"Clean Energy Storage for Grid Load Leveling"
The Metlakatla Battery Energy Storage System
Twelve Years Of Success

IRENA CONFERENCE

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PORT VILA

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The Metlakatla Community

- Island community at the southern tip of Alaska about 20 miles from Ketchikan and 575 miles from Seattle
- Home to about 1,000 residents plus a commercial cold storage cannery facility and a lumber mill
- Primary electrical service is provided by two rain-fed hydro units generating 4.9MW
- System frequently encountered brown-outs, overvoltage and frequency fluctuation in responding to demand on the grid

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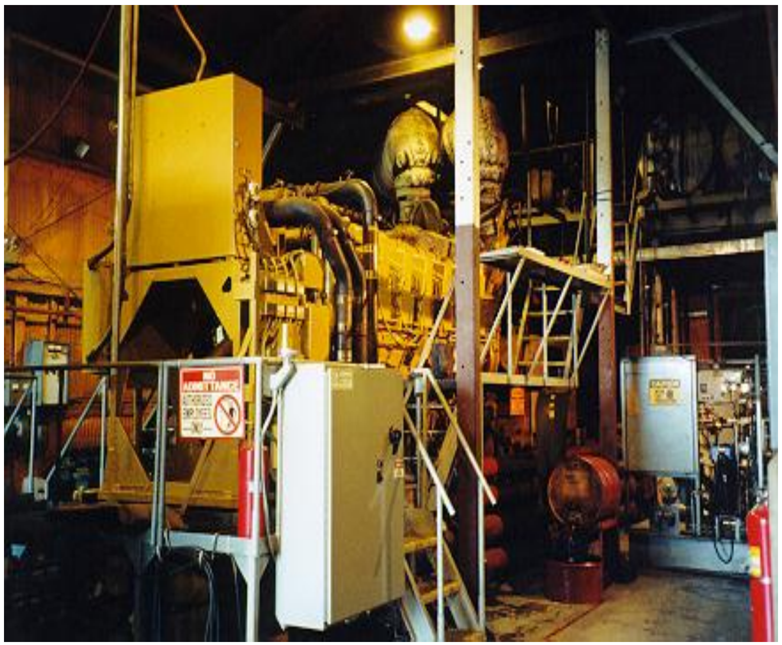
MP&L's Solution



- MP&L installed a $2 million, 3.3-MW diesel generator
- Operated diesel at 80% capacity to handle load swings and for overall efficiency
- Caused shift of 55% of system load to the diesel
- Fuel usage increased to 475,000 gallons / year in 1996 at a cost of $400,000 with oil at $19 a barrel
- Still system problems persisted

The BESS Solution

- GNB / GE/ Sandia study concluded that a BESS could solve MP&L's problems
- BESS has a nominal load rating of 800 kVA continuous with a peak capability of 1,200 kVA
- BESS connects to the MP&L system at the 12.47-kV switchyard
- A 40 x 70 foot Butler building houses the battery, power conditioning equipment and BESS control room with space for a second battery set
- The entire system was built using readily available commercial industrial equipment

Presentation Outline

- Economic / Environmental Benefit Of BESS
  - Operational Costs Without The BESS
  - Operational Costs With The BESS
  - Reduction Of Carbon Dioxide Emissions
- Achievements Of The ABSOLYTE® BESS Battery
  - Battery Configuration And Operational History
  - Performance Testing Of Field-Aged BESS Cells
  - Examination And Analysis Of Cell Materials And Components
  - Ageing Effects Estimates
- Summary / Conclusions

