PV-HYBRID SYSTEM FIELD-TEST MONITORING AT STAR

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ACKNOWLEDGEMENTS

- DOE Energy Storage Program - Funding source
- SNL: Garth Corey, Technical Liaison
- Arizona Public Service: Herb Hayden
- EECI: Dr. Phil Symons
- Spencer Everingham, Co-author

OVERALL GOALS

- Enhance a Partnership With a Progressive Electric Utility [APS] with Mutual Interests
- Support the Development of the “Alternative Configuration” to Equalize Individual Strings of a Battery Bank
- Monitor Batteries in Large Remote Hybrid PV Systems
- Evaluate Battery Test Equipment
- Support IEEE SCC21 Energy Storage Subsystem Working Group

WHY

- **Reduce the Life-Cycle Cost of Remote Hybrid Systems**
- **Increase the reliability, durability and confidence in Remote Hybrid Systems**
- **Make above information available to users (e.g., via IEEE Standards)**
- **Determine which battery test equipment can best predict battery failure**

PROJECT HISTORY

- Dec. 1996: APS Hybrid Test Facility Completed
- Q1 1997: SNL-APS "Partnership" Formed
- Jun. 1997 - Jun. 2000: First Hybrid System
- May 1998 - SNL-ASU Contract
- Jul. 1999: San Juanico, Mexico; Fishing Village
  - 17 kW PV, 10 10-kW Wind, 80 kW Diesel, 70 kW Trace, L16 Bat.
- Jan. 2000: YPG, 105 kW, ABS IIP
- Jan. - Aug. 2001: Dangling Rope Sys. at STAR
- Aug. 2001 -Present: AES Inverter Evaluation
- Jan. 2001 - Support Alternative Configuration

