch Vehicle; Skylab; High Energy Astronomy Observatory (HEAO); Lunar Roving Vehicle (LRV); and Hubble Space Telescope (HST).

Center to Contact for More Information:

Marshall Space Flight Center

Implementation:

Primary batteries, those which are not recharged are and useful for short duration, are used principally for providing electrical power for launch vehicles. These batteries must have high energy density, high current capabilities, and good reliability. MSFC has had experience with Lithium/Monoflouride (Li/CF), Lithium/Thionyl Chloride ($Li/SOCl_2$), and Silver/Zinc (Ag/Zn) primary batteries.

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Secondary batteries, those which are discharged and then recharged numerous times, are principally used for spacecraft, satellite, and other long-term space-oriented applications. In space applications, reliability,

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costs producibility, responsiveness, risks, , safety, and maintainability are more important than high current content. MSFC has had experience with Silver/Zinc (Ag/Zn), Nickel/Hydrogen (Ni/H_2), Nickel/Cadmium (Ni/Cd), Nickel/Metal Hydride (Ni/MH), and Bi Polar-Lead Acid (Bi-Pb/Acid).

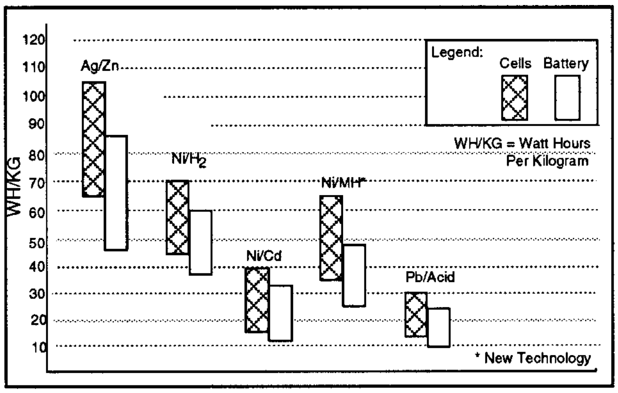

Figure 1. Specific Energy Comparison of Secondary Battery Systems

Battery types are selected for specific applications based on a number of factors including specific energy and energy density (see Figures 1 and 2), lifetime, number of cycles, discharge rate, charge retention, shelf life, ruggedness, operating temperature, and other factors. Figure 3 presents these factors for various battery types. Figure 3 should be used by the designer as an initial tool for selecting the required battery type. The design of batteries for space flight should be accompanied by battery level electrical, mechanical and thermal analysis.

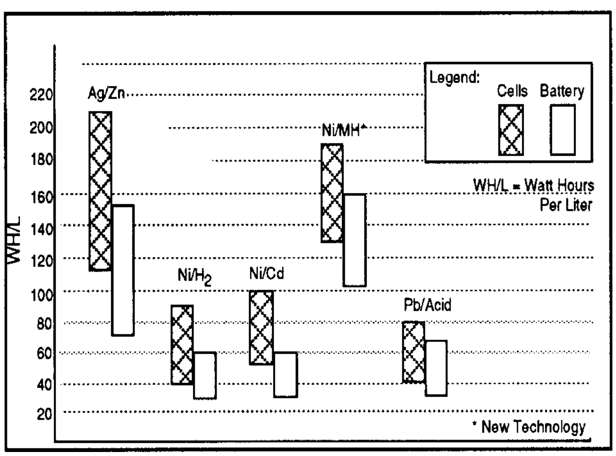

Figure 2. Volumetric Energy Density Comparison of Secondary Battery Systems at 20 Deg. C

A typical battery selection flow chart is shown on Figure 4. After the program is identified and electrical power requirements are established, a trade study should be performed to determine the actual battery (primary or secondary) that will fulfill the requirements at a reasonable cost. Cell selection includes charge voltage, discharge capacity, and discharge voltage after cycling. Establishing the battery size is determined by the number of cells required to provide the required electrical power, i.e., a 24-volt battery using a 1.5 volt cell will require 16 cells. Mechanical packaging of the cells into a battery requires such parameters as cell type, number of cells, weight, length, height, temperature requirements, mounting method, vibration environment, electrical feed through, and venting requirements to ensure proper functioning of the battery. Perhaps the most important part of selecting a battery is the selection of a reliable cell/battery manufacturer. Preferably one that has consistently produced high quality and reliable

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BATTERIES FOR SPACE POWER[1]