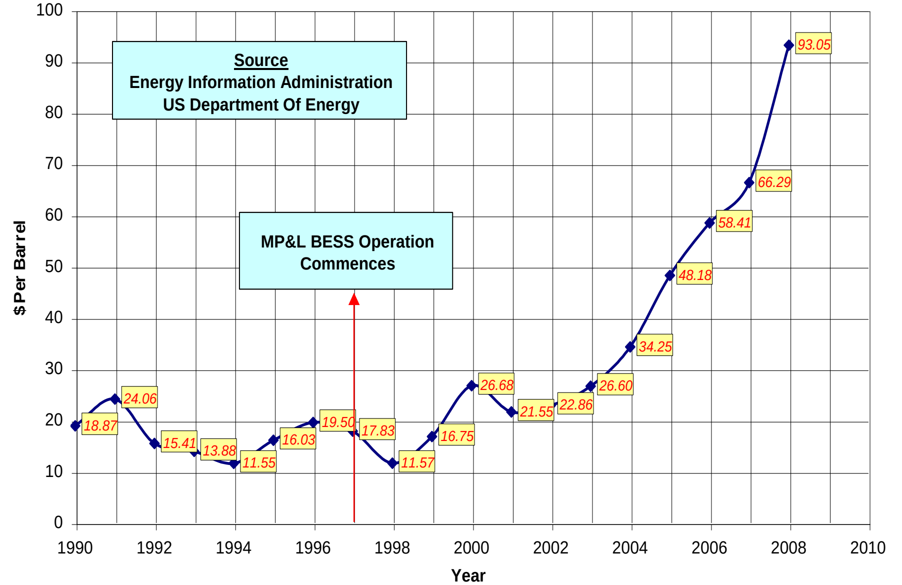
MP&L BESS - Purpose

The purpose of this installation was to stabilize the island community's utility power grid providing instantaneous power into the grid when demand was high from local industry, and to absorb excess power from the grid to allow its hydroelectric generating units to operate under steady-state conditions

MP&L BESS - Economic Benefit Analysis

Analysis Parameters

- Diesel fuel usage remains constant at 1996 level, 475,000 gals/year without BESS
- Diesel use with BESS at 50 gals/hr and 15 days per year
- Base fuel price based on annual spot market average
- Differential between spot market and actual delivered price held constant at 37¢/gal *(1996 level)*
- Diesel Overhaul (1997–2008):
  - 4 minor / 2 major without BESS
  - 2 minor 1 major with BESS
- Battery Replacement with BESS



Average annual spot market price for oil ($/barrel) from DOE data

MP&L BESS - Economic Benefit Analysis

Year	Oil ($/Barrel)	Fuel Cost w/o BESS	Fuel Cost with BESS
1997 from Feb	$17.83	$185,287	$7,004
1998	$11.57	$131,179	$4,959
1999	$16.75	$189,917	$7,179
2000	$26.68	$302,528	$11,436
2001	$21.55	$244,383	$9,238
2002	$22.86	$259,202	$9,798
2003	$26.60	$301,549	$11,399
2004	$34.25	$388,364	$14,680
2005	$48.18	$546,311	$20,651
2006	$58.41	$662,262	$25,034
2007	$66.29	$751,622	$28,411
2008 to Sept	$106.02	$901,528	$34,078
Total		***$4,864,133***	***$183,865***

Assuming constant usage at 475,000 gals/year without BESS, and 50 gals/hr for 15 days/year with BESS

Fuel oil costs at spot market prices for crude oil based on DOE data

MP&L BESS - Economic Benefit Analysis

	Operating Cost w/o BESS	Operating Cost with BESS
Fuel Oil At Spot Market Prices	$4,864,133	$183,865
Surcharge To Deliver Fuel To Island	$2,038,700	$78,000
Diesel Maintenance	$1,100,000	$400,000
Battery Replacement	N/A	$681,890*
Diesel Operation During Battery Change out	N/A	$20,875
Total Operating Cost (1997 – 2008)	***$8,002,833***	***$1,364,630***

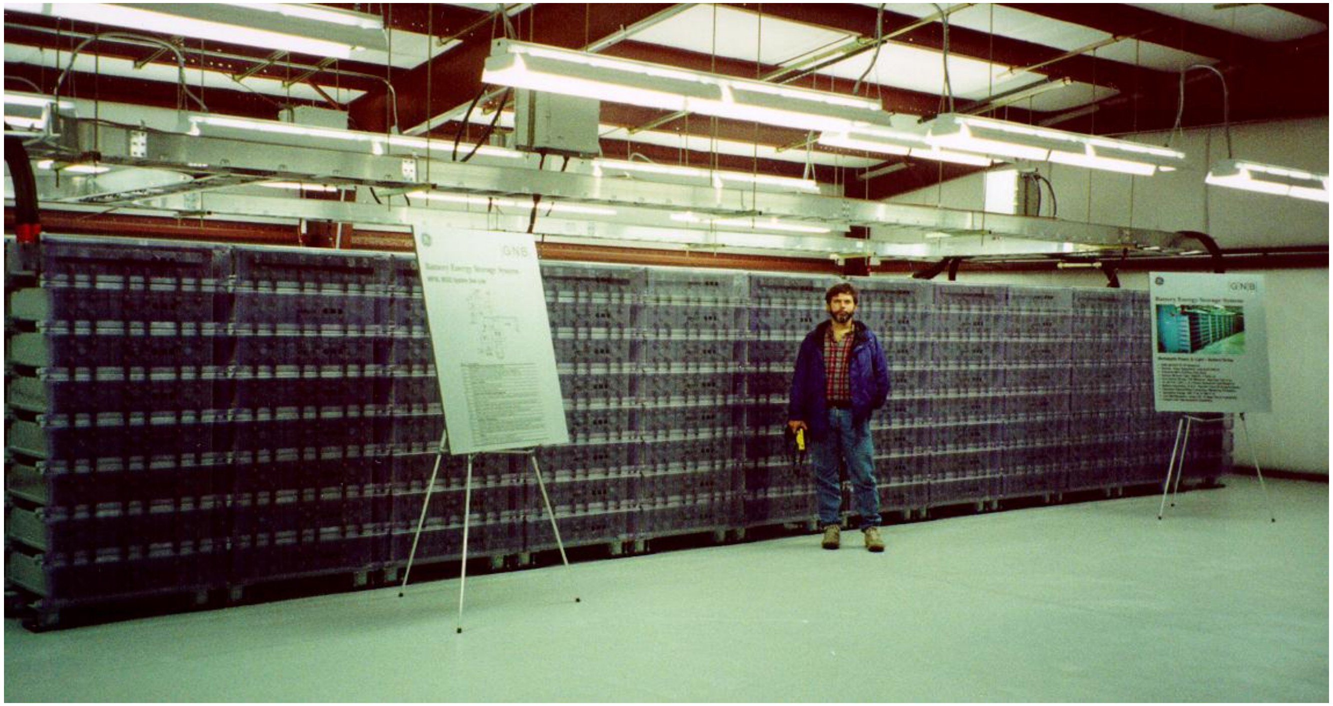
** Includes Shipping, Removal / Installation Labor, Recycling*

