Desulfation Tests of the HD-1224 Conducted by Canadus Power Systems

The following are the results of an in house desulfation test performed by Canadus Power Systems on sulfated batteries pulled from the field from in service emergency vehicles using the Canadus HD-1224 battery desulfator.

Canadus HD-1224 Capabilities:

Batteries ultimately fail for a number of reasons; loss of capacity over time, cracked plates, shorted cells, corrosion of the grid plate, loss of active plate material, over charging, undercharging, vibration-related grid fatigue, extreme heat, etc. The root cause of 80% of these battery failures is chemical in nature, caused by a normal aging process called sulfation. Much like when water freezes, lead-sulfate expands when it forms and grows into larger and larger crystals over time. The larger these crystals grow, the more space they take up, and the more mechanical damage they inflict on the plate surface and grid integrity. While the Canadus HD-1224 is capable of dissolving these crystals, as demonstrated by an increase in the electrolyte's specific gravity, it cannot reverse any mechanical damage already caused by the hardened lead sulfate crystals, such as plate warping, breakage, or loss of active material. Therefore, while we expect that nearly every battery will improve to some extent as a result of its exposure to the HD-1224, the level of improvement will be related to the degree to which the battery has been mechanically damaged which in turn affects electrical performance.

It should be noted that no battery will improve on its own and that without intervention, a fully formed battery's capacity will always diminish over time. Therefore, these tests should not focus on the degree to which desulfation has occurred, as each battery will respond differently based on how and for how long it became sulfated, but whether desulfation has indeed occurred at all. If the Canadus HD-1224 desulfates an aged, sulfated battery by a measurable amount, it will certainly achieve its ultimate goal of preventing sulfation in the first place. Eliminating sulfation from occurring in new batteries has the additional benefit of also preventing sulfation-specific mechanical damage that would have otherwise occurred (such as plate warping or breakage from expanding lead sulfate crystals). Therefore, the HD-1224 is capable of eliminating 80% or more of the batteries' normal failure mechanisms. With regard to batteries already in service, while the HD-1224 will not fully recover most of the older batteries to "like-new" condition, any measurable improvement will be accompanied by the immediate arrest of the normal battery capacity decline, thereby extending battery life.

Test Methods:

Canadus will be performing a controlled test performed to EN50342-1:2006 specification in a laboratory environment to validate the HD-1224 independently. This test was performed in-house as part of our product development efforts.

The test was performed using two methods;

Cold Cranking Amps (CCA):

CCA values were collected with were collected with an OTC/SPX 3184 CCA Meter. The values collected (labeled below as RAW-CCA) were then temperature corrected with Canadus' temperature correction Algorithm (TC-CCA). This correction is necessary because no CCA meters on the market today correct for temperature even while the reading is highly dependent on it.

Load Test:

For expediency we chose not to test each battery independently and rather group them together by CCA in three's (In the controlled tests each battery condition will be measured independently). This allowed us to use a Lester 17770 36V/48V golf cart battery load tester. This tester uses a fixed resistance to time the discharge until a minimum voltage is reached. This test method has two differences when compared to the EN50342-1:2006 test. First, the current is much higher (75 amps vs. 25 amps), resulting in a shorter discharge time (though not linear, owing to the aggressive current draw and thus greater stress on the batteries). The second difference is that each battery is not tested individually with regard to reserve capacity, and thus one poorly performing battery can affect the result of the other two batteries. By sorting the batteries according to CCA prior to the start of the test, and making sure that batteries in similar condition were grouped together, this difference was somewhat mitigated, and the idea was simply to show whether or not there was any improvement in battery capacity.

Batteries:

- 6 Exide, Commercial Series, 31D batteries
- Age: Approximately 2 years old, and batteries were still in service on emergency vehicles and not due for replacement.
- Rating: 660 CCA / 160 minutes of Reserve Capacity at 25 amps

