



GS BATTERY (U.S.A.) INC. Test Results of Field Study Sites

Revisions
March 14, 2017 1.0
January 17, 2018 2.0
February 21, 2019 3.0

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January 2018

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For the past 17 years GSB has partnered with our telecom customers in an effort to better understand the applications. These applications include wireline, wireless, renewable, and FTTx.

We have installed data logging equipment at locations across the United States and entered into long term studies with our customers to ensure our products offer the best possible service life and performance. This is in addition to our ongoing commitment to harvest aged samples of our products for testing and tear-down in our labs. We believe these efforts are mutually beneficial to GSB, our parent company GS Yuasa and our customers.



Study Sites

- Wireline Applications
 - Milford CT
 - Addison, Texas
 - Chappell Hill, Texas
- Wireless Applications
 - Paris, OH
 - Tempe, AZ
 - Outside Air Cooled Cabinet
 - Outside Air Cooled Customer Premise

January 2018

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The list above include sites from wireline and wireless carriers. GSB is committed to continue these sites for several years until product end of life. We welcome the opportunity to partner with our customers to add additional study sites.



Commscope 52B (ARAM) Milford, CT
MLFRCT95



AVERAGE	54.1913	13.3874406	14.93
MAX	54.506	41.21	39.53
MIN	49.455	-12.34	0.58
	Volts	Amb C	Bat C

Annual summary of the data logger results.
'Amb C' is outdoor temperature.

March 2017

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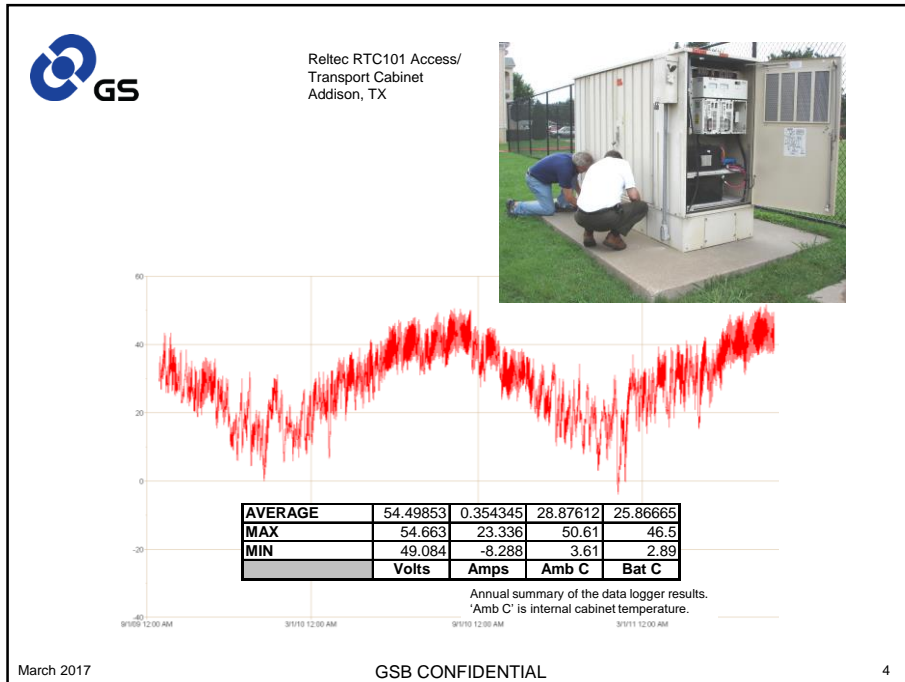
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This string of PWL12V125FS was shipped in September 2006. We believe the string was installed between October 2006 and April 2007. The actual installation date is not known. **Therefore the time in service is between 9.70 to 10.24 years.**

A data logger was installed at the site in March 2008. At which time the power system controller settings were modified to enable low temperature compensation and begin high temperature compensation at 25°C instead of 35°C. In July 2008 a temperature probe was added to the power system controller and a outside temperature sensor added to the data logger. This power system was previously not equipped with a temperature probe.

The logger was removed in October 2014 following the sale of this franchise territory. During the course of that final site visit, we discovered the power system controller had again failed suspending temperature compensation for a period of time. It is not possible to determine the exact time period where temperature compensation was suspended at this site. It was at minimum 13 months based data retrieved from the data logger.

The new owner of this franchise returned the samples to GSB for testing in January 2017. There was no evidence of swelling, leaking or post seal failure. The samples were floated for 7 days and discharged at the 8 hour rate. **The string produced 133.7Ah or 107% of rated.** This is the oldest string recovered from a cabinet application by GSB.



This structure and in particular this site was identified by the customer as a high temperature application where batteries had historically not performed well. This site and structure was selected by the customer as their most demanding application.

Outside air is drawn in on one end, forced through the electronics compartment and exhausts through the power and battery compartment. The Lorain A150CAB was not equipped with temperature compensation. However, a method had been devised using the boost feature to clamp float voltage when the batteries reached approximately 50C. Unfortunately some technicians would replace a rectifier and fail to 'reverse' adjust the boost setting and instead of clamping at 50C, the voltage would increase. This happened at least once during period our batteries were installed at this site.

The string located in the power compartment was removed from the site in March 2012 and the final 8 hour rate discharge was conducted. After 5.35 years in service the string produced 86% of rated capacity. We are highly confident, that if this site was equipped with a temperature compensated plant a seven year warranty threshold would have been met.