Total Cost Savings = $6,638,203

MP&L BESS - Environmental Benefits

- Reduced Fuel Oil Consumption
  - From 475,000 Gallons to 18,000 Gallons Per Year
  - Saved 5.3 Million Gallons Since BESS Was Installed
- Reduced Carbon Footprint
  - From 5,272 Tons of CO_2 to 200 Tons of CO_2
  - Saved 58,843 Tons of CO_2 Since BESS Was Installed
  - Possible Income By Selling Carbon Offsets?
- Reduced Noise
  - Diesel Was Noisy / Battery Electrons Are Quiet
- Reduced Risk For Environmental Catastrophe From Oil Spills

The Battery – The Heart Of The BESS



- The Battery Consists of 378 GNB ABSOLYTE IIP Valve-Regulated Lead-Acid 100A75 Modules
- Nominal 756-volt, 3,600-Ah at C/8 Rating
- System Rating: 1.4MWH at 1.0MW (approx 90 minutes)

The Battery – Questions?

- How Do You Operate The Battery?
- Will The Battery Lose Capacity In Operations?
- How Often Will The Battery Need To Be Fully Recharged?
- Will The Battery Suffer Permanent Degradation?
- Will The Battery Require Excessive Maintenance?
- Is The VRLA Battery The Best Choice?
- Will The Battery Survive For 8+ Years In The Application?

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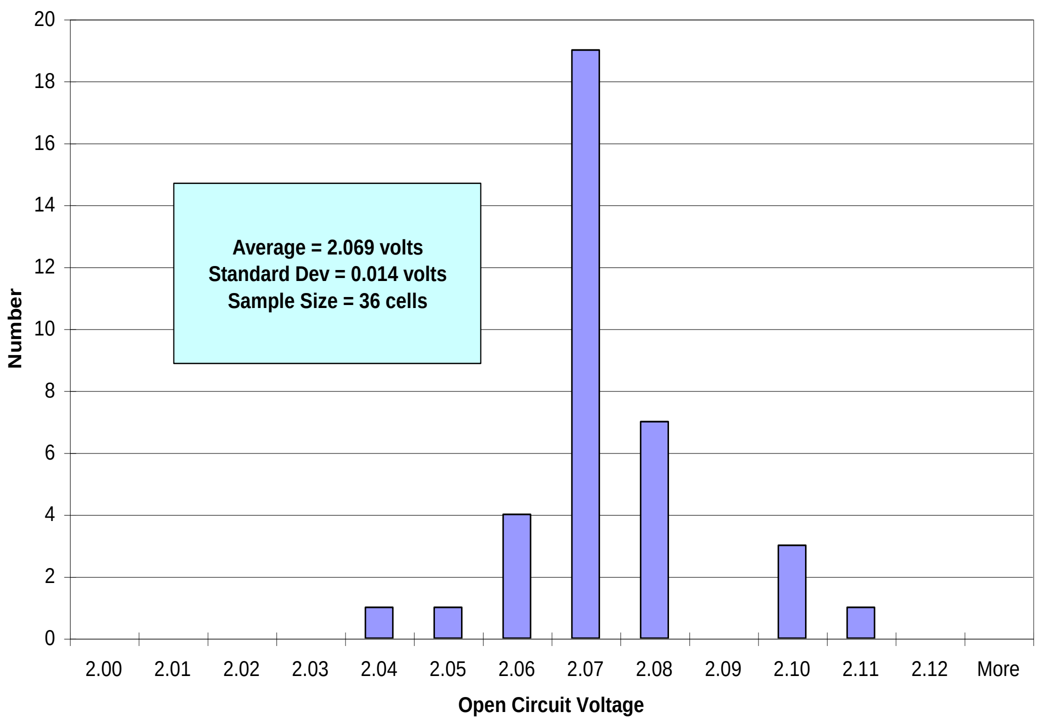
The MP&L BESS Battery – The Big Picture