Procedure

1. **Battery Baseline Data Collection**
    - **a.** The batteries were given a full charge and were maintained at 14.4V/28.8V for over 24 hours with 4 independent adjustable power supplies. The batteries were charged in both 12V and 24V configurations to test the 12v and 24V modes of the HD-1224.
        - **i.** Power Supply 1, Charging Voltage = 28.8V, Batteries 1, 3
        - **ii.** Power Supply 2, Charging Voltage = 14.4V, Battery 4
        - **iii.** Power Supply 3, Charging Voltage = 14.4V Batteries 2
        - **iv.** Power Supply 4, Charging Voltage = 28.8V Battery 5, 6
    - **b.** After charging, the batteries were allowed to sit a few hours to remove surface charge.
    - **c.** Their temperature was then measured using a Raytech infrared thermometer, and they were then tested for their raw CCA rating using an OTC/SPX 3184 CCA Meter. The raw CCA reading was then adjusted for temperature using Canadus' proprietary algorithm (TC-CCA).
    - **d.** The batteries were then subjected to a load test (reserve capacity test) using the Lester Load Tester.

e. The measurements recorded for these initial tests represent the baseline of the batteries prior to installation of the HD-1224 battery desulfators.

2. **Battery Test Data Collection**
   - **a.** 4 HD-1224's were then installed on the batteries in the configurations listed above.
   - **b.** Steps 1a through 1d were repeated three additional times, 4-days, 4-days, and then 8-days apart. The batteries were subjected to constant charging at the listed voltages between the tests.
   - **c.** The measurements recorded for these tests represent the condition of the batteries following the installation of the HD-1224 battery desulfators.

Results:

CCA (See Appendices I and 3 for the individual results):

- All 6 batteries showed an average absolute increase in temperature corrected CCA's (TC-CCA) of **28.3% after 16 days** of exposure to the Canadus HD-1224 based on the original rating of the batteries.
- The 6 batteries improved from an average rating of 397 CCA (60.2% of OEM spec) to an average rating of 584 CCA (88.5% of OEM spec).

Load Test (See Appendices 2 and 3 for the individual results):

- GROUP 1, Batteries 1, 3 and 4 showed an increase in discharge times of **6.2% after 16 days** of exposure to the Canadus HD-1224**.**
- GROUP 2, Batteries 2, 5 and 6 showed an increase in discharge times of **16.0% after 16 days** of exposure to the Canadus HD-1224**.**
- The average improvement in discharge time for all batteries was 11.1%

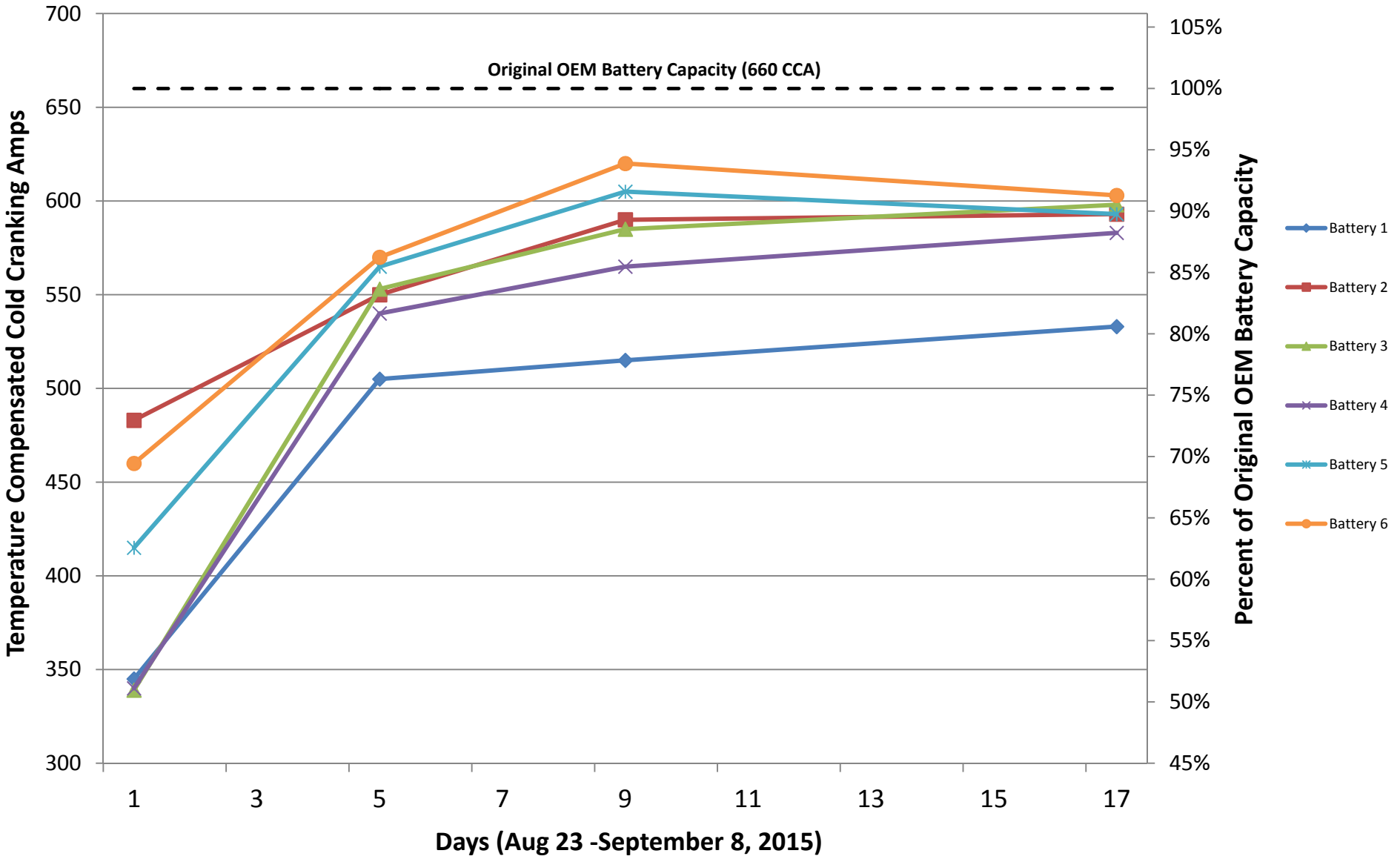
Conclusions:

Once the baseline conditions of the batteries were established, the addition of the HD-1224 significantly improved the capacity of all of the test batteries over a period of 16-days. CCA improved by an average of 49.9%, with 5 of the 6 two-year old batteries reaching ~600 CCA, or ~90% of the original OEM capacity, from a starting capacity in the range of 345 – 483 CCA. Similarly, battery discharge time improved by an average of 11.1% during the same time period, with every battery showing improvement. It should be noted that most of the capacity was recovered in the first 4-days of the test, or the first quartile, demonstrating the power of the HD-1224.

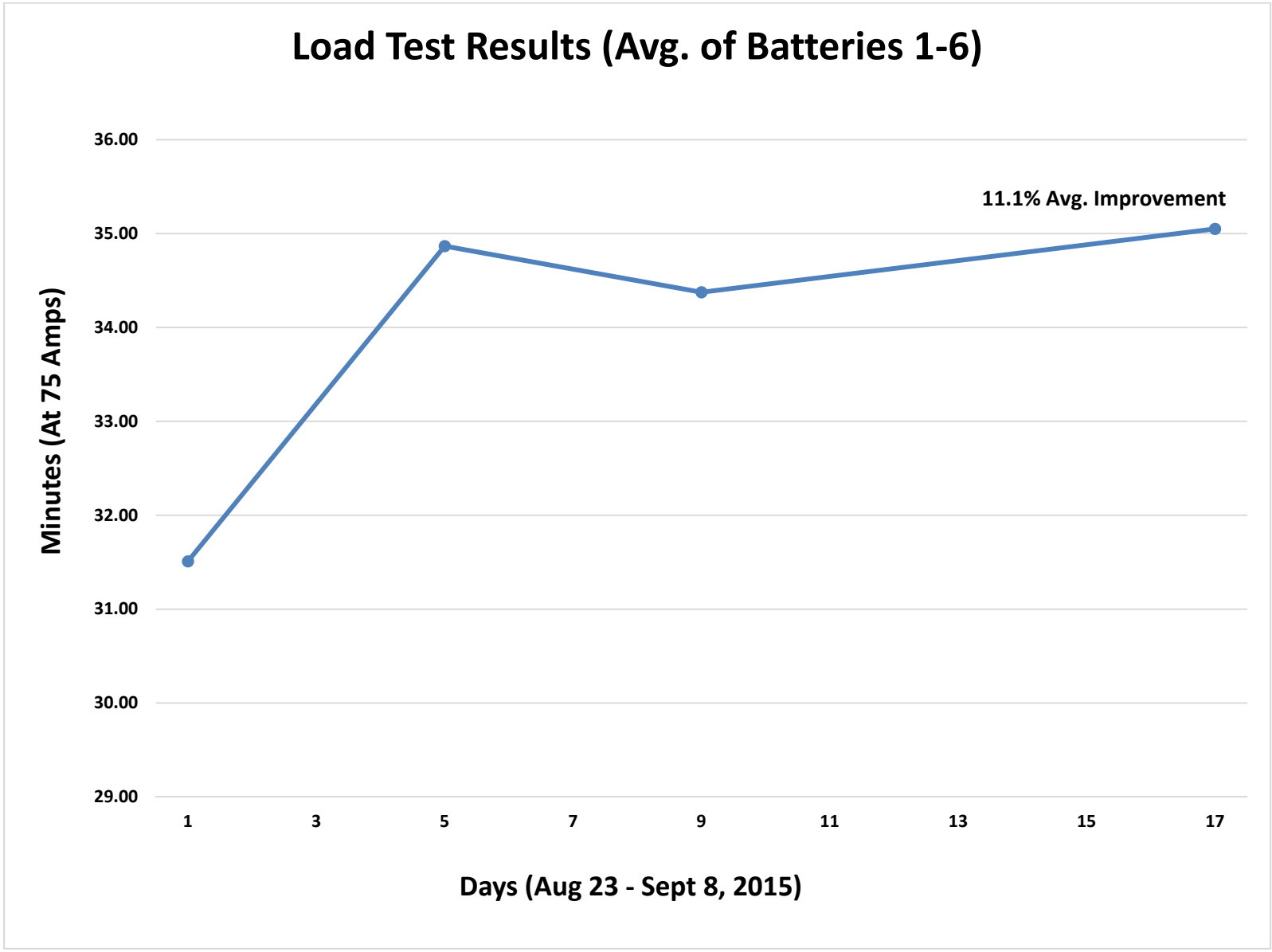
As stated earlier, no lead acid battery can improve on its own over time. Batteries can fail in only one of two ways; mechanically or chemically (as a result of sulfation). Since it is impossible to improve mechanically damaged batteries without cell replacement, the loss in capacity of the baseline-condition batteries in this test was caused by normal chemical aging defined as sulfation. Thus the addition of the HD-1224 significantly improved the capacity of every test battery by reducing the sulfation level.

