Storage Characteristics of Li-Ions for Future NASA/JPL Missions to the Outer Planets

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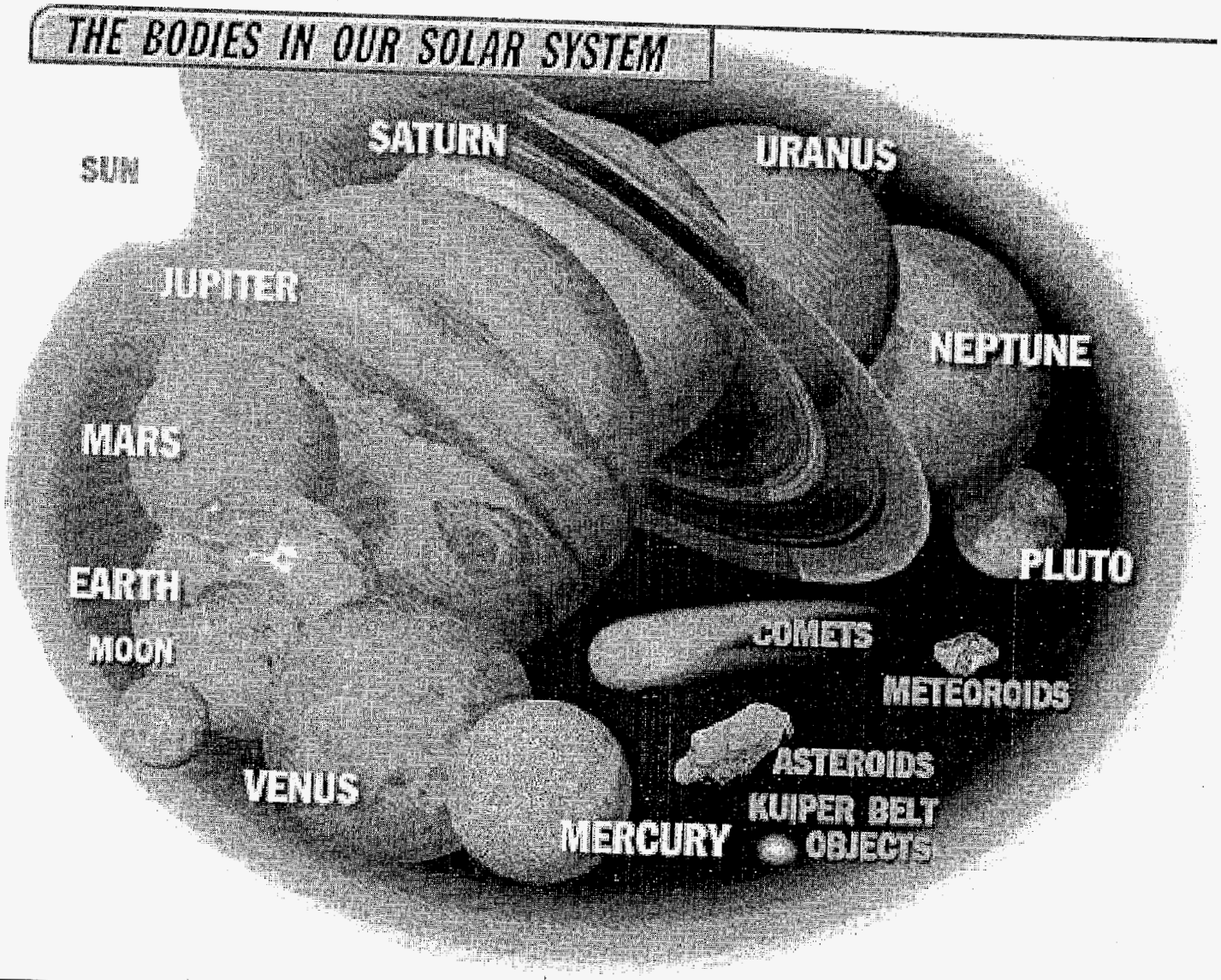
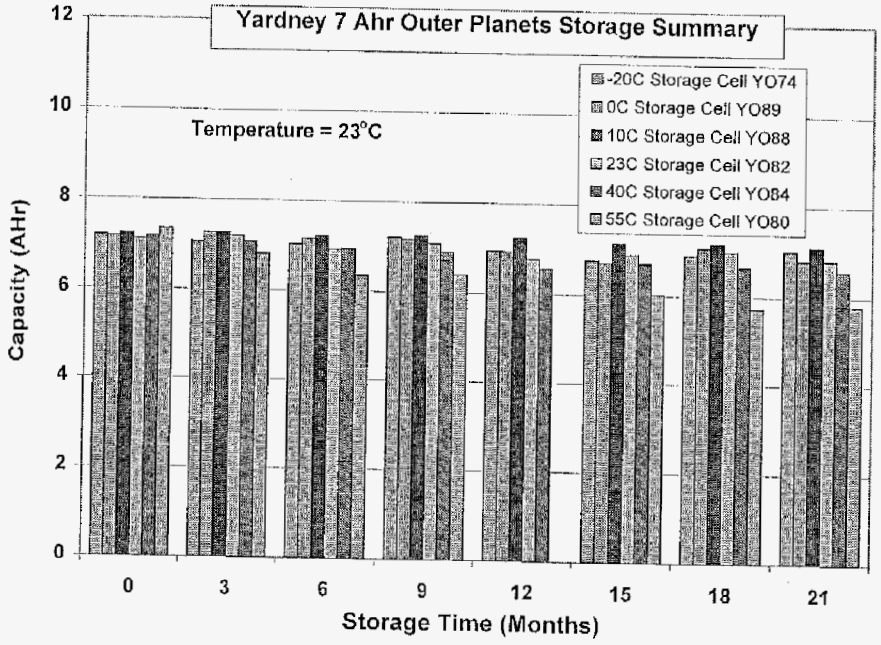
INTRODUCTION



Test Conditions

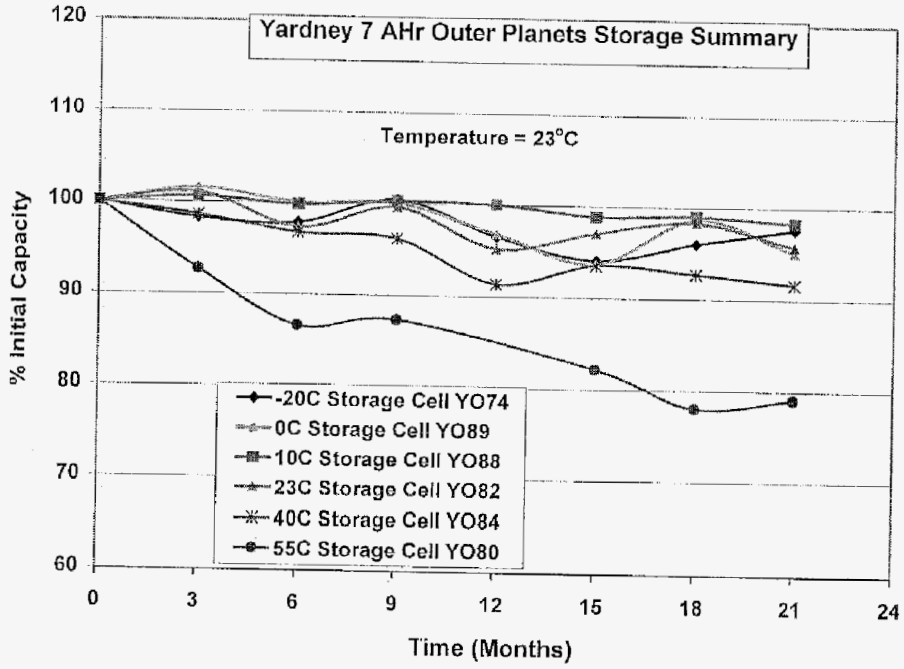
- *18 Yardney7 Ahr Prismatic Cells*
  - Storage Temperatures of 55°C, 40°C, 23°C, 10°C, 0°C, and -20°C.
  - Constant Applied Storage Potential of 3.650 V (50% State-Of-Charge).
  - Capacity Checks after incremental 3 Month Storage at 23°C and 0°C.
  - EIS measurements at 23°C after each 3 Month Storage period.
- *18 SAFT 9 Ahr Cylindrical Cells (DD size)*
  - Storage Temperatures of 55°C, 40°C, 23°C, 10°C, 0°C, and -20°C.
  - Constant Applied Storage Potential of 3.650 V (50% State-Of-Charge).
  - Capacity Checks after incremental 3 Month Storage at 23°C and 0°C.
  - EIS measurements at 23°C after each 3 Month Storage period.

Capacity Check & Capacity Retention vs. Storage Temperature
Yardney Li-Ion Cells - Discharge at 23°C



Capacities

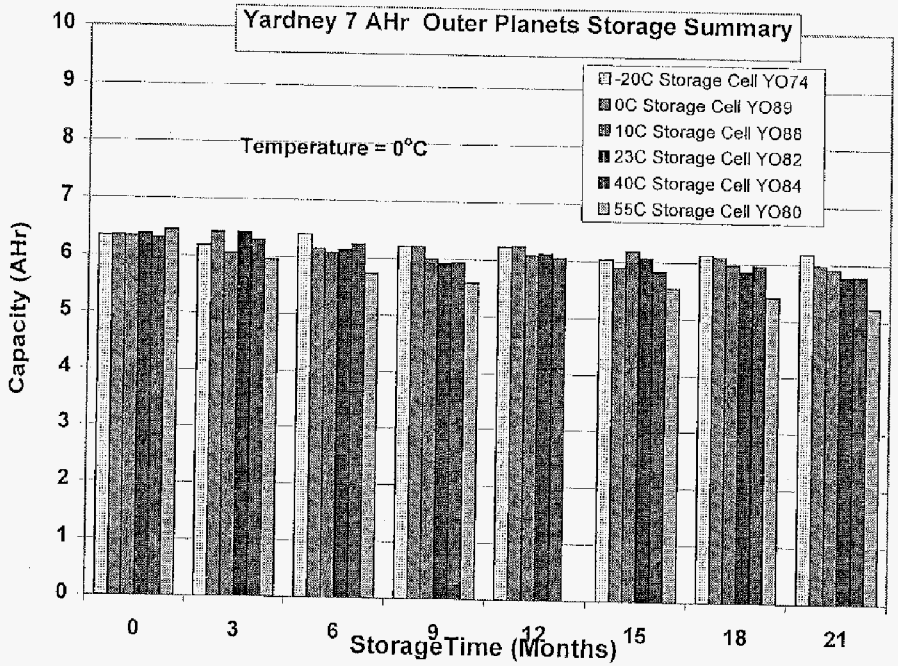
- Storage Temperatures of 10°C and 0°C exhibited highest capacities.
- Storage Temperatures of 55°C exhibited lowest capacities.



