# STATUS OF SPV/CPV TESTING

NAVAL SEA SYSTEMS COMMAND

NSWC

Naval Surface Warfare Center

CRANE DIVISION

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1998 NASA AEROSPACE BATTERY
WORKSHOP
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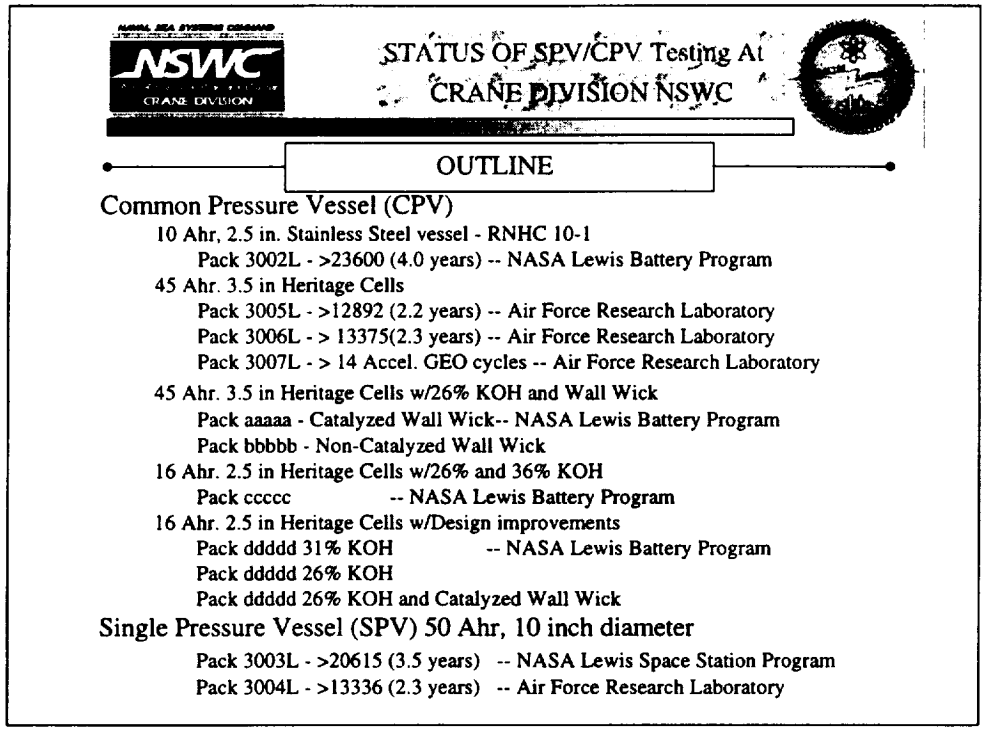
Introduction Slide.



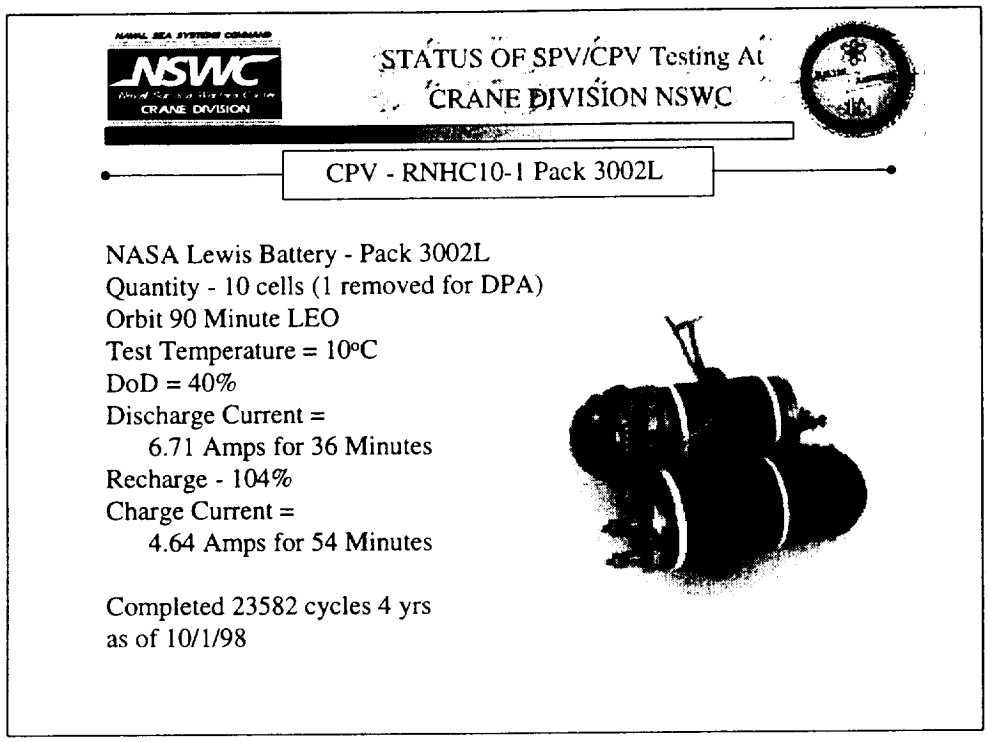

This slide summarizes the SPV and CPV test that are on going or planned at Crane.

The SPV's will be covered in detail. Both NASA and Air Force have a battery under test.

The CPV's 2.5 in RNHC 10-1 design is a part of NASA Lewis CPV Technology program.

The 45 Ahr. 3.5 in Heritage cells were purchased by Air Force as a commercial procurement without a government spec. These tests are also a part of a NASA/ Air Force Joint program to evaluate CPV designs.

The remaining tests are planned. These cells evaluate the Design improvements that NASA has been evaluating on IPV cells. One group 16 Ahrs also includes design improvements incorporated by the manufacturer EP.



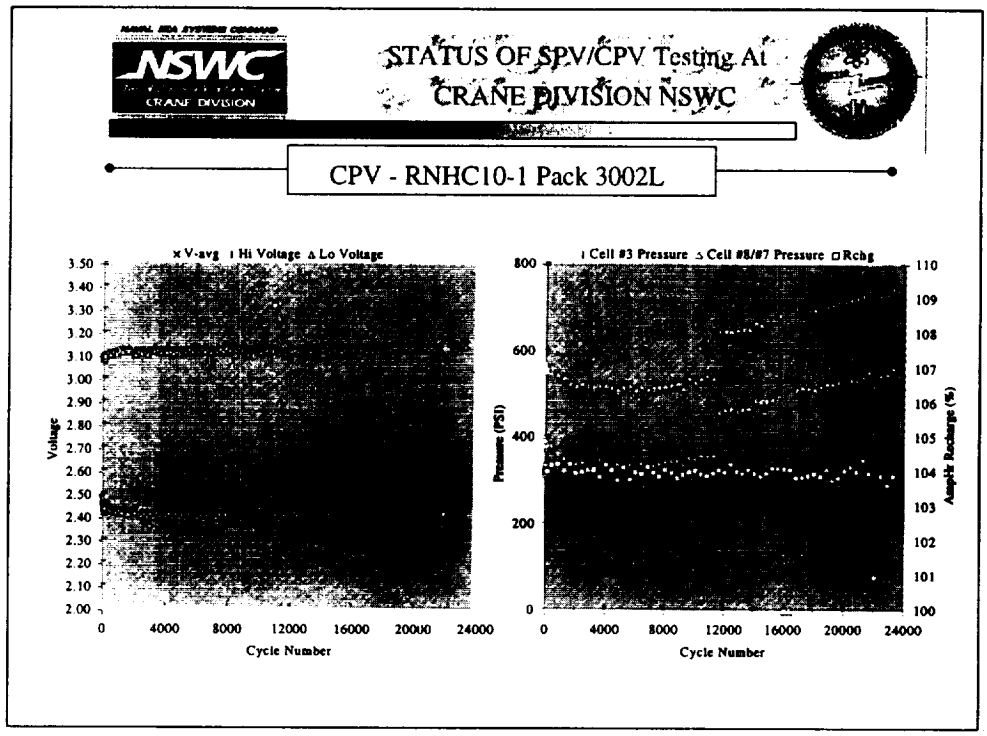

This Pack has completed 4 yrs of cycling under a LEO regime.