- Began Operations: February 3, 1997
- Operating Regime:
  - Online 24/7 Continuously
  - Maintained At 50-80% State-Of-Charge
  - Semi-Annual Charge and Equalization
- Some Early Issues Resolved
  - Humidity Causing Ground Faults / Weeping Cell Terminal Posts
- MP&L Plans To Replace Battery In 2008
  - Battery Had Already Exceeded 8-Year Life Projection By 50%
  - Starting To Observe Some Voltage Weakness
  - <u>Couldn't Afford</u> To Have BESS Go Down And Return To Diesel
- Battery Replaced: September 23, 2008
  - Total Operational Life: 11Years / 7 Months / 20 Days
  - Replacement Effort: 6 Days / 2 GNB Installers / 4 MP&L Helpers
- Old Battery Returned For Recycling / Recycled Lead and Plastic Used In New Battery

The MP&L BESS Battery – The Changeout

- New modules were unpacked,stacked and pre-assembled
- As stacks of old modules were removed, pre-assembled stacks of new modules were moved into position
- After all electrical connections were made, the new battery was given an equalization charge
- Old modules were packed into the shipping crates and returned to GNB to be recycled
- Total change out effort took 2 installers and 4 helpers, 6 days, working 8-10 hours per day to complete
- Random samples (qty = 36) were sent to GNB for testing and examination

Field-Aged MP&L Cells – "As Removed" Open Circuit Voltage



- Measurements were taken before any other electrical testing
- Cells were removed from the BESS while still in the partial SOC condition
- The average open circuit voltage, 2.07 volts, is consistent with a 50-60% state-of-charge
- The variability among the samples is reasonable considering the BESS was nearing the end of a 6-month operating period

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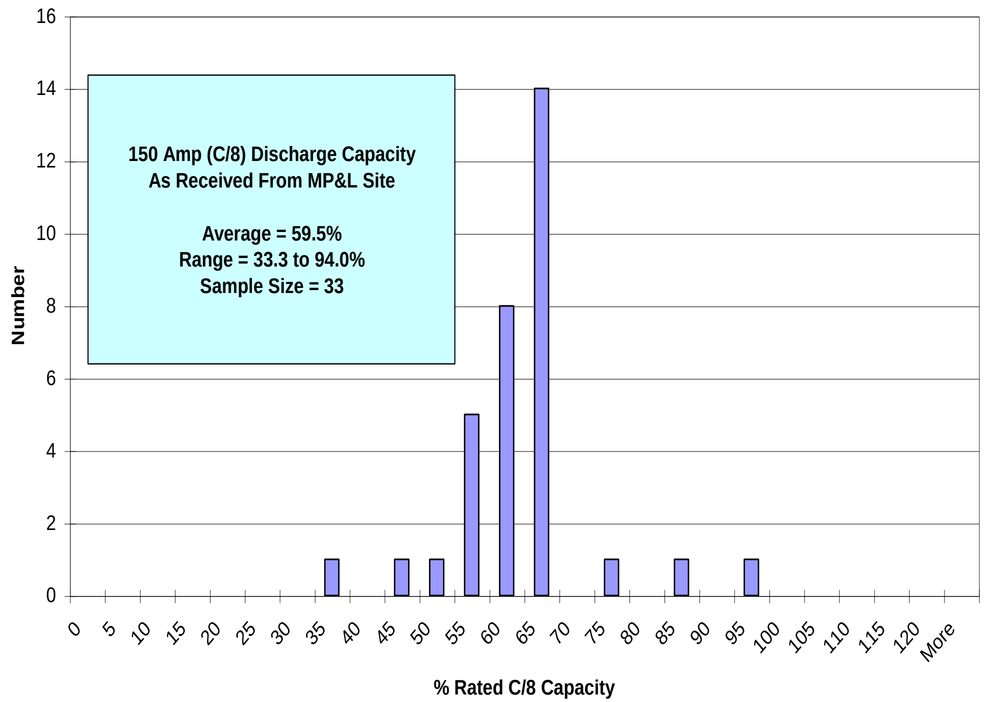
Field-Aged MP&L Cells – "As Removed" C/8 Capacity