Capacity Retention

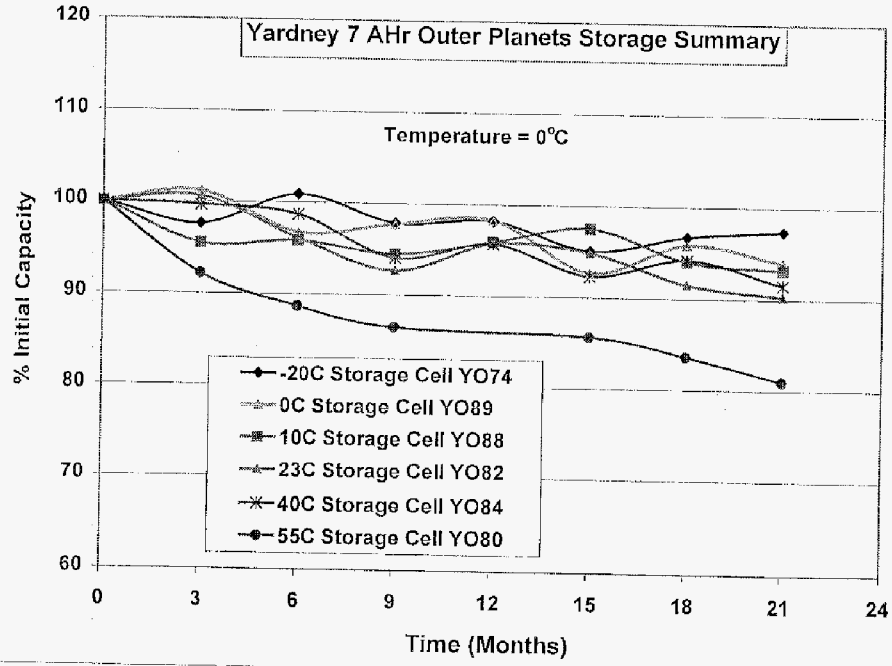
- Storage Temperatures of 55°C exhibited capacity retention less than 80%.

Capacity Check & Capacity Retention vs. Storage Temperature
Yardney Li-Ion Cells - Discharge at 0°C



Capacities

- Storage Temperatures less than 10°C exhibited highest capacities.
- Storage Temperatures of 55°C exhibited lowest capacities.

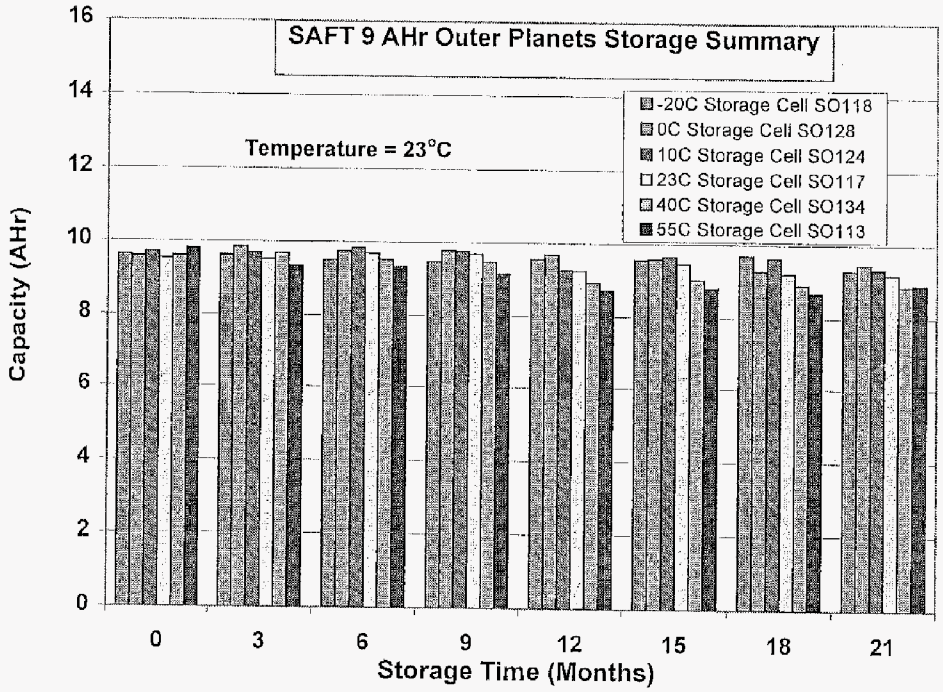


Capacity Retention

- Storage Temperatures of 55°C exhibited capacity retention less than 85%.

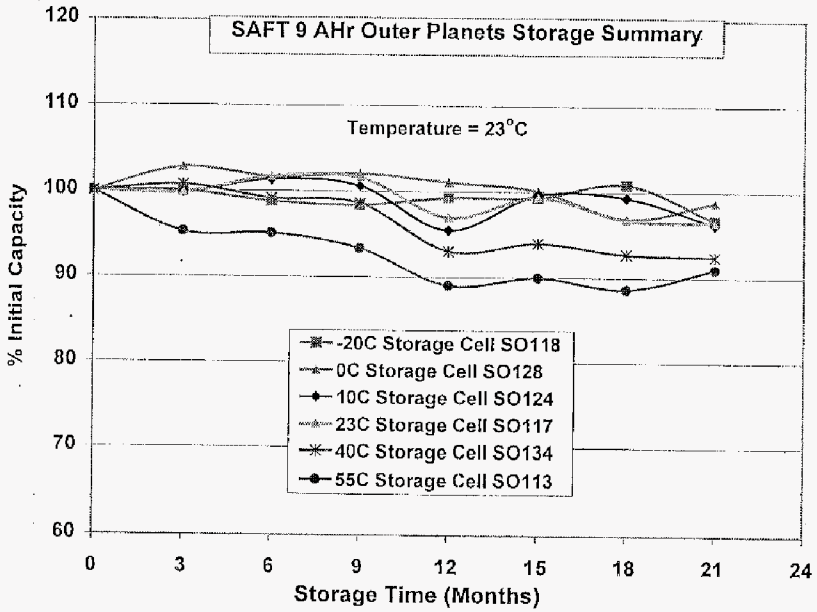
Capacity Check & Capacity Retention vs. Storage Temperature

SAFT Li-Ion Cells - Discharge at 23°C



Capacities

- Storage Temperatures less than 10°C exhibited highest capacities.
- Storage Temperatures of 55°C exhibited lowest capacities.

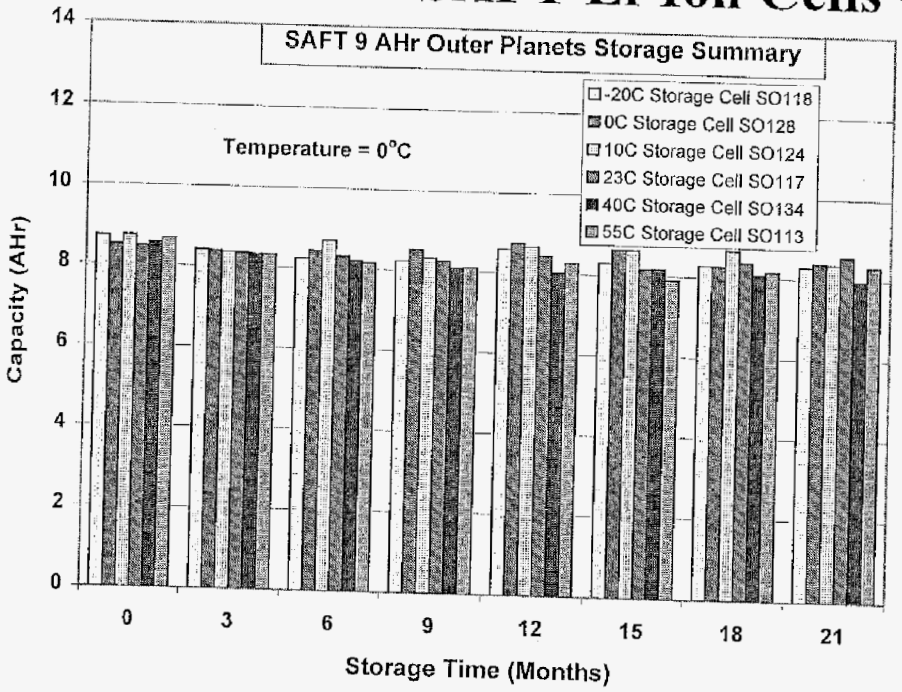


Capacity Retention

- Storage Temperatures of 0°C exhibited highest capacity retention.
- Storage Temperatures of 55°C exhibited capacity retention less than 90%.

Capacity Check & Capacity Retention vs. Storage Temperature

SAFT Li-Ion Cells - Discharge at 0°C

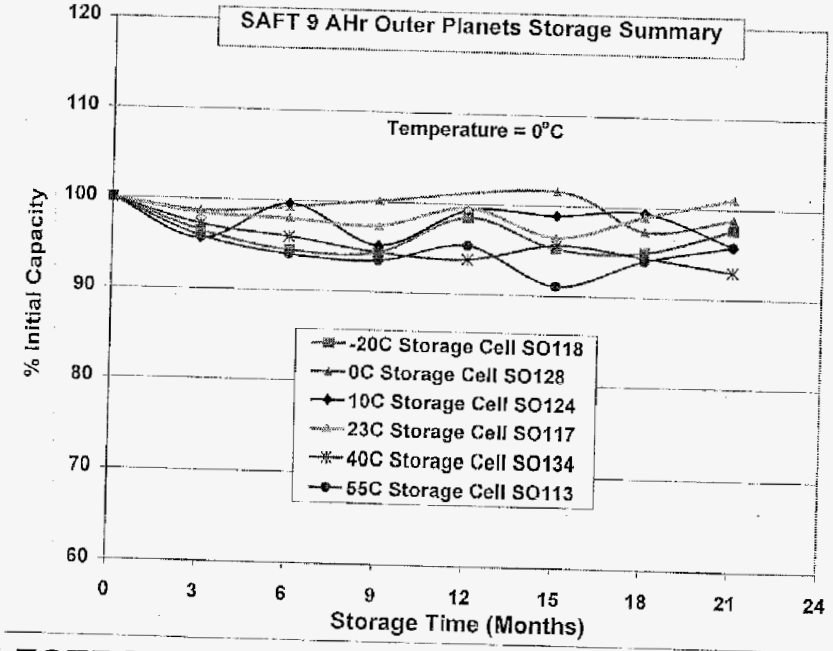


Capacities

- Storage Temperatures of 10°C and 0°C exhibited highest capacities.
- Storage Temperatures of 55°C exhibited lowest capacities.