ConHut - Chappell Hill Texas SLC5, SLC96: PWL12V28 -10 Strings, 10 Years

Test site for development of the GSB 300mA String Charge Controller

Bay/Loc	Power	Siemens%Ref	Ah Rem	%Rated
RR1-Str 1	WECO 3B	75%	23.48847	94.69%
RR1-Str 2	WECO 3B	49%	12.51667	50.40%
RR2-Str2	WECO 3B	55%	13.52549	54.41%
RR2-Str1	WECO 3B	74%	25.15807	101.34%
RR3-Str1	Lucent J1C182BA	73%	21.15542	85.29%
RR3-Str2	Lucent J1C182BA	74%	23.3477	94.12%
RR4-Str2	Lucent J1C182BA	68%	20.24719	81.61%
RR4-Str1	Lucent J1C182BA	77%	23.7178	95.59%
RR6-Str2	WECO 3B	48%	17.15643	69.15%
RR6-Str1	WECO 3B	59%	20.24993	81.63%



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AVERAGE	56.256	24.05	24.18	1.797
MAX	60.145	38.28	38.96	
MIN	49.06	2.27	3.65	
	Volts	Amb C	Bat C	O-V

AVERAGE	54.5373	21.16	21.48	-0.116
MAX	60.14	25.25	28.36	
MIN	48.91	11.50	12.32	
	Volts	Amb C	Bat C	O-V

Forty (40) PWL12V28 were installed **December 11, 2007** in a wireline concrete hut in Chappell Hill near Brenham Texas. These were installed in a combination of SLC Series 5 (Lucent J1C182BA Power, Ringing Plant) and SLC96 (WECO 3B Battery Charger) Distributed Power RT Bays. A data logger was installed on RR1, String 2 to monitor float voltage, ambient and battery temperature. The structure was equipped with HVAC.

•This is one of several sites where the charging voltage presented by the J1C182BA or 3B Battery Charger could not be controlled by the 100mA version of the GSB SCD.

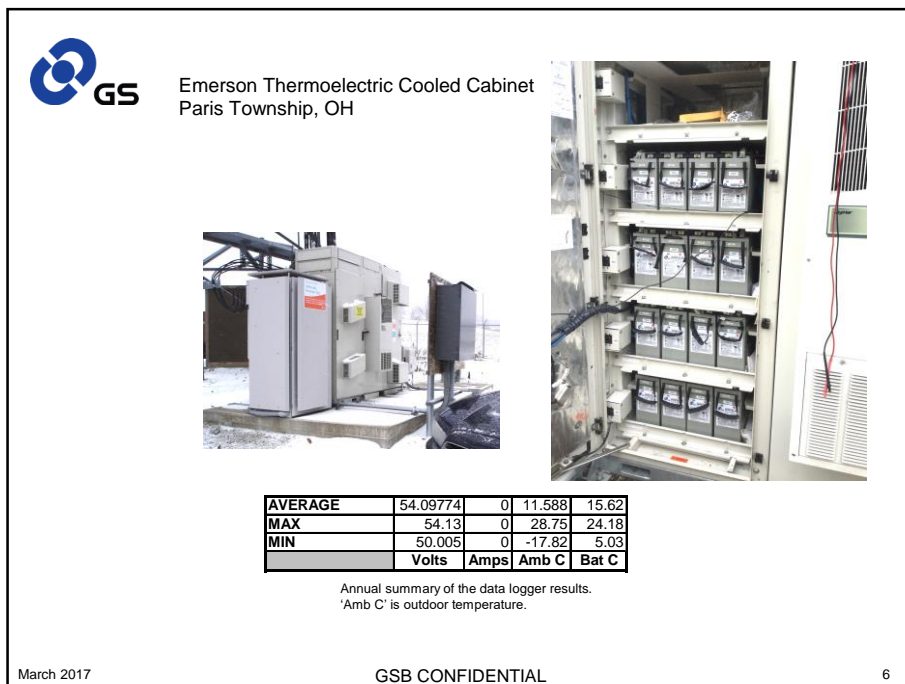
- An experimental 300mA version of the SCD was deployed here for testing following the 4th service year.

•Typical operating temperature and float voltage:

- **Table A** – First 4 service years prior to development of 300mA SCD.
 - Severe overcharging with battery temperatures reaching 38C
- **Table B** – Remaining 6 service years after installation of 300mA SCD.
 - Charge voltage controlled.

•All 10 strings were removed **November 27, 2017** and returned to our lab to be discharged at the 8 hour rate (Table C).

- Seven (7) strings were above 80% of rated after 10 years in service, **ranging 81.5% to 101.3% of rated.**
- Three (3) strings were below 80% of rated, **ranging 50.4% to 69.15% of rated.**



