Military Battery Testing, Charging and Recovery

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Abstract:

Beginning in 2004, Midtronics Inc. received Congressional Plus-UP contract number W15P7T-05-R010 to investigate what are being called passivation failures reported with 6-TMF lead/acid vehicle batteries. The objective was to find potentially good batteries that were being returned and scrapped prematurely. The two main questions we were attempting to ask and answer were first, could we find passivated batteries and second, what methods could be used to reasonably recover these batteries to serviceable condition? Field visits were made to multiple Military posts where testing and initial screening was done on over 2000 "as found" battery cores for State of Health (SOH) and State of Charge (SOC) data. Of these samples, ~300 battery cores were shipped to Midtronics laboratory for specific testing and algorithm development. The results of this study were very encouraging. This paper will provide data showing the potential economies that are available if vehicle batteries are tested and properly charged.

Key words: Passivation; Conductance; diagnostic charger; charge acceptance

Introduction

Field investigation revealed four prominent factors relating to how batteries are being returned in error. The facts are;

1.) We found no consistent process for testing, charging or servicing vehicle batteries among the field location visited.

2.) Training materials for the soldier or contractor could not be verified. If a battery is removed from a vehicle, they are simply being turned in for scrap without first being diagnosed at the field maintenance level.

3.) By using the diagnostic battery chargers based on Midtronics standard GR-1, we were able to recover a significant percentage of these returned batteries.

4.) Consistent methods for battery training, testing, charging and handling need to be adopted. A dedicated process and procedure will eliminate the variables that seem to contribute to field decisions that are unproductive and expensive.

The work needed to address these referenced issues is already well underway. This paper will provide insight into the work that has already been done and how it relates to military preparedness. The final goal is to help protect the soldier by improving the overall condition of our military vehicle fleet.

Field Objectives

The challenge for US Military vehicle maintenance personnel is - what are the proper steps to safely test and charger vehicle batteries? Field personnel need an effective way to judge the critical parameters of battery SOH and SOC. With that information, an appropriate decision can be made regarding the suitability for each battery to either remain in service or to be replaced. Vehicle batteries are working harder than ever to provide power for more complex and sophisticated systems than ever before, not just to provide cranking power for engine starting. Vehicles now routinely operate with the engine OFF for "Silent Watch" periods where the batteries are the sole source of power. Silent Watch is obviously used to reduce the vehicle acoustic and thermal signatures to help conceal their position from enemy forces while stationary – which is a good thing.

The 6-TMF Battery

This study focused primarily on 6-TMF battery with a lead/tin grid, see Table 1. Several battery types were found while testing, but the largest numbers of batteries in use today are the 6-TMF variety.

Table 1: *Battery Specification*

6TMF Performance Specifications	
Amps to 7.2V and 30 seconds @ -18C @ -40C	725 350
Reserve Capacity (minutes)	200
Ampere-Hours (C/20)	120
Nominal Weight (kg)	34
Electrolyte Sp. Gr. (60F)	1.277-1.285
Dimensions (L x W x H – mm Max)	286 x 267 x 230
Nominal Voltage	12V
Life Cycle Capacity	235 cycles
Water Loss Hours	4500

Batteries, Storage: Lead-Acid, "Maintenance Free"
Performance Specification ATPD 2206
Revision No 7: 13 Aug 2001

Field Screening

While doing the initial battery screenings, nearly 70% the all vehicle batteries found in the return piles were below 9.99 volts. That's a huge percentage of badly discharged batteries. With their fairly unique size, capacity and the 6-TMF construction, efforts had to be made to quantify the appropriate screening method for field returns. After visiting a total of eight active military and National Guard installations during 2004 and 2005, more than 2,000 vehicle battery returns were tested using a Midtronics Micro series hand held battery tester. Batteries needed for this study had to measure 10.0 DC volts or lower and have zero battery conductance in "as found" condition. The low voltage and zero CCA batteries were separated for a second charge acceptance screening process to identify exactly how bad their charge acceptance was.