Capacity Retention

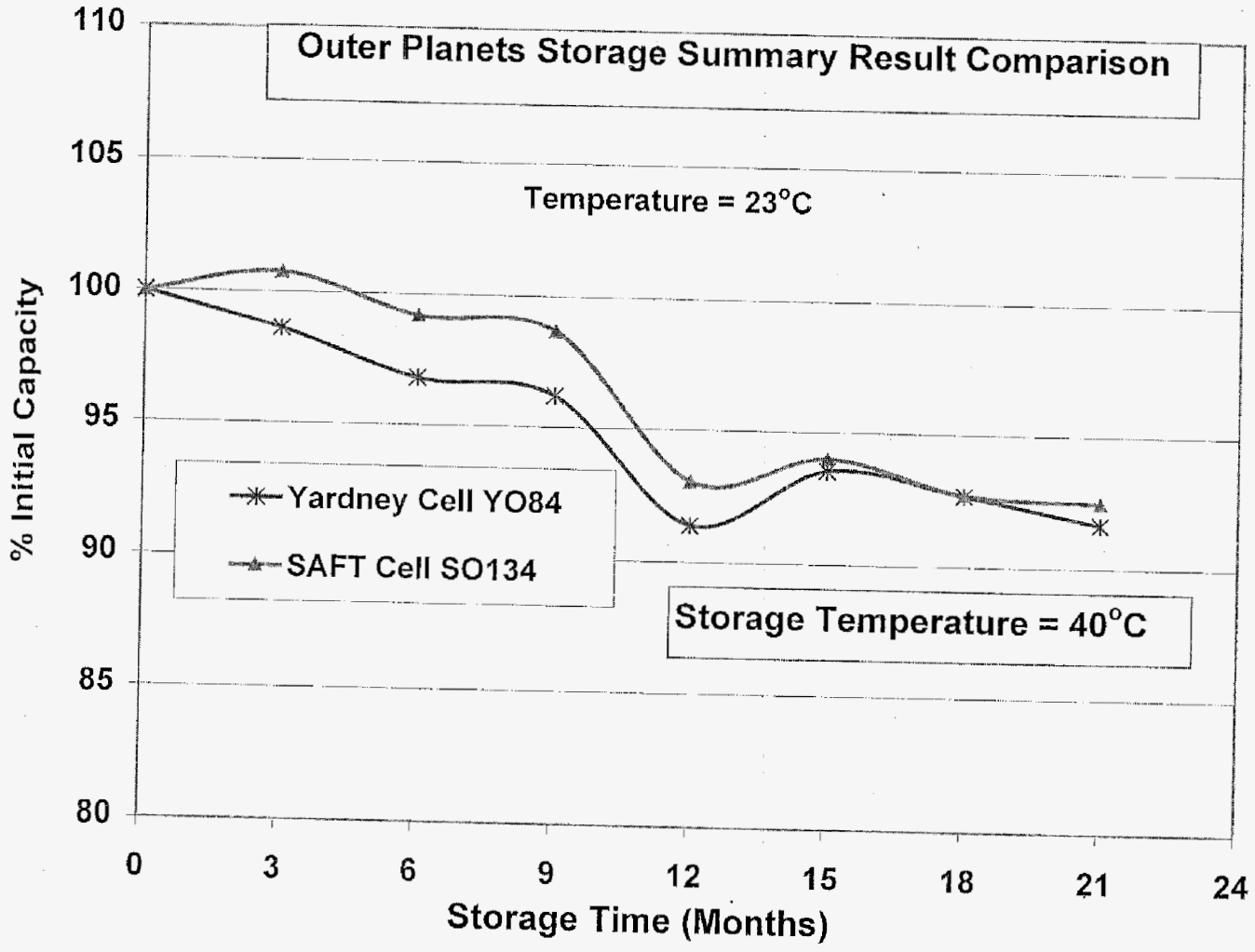
- Storage Temperatures of 0°C exhibited highest capacity retention.
- Storage Temperatures of 55°C exhibited capacity retention greater than 90%.



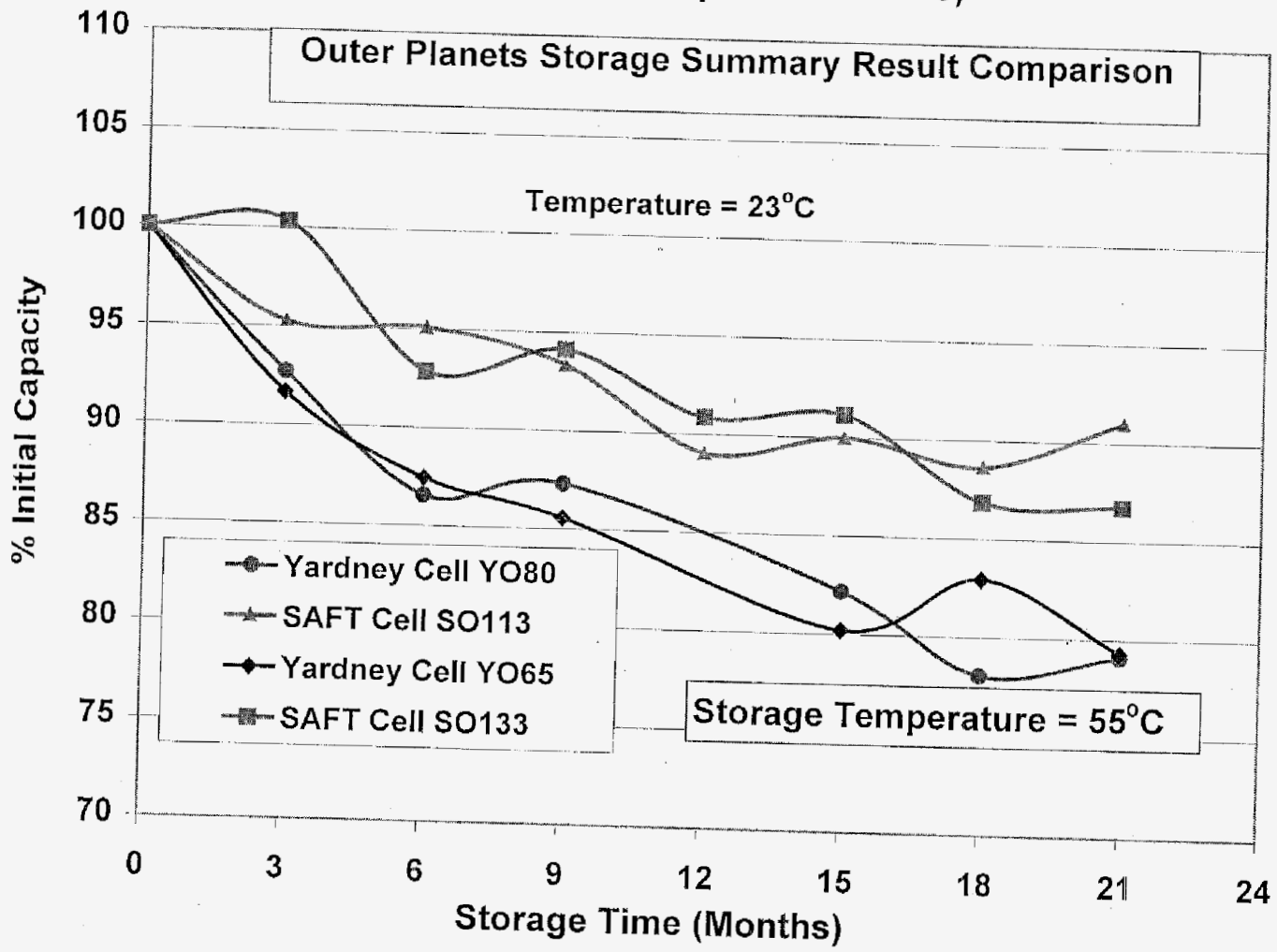
Capacity Retention of Yardney and SAFT Cells on Storage

Storage Temperature = 40°C

(Discharge Temperature = 23°C)



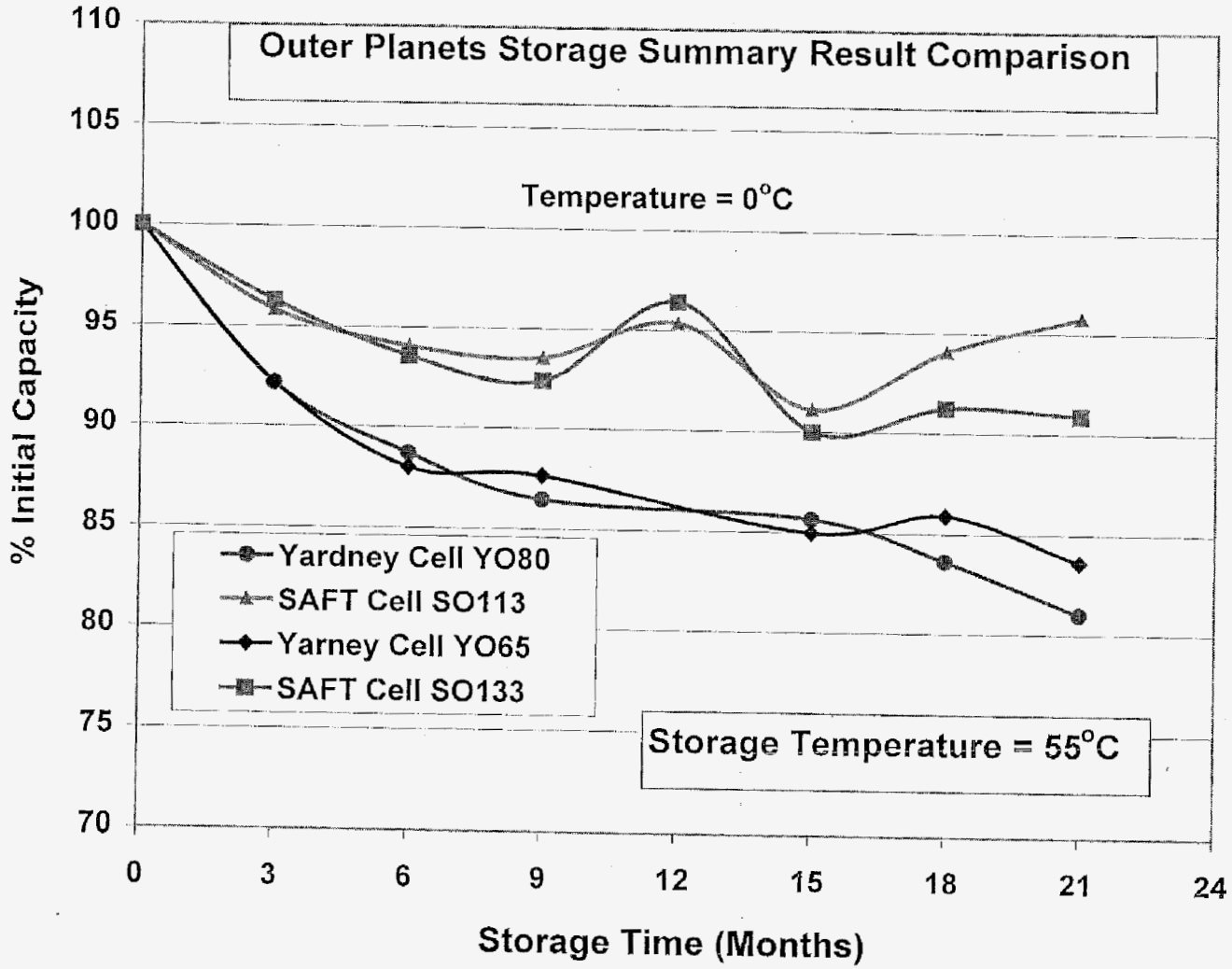
Capacity Retention of Yardney and SAFT Cells on Storage
Storage Temperature = 55°C
(Discharge Temperature = 23°C)