At 2 yrs one cell was removed and subjected to DPA. No anomalies were found.

Picture and cell design to be included..

This test sponsored by NASA Lewis CPV Technology Program.

POC Mr. Tom Miller




Life cycle voltage and pressure trend plot for Pack 3002L.

There has been little change in the end of discharge and charge voltages of the cells over the 23500 cycles. The change in pressure is due to a change in the measuring strain gage. Cell 8 (original pressure measurement) was removed for DPA. The step increase in the pressure curve occurred when Cell 7 replaced Cell 8 in recording data.

This test sponsored by NASA Lewis CPV Technology Program.

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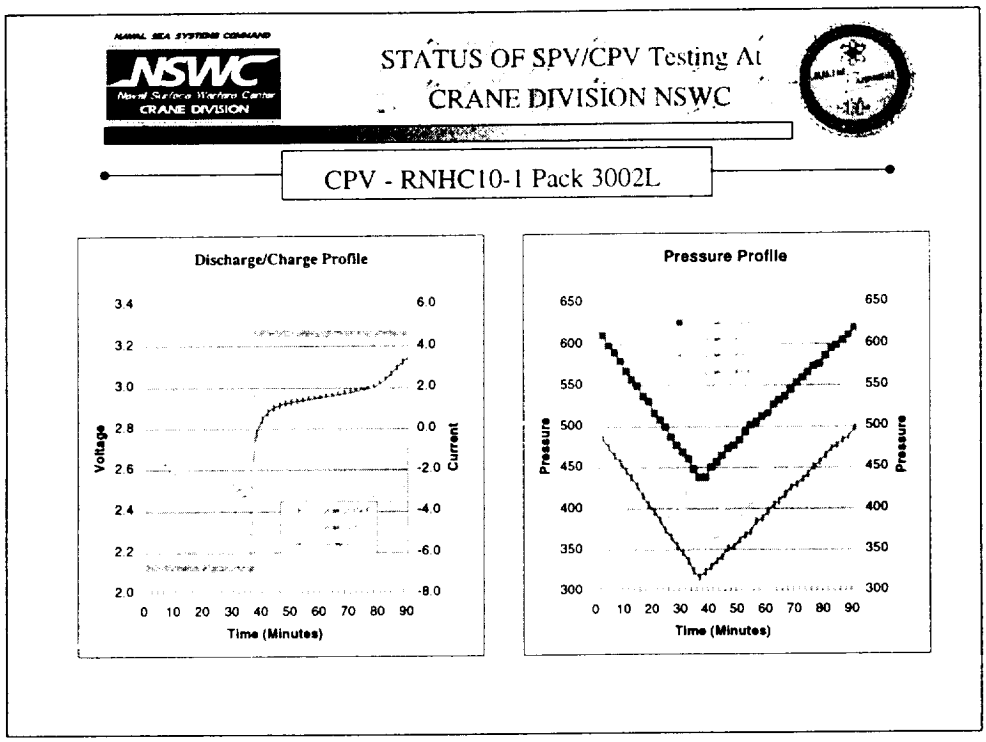


Voltage and Pressure Plot of cycle 500 and 23500. NOTE there is no significant change in the discharge/charge curve and no change in the end of discharge voltage. One would expect a drop in the EOD voltage with life. The Pressure plot is normal in that pressure decreases initially then increases with cycling.

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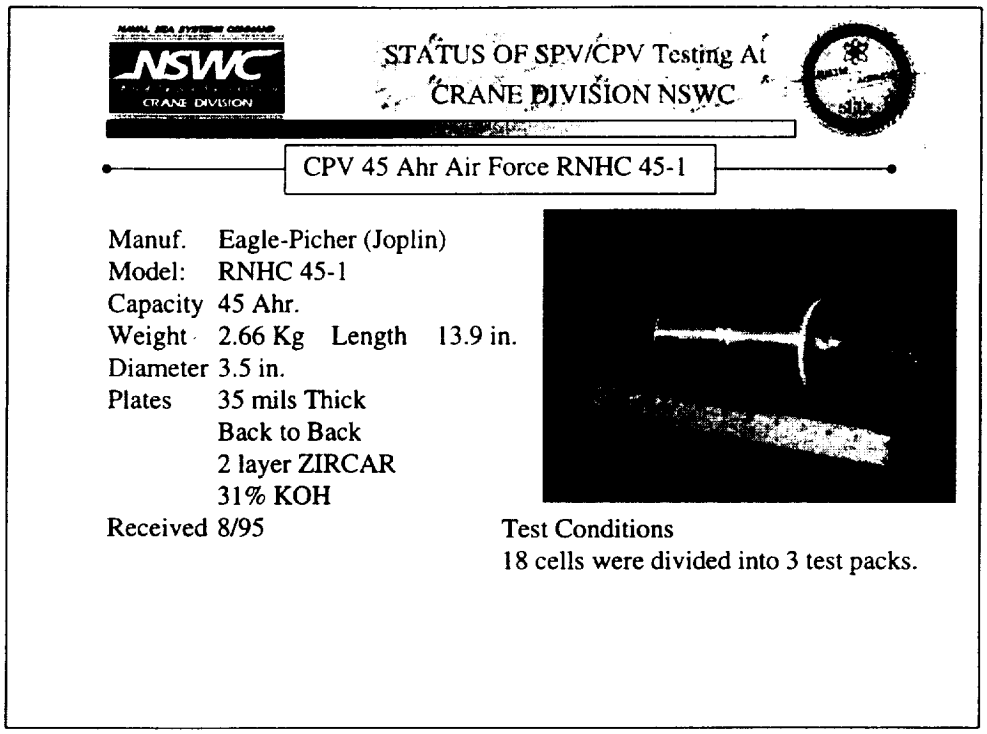
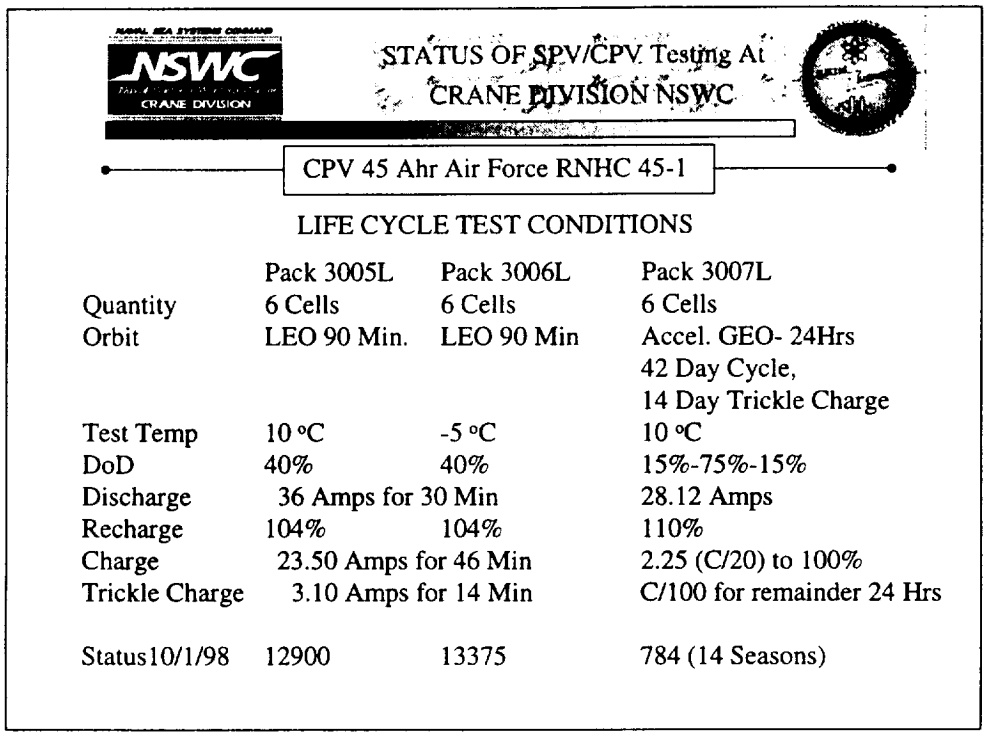



The design parameters for the CPV cells was taken from Eagle-Picher commercial specification.