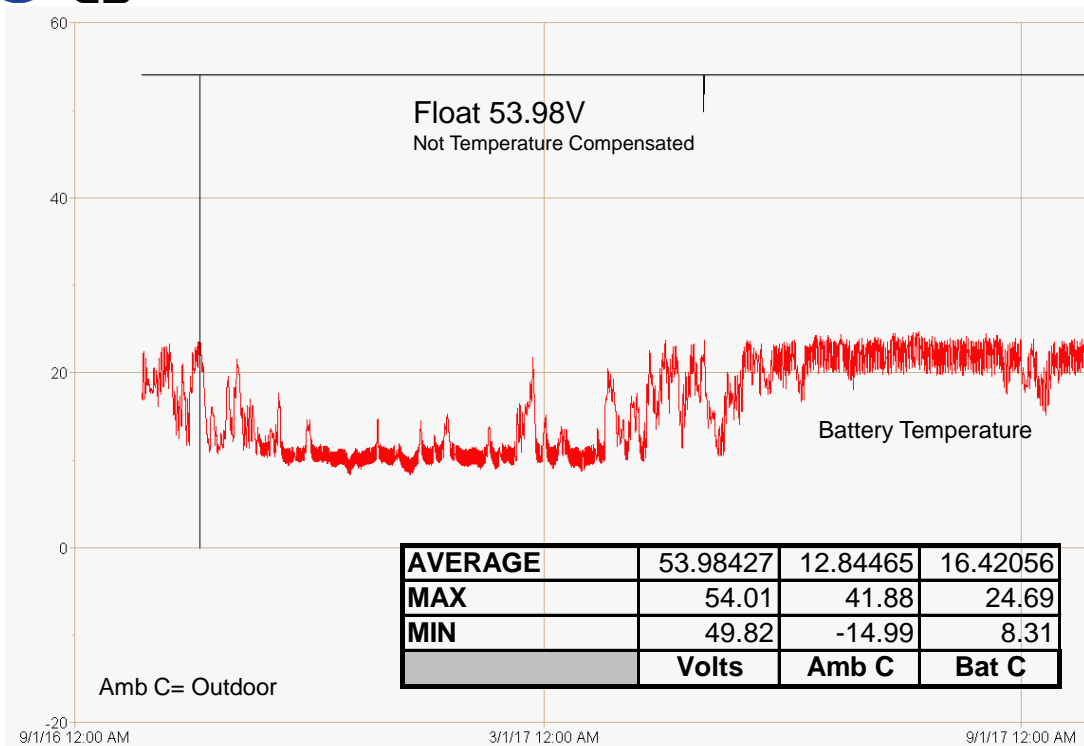
PYL12V185FT and PYL12V155FT samples were installed in wireless cabinets near Paris Township, Ohio September 2013. A data logger was installed to monitor float voltage, battery temperature, and outdoor temperature.

The TEC system at this site is the only reliable system of this type we have observed among the cabinets equipped with this type cooling. Temperature compensation is disabled and for a significant period the batteries were floated at 53.6V. The float has been increased to 54V but temperature compensation remains disabled. For the majority of the service life, these batteries have been floated below the recommended voltage and operated without temperature compensation.

At the request of the customer, we removed the string monitored by the logger and transported it to our lab. **The string was discharged at the 8 hour rate. It produced 207.10Ah or 112% of rated capacity after 3.05 years in service.** The string was reinstalled and the study continues.



2017 Update – Emerson TEC Cabinet Paris Township, OH



The PYL12V185FT string reached **four (4) years in service September 2017**. A summary of the 12 month dataset Oct 2016 through Sep 2017 is shown here.

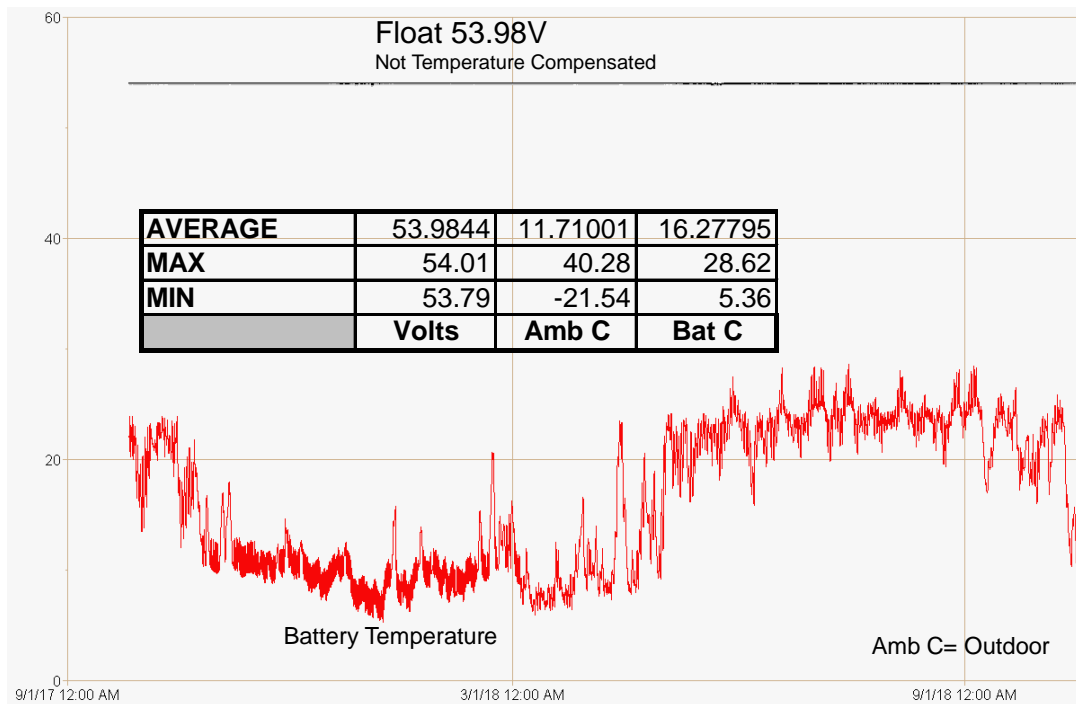
Logger Data October 1 2016 – September 30 2017:

- The average **battery temperature for this period was 16.42C.**
- The average battery temperature July-September was **21.7C.**
 - Maximum battery temperature during this period and for the period Oct-Sep was **24.69C.**
- Analysis of battery temperature and float voltage:
 - Temperature compensation is not active.
 - Strings are equipped with temperature probes.
 - The string is under charged during this period average ~630mV.
 - Significant Undercharging 11-1-2016 to 3-31-2017
 - Average battery temperature 11.5C.
 - The string was significantly under charged during this period at average 986mV.