Capacity Retention of Yardney and SAFT Cells on Storage

Storage Temperature = 55°C

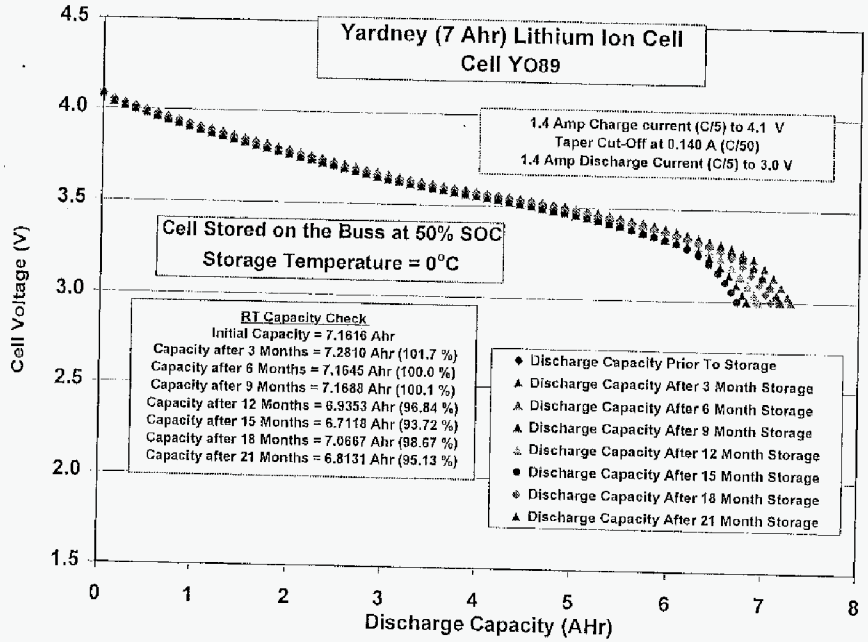
(Discharge Temperature = 0°C)



Yardney 7 Ahr Li-Ion Cells

Capacity Check at Room Temperature and 0°C

Storage Temperature = 0°C

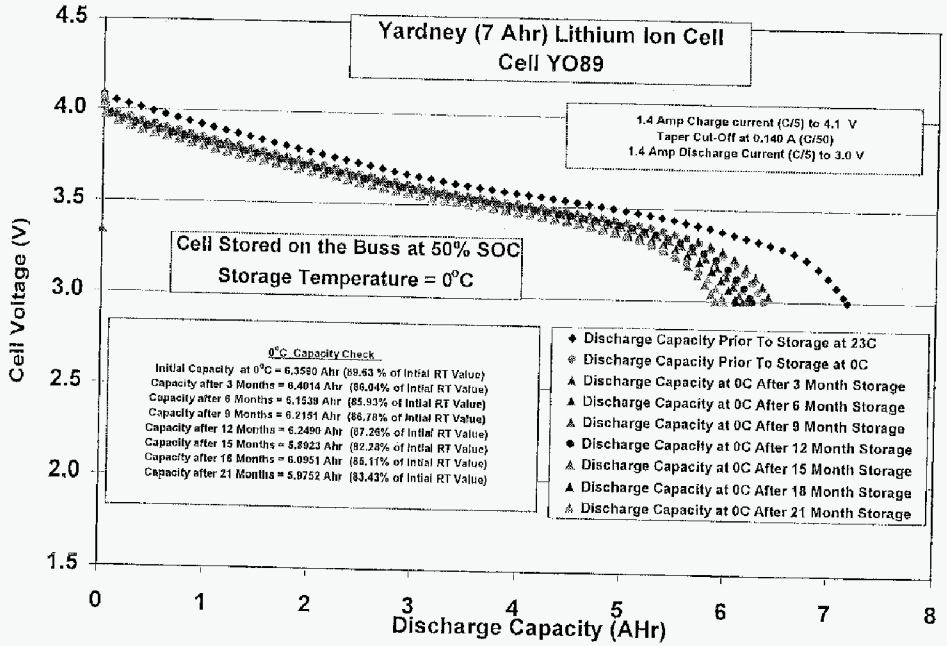


RT Capacity Check

7.1616 Ahr - Initial Capacity

6.8131 Ahr – 21 Month Storage (95 %)

Capacity Fade Rate = 0.24 % per Month



0°C Capacity Check

6.3590 Ahr - Initial Capacity (90% Initial RT)

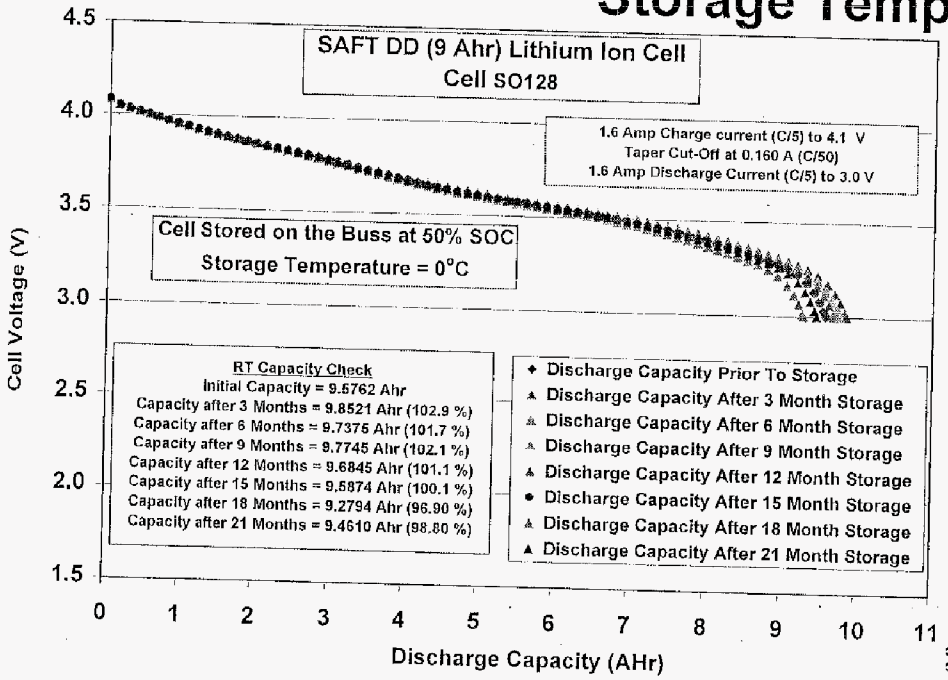
5.9752 Ahr – 21 Month Storage (94 %) (86% Initial RT)

(Capacity Fade Rate = 0.29 % per Month)