This test sponsored by Air Force Research Laboratory.
POC Mr. Ralph James, Dan Radzykewycz.
Technical Direction: The Aerospace Corporation
POC Ms. Carole Hill




The cells are being subjected to conditions shown. The LEO Packs have completed over 2 years of test with no anomalies. The GEO pack has completed 14 accelerated seasons.

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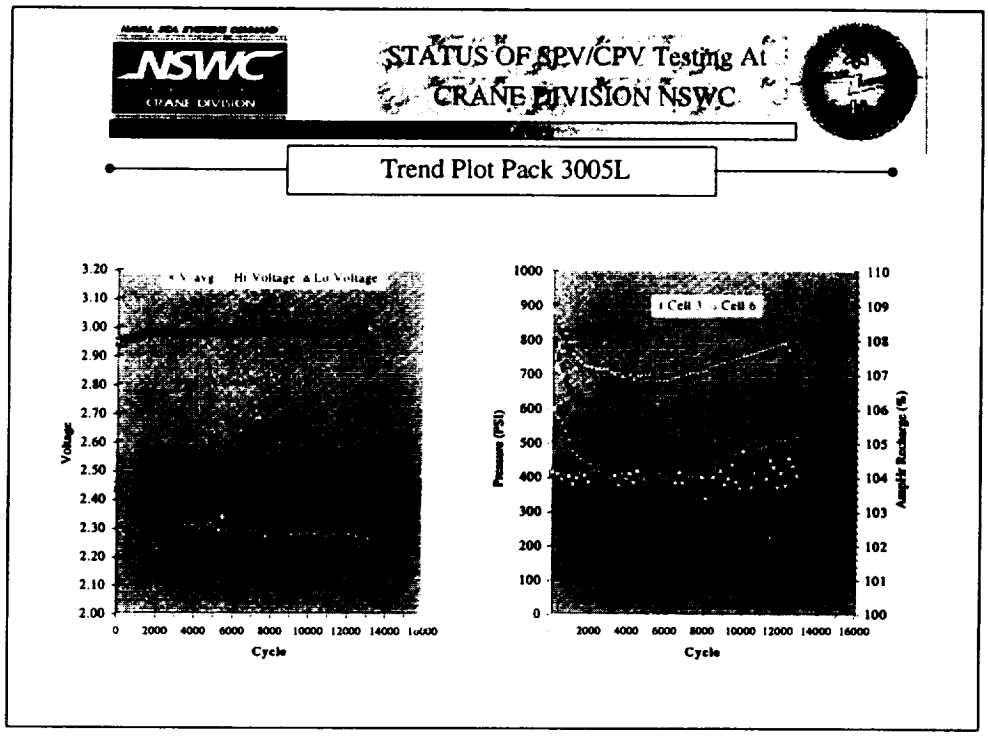


Life cycle voltage trend plot of Pack 3005L.

Life Cycle Pressure and Recharge Trend plot of Pack 3005L

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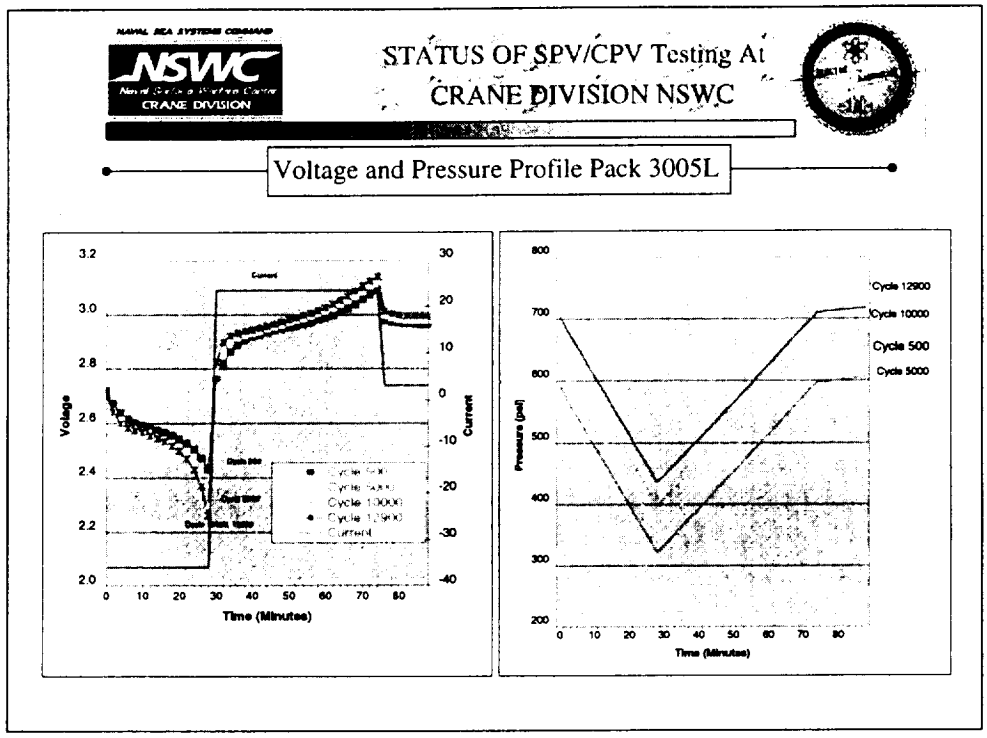


Typical discharge/charge cycle for Pack 3005L.

Typical pressure cycle for Pack 3005L

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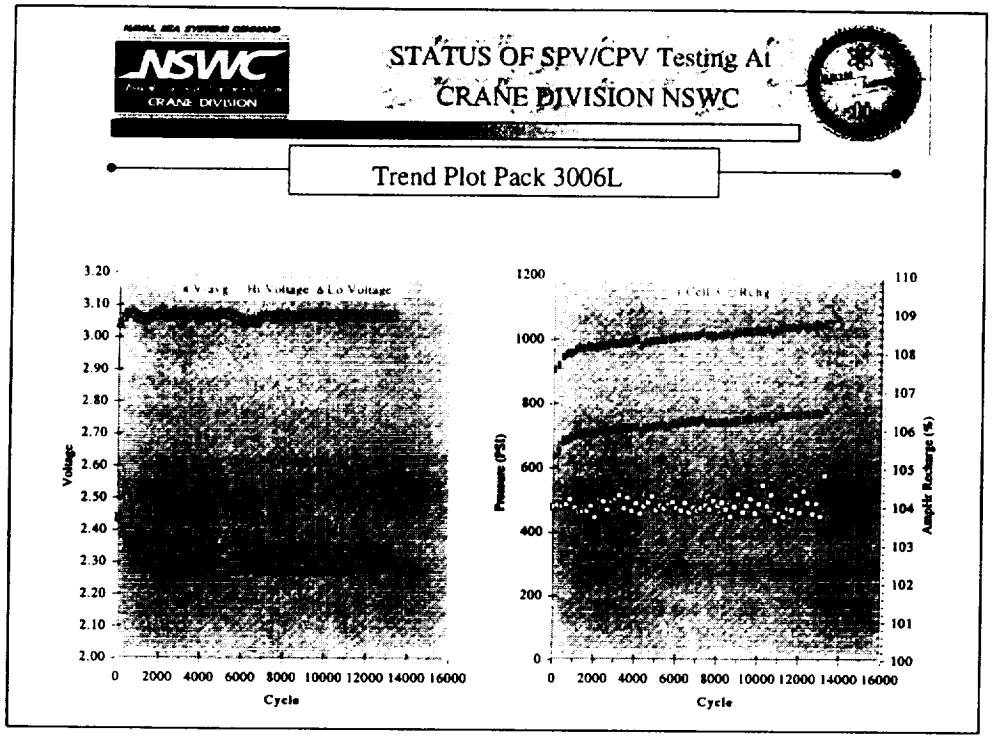


Life Cycle voltage trend plot of Pack 3006L. The pressure curve for this pack is different from that of Pack 3005L. The only difference between the two packs is the temperatue. Pack 3006L is tested at -5C.