THE SITE - STAR

Dedicated Jan. 1988

THE SITE - STAR

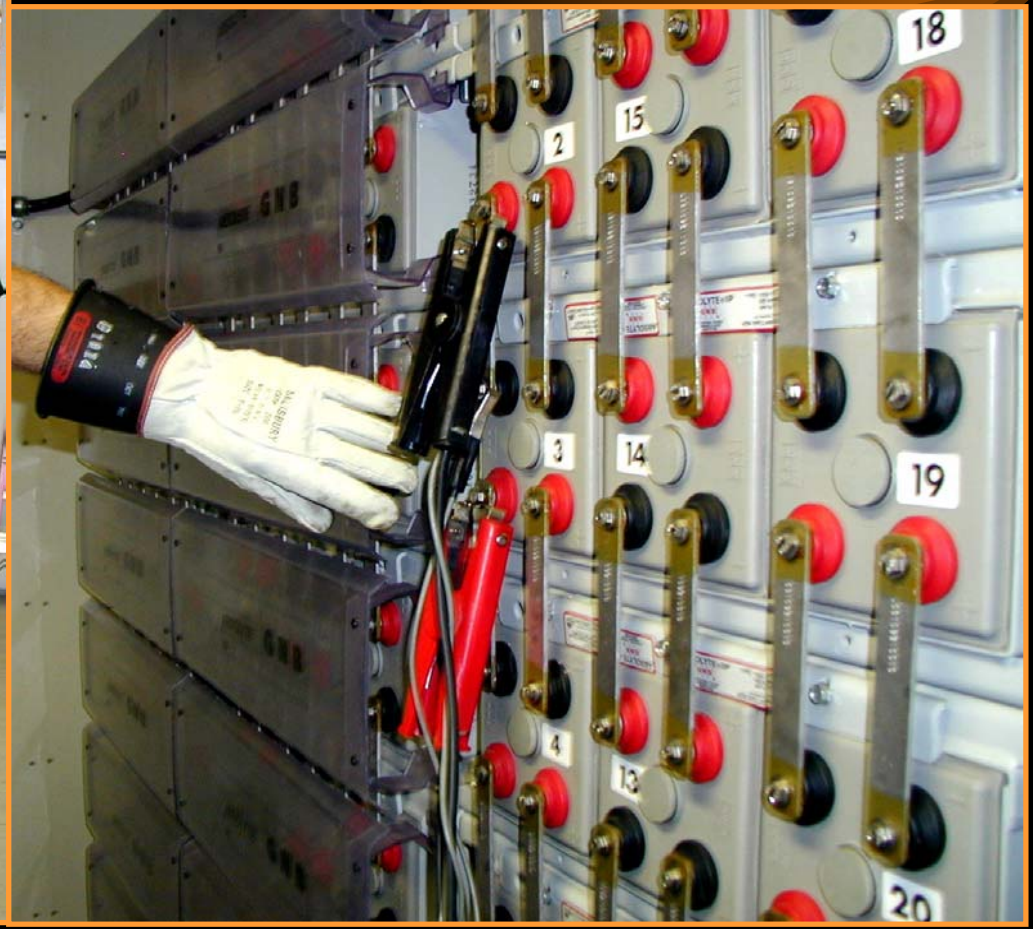
Ocotillo Power Plant

HYBRID "EXPERIENCE" - CSM

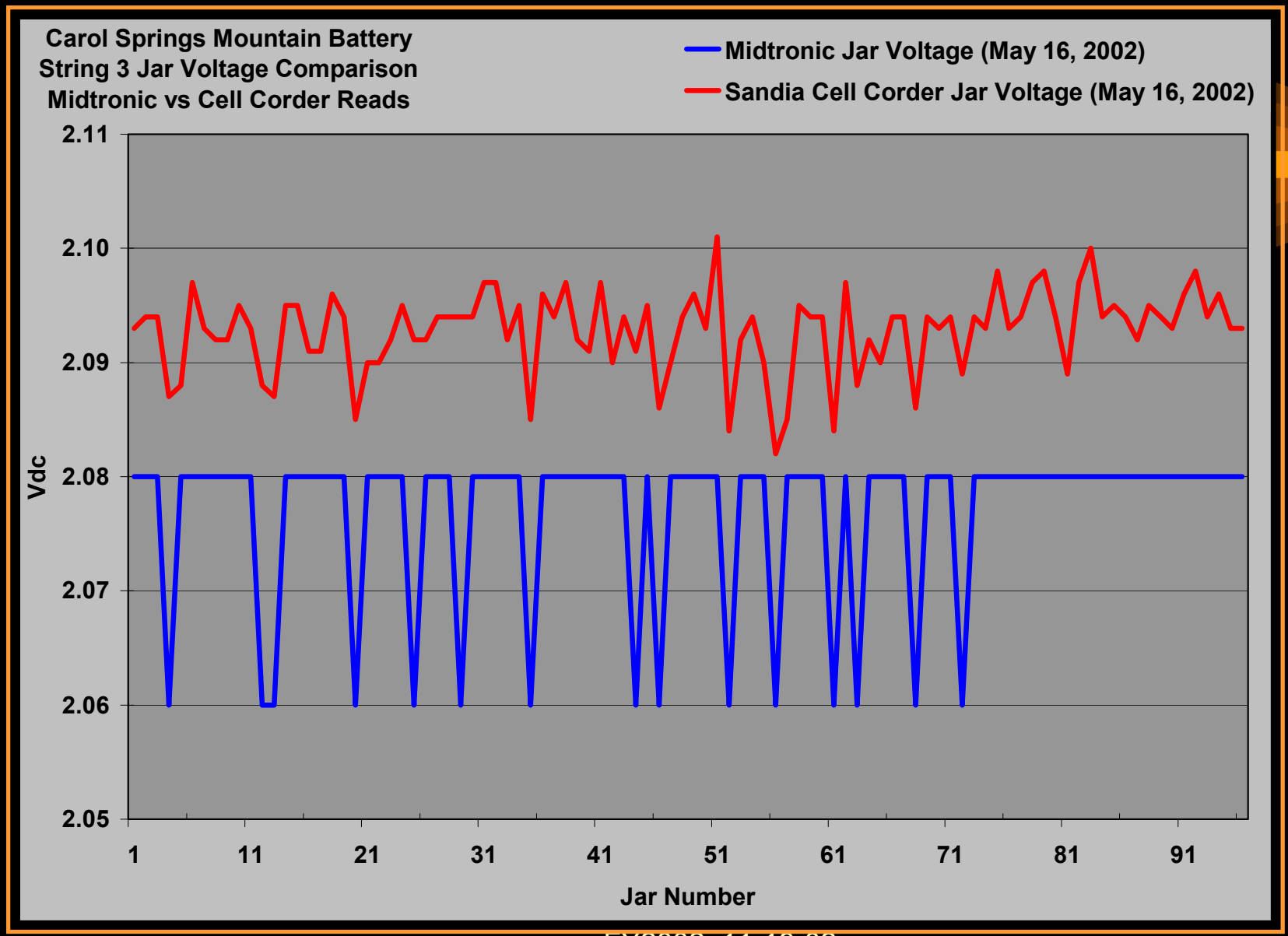
Installed Oct. 1995

Abacus Inverter, S/N #1

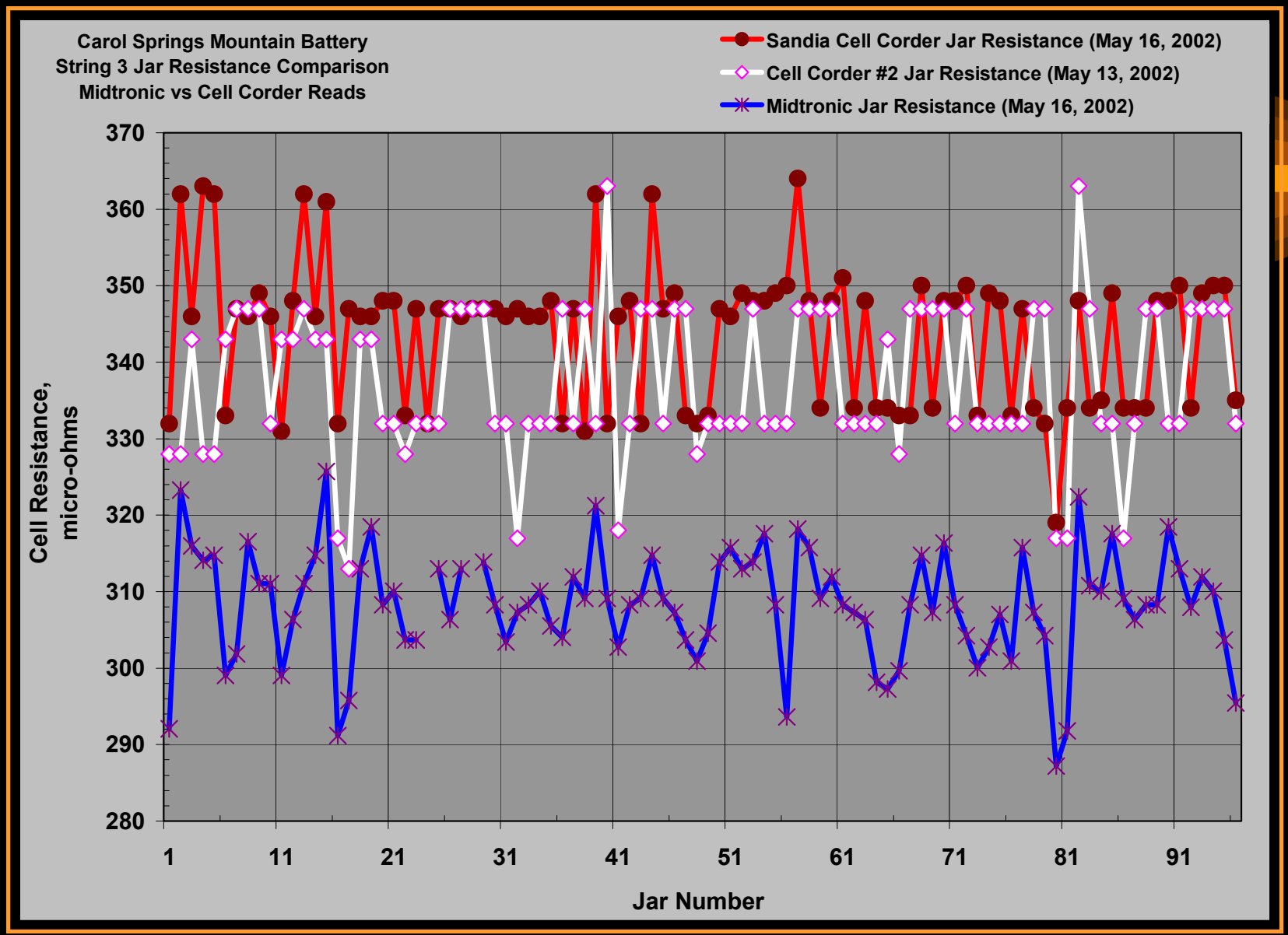
New Battery: GNB ABS IIP, 05/13/02