SAFT 9 Ahr Li-Ion Cells

Capacity Check at Room Temperature and 0°C

Storage Temperature = 0°C

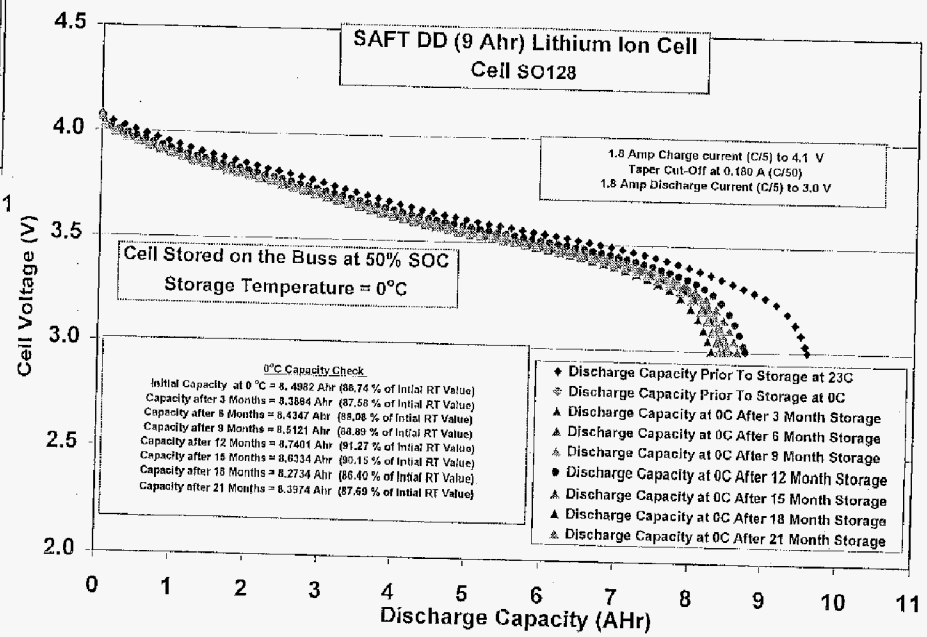


RT Capacity Check

9.5762 Ahr - Initial Capacity

9.4610 Ahr – 21 Month Storage (99 %)

Capacity Fade Rate = 0.05 % per Month



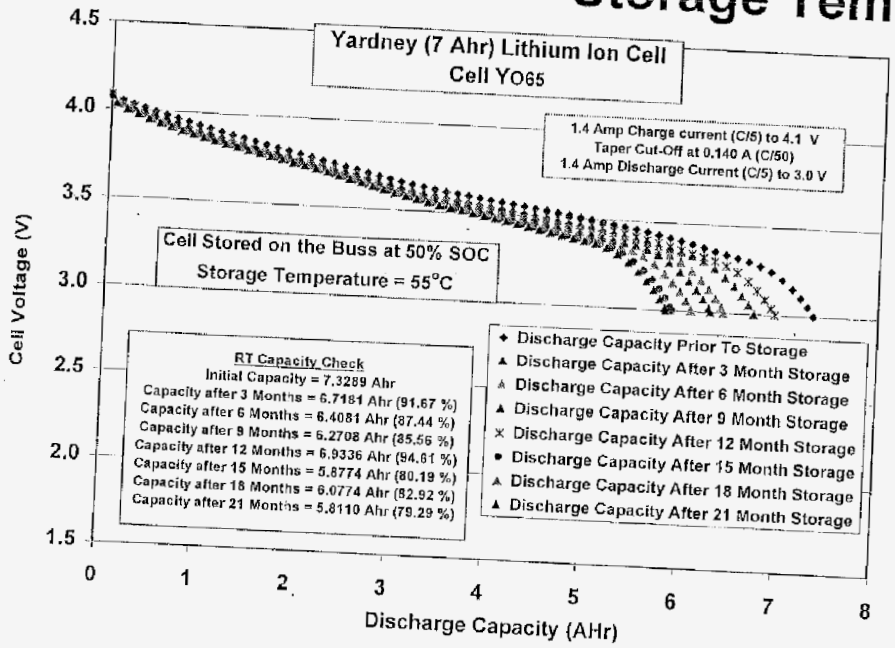
0°C Capacity Check

8.4982 Ahr - Initial Capacity (89% Initial RT)

8.3974 Ahr – 21 Month Storage (99 %) (88% Initial RT)

(Capacity Fade Rate = 0.05 % per Month)

Yardney Ahr Li-Ion Cells
Capacity Check at Room Temperature and 0°C
Storage Temperature = 55°C

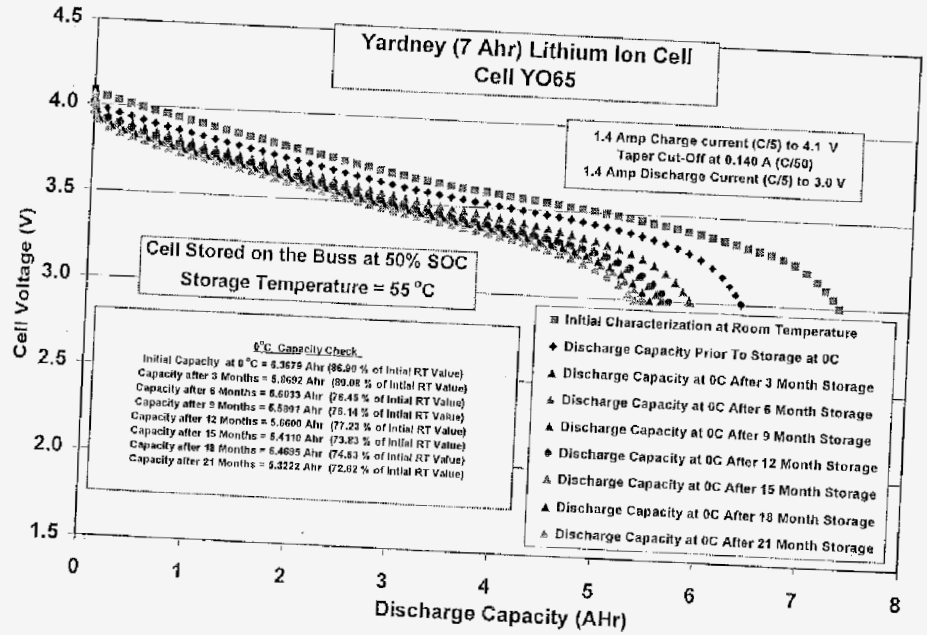


RT Capacity Check

7.3289 Ahr - Initial Capacity

5.8110 Ahr – 21 Month Storage (79 %)

Capacity Fade Rate = 1 % per Month



0°C Capacity Check

6.3679 Ahr - Initial Capacity (87% Initial RT)

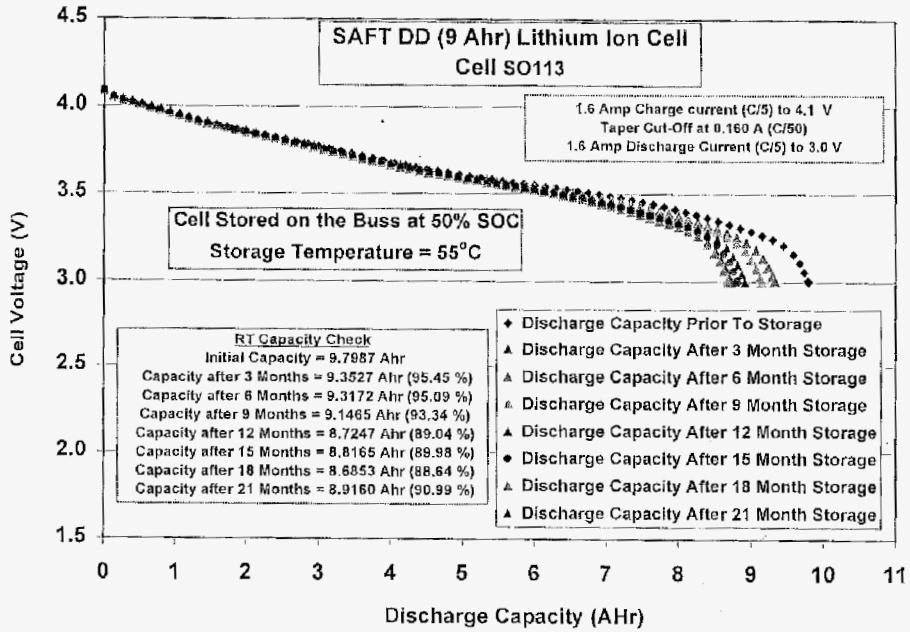
5.3222 Ahr – 21 Month Storage (84 %) (73% Initial RT)

(Capacity Fade Rate = 0.76 % per Month)

SAFT 9 Ahr Li-Ion Cells

Capacity Check at Room Temperature and 0°C

Storage Temperature = 55°C

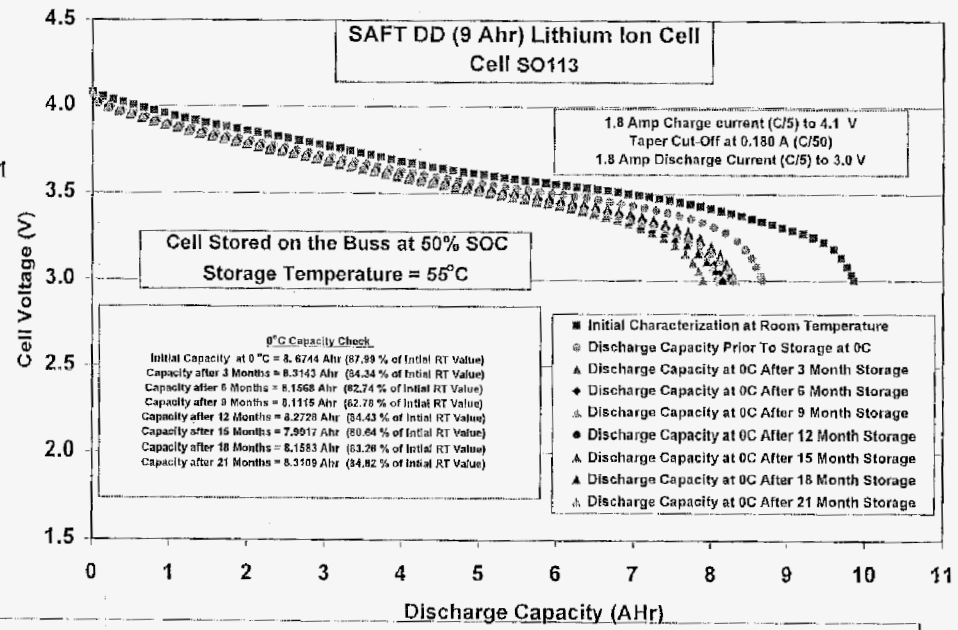


RT Capacity Check

9.7987 Ahr - Initial Capacity

8.9160 Ahr – 21 Month Storage (90 %)

Capacity Fade Rate = 0.47 % per Month



0°C Capacity Check

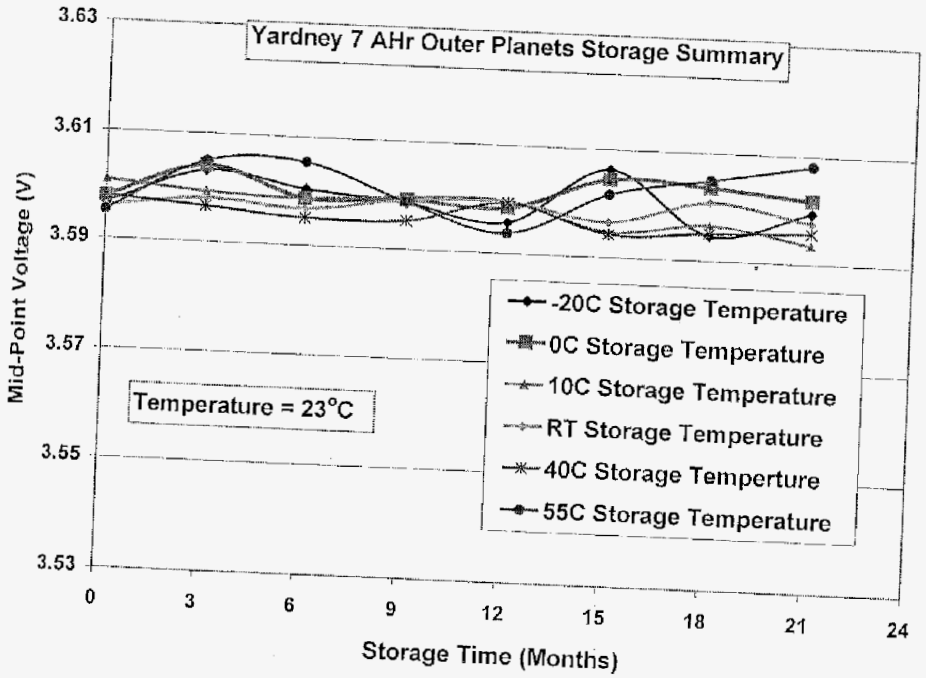
8.6744 Ahr - Initial Capacity (88 % Initial RT)