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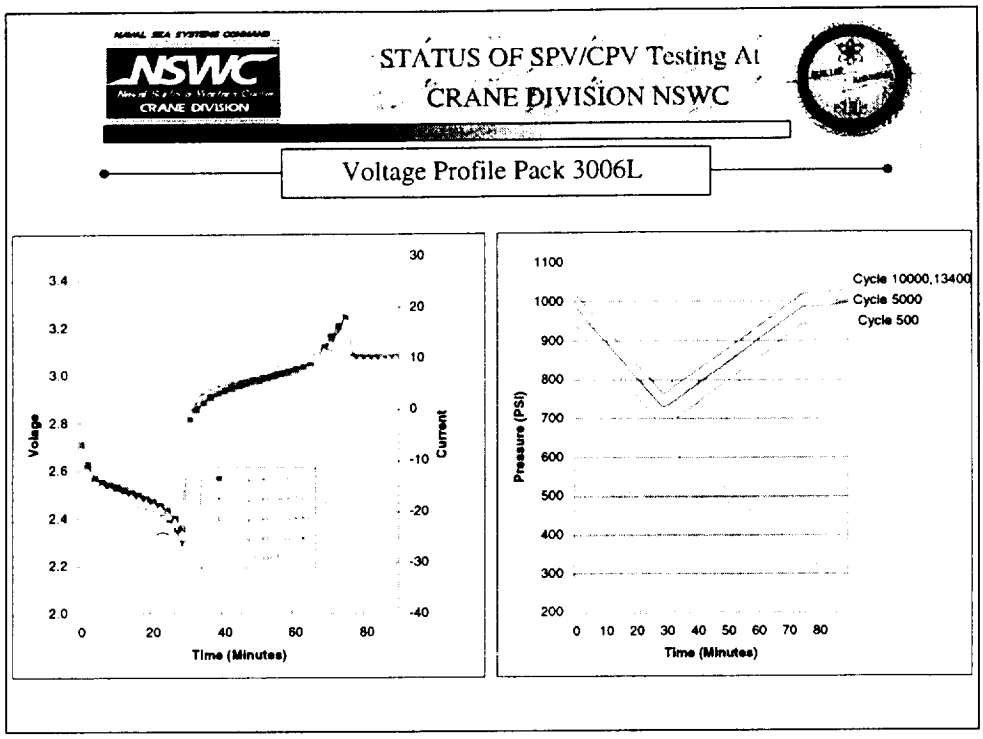


Typical discharge/charge curve for Pack 3006L

Typical pressure plot for Pack 3006L. This pack does not exhibit the characteristic pressure profile decrease from 500 to 5000 then increase for the remainder of life.

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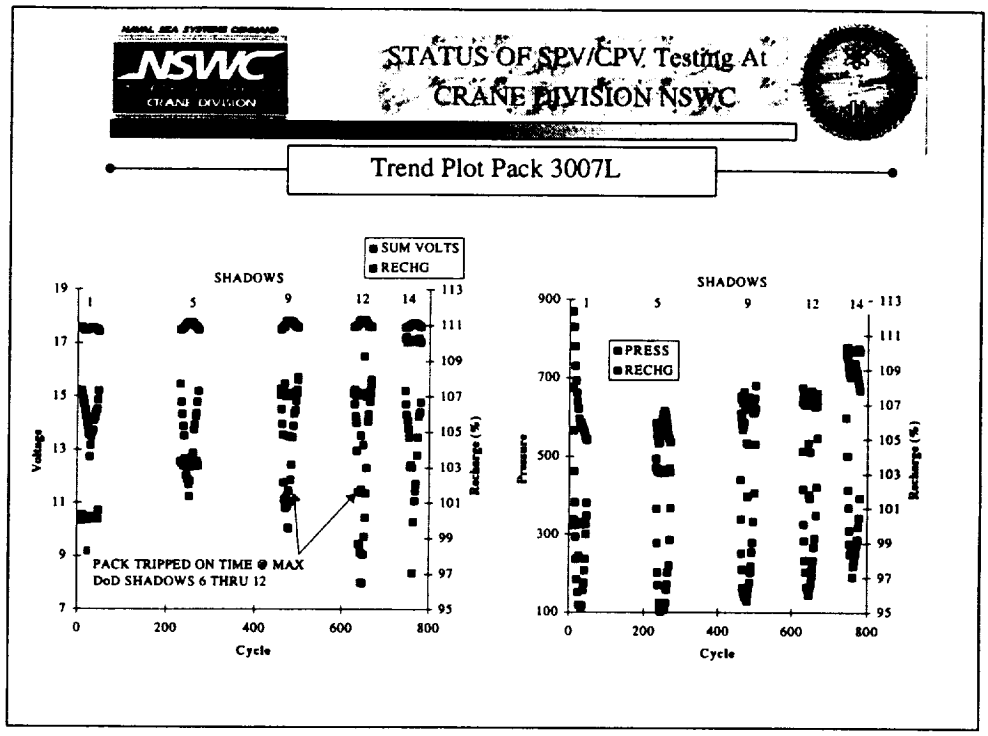


Life Cycle Trend plot for Pack 3007L. The curves represent the discharge during the shadow period from 15% to 75% to 15% DoD.

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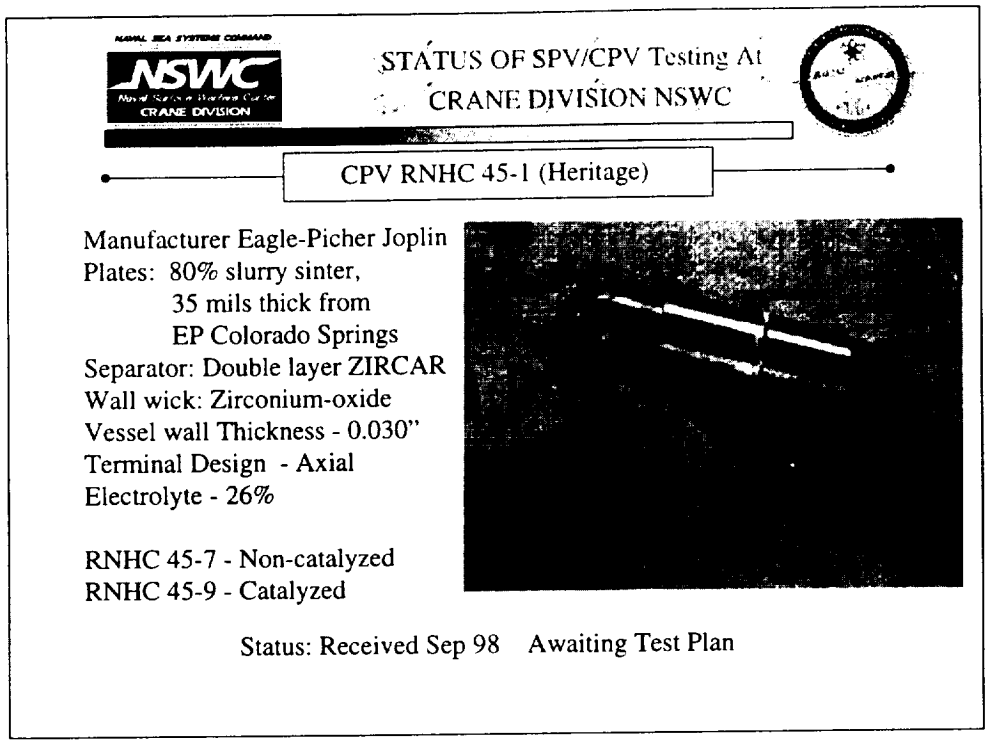


Design parameters for RNHC 45-7 and 9 cells. The RNHC 45-1 Heritage design is the design previously shown in test as Packs 3005L, 3006L, and 3007L.

This test sponsored by NASA Lewis CPV Technology Program.