- Without any recharge, the MP&L samples were tested at the C/8 discharge rate
- Average capacity was 59.5% ranging from 33.3% to 94.0%
- Capacity correlated well with the measured Open Circuit Voltage
- BESS control algorithm attempts to maintain battery at 50-80% SOC

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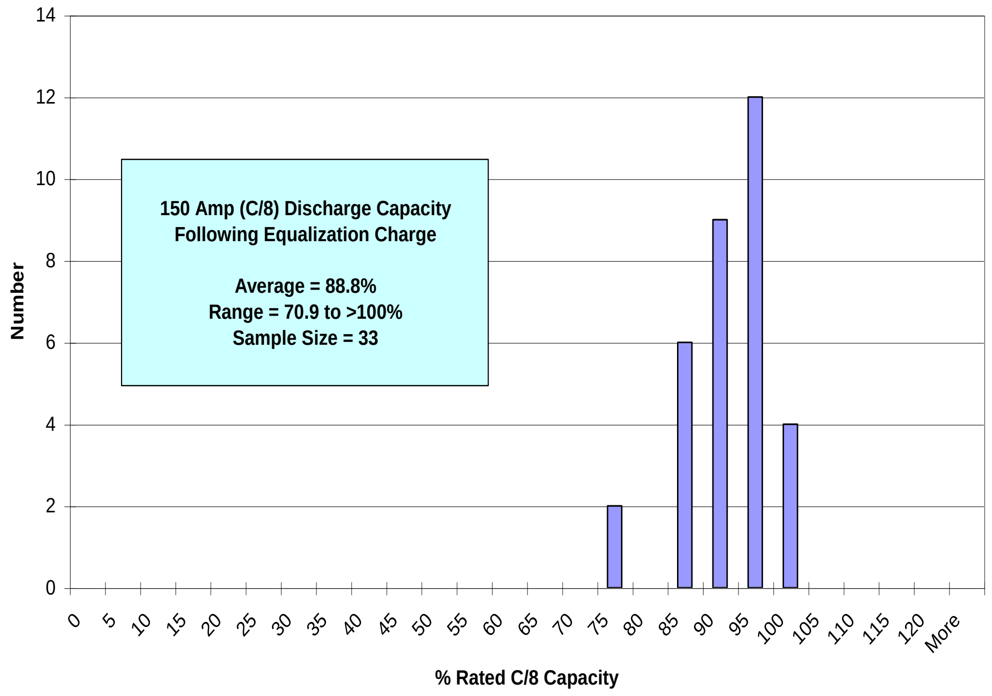
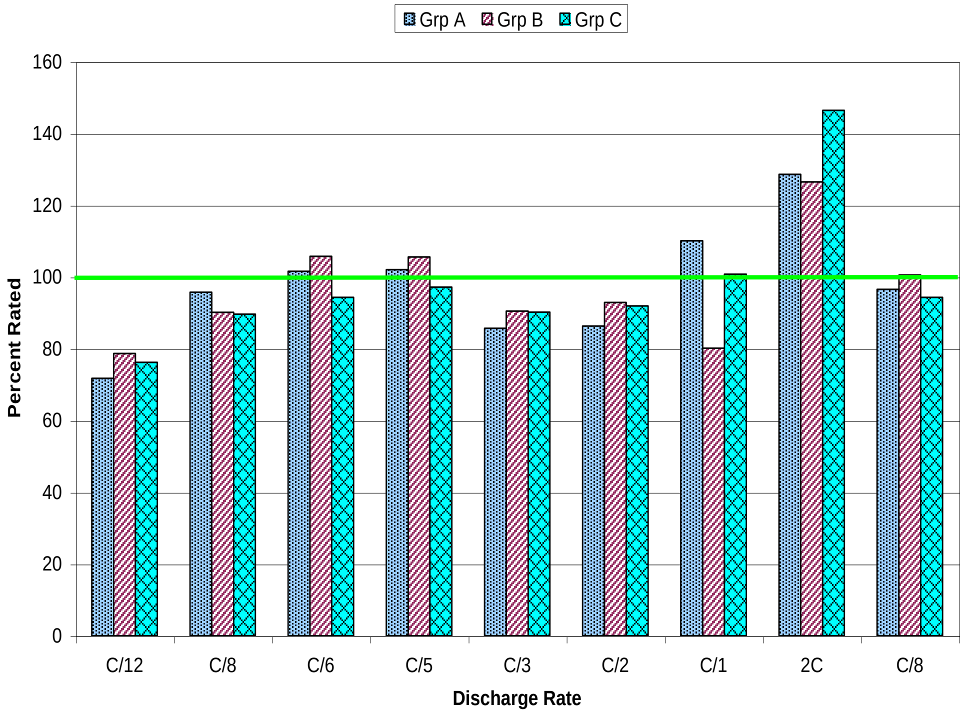
Field-Aged MP&L Cells – C/8 Capacity After Equalization Charge