8.3109 Ahr – 21 Month Storage (96 %) (85 % Initial RT)

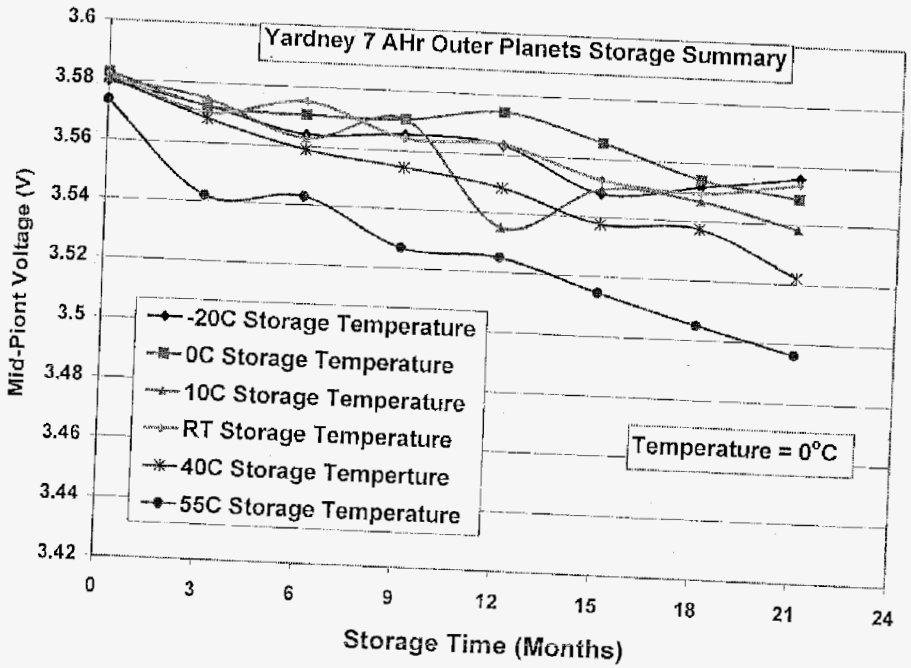
(Capacity Fade Rate = 0.19 % per Month)