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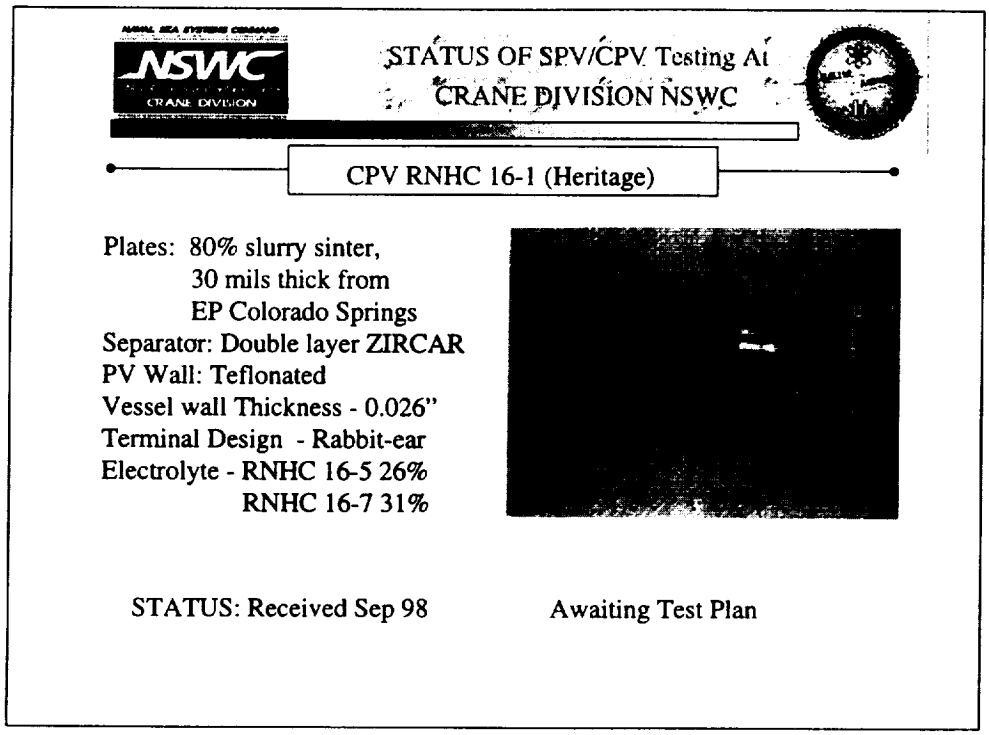


This test will evaluate the RNHC 16-1 design with modification of the electrolyte concentration to evaluate using 26% KOH in the cell.

This test sponsored by NASA Lewis CPV Technology Program.

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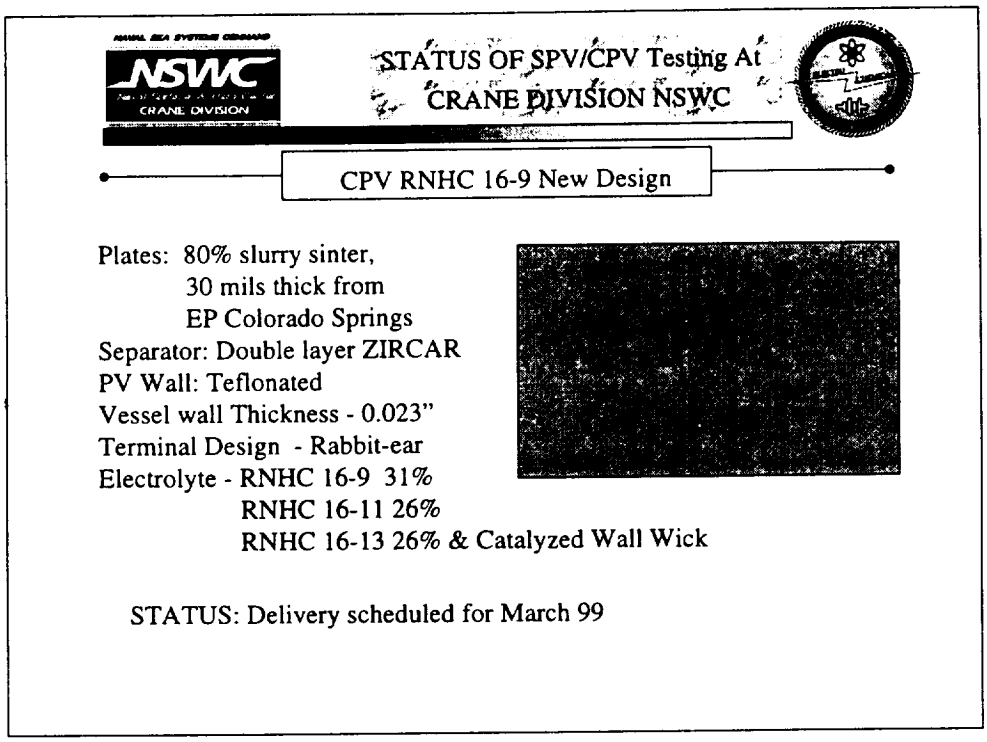


This test will evaluate design changes incorporated by the manufacturer and NASA improvements - 26% KOH and catalyzed wall wick

There are several design changes in the RNHC 16-9 cell. These include:

Incorporation of the fill tube in the positive terminal.

$ZrO_2$ coating of the CPV wall

Geometry change in the pressure vessel (Hydroformed/Spherical to Deep Drawn/Torospherical.

Other changes that may be proprietary to EP. Contact EP for details.

This test sponsored by NASA Lewis CPV Technology Program.
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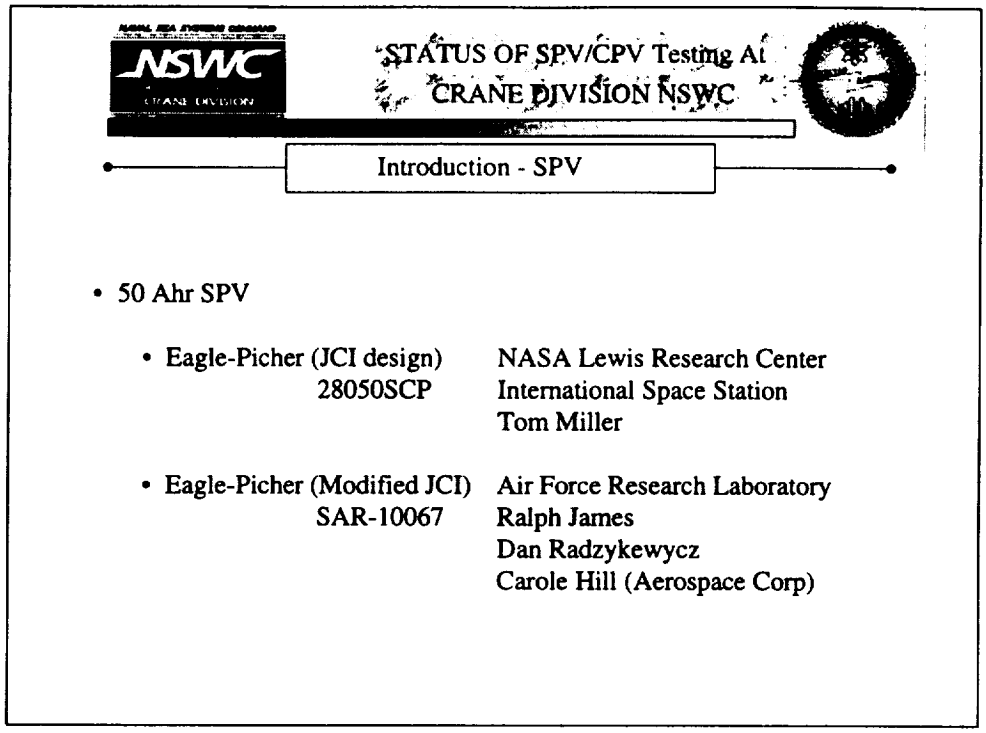
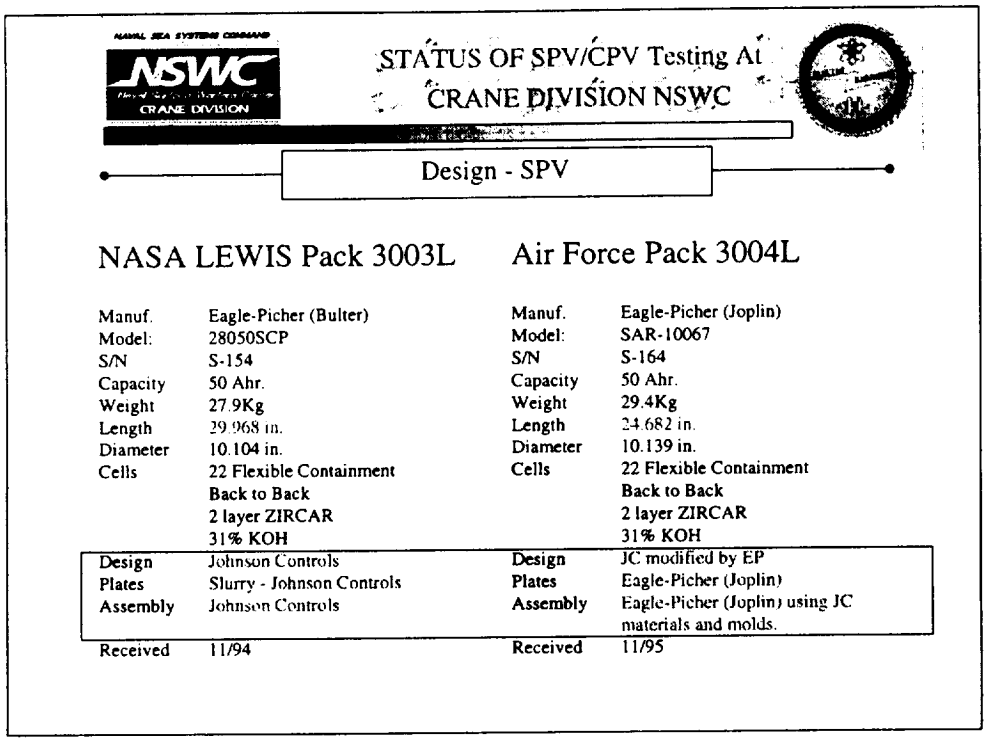