- The cells were then given an equalization charge, and again discharged at the C/8 discharge rate
- Average capacity rose to 88.8%
- Individual cell capacities all increased ranging from 71% to greater than 100%
- The cells readily recovered from their partial state-of-charge operation

Field-Aged MP&L Cells – At Various Discharge Rates

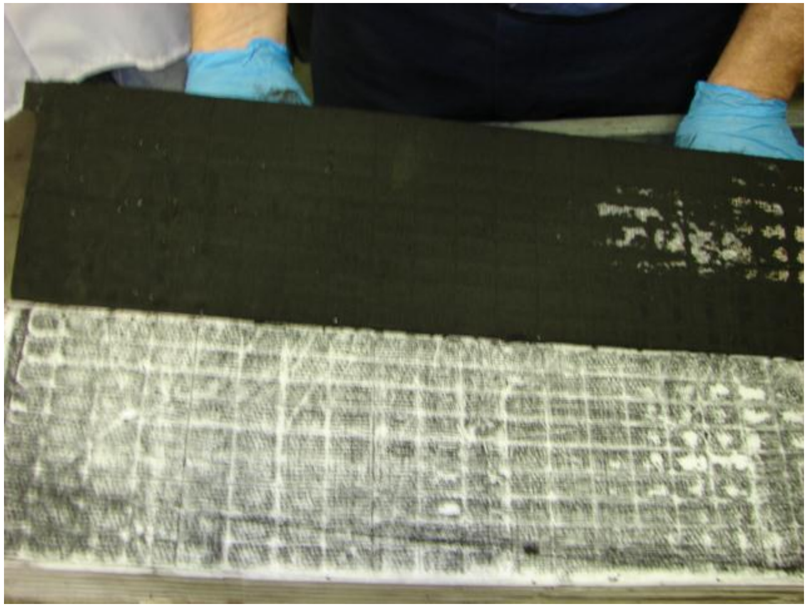


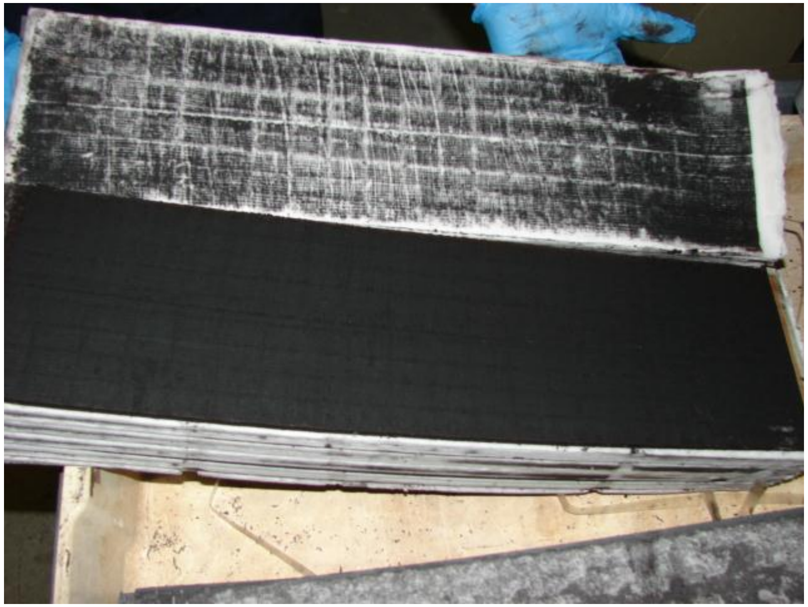
- The sample cells were grouped into three sets of 6 cells each
- Then discharge tested at C/12 to 2C rates
- Final test was another C/8 discharge
- Overall performance at all discharge rates was greater than 95%
- Even at the 2C (i.e., 30-minute) rate, performance was excellent
- Capacity improved with additional cycling

MP&L Cell Exam – Internal Element Assembly

- Cell elements were in excellent condition
- No torn separators; no plate misalignment or growth
- Plate lugs and terminal straps are corrosion free