2018 Update Follows



2018 Update – Emerson TEC Cabinet Paris Township, OH



The PYL12V185FT string reached **five (5) years in service September 2018**. A summary of the 12 month dataset Oct 2017 through Sept 2018 is shown here.

Logger Data October 1 2017 – September 30 2018:

- The average **battery temperature for this period was 16.27C.**
- The average battery temperature July-September was **23.46C.**
 - Maximum battery temperature during this period and for the period Oct-Sep was **28.62C.**
 - The TEC appears to be less effective as compared to prior years.
- Analysis of battery temperature and float voltage:
 - Temperature compensation is not active.
 - Strings are equipped with temperature probes.
 - The string is under charged during this period average 644mV.
 - Significant Undercharging 11-1-2017 to 3-31-2018
 - Average battery temperature 9.95C.
 - The string was under charged during this period at average 1.099V.



Customer Premise
Wireless Outside Air Cooled
Cabinet
S. Rural Rd.
Tempe, AZ



- Site identified in July 6, 2016 as a high temperature application.
- PYL12V185FT installed 8/2015
- Ambient 57C
- Battery Temp 39C
- Temperature Compensation DISABLED

March 2017

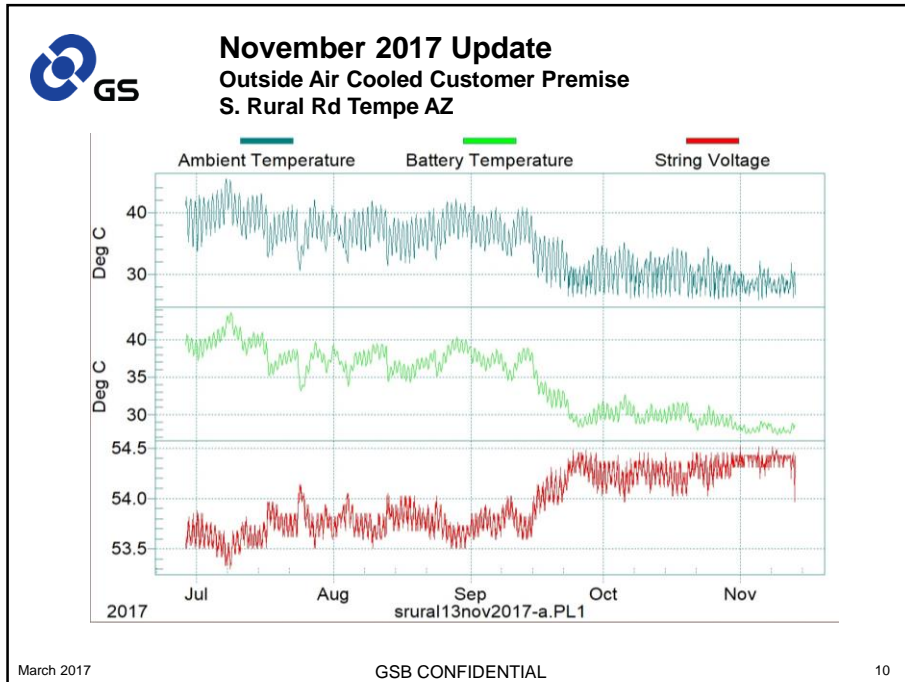
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The customer identified this site as an 'outside air cooled' high temperature application. Two strings were removed from this site at the end of the summer in November 2016 for testing. They were taken to the customer's facility and discharged at the 8 hour rate. A data logger will be installed at this site in 2Q2017.

After 1.29 years in service under these conditions the strings produced 110% and 103% of rated capacity. The next test was performed in November 2017 in association with other long term life studies under way in Arizona.

2017 Follows



In **June 2017** a data logger was installed at this site. String float voltage, battery and ambient temperature are recorded. These data were recorded June 28, 2017 through November 15, 2017. The site will be visited again after November 15, 2018 to recover a 12 month data set.