CSM Cell Voltage Reads



CSM Cell Resistance Reads



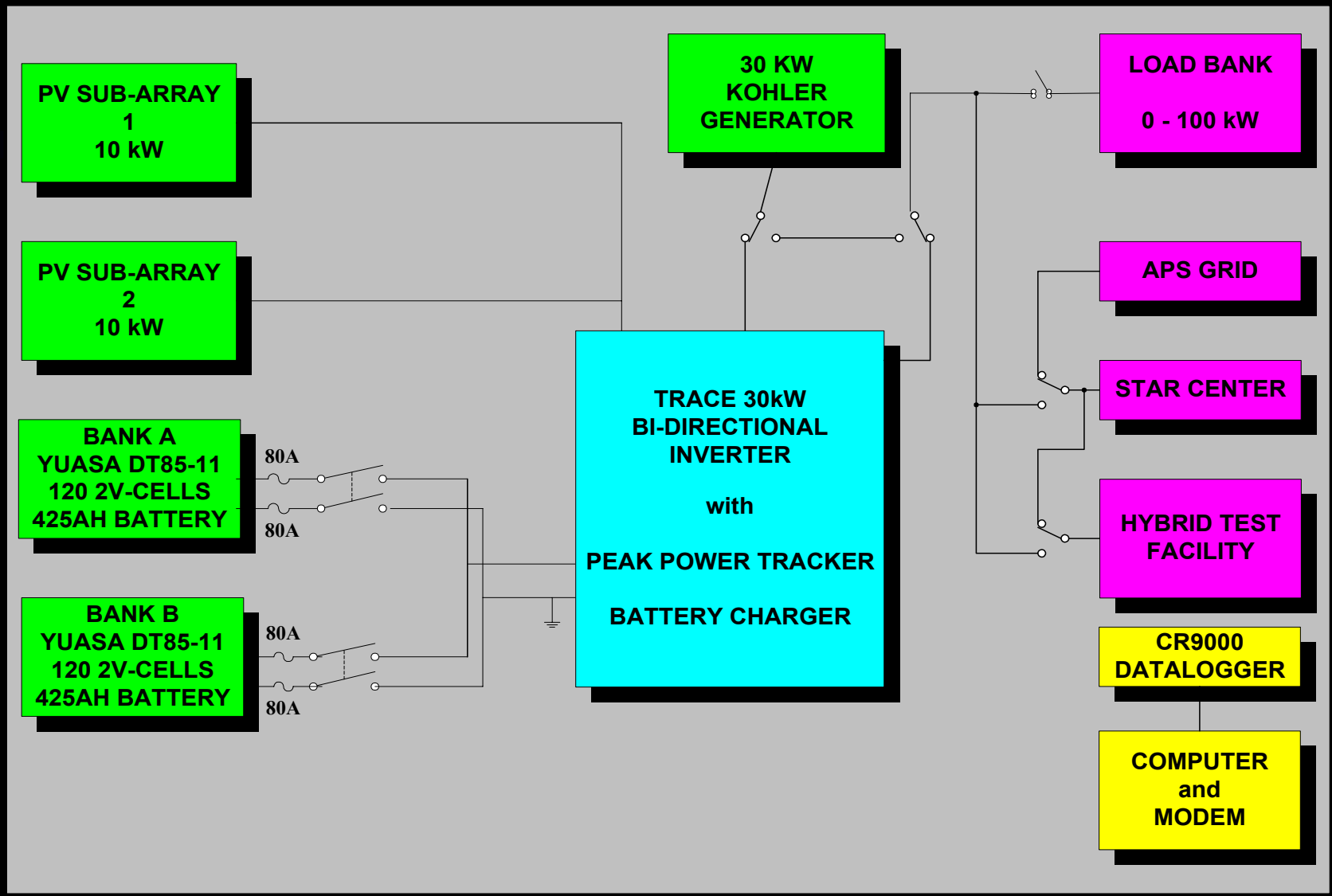
CELLTRON VS. CELLCORDER

CELLTRON VS CELLCORDER

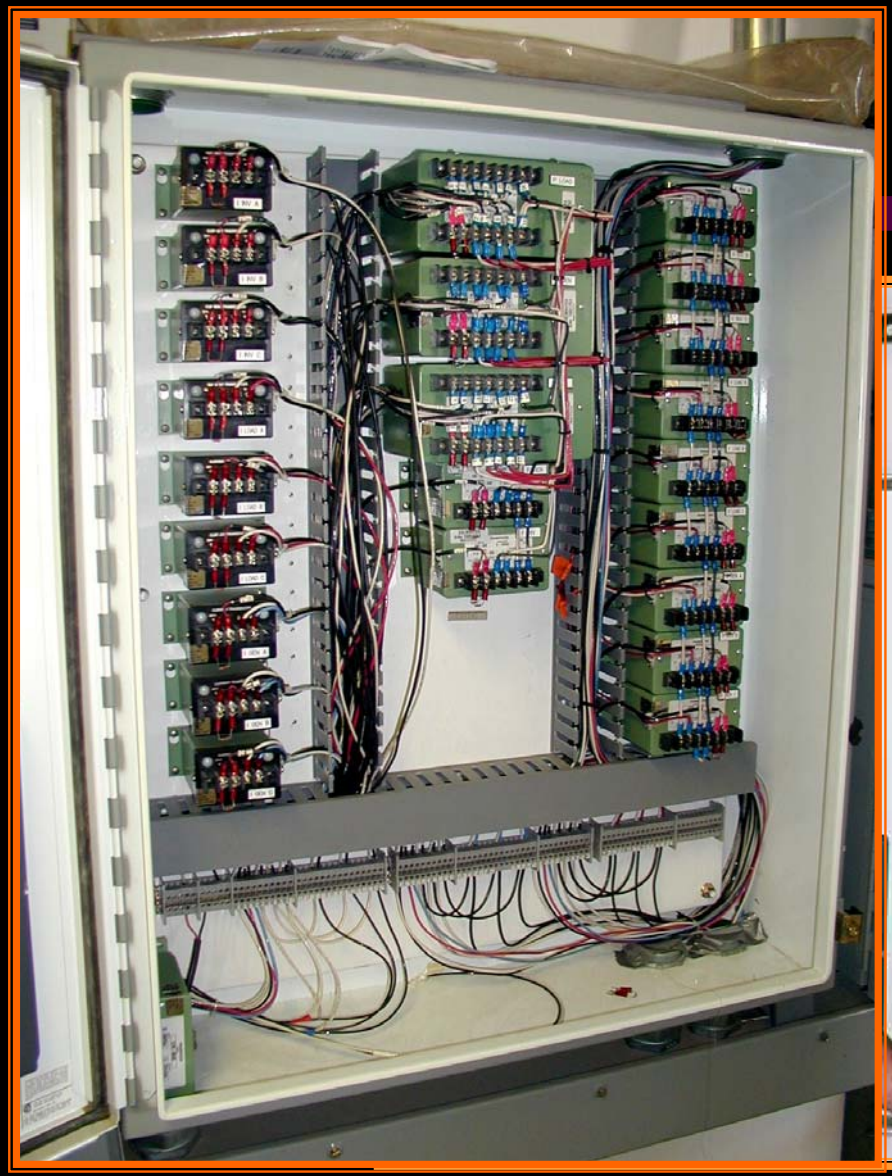
SPECIFICATION COMPARISON		
PARAMETER	**MIDTRONICS CELLTRON CTM-300**	**ALBER CELLCORDER**
Application	2, 4, 6, 8, 10, 12 V Jars	2V, 6V, and 12V Batteries
Voltage Accuracy	2%	0.1% of reading +/- 1 LSD
Voltage Resolution	**10 mV [20 mV actual]**	**1 mv**
Memory	252 Test Results	1792 Test Results 7 Strings of 256 Cells
Weight (tester)	1 pound (500 grams)	8.5 pounds, not including leads or carry case
Size	9” x 4” x 2.5” w/case	11” x 10” x4”
Ease of use (10 = easiest)	8	5
Data collection & storage time	55 seconds	40 seconds
Battery Life	1 hour	6 hours
Cost (including software)	$4935	$5400
Software sold separate	Yes, $620	No
Ability to predict battery failure	UNKNOWN	UNKNOWN