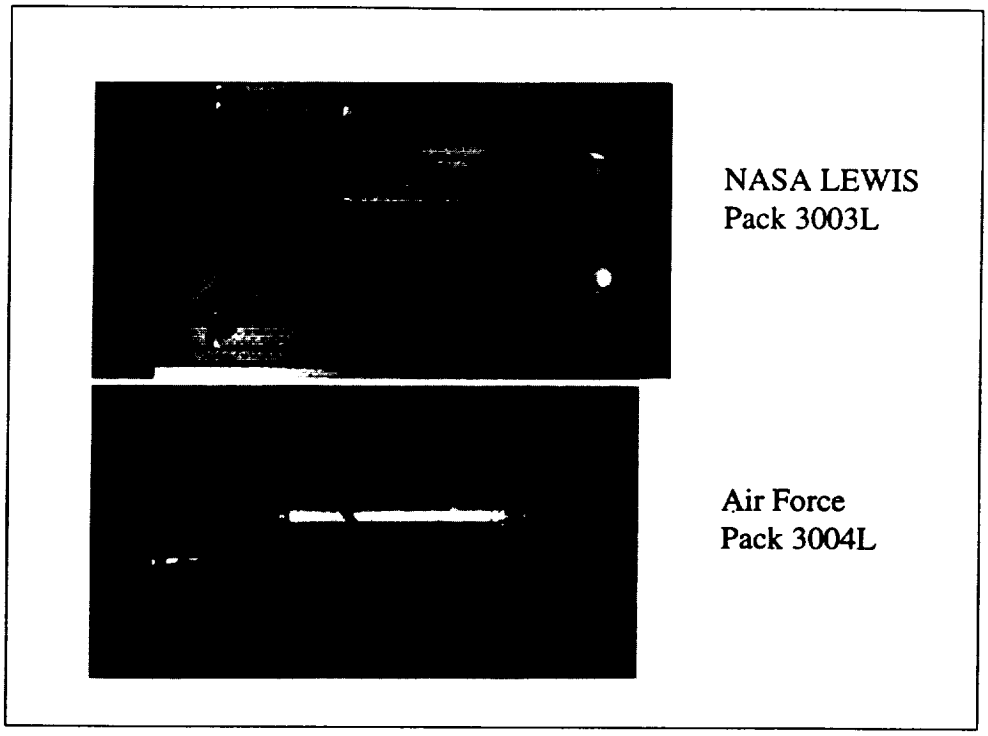

Eagle-Picher (JCI Design) - This battery is completely a Johnson Controls Industry (JCI) design, manufactured, assembled, and tested at the JCI facility in Butler, WI. The battery was delivered in Nov 1994. This was after EP purchased the facility.

Eagle-Picher (Modified JCI) - This battery was contracted from EP in 1994 before the move from Butler. The battery was originally bid as the JCI design, but in Jan 95 EP moved the facility from Butler, WI to Joplin, MO. Parts for the battery had been manufactured at Butler but the battery had not been assembled. The plate handling during the move was suspect. Thus EP manufactured new plates using the EP process at Joplin and modified the battery size.

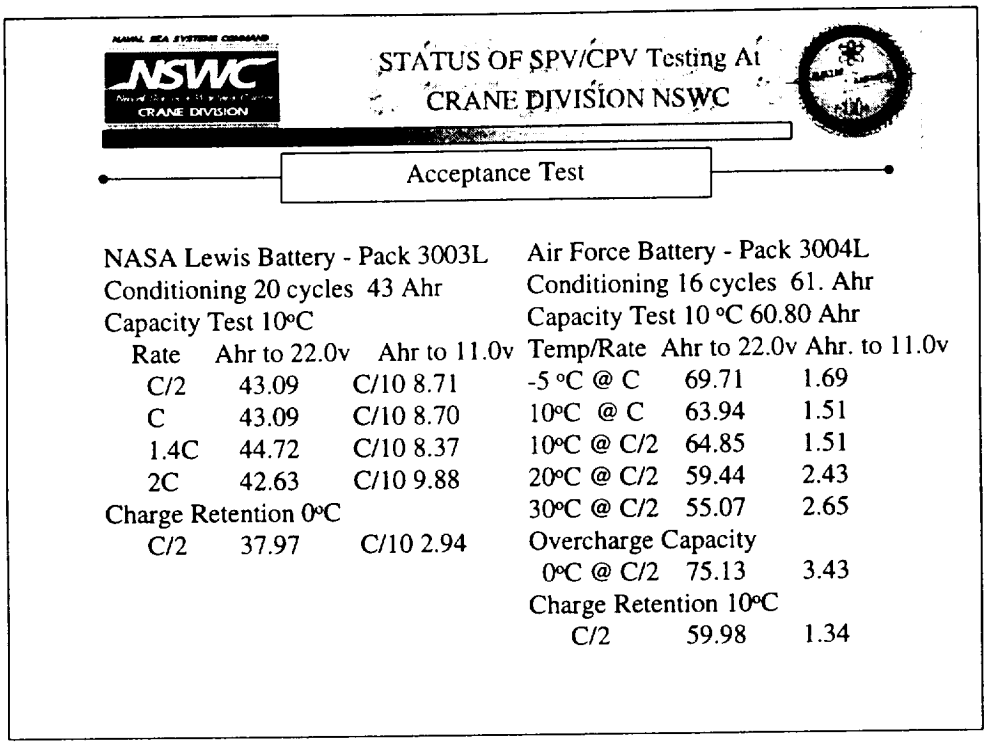



The differences in the design are shown in this slide. The AF battery is about 5 inches shorter and the plates were manufactured at Joplin. The assembly was at Joplin facility using the JCI materials and molds.

The design modification (shorter) reflect changes implemented in the commercial contract.