Mid-Point Discharge Voltage on Storage Yardney 7 Ahr Li-Ion Cells

Discharge at 23°C

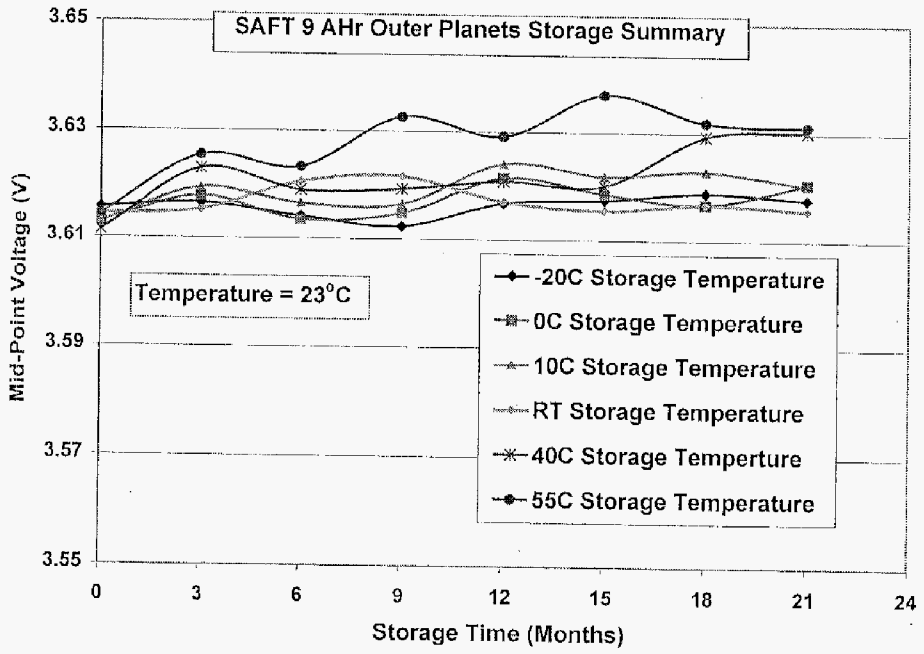


Discharge at 0°C

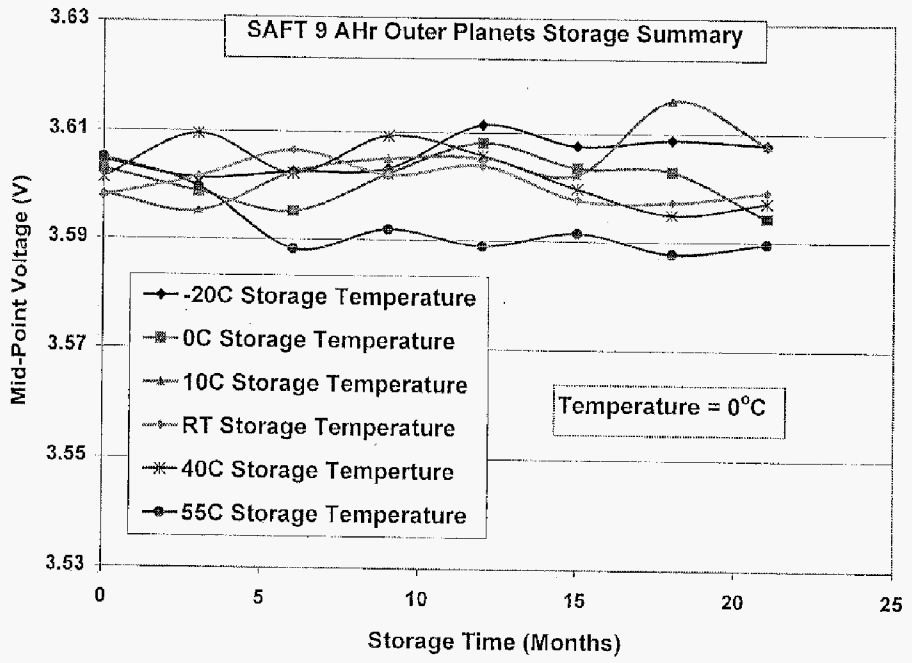


Mid-Point Discharge Voltage on Storage SAFT 9 Ahr Li-Ion Cells

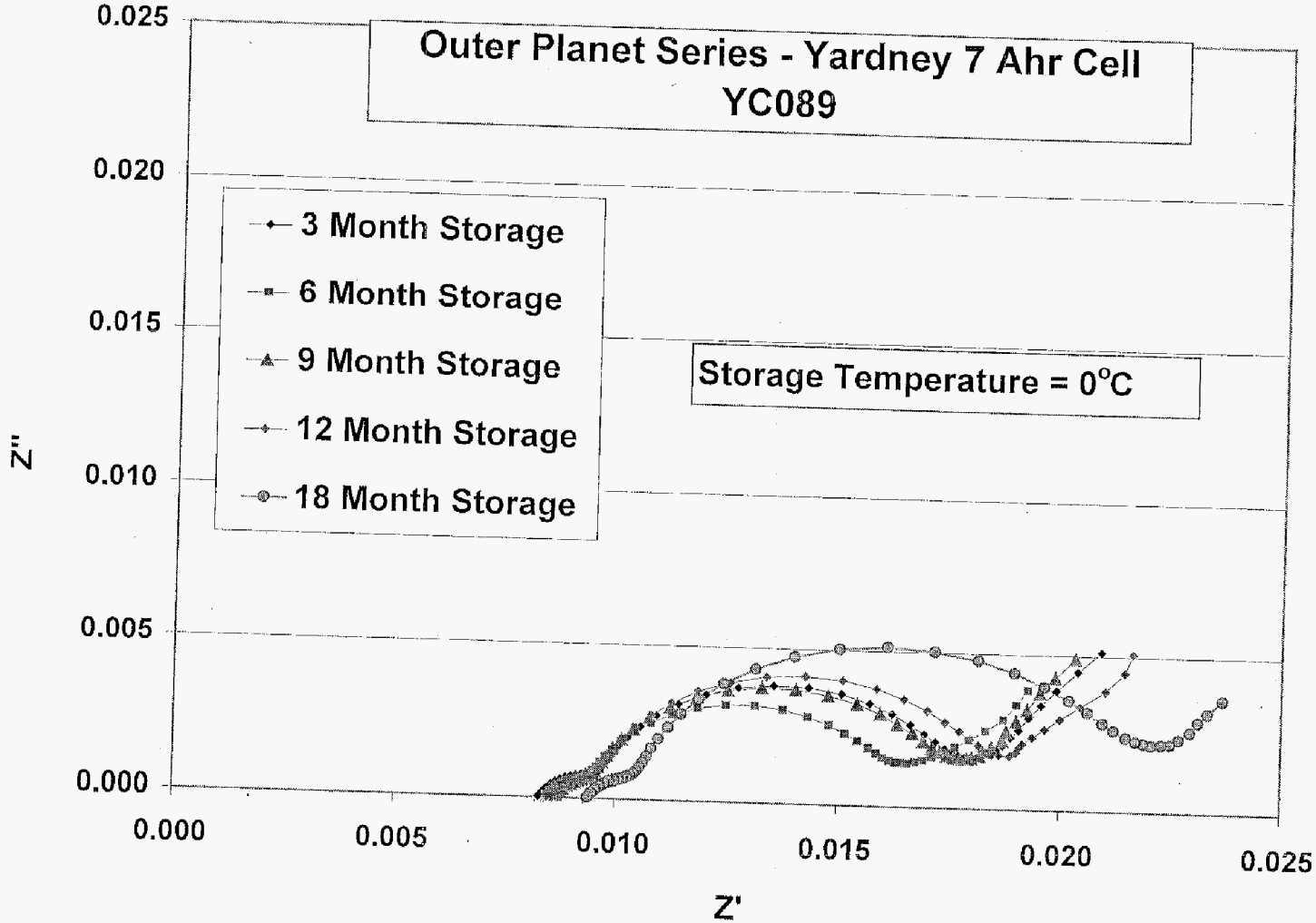
Discharge at 23°C



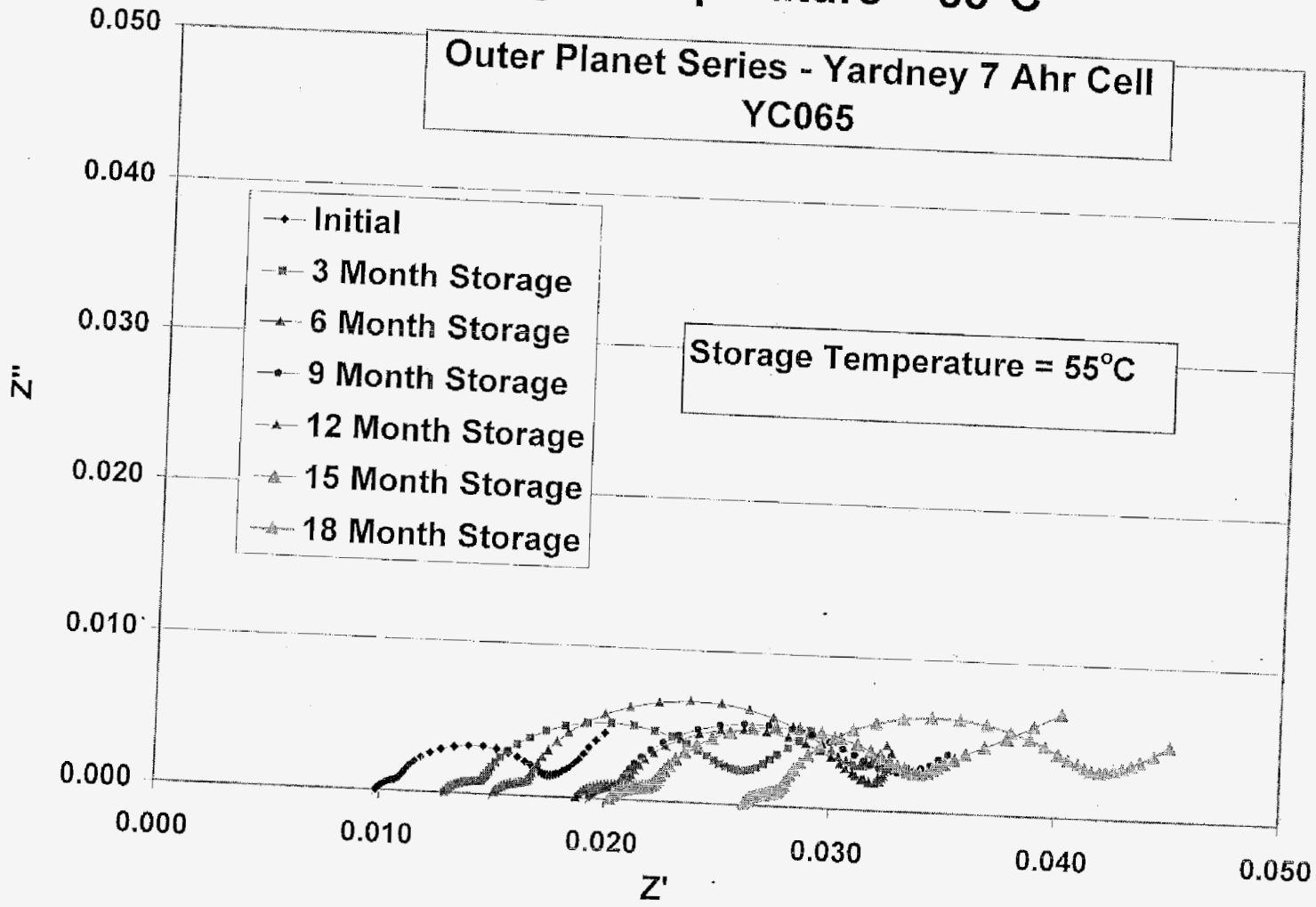
Discharge at 0°C



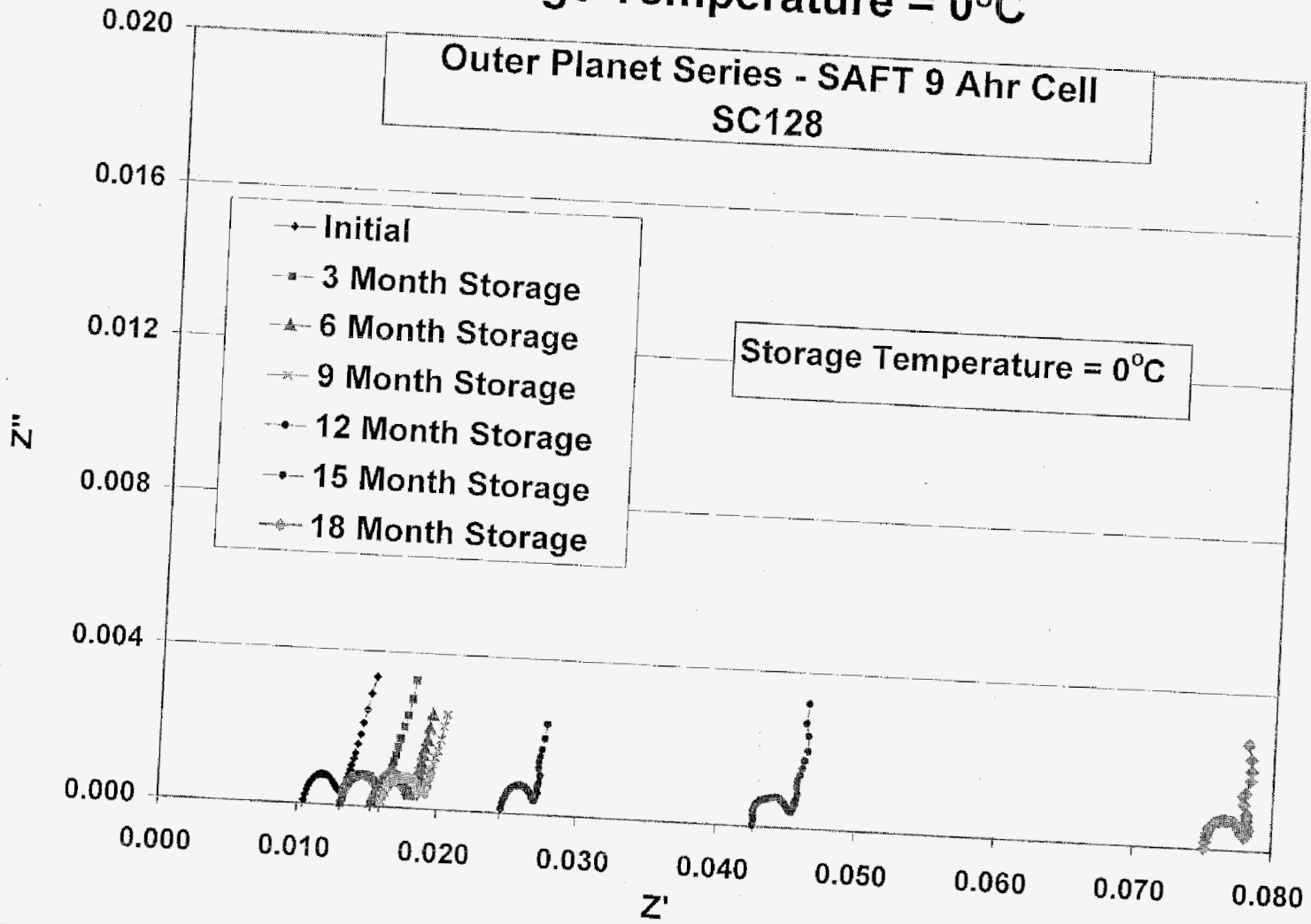
Yardney 7 Ahr Li-Ion Cells
Nyquist Plots At Various Temperatures
Storage Temperature = 0°C



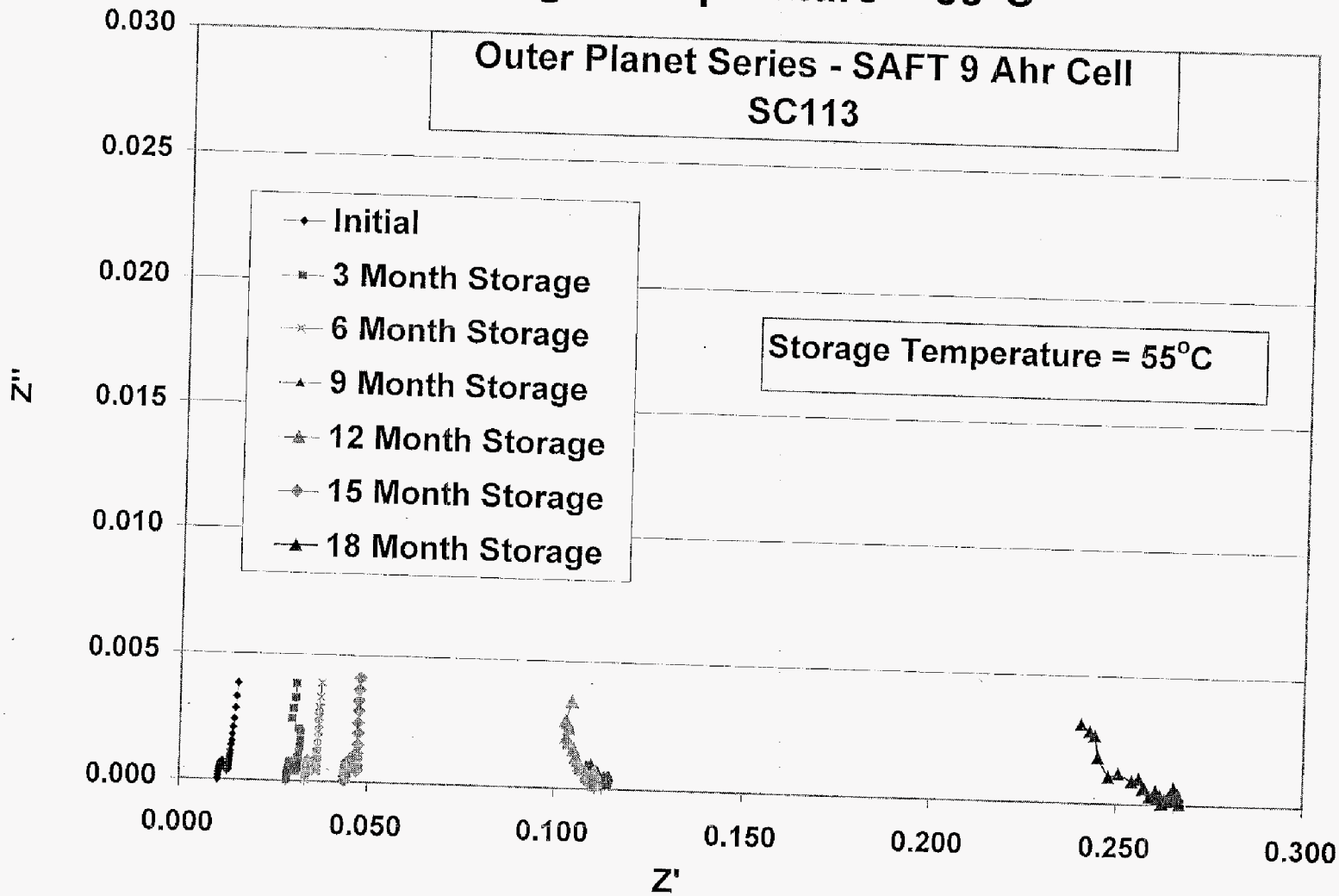
Yardney 7 Ahr Li-Ion Cells
Nyquist Plots At Various Temperatures
Storage Temperature = 55°C