Since the HD-1224 has been shown to remove sulfation once it has formed in these tests, by using the HD-1224 on new batteries, sulfation can be prevented from the start. This has the additional benefit of preventing those components of mechanical damage that sulfation would have caused had the HD-1224 not been used. Together, these preventative desulfation mechanisms help the HD-1224 significantly extend the life of lead-acid batteries.

Appendix I: CCA Results



Appendix II: Load Test Results



Appendix III: CCA and Load Test Data

Temperature Corrected CCA Results														
DATE	1		2		3		4		5		6		AVERAGE	
	TC-CCA	% of SPEC	TC-CCA	% of SPEC	TC-CCA	% of SPEC	TC-CCA	% of SPEC	TC-CCA	% of SPEC	TC-CCA	% of SPEC	TC-CCA	% of SPEC
August 23, 2015	345	52.3%	483	73.2%	339	51.4%	340	51.5%	415	62.9%	460	69.7%	**397**	**60.2%**
August 27, 2015	505	76.5%	550	83.3%	553	83.8%	540	81.8%	565	85.6%	570	86.4%	**547**	**82.9%**
August 31, 2015	515	78.0%	590	89.4%	585	88.6%	565	85.6%	605	91.7%	620	93.9%	**580**	**87.9%**
September 8, 2015	533	80.8%	593	89.8%	598	90.6%	583	88.3%	593	89.8%	603	91.4%	**584**	**88.5%**
Absolute Battery Improvement	**188**	**28.5%**	**110**	**16.7%**	**259**	**39.2%**	**243**	**36.8%**	**178**	**27.0%**	**143**	**21.7%**	**187**	**28.3%**
Relative Battery Improvement	**54.5%**		**22.8%**		**76.4%**		**71.5%**		**42.9%**		**31.1%**		**49.9%**	

Load Test Results			
Date	Discharge minutes at 75 Amps		
	Batteries 1,3,4	Batteries 2,5,6	Batteries 1 - 6
8/23/2015 (Baseline)	**30.52**	**32.50**	**31.51**
8/27/2015	**32.95**	**36.78**	**34.87**
8/31/2015	**31.85**	**36.90**	**34.38**
9/8/2015	**32.40**	**37.70**	**35.05**
Increase in Discharge time	**6.2%**	**16.0%**	**11.2%**