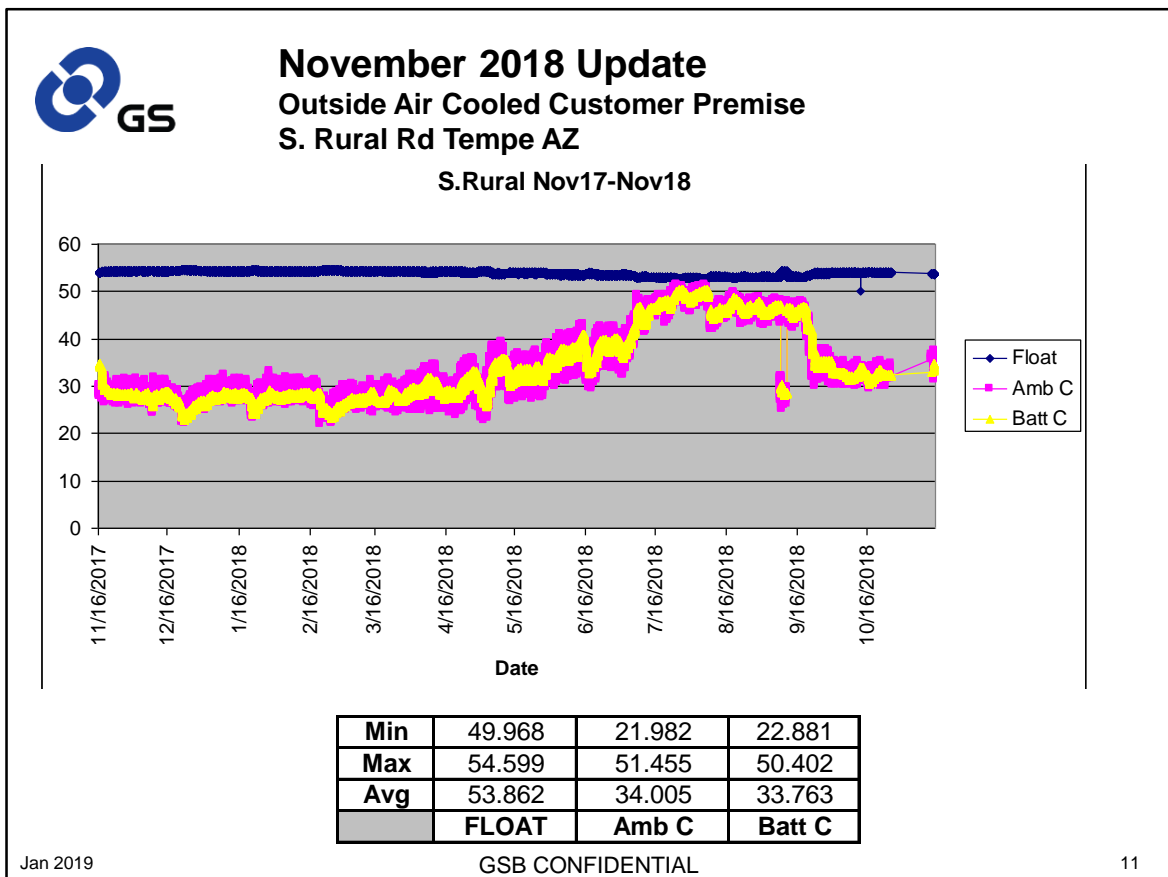
Logger Data June 2017-November 2017:

- The average battery temperature during this period June – November 2017 was 34.39C and the average float 53.96V.
- During the period June 28 through September 28 the average battery temperature was 36.85C and the average float 53.80V.

Discharge Test Results November 2017:

- The two strings were removed for testing the week of November 13, 2017.
- After 2.29 years in service these strings produced **108% and 109.5%(1) of rated capacity**.

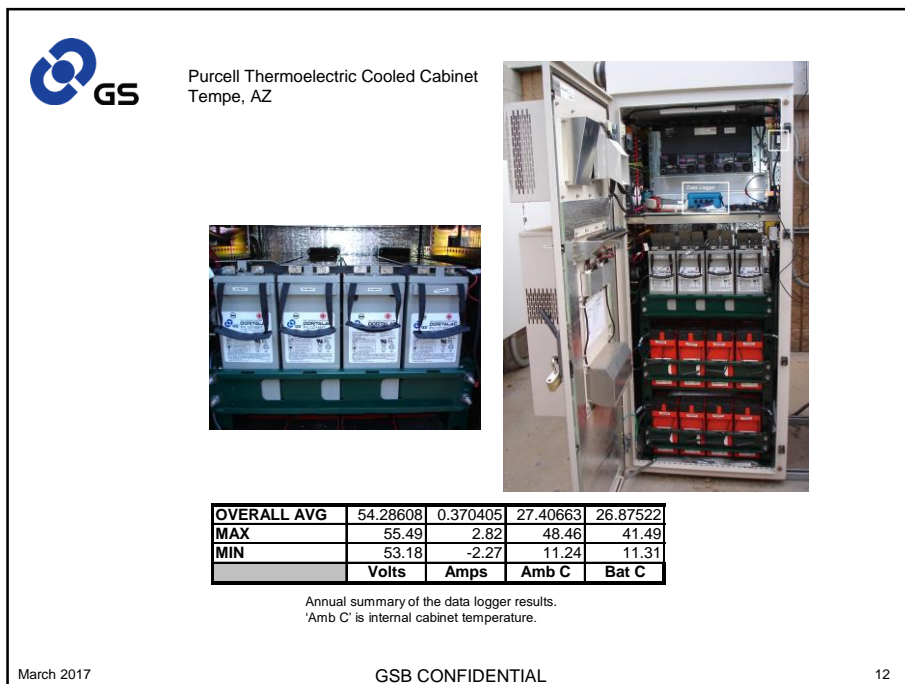
(1) The average temperature during the test was 27.38C. The rated capacity after applying a correction factor is 109.57% of rated.



The first full year of data was retrieved from the logger.