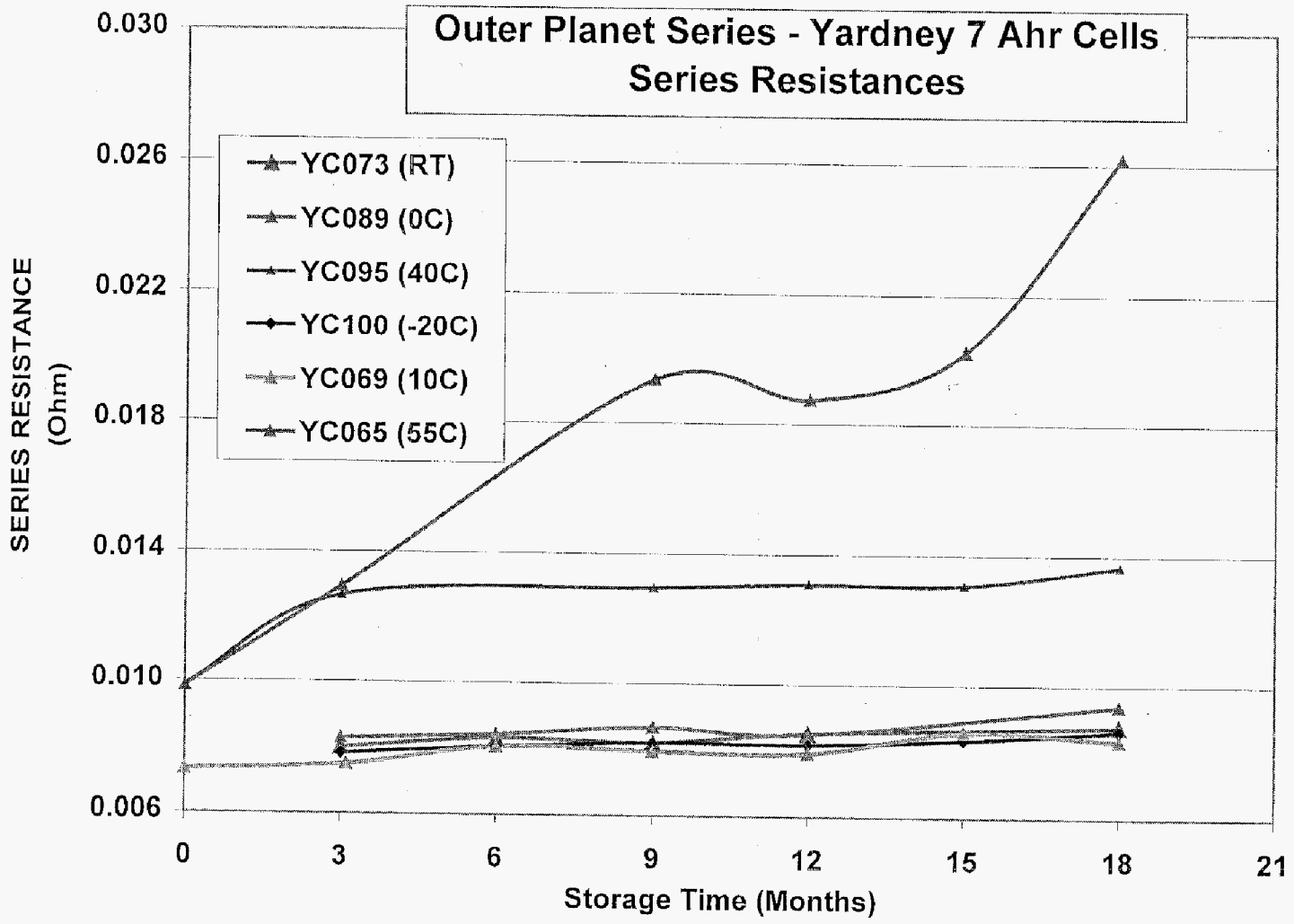
SAFT 9 Ahr Li-Ion Cells
Nyquist Plots At Various Temperatures
Storage Temperature = 0°C



SAFT 9 Ahr Li-Ion Cells
Nyquist Plots At Various Temperatures
Storage Temperature = 55°C

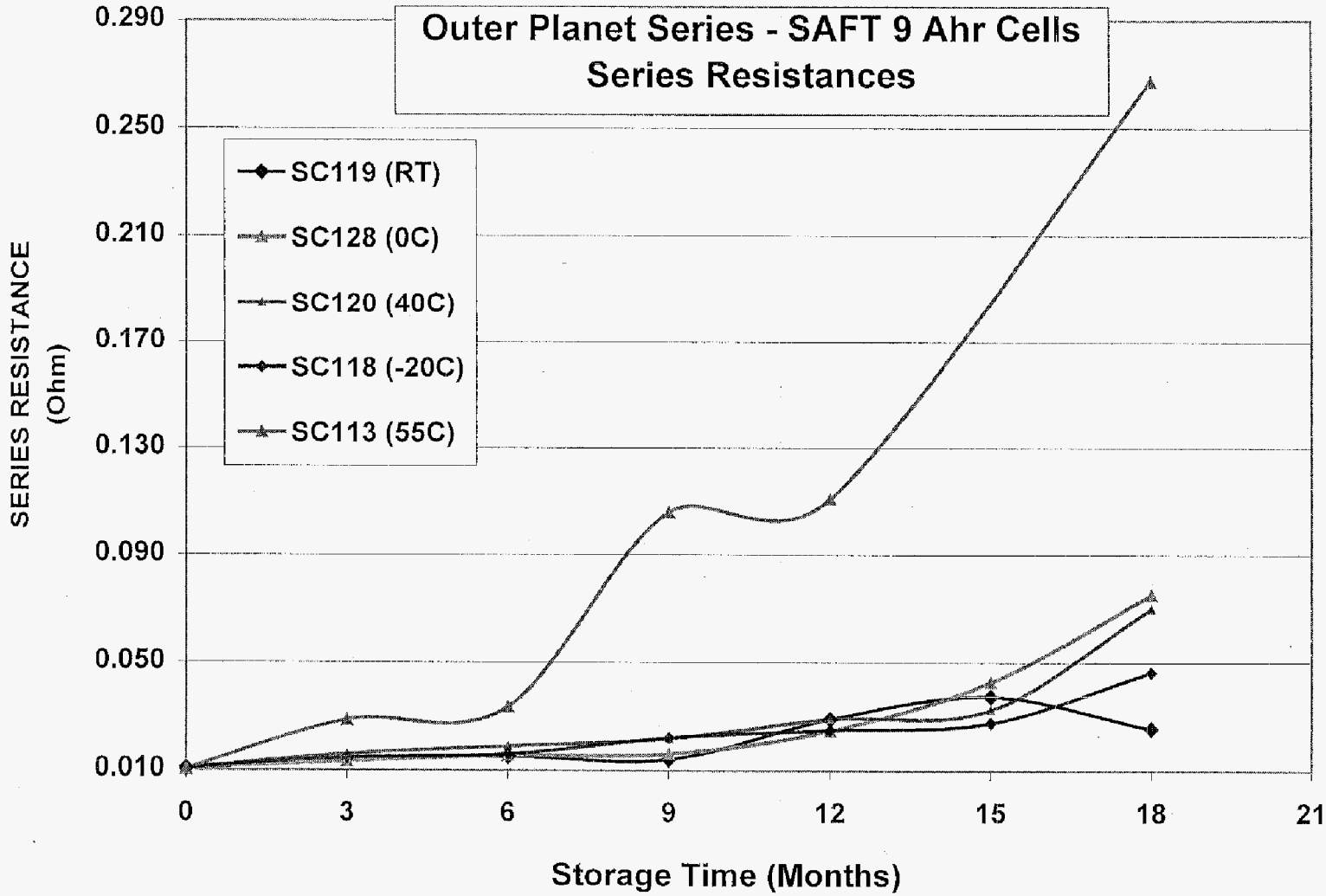


Yardney 7 Ahr Li-Ion Cells
Series Resistance At Various Temperatures



SAFT 9 Ahr Li-Ion Cells

Series Resistance At Various Temperatures



Summary

- Excellent capacity retention during on-buss storage has so far been exhibited by both Yardney and SAFT prototype cells.
  - Capacity loss less than 5 % after 2 years of storage at low temperatures (T = ~0°C).
  - Capacity loss expectedly increases with storage temperature and is more noticeable during discharges at low temperatures.
- Consistent with the capacity changes, the EIS characteristics (Series Resistance) are relatively unchanged during low temperature storage, but increase at high storage temperature.
  - SAFT cells with case-negative design show higher series resistance.
- Lithium ion cell chemistry appears promising thus far for NASA's future mission to outer planets.

Test On-Going . . .

Acknowledgement

The work described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration and was supported by the OPSP Program (Outer Planets-Solar Probe) and NASA Code S Battery program.