	PRIMARY			SECONDARY				
CHEMISTRY:	LiCF	$LiSOCl_2$	AgZn	AgZn	NiH2	NiCd	NiMH[2]	Bipolar PbAcid[2]
Lifetime (cycles)	Not Applicable		Not Applicable	200+[3]	45K+[4]	40K+[4]	2	500+
Watt-Hours/Kilogram	130	185	110	100	65	35	55	20
Watt-Hours/Liter	160	240	200	185	80	85	180	200
Discharge Rate	Low	Mod+[5]	High	High	Mod+	High	High-	High++
Charge Retention	Not Applicable		Not Applicable	High	Low[6]	Mod	Mod	Mod
Memory	Not Applicable		Not Applicable	No	No	Yes	No	No
Wet Shelf Life	Long		Short[7]	Short[7]	Mod	Mod	Long	Long
Failure Tolerance	Low[9]		High	High	High	Mod[8]	High	Mod
Notes:	Not Sensitive within limits[9,10]		Activation req'd at time of use; May have free Electrolyte		Pressure Vessel; Capacity loss concerns after storage	Not Sensitive[10]	2	Activation req'd at time of use; May have free Electrolyte[10]
Operating Temp	0°C - 100°C		10°C - 50°C	0°C - 45°C	0°C - 20°C	0°C - 50°C	5°C - 10°C	2
Venting Requirements	Burst vent req'd		Can be sealed	Can be sealed	None	Can be sealed	None	Req'd
Cell Voltage (Operating)	2.95V	3.1V	1.5V	1.5V	1.3V	1.25V	1.32V	2.1V
Experience Level	High	Mod	High	Low	Moderate	High	Low-	Low--
Costs	Low	Low	Low	Low	High	Mod	High	High

1 Based on MSFC applications (EB12)
2 New Technology
3 Approximately 50% depth of discharge
4 Refers to 61 minute sun and 35 minute eclipse low earth orbit cycle with approximately 5500 cycles per year at less than 20% depth of discharge
5 Can be designed for high rate use
6 Significantly improves with lower temperature (0° C)
7 Lifetime is limited to 90 - 200 days depending on construction
8 High temperature buildup on "high-rate" overcharge
9 Unstable at very high temperatures and high rate of discharge
10 Environmental concerns with constituent materials

1992 EB12

Figure 3. Approximate Battery Comparisons for Space Power Applications

batteries. Manufacturing engineers should critique the design for producibility and testability early in the design process and make corrective suggestions when problems are discovered.

Accelerated life testing of batteries is extremely difficult due to the nature of the chemical reaction between the electrolyte and the positive and negative electrodes. Therefore, preferred type and configuration of the battery should be selected early in the program to allow for lifetime testing.

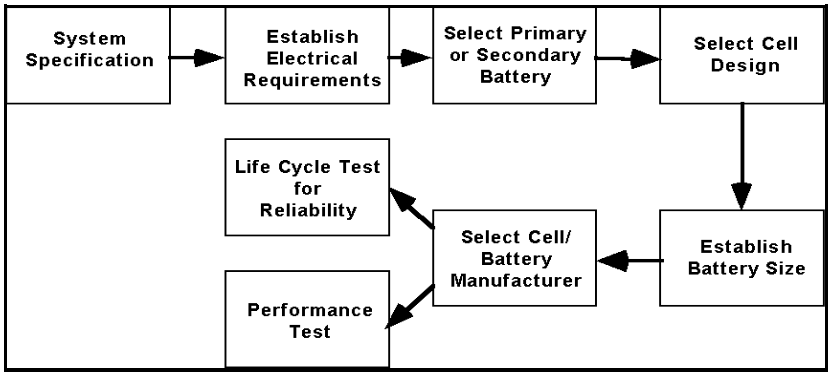

Figure 4. Typical Battery Selection Flow chart

Performance testing of the selected battery can be accomplished in parallel with life testing. Performance testing should be accomplished in an environment to which the battery is expected to be exposed during operation. The battery should demonstrate during testing that it will deliver the required electrical power and will charge and discharge as designed.

Technical Rationale:

MSFC's aerospace flight battery experience comes from a combination of its own in-house laboratory experience on numerous programs; from coordination with battery manufacturers, prime contractors, and subcontractors for a number of launch vehicles, space vehicles, and experiments; and from many years of participation in NASA/industry aerospace battery workshops. Two such workshops, hosted by the Marshall Space Flight Center in Huntsville, Alabama, were attended by approximately 200 persons each, representing both Government and industry. Credit must be given to the interdisciplinary efforts of Goddard Space Flight Center, NASA Headquarters, Jet Propulsion Laboratory, Johnson Space Center, Kennedy Space Center, Ames Research Center, Langley Research Center, Lewis Research Center, and their suppliers and contractors, as well as to many academic and nonprofit organizations who have contributed to the battery research leading to this body of knowledge.

Impact of Non Practice:

Failure to adhere to proven battery selection practices could cause shortened mission life, premature cessation of component or experiment operation, mission failure, and in extreme cases, loss of mission or life. All phases of battery use, from battery selection to installation in

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the launch vehicle or orbiting spacecraft, must adhere to the proven design and safe battery practice.

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