Logger Data November 2017-November 2018:

- The average battery temperature during this period Nov 2017 – Nov 2018 was **33.76C** and the average float 53.86V.
- Maximum battery temperature was **50.4C**.
- Temperature compensation during this period was accurate.
- During the period June 1 through September 30 the average battery temperature was **42.69C**.
- The data logger was removed in January 2019.
- These strings were not discharged at this time.
 - They are to be removed to measure capacity in August 2019 after they have reached 4 years in service.



A string of PYL12V185FT samples were installed in a Purcell TEC (Thermo Electric Cooling) cabinet in Tempe, Arizona. This string was part of a group of samples aging on float in our warehouse in Georgia since September 2013. The string was relocated to Tempe, Arizona and installed in this cabinet May 2014. A data logger was installed to monitor float voltage, discharge/charge current, battery temperature, and internal cabinet temperature.

It is important to note that the TEC system in this cabinet is plagued with frequent failures sometimes lasting for 30-90 days. This wireless service provider is in the process of eliminating TEC due to reliability issues. The maximum temperature occurs when TEC has failed. However, temperature compensation is operational and the float is well managed thus mitigating the effects of high temperature operation when the TEC is not functioning.

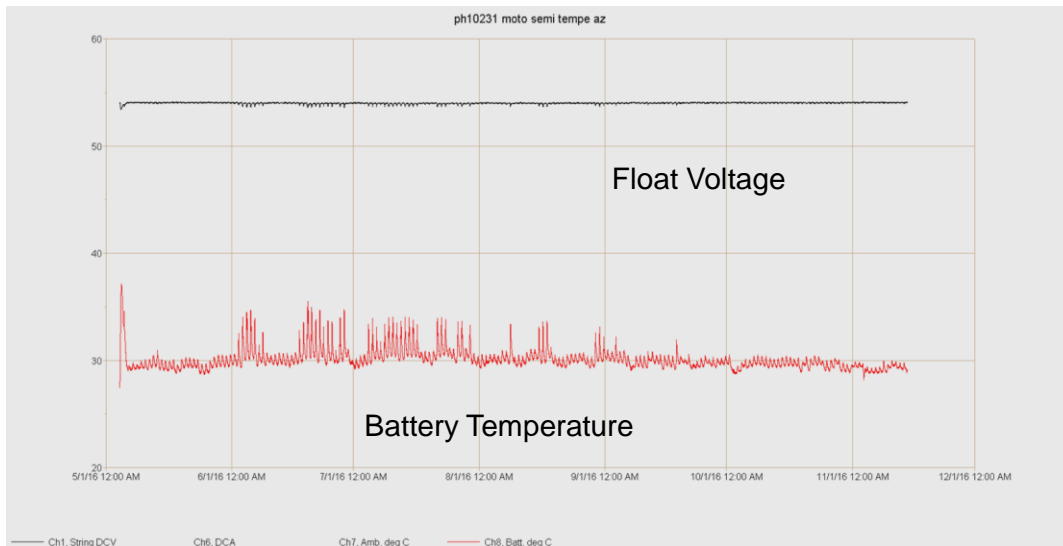
The string was removed May 2016 and discharged at the 8 hour rate at the customer's facility in Tempe. **It produced 202.45Ah or 109.6% of rated capacity after 2.65 years in service.** The string was reinstalled and the study continues.



Final data from the logger before moving the string from Elliott Rd. Tempe to Scottsdale for the period May – Nov 14 2016

MIN	53.43	-2.95	27.27	27.52
MAX	54.18	3.59	44.76	37.14
AVG	54.03	0.43	29.56	30.09
	Volts	Amps	Amb C	Batt C

'Amb C' is internal cabinet temperature.



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November 2016

The Elliott Rd (Tempe) cabinet has experienced reliability issues with the TEC for the duration of this study. The cabinet was identified as a candidate to be converted to air-cooled and eliminate the troublesome TEC at this site.

In order to continue aging these PYL12V185FT samples in a TEC cabinet application, the samples were relocated to 524 N. 92nd St. Scottsdale (Casino Arizona lot).

The final dataset from this logger prior to relocating the string to Casino Arizona-Scottsdale is shown. Although it appears the TEC was functioning during the summer months it was out of service when we visited the cabinet in November 2016.

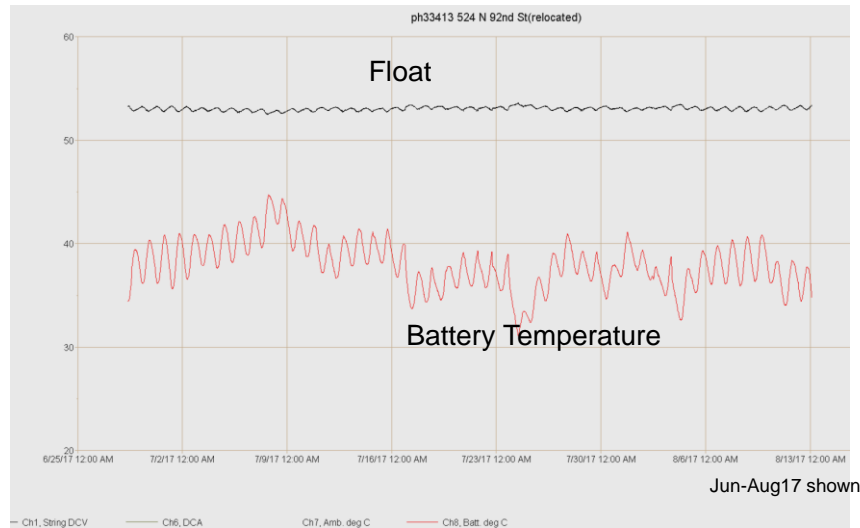
2017 update follows



The first logger summary for the period Nov 2016 – Nov 2017. The TEC is not functional in this cabinet.