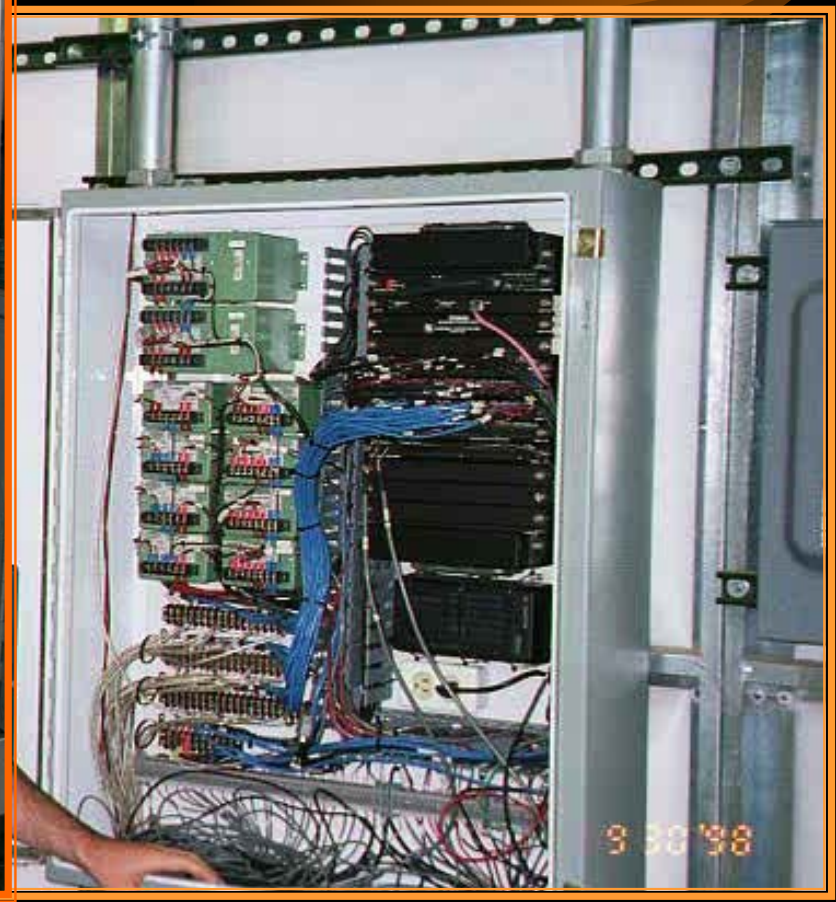
THE HYBRID TEST FACILITY

YUASA EVALUATION: JUNE 1997 - JUNE 2000



CR9000 DAS, SIGNAL CONDITIONER





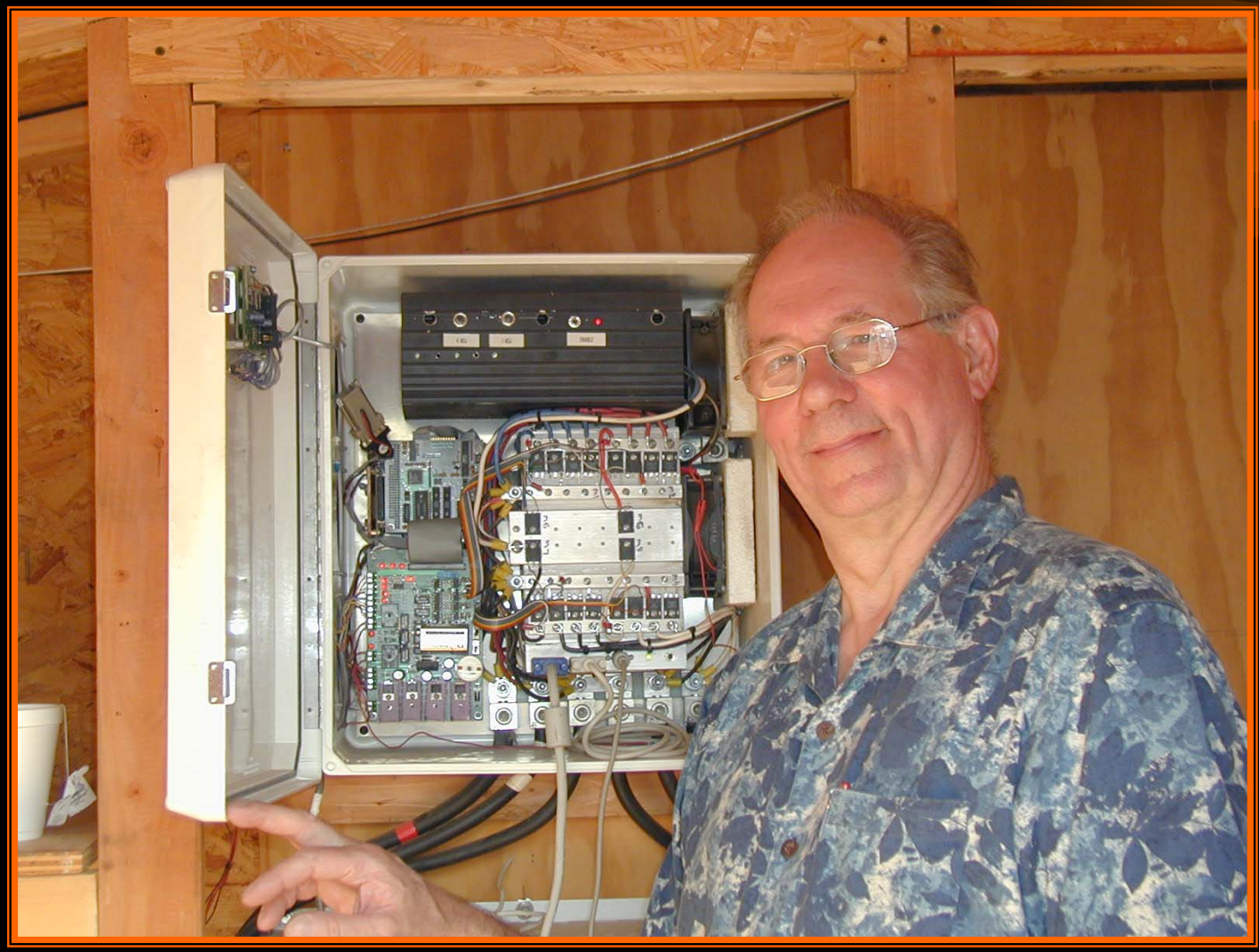
D.R. TEST BATTERIES AT STAR

ALTERNATIVE CONFIGURATION

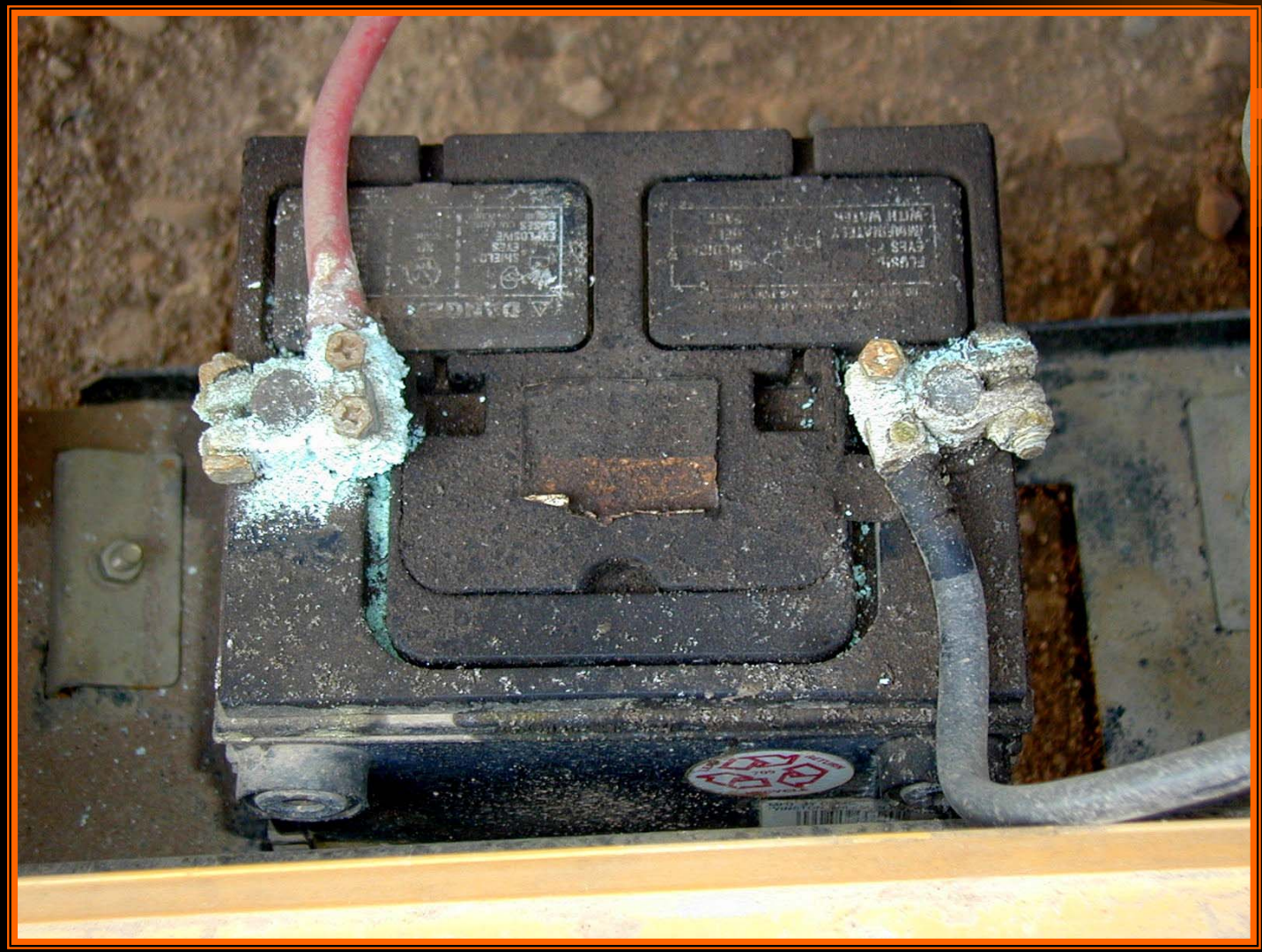
- **Support the Development of a New Proprietary Technique to Equalize Individual Strings of a Battery Bank**
  - **Test site located at the APS STAR Center**
  - **Support via data collection, data quality control, data processing and on-site system management/repair as required by:**
    - **Dr. Phil Symons (EECI) and**
    - **Mr. Garth Corey (SNL Program Manager)**

ALTERNATIVE CONFIGURATION
Equipment Building

ALTERNATIVE CONFIGURATION



GENSET STARTING BATTERY



A.C., LOAD SHACK - EXTERIOR

A.C., LOAD SHACK - INTERIOR

A.C., CHECKLIST

Alternate Configuration Project Checklist.	11-Oct 12:00
Are the lights ON (Timer: 6-9 PM)?	N
Is the refrigerator running?	Y
Is the swamp cooler running?	N
Is the load shed door latched?	N
Is the battery shed door closed?	Y
What is the generator state? [ON or OFF]	Off
What is the fuel level in percent of full?	78%
Does the monitor turn on?	Y
Are the fans running?	Y
What is the start time of the current battery cycle?	10/10/01 17:40
What is the state of the battery?	Discharge
If in FINISH CHARGE, are charger lights active?	N/A

IEEE STANDARDS

1. **IEEE P1361/D15.** ***Draft Guide For Selection, Charging, Test and Evaluation of Lead-acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems***

2. **IEEE P1561/D5.** ***Recommended Guide For Optimizing the Performance and Life of Lead-Acid Batteries In Hybrid Remote Systems***