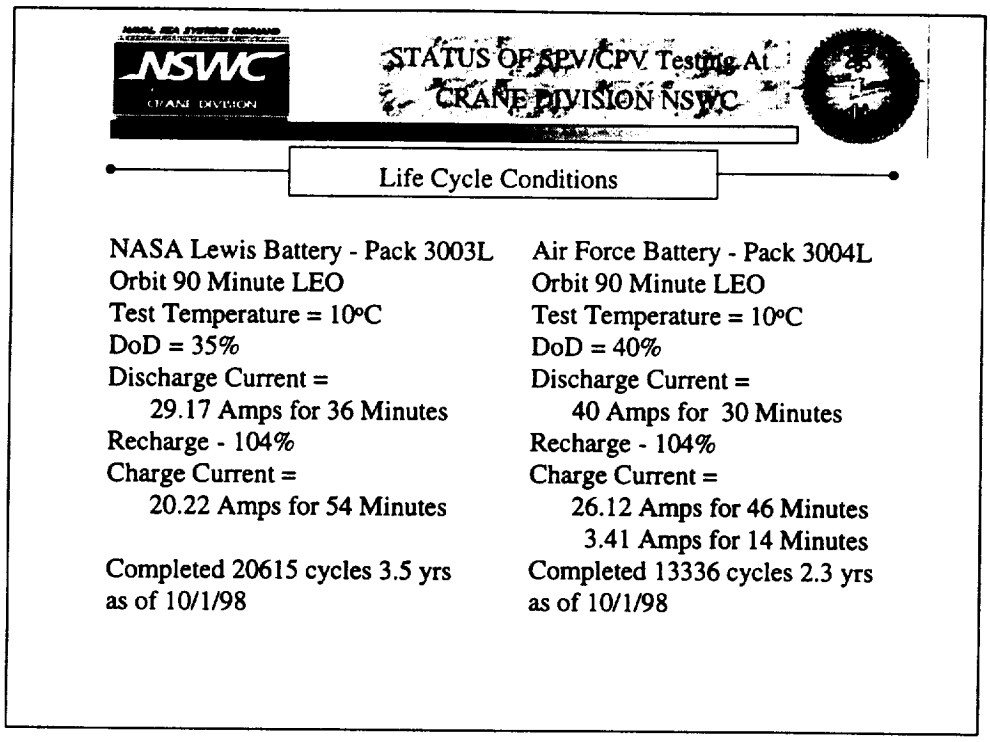



The differences in the design are shown in this slide. The EP design is about 5 inches shorter and the plates are manufactured at Joplin. The assembly was at Joplin facility using the JC materials and molds.




Pack 3003L - After 20 conditioning cycles the battery delivered on 43 Ahr. This was less then at the manufacturer's acceptance test. The battery had provided 54.6 Ahr. After some discussion it was decided to go ahead and test the battery.

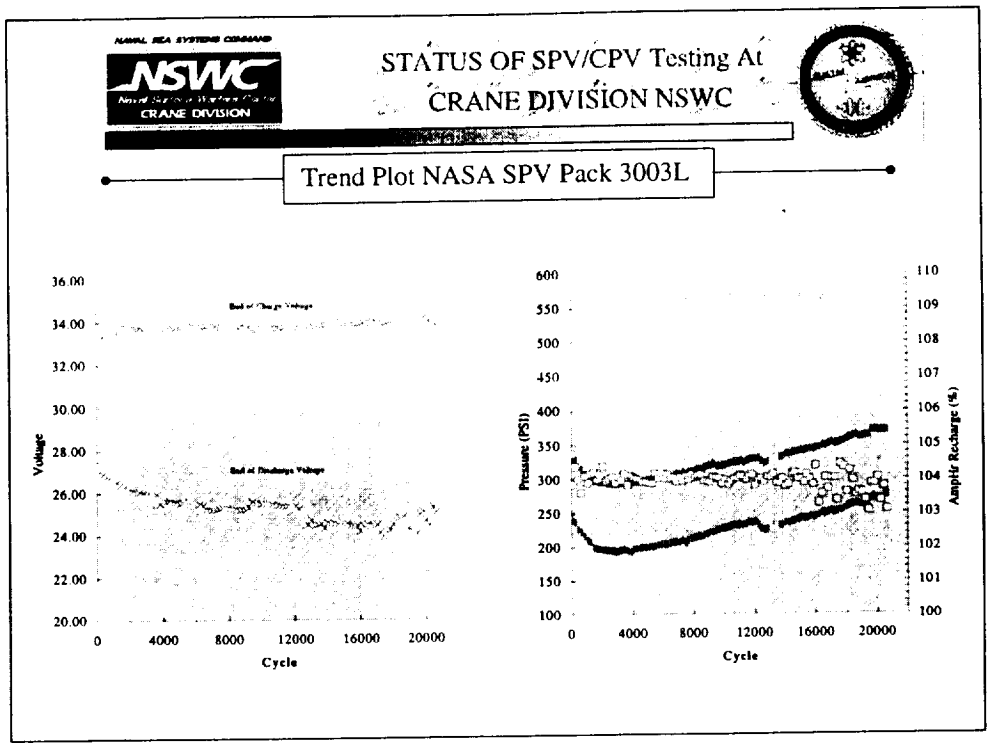
Pack 3004L - This battery gave no problems during acceptance tests.




The Life Cycle test conditions are shown above.

The batteries although on slightly different regimes can be compared.

In terms of life the batteries are cycling 1 year apart.




Trend Plot of Voltage vs Cycle for Pack 3003L.

The top line is the End-of-Charge (EOC) voltage.

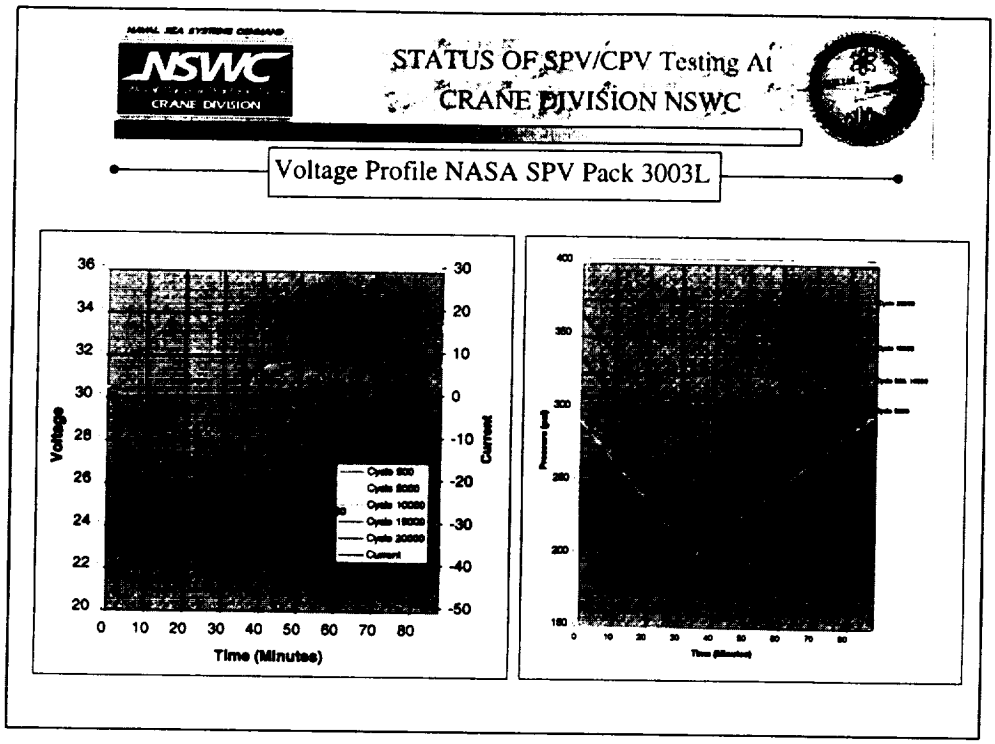
The bottom line is the End-of-Discharge (EOD) voltage

At 26 volts EOD = 1.18 v/cell

At 34 volts EOC = 1.54 v/cell

Trend Plot of Pressure and Recharge vs Cycle for Pack 3003L.

The lower % Recharge may have caused the lower difference in EOD note in previous slide around 20000.




If the curves are not in color: The lowest EOD curve is cycles 20000 and 15000.