MP&L Cell Exam – Positive Plates

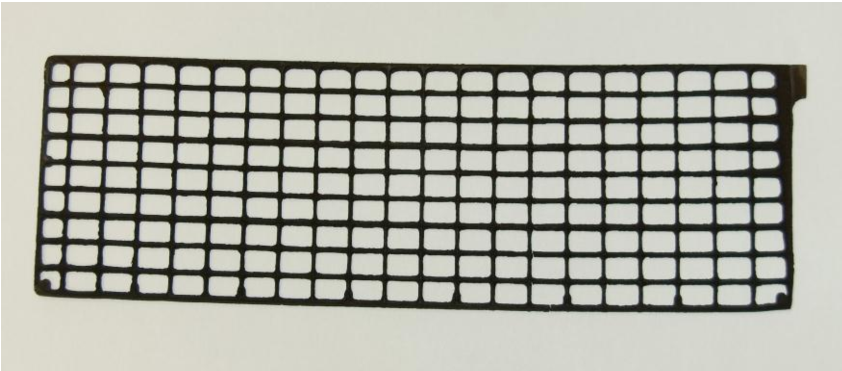


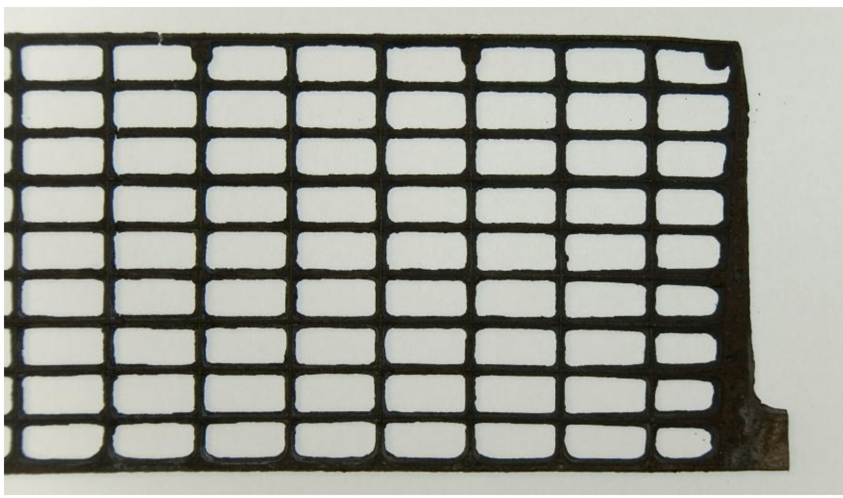


- Positive plate from an untested cell in a partial SOC condition shows only a very small amount of surface sulfation
- Plates were moist and active material was solid

- Positive plates from cycled and tested cells were completely free of sulfation
- Adequate recharge removed any surface sulfation
- Plates were moist and active material was solid

MP&L Cell Exam – Positive Grids





- A surprising observation in the examination of the MP&L cells was the condition of the positive grid
- Even after 12 years of operation, the positive grids were completely intact
- Typically positive grid corrosion causes the grid to become fragile, and to easily break apart and crumble when handled, especially for older cells

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MP&L Cell Exam – Electrolyte & Active Material Analysis

	Top	Middle	Bottom
As Returned #1	1.210	1.211	1.212
As Returned #2	1.196	1.195	1.195
Low Capacity Test	1.206	1.211	1.212
High Capacity Test	1.289	1.291	1.290
Cycled Group A	1.285	1.286	1.288
Cycled Group B	1.306	1.310	1.311
Cycled Group C	1.290	1.292	1.288

Cell State	Lead Dioxide	Lead Sulfate
As Retuned	81.%	18.2%
Single Cycle	89.8%	9.5%
Cycled	90.8%	8.4%

- Electrolyte gravity is consistent with cell condition – lower gravity in partially discharged cells / higher gravity in fully charged cells
- No stratification from top to bottom / Equally moist throughout

- Active material composition consistent with cell condition – more sulfate in partially discharged cells / less sulfate in fully charged cells
- Discharged material readily converted. No permanent sulfation or material degradation