MIN	50.49	-33.47	16.34	20.12
MAX	54.35	3.59	46.80	44.73
AVG	53.87	0.40	27.99	28.14
	Volts	Amps	Amb C	Batt C

The data logger stopped working in August 2017 resulting in the loss of Data August – November 2017.



'Amb C' is internal cabinet temperature.

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November 2017

The samples have spent a full year in the TEC cabinet at Casino Arizona in Scottsdale. This cabinet is identical to the Purcell cabinet at Elliott Rd. The TEC was not working when we installed the samples at this site in November 2016.

The data logger stopped recording in August 2017. Data from mid-Aug-Nov 2017 is missing.

Notice the maximum battery temperature is 44.7C with the non-functional TEC and period average is 28.1C. Substantially higher than experienced in the Elliott Rd TEC cabinet. The average would likely have been higher if this dataset included through mid-October.

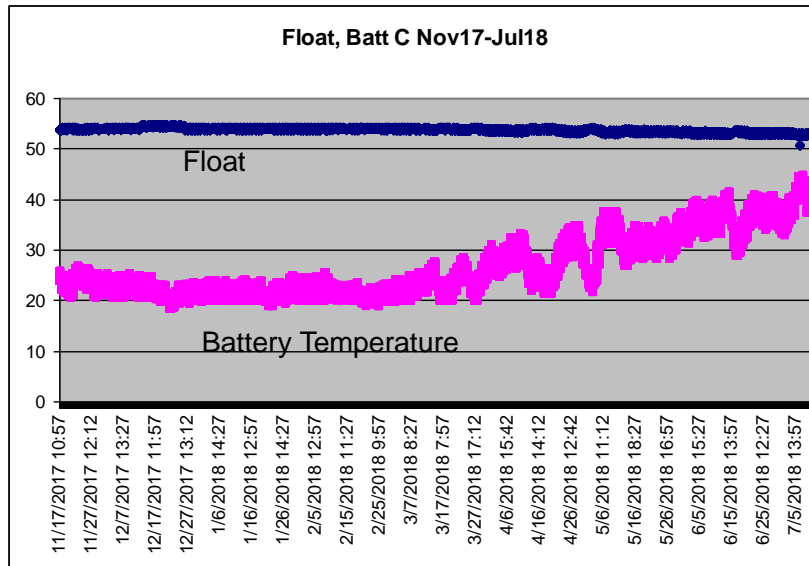
2018 update follows



The logger summary for the period Nov 2017 – Nov 2018.

MIN	50.54	-35.33	16.87	19.72
MAX	54.88	5.82	46.25	44.55
AVG	53.95	0.33	29.05	28.29
	Volts	Amps	Amb C	Batt C

There is a memory fault in this logger.
It will be replaced in January 2019.



The logger temperature readings became unreliable after a discharge event July 9, 2018. The chart is therefore limited to Nov 17-Jul 18.

'Amb C' is internal cabinet temperature.

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November 2018

These PYL12V185FT samples have spent two years in the TEC cabinet at Casino Arizona, November 2016 through November 2018. The TEC remains non-functional. Some leads have been disconnected and appear to have burned.

Data recovered from this logger is once again been corrupted. There appears to have been a lightning or power event about July 9, 2018 at 17:12. The logger recorded a discharge event (50.55V) and at the same time battery temperature dropped from 40.07C to 24.28C. Internal cabinet temperature also dropped from 41.38C to 26.44C in 15 minutes. All subsequent temperature readings after July 9, 2018 appear to be inaccurate. This event may be related to the burned TEC leads. I suspect the average battery temperature November 17- Jul 9, 2018 is accurate, **averaging 38.28C**. This event may also have caused the data corruption. The logger is no longer reliable and will be replaced in January 2019.

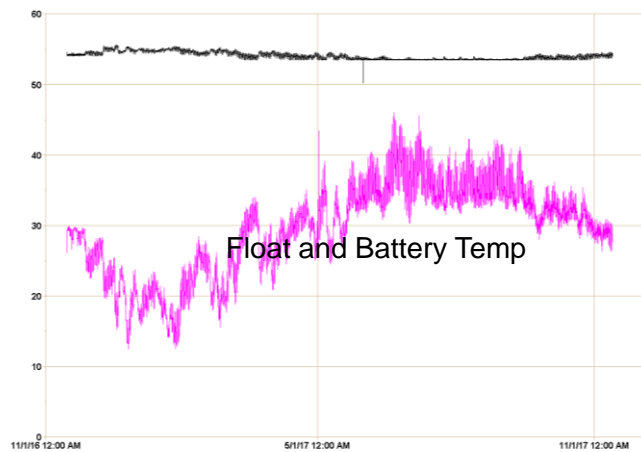
The maximum battery temperature at **44.55C** is similar to that observed between Nov16-Nov17. The average battery temperature of **28.29C** for this period Nov17-Nov18 is unreliable given the event mentioned above.

The string was removed November 2018 and discharged at the 8 hour rate. **It produced 177.27Ah or 95.93% of rated capacity after 5.22 years in service.** Being satisfied with the results the customer elected to conclude the study at this time. The samples have been returned to the factory for tear-down and analysis.