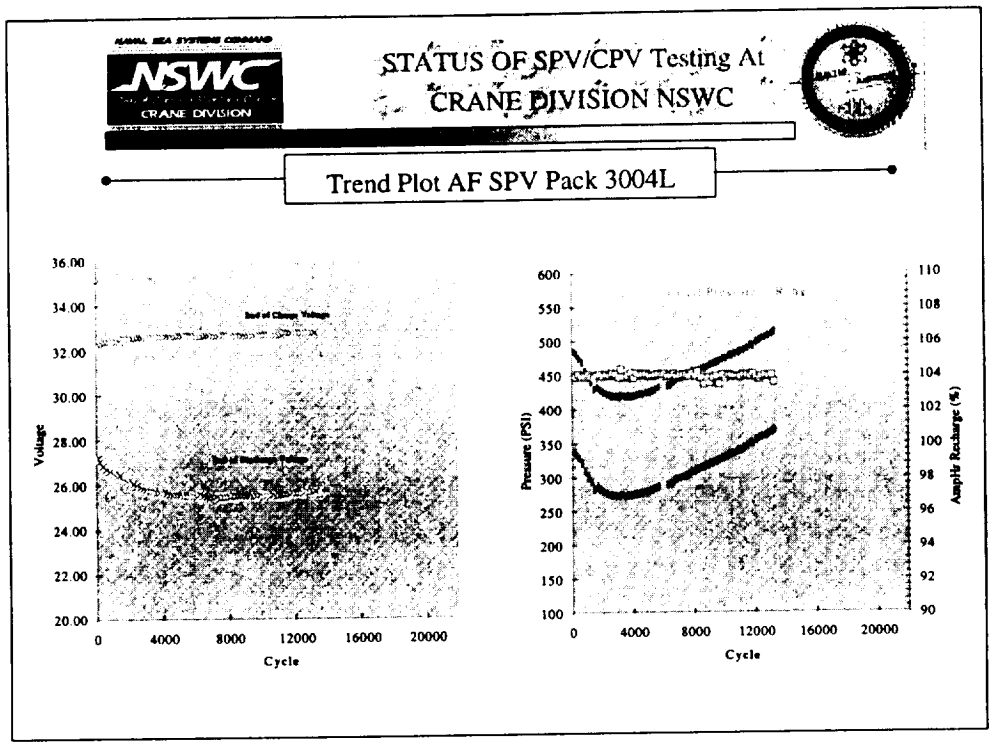
Cycles 5000 and 10000 are in the middle, and cycle 500 is the top curve.

Note that the as the EOD is lower, EOC increases.

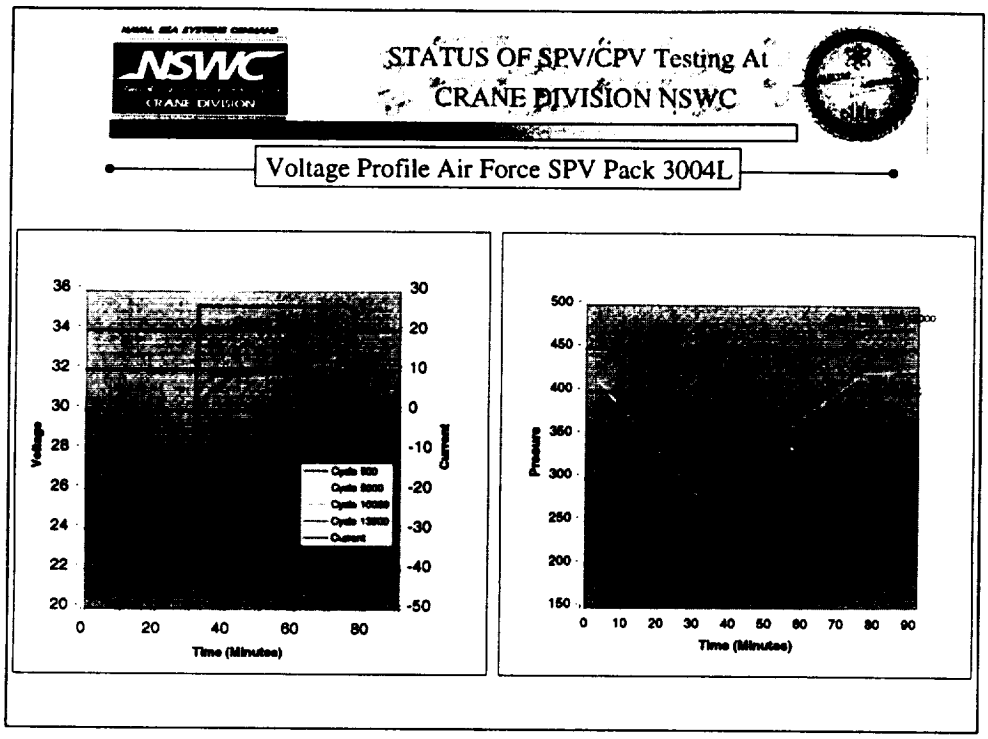
| Cycle | EOD | EOC |
|---|---|---|
| 500 | 26.86 | 33.43 |
| 5000 | | |
| 10000 | 25.42 | 33.67 |
| 15000 | | |
| 20000 | 24.77 | 33.99 |

Pressure change is very consistent. The pressure changes in the first 500 cycles. The curves remain linear. If Pressure is used as a state of charge, a recalibration must be done overtime.

| Cycle | EOC | EDO |
|---|---|---|
| 500 | 314 | 227 |
| 5000 | 292 | 200 |
| 10000 | 314 | 227 |
| 15000 | 335 | 241 |
| 20000 | 365 | 271 |




Voltage, Pressure and % Recharge Trend Plot for PACK 3004L




Voltage Profile for Cycles 500, 5000,10000, and 13000

Cycle 500 EOD = 26.82 EOC High Rate = 33.44 Trickle = 32.31

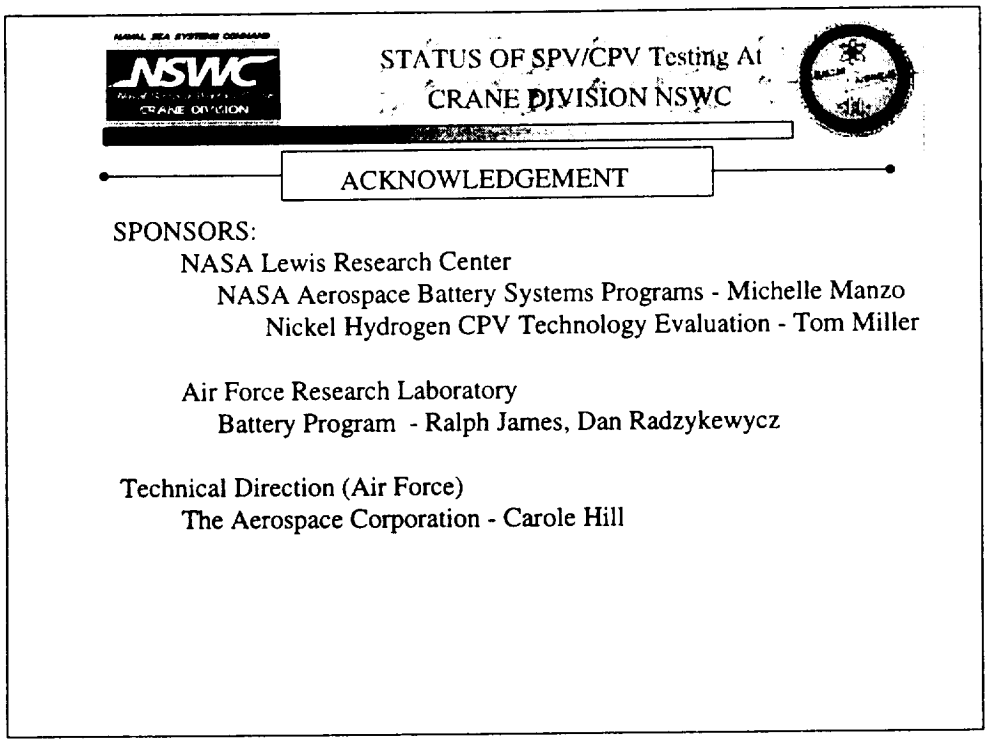
Cycle 13000 EOD = 25.47 EOC High Rate = 33.90 Trickle = 32.61

Pressure Profiles for the cycles

Cycles 500, 10000 and 13000 are the upper curve

Cycle 5000 is the lower curve

| Cycle | EOD | EOC |
|---|---|---|
| 500 | 329 | 464 |
| 5000 | 280 | 405 |
| 10000 | 329 | 464 |
| 15000 | 329 | 464 |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