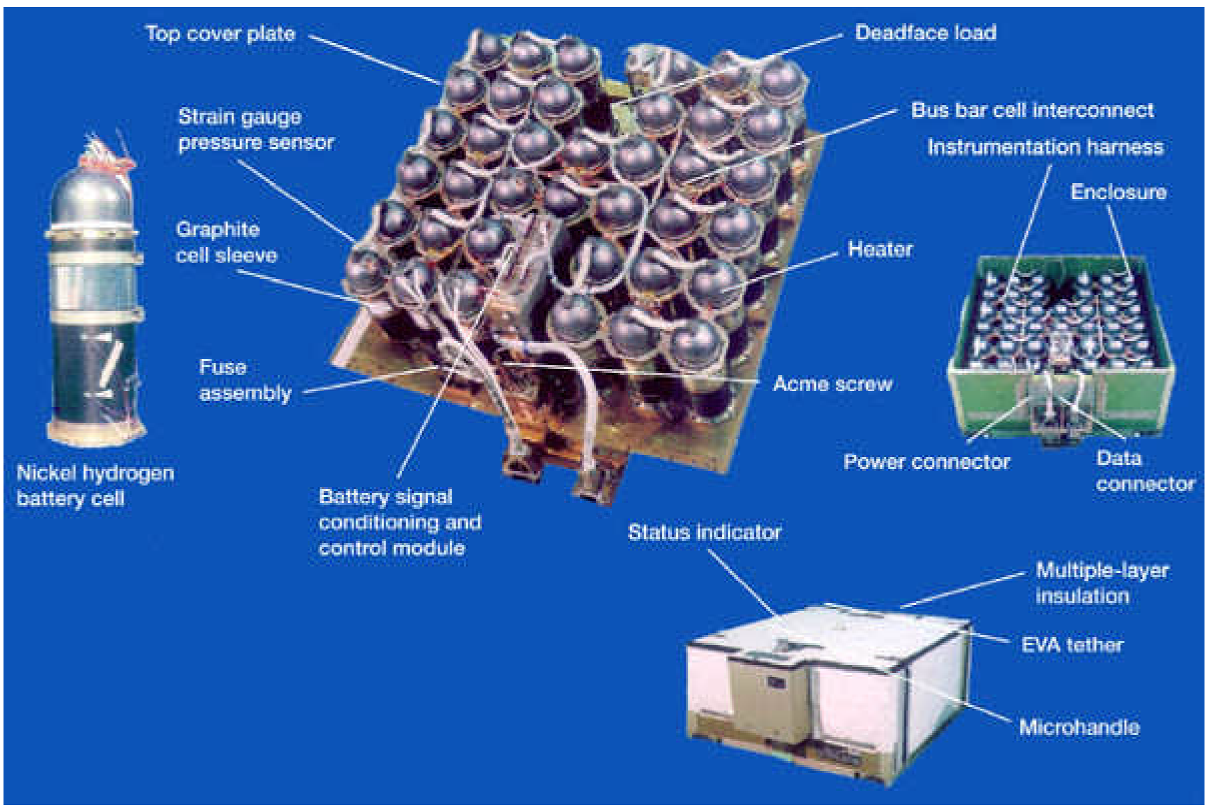
Nickel-Hydrogen Battery Cell Life Test Program Update for the International Space Station

NASA and Boeing North America are responsible for constructing the electrical power system for the International Space Station (ISS), which circles the Earth every 90 minutes in a low Earth orbit (LEO). For approximately 55 minutes of this orbit, the ISS is in sunlight, and for the remaining 35 minutes, the ISS is in the Earth's shadow (eclipse). The electrical power system must not only provide power during the sunlight portion by means of the solar arrays, but also store energy for use during the eclipse. Nickel-hydrogen (Ni/H_2) battery cells were selected as the energy storage systems for ISS. Each battery Orbital Replacement Unit (ORU) comprises 38 individual series-connected Ni/H_2 battery cells, and there are 48 battery ORU's on the ISS. On the basis of a limited Ni/H_2 LEO data base on life and performance characteristics, the NASA Glenn Research Center at Lewis Field commenced testing through two test programs: one in-house and one at the Naval Surface Warfare Center in Crane, Indiana.



International Space Station battery Orbital Replacement Unit.

Under the in-house test program, Glenn constructed a Ni/H_2 battery cell test facility with an automated data acquisition system to assess the performance of cells from different vendors. The resulting 39-cell test matrix consisted of 13 different battery cell configurations. The cells were placed on a LEO endurance life test at a 35-percent depth-of-discharge (DOD) stress condition at either –5 or 10 °C. As of September 1999, 29 cells had completed over 5 years of life testing (29,200 charge and discharge cycles). Currently, there are 16 cells in active operation. The number of life cycles tested ranged from 50,100 (8.5 years) to 59,800 (10.25 years) in LEO.

To verify the ISS operational life requirement of 6.5-year life at 35-percent DOD, researchers are testing a statistically significant number of Ni/H_2 battery cells at the Naval Surface Warfare Center. The test matrix contains cells from three different manufacturers. All battery cell endurance life testing is being performed in either 10-, 8-, or 5-cell series-connected test packs at 35- or 60-percent DOD and operating temperatures of –5 or 10 °C.

All 100 Ni/H_2 cells from Yardney Technical Products have failed. Battery pack failures tested at the 35-percent DOD condition ranged from 37,000 to 48,300 cycles (6.3 to 8.3 years). Failures of packs tested at the higher 60-percent DOD stress condition ranged from 420 to 4750 cycles (1 to 10 months). The 112 Ni/H_2 cells from Gates Aerospace Batteries were also tested at the Naval Surface Warfare Center facility to benchmark their performance. Thirty of the Gates cells were used to assess the impact of potassium hydroxide electrolyte concentration with various charge management schemes. Packs tested at the 60-percent DOD condition exhibited failures ranging from 7500 to 36,900 cycles (1.3 to 6.3 years). Because of funding limitations, the packs operating at 35-percent DOD were terminated. At that time, the various packs had accumulated from 24,600 to 42,000 cycles (4.2 to 7.2 years). The 120 Eagle-Picher Industries, Inc., Ni/H_2 cells have only shown failures at the 60-percent DOD operating point. Pack failures ranged from 6200 to 40,200 cycles (1.1 to 6.9 years). Packs operating at 35-percent DOD, which continue to cycle, now range from 42,200 to 46,400 cycles (7.2 to 7.9 years). Forty-eight of the Eagle-Picher cells are undergoing a special charge control study. Some of the cells are being charged using the ISS baseline charge profile, which incorporates a constant current charge followed by a taper charge to 100-percent state of charge. The other cells are being charged at a constant current terminating at either a 90 or 94-percent state of charge.

Through a competitive down-selection process, Eagle-Picher is the sole supplier of Ni/H_2 battery cells for the ISS. The results to date provide the necessary confidence in achieving a 38,000 cycle (6.5 years) LEO life for Ni/H_2 battery cells at the 35-percent DOD operating condition, which is the design point for the International Space Station. In general, prolonged cycle life is achieved by selecting a properly designed battery cell configuration, incorporating the reduced 26-percent potassium hydroxide electrolyte concentration, and by using the ISS baseline charge control methodology of taper charging.

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