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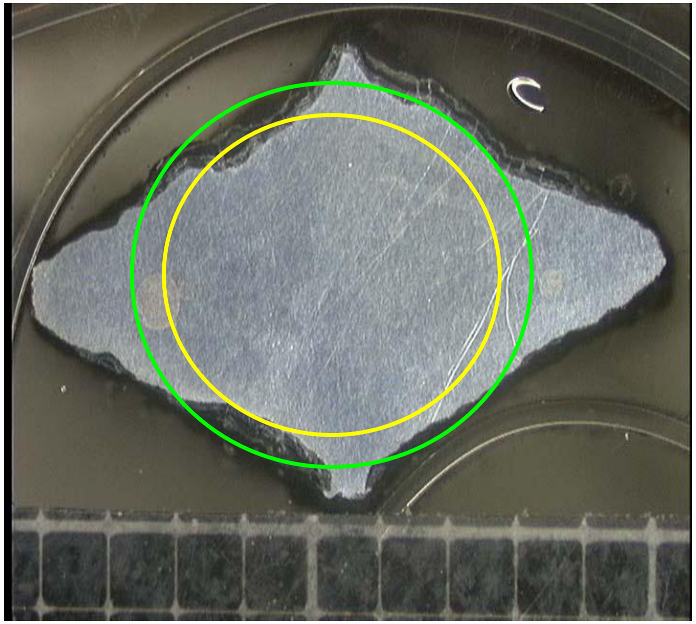
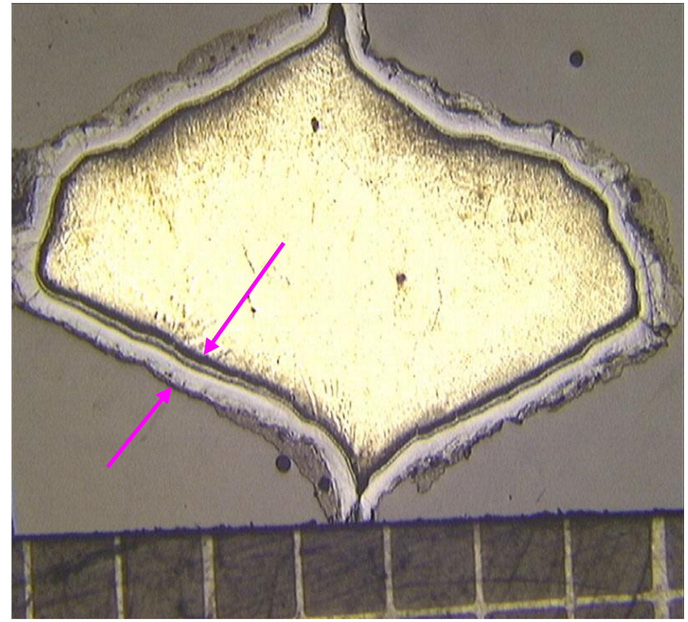
MP&L Cell Exam – Positive Grid Corrosion



Sample At 30 Months

- Corrosion decreases the cross sectional area of the grid wires
- Design life based on corrosion rate of 0.003 in/year
- Measured rate = 0.0024 in/year
- Critical factor in decision to extend operational life from 8 years to 12



Sample At 140 Months

- Measured rate = 0.0009 in/year
- Corrosion layer thickness = 0.0104 inch
- Actual corrosion rate in BESS samples much less than expected
- Could take up to 20 years to reduce cross section area to 50%

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MP&L BESS – Battery "Age"

- Warranty Life – 8 Years
- Actual Calendar Life – 11.6 Years (139.8 Months)
  - Installed February 1997 / Decommissioned September 2008
- Battery "Age" Based on Use / Condition
  - Throughput / Total Discharge Capacity / Basis In Cyclic Use
    - Expected: 3,456,000 AH / 1,200 cycles / 80% Depth of Discharge
    - Actual: 3,562,350 AH / 1,237 cycles / 103% of anticipated
  - Overcharge / Basis In Standby Float Use
    - Expected: 283,824 AH / 20 years / At 2.25vpc and 25ºC
    - Actual: 25,046 AH / 11.6 years / 15% of anticipated
    - Would have been considered severely undercharged
  - Positive Grid Corrosion
    - Expected: Corrosion Rate = 0.0025-0.0030"/yr / 8.3 years to 45% cross sectional area
    - Actual: Corrosion Rate = 0.0009"/yr / >20 years to 45% cross sectional area
    - Corrosion rate much less than expected when operating in a partial SOC regime
- Not Unreasonable To Project 15-Year Life In Similar Applications

MP&L Battery Energy Storage System – A Great Success

- Battery Energy Storage Is An Economic / Environmental Success
  - Saved Metlakatla Over $6.5 Million In 12 Years Of Operation
  - Saved Almost 59,000 Tons Of Carbon Dioxide Emissions
  - Virtually Eliminated Reliance On “Imported” Petroleum Fuels
  - MP&L Grid Is Almost 100% Renewable
- Battery Energy Storage Is A Technological Success
  - Met Every Operational Challenge
  - Industrially Robust Equipment and Installation
  - Readily Integrated with Other Generating Resources
  - Exceeded Life Projections By Wide Margin
- Battery Energy Storage Is **NOW!**
  - All Components Are Commercially Available
  - Components Are Modular and Readily Scaled
  - Battery Manufactured Using Recycled Materials / Is Readily Recycled
  - Systems Can Be Up and Operating In Matter Of Months, Not Years