IEEE 1561: USER QUESTIONS

CAROL SPRINGS MOUNTAIN
REMOTE HYBRID SYSTEM

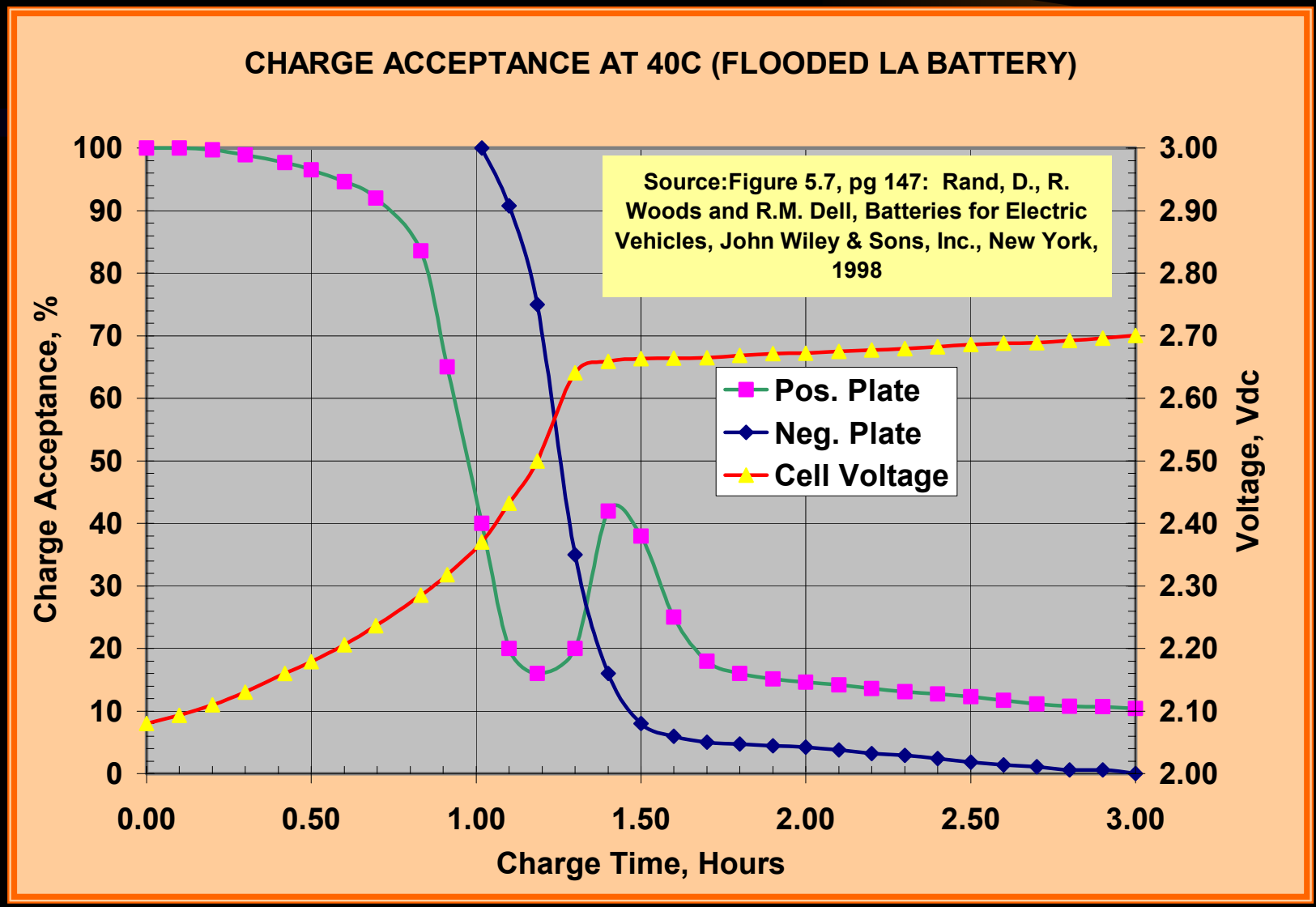
1. For a nominal load, what is the relationship between State of Charge (SOC) and Vbb?
2. What methodology should be used to measure SOC? AmpHour counting? Vbb? Both?
3. What is the recommended charging technique? Equalization frequency?
4. For the Remote Solar Electric System (RSES), how should those batteries be managed?
5. Temperature compensation – charge set points only? Discharge set points?
6. VRLA/CSM : How do the battery characteristics change with age.
7. CSM: Equalization frequency? Finish charge every two weeks? 5% Overcharge (Ah)?
8. Why is there not a smart controller that can anticipate daytime PV availability and decide when to start the genset?

IEEE 1561: USER QUESTIONS

GRAY WOLF HYBRID REMOTE SYSTEM

1. How does load affect genset start/stop and Low Battery cutoff (LBCO) set points? How do we compensate for the effects of load?
2. What is an authoritative reference for temperature compensation of Charge and Discharge set points?
3. Equalization: How often? Procedure?
4. Where do you measure Temperature, Voltage, Current? How do you measure these parameters?
5. How are above answers affected by battery age?
6. How is battery resistance measured?
7. How effective is Amp-hour counting? Pros and cons? Procedure? When is counter reset?

IEEE STANDARDS: P1561



CONCLUSIONS - 1

- **Lead-acid Battery Technology is Mature. Battery Management in PV Systems is still in the early stages of development.**
  - **Need charge controllers that include amp-hour counting**
  - **The Alt. Config. management system is a major step forward**
- **Proper Battery Management Information is not readily available to the System Integrator/User.**
  - **System Integrators still have more questions than answers**

CONCLUSIONS -2

- The Alber Cellcorder has 20 times greater voltage resolution than the Midtronics Celltron. Time will tell which instrument is better at predicting battery failure.
- The partnership between APS and DOE/SNL is an excellent means of leveraging the resources of both organizations in order to improve function and reliability of hybrid systems, and to reduce the costs of hybrid systems

PLANS FOR THE FUTURE

- CONTINUE TO SUPPORT:
  - Alternative Configuration Development
  - STAR, Hybrid Test Facility
  - STAR, CSM Battery Management/Optimization
  - Battery Standards
  - On site Liaison between APS and DOE/SNL

THANK YOU

QUESTIONS

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