This second screening method was very specific. By placing a constant voltage power supply across the battery terminals, initial charge acceptance could be observed. If they wouldn't charge, those were the battery examples we could work with. Using a regulated power supply set at 15.0 DC volts, the immediate charge current acceptance was measured. *See Figure 1.* If charge acceptance stayed below a predetermined value of two amps for two minutes, we knew we had a good candidate for detailed laboratory performance testing.

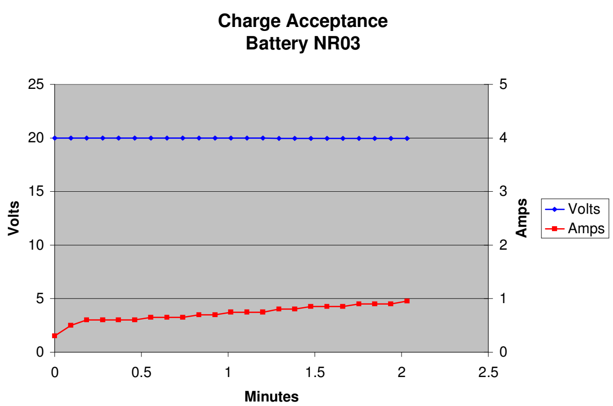

Figure 1: Low Charge Acceptance

This screening process was necessary to reduce the total number of batteries that would have to be transported back to Midtronics' laboratory. Even so, over 300 scraped battery cores were shipped back to provide the detailed data basis for this project. Mixed together were different battery types with a wide distribution in their measured test values. This wide variety of batteries with different SOC and SOH values would be important for developing to proper charge and test profiles. There needed to be a comprehensive understanding of how these batteries would respond to gauge their recovery potential from various conditions.

Passivation Problem

With lead/acid vehicle batteries that have become hard to charge, the term "passivation" has been used to describe this performance issue. (1) This is a process that occurs at the plate surface when active material becomes passive and resistant to charge or discharge energy. Battery response data has been used to hone charge algorithms specifically for high capacity batteries like the 6-TMF. A diagnostic charger platform was the obvious choice for implementing the necessary charging algorithms to diagnose and recover these batteries. Work started based on Midtronics GR-1 commercial charger, and the resulting product is being called a GR1 240US. This platform allowed the diagnostic charge algorithm to be developed, tested and validated. New software for this HD charger includes menu selections for a wide variety of high capacity 12 volt automotive batteries with several specific military battery models are preprogrammed menu selections. These units will be available for military, marine, heavy equipment and other users with large batteries that because of their vehicle usage patterns may also be exposed to extended storage periods.

As of this writing, several prototype GR1-240US chargers are already in service with US Military forces stationed in Iraq and elsewhere. These units are providing critical support for vehicle maintenance teams. Additional unit deployments are being scheduled and these additional units should help expand our data base for field performance validation.

Keep in mind, the distinction between SOC and SOH had to be carefully considered and the distribution between them has been important for developing to correct diagnostic charging profile. The laboratory test results gave our team enough data to form a comprehensive understanding of how these batteries would respond when charged in various conditions. Of all the batteries tested, roughly 40% were slow to respond to initial charge energy and these samples were carefully analyzed for charge acceptance and recovered capacity performance.

Soldier Comments

Field personnel in two locations described how they handled vehicles when they encountered a NO START. It was common procedure to "slave start" the truck or track vehicle and let it run for maybe half an hour. Their expectation was that the batteries did not need much time on charge because the vehicles have high output alternators. If the battery charge acceptance is low, not much energy will actually be returned to the batteries with a short charging session. The dashboard volt meter will go to the proper level almost immediately with the engine running but the battery is not accepting a charge. The vehicle gets shut off and when they try to start the engine several hours or a day later, nothing happens and you guessed it – the discharged batteries are all removed and exchanged for new ones. The batteries must have been bad – so the batteries get changed to "fix" the vehicle! Good news, we can take the truck off the deadline report.

This situation is probably more common than would be desired. From that, it is hard to quantify what the total number of batteries that are getting replaced prematurely. The cost associated with replacing good batteries with other good batteries implies there are significant operating costs that are not very productive. For example, an LMTV will use four 6-TMF batteries. If the batteries cost around ~$100.00 each and you add in a couple hours of labor to exchange all four batteries, that probably costs more than $500.00 for the exchange. This conservative figure does not include the total logistical cost however for transportation of the new batteries and disposal of the old batteries. Some quick math on a sample of perhaps 10,000 military vehicles would incur and unnecessary annual expense of over five million dollars.