Outside Air Cooled Cabinet, Tempe Arizona Data Logger results Nov16 – Nov17

ElliottRd_AirCooled_PH12031B



AVERAGE	54.07506	29.486	29.52	26.7761
MAX	55.57	49.3	46.03	50.03
MIN	50.21	11.07	12.46	6.89
	Volts	Cab C	Bat C	Out C

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A string of PYL12V185FT samples were installed in a Purcell TEC cabinet in Tempe, Arizona **November 2016 (Elliott Rd Tempe)**. As part of a customer initiated test, this cabinet was converted to outside air cooling. A data logger was installed to monitor float voltage, cabinet temperature, battery and outdoor temperatures. A summary of the first 12 month dataset is shown here.

Logger Data November 2016 – November 2017:

- The average **battery temperature for this period was 29.52C**, slightly higher than the average outdoor temperature of 26.77C.
- With exception of a few brief periods, the **float voltage was within the operating range of this battery** during this period.

The string was removed November 14, 2017 and discharged at the 8 hour rate.

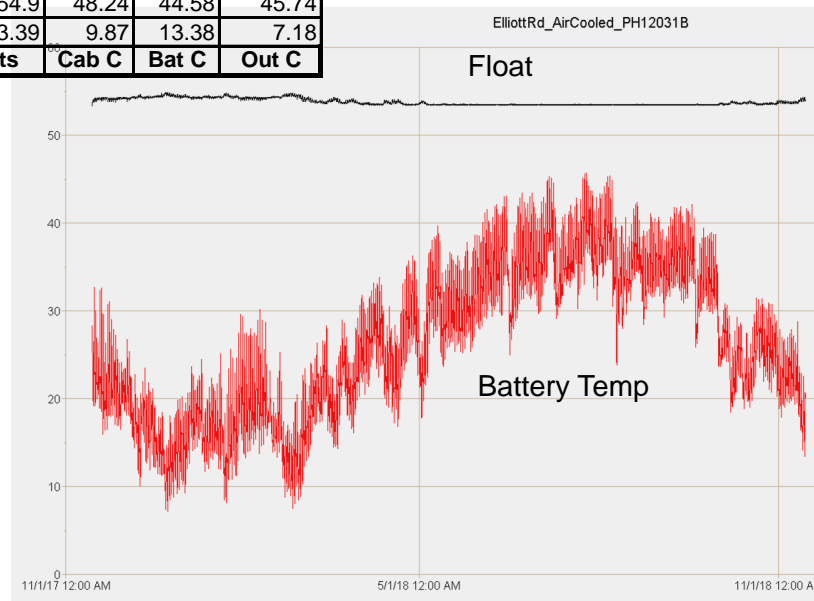
- The string was found to be at **106.54% (1) of rated capacity after 1.03 years in service.**
- The string was reinstalled and the study continues.

(1) The string produced 110.02% at 28.28C. After applying a temperature correction factor, the string is rated 106.54%.



Outside Air Cooled Cabinet Tempe Arizona Data logger results Nov17 – Nov18

AVERAGE	53.83575	29.527	29.157	26.4186
MAX	54.9	48.24	44.58	45.74
MIN	53.39	9.87	13.38	7.18
	Volts	Cab C	Bat C	Out C



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The PYL12V185FT string reached two years in service November 2018. A summary of the second 12 month dataset Nov17-Nov18 is shown here.

Logger Data November 2017 – November 2018:

- The average **battery temperature for this period was 29.15C**, slightly higher than the average outdoor temperature of **26.41C**.
 - Similar to Nov 2016-Nov 2017.
- The July-September average battery temperature was **35.9C**.
 - Maximum battery temperature was **44.58C**
- Analysis of battery temperature and float voltage:
 - High-Temp-Comp is maintaining the float within the battery operating range.
 - Low-Temp-Comp at times is under-charging ~200mV. This should not affect battery life but may be an indication of an incorrect temperature compensation setting in the plant.
 - Being satisfied with the accumulated data for this site, the customer requested the data logger be removed in January 2019.
- During the summer months, fans do not appear to operate when the outside air is cooler during pre-dawn hours. This is a missed opportunity to lower the temperature of the thermal mass (batteries).



Site Summary

<i>Location</i>	<i>Structure</i>	<i>Time In Service</i>	<i>Most Recent Discharge Results</i>	<i>Average Temperature</i>		<i>Comments</i>
				<i>Amb.</i>	<i>Bat.</i>	
Milford, CT	OSP Cabinet	Approx. 10 Years	107% (10 Years)	13.4	14.9	
Addison, TX	OSP Cabinet	5.35 Years	86% (5.5 Years)	28.8	25.9	Float Voltage and Temp Comp Issues
Paris, OH	OSP Cabinet	3.0 Years	112%	11.7	16.2	Float Voltage and Temp Comp Issues
Tempe, AZ (Rural Rd.)	OSP Cabinet	3.5 Years	108%/110% (2.3 Years)	34.0	33.8	
Tempe, AZ (Elliott Rd.) to Scottsdale	OSP Cabinet (TEC)	5.2 Years	95.9% (5.2 Years)	27-29	27-30	TEC Unreliable
Tempe, AZ (Elliott Rd.)	OSP Cabinet (Air Cooled)	2 Years	106.5% (1 Year)	26	29	

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