Now, what can be done about these issues?

GR1-240US Diagnostic Charger

Midtronics has been building commercial battery chargers for many years. The new model diagnostic chargers that combine the passive conductance testing along with load test performance while observing battery charge acceptance. One objective of the congressional contract was to come up with substantive ways to address these large numbers of hard to charge batteries in the field before they are returned for scrap. The good news was that batteries in the field with low charge acceptance weren't hard to find. Battery age was not a significant factor. Scrap pile batteries ranged in age from just 4 months to 9 years of age, but the absolute majority were less than three years old. The majority of these field returns were discharge and some were never used while others were fully charged batteries in good condition.

Each war fighter has one primary objective – keeping themselves and their equipment ready to perform at peak level. To that end, we approached this project with the intention of providing a meaningful impact on a huge logistical and economic burden currently restricting our military vehicle preparedness.

In Figure 2, we show a small sample of the kind of data used in our diagnostic approach. Because we had identified specific properties of low charge acceptance 6-TMF batteries, new experiments created to see what could be done if anything to reliably bring these batteries back to serviceable conditions in a reasonable amount of time. Some battery samples were slow to respond even when held at high voltages for several hours. When measured in Amp Hours, there were some cores that were charged to as much as 170% of their rated Amp/Hr capacities before they would respond. The moral was, if you have enough time and a huge amount of patience, in some rare cases some old batteries might slowly recover. This of course would not be impractical based on time alone, plus what faith would you put in a used battery that is hard to charge?

		Fully Recharged				
No.	GR1 Results	OCV	CCA	Decision	Load Test 15" V	Decision
H005	Replace	12.86	776	Good	10.42	Good
H006	Disassembled--Recharging Turned Good					
H015	Replace	Defect		Replace	not testable	Replace
H017	Replace	12.92	881	Good	10.70	Good
H018	Replace	Defect		Replace	not testable	Replace
H019	Replace	12.82	626	Good	9.85	Replace
H021	Replace	Defect		Replace	not testable	Replace
H025	Replace	Defect		Replace	not testable	Replace
H026	Good	12.87	882	Good	10.57	Good
H027	Replace	12.79	801	Good	10.36	Good
H028	Replace	12.92	588	Replace	9.90	Replace
H029	Replace	12.99	884	Good	10.67	Good
H030	Good	12.90	934	Good	10.68	Good
H031	Replace	Defect		Replace	not testable	Replace
H032	Replace	6.13	15	Replace	not testable	Replace
H049	Replace	Defect		Replace	not testable	Replace
H050	Replace	Defect		Replace	not testable	Replace
H051	Replace	11.98	61	Replace	not testable	Replace
H052	Replace	Defect		Replace	not testable	Replace
H053	Replace	12.76	780	Good	10.31	Good
H054	Replace	12.79	268	Replace	3.48	Replace
H055	Replace	13.02	874	Good	10.71	Good
H056	Replace	Defect		Replace	not testable	Replace
H061	Replace	Defect		Replace	not testable	Replace
H062	Replace	Defect		Replace	not testable	Replace
H063	Replace	12.89	801	Good	10.33	Good
H070	Replace	Defect		Replace	not testable	Replace
H075	Replace	Defect		Replace	not testable	Replace
H079	Disassembled--Grids Fracturing					
H081	Replace	Defect		Replace	not testable	Replace
H082	Replace	12.80	771	Good	10.37	Good
H085	Disassembled--Sent for Analysis					

Figure 2: Fort Hood Battery Data

Recovery Time

Now that we had some data to work with, diagnostic limits for the charge algorithms really took shape. Several qualifiers are built into the diagnostic charging algorithms. The GR1-240US first measures battery conductance and the terminal voltage in an analysis phase that takes about two minutes. If the initial test shows conditions that indicate the battery is bad, the charge session is terminated and the operator gets the audible beep and display showing "Bad Battery". If there are no catastrophic faults detected, the charge process will begin using combinations of conductance measurements, load performance along with current and voltage algorithms tailored to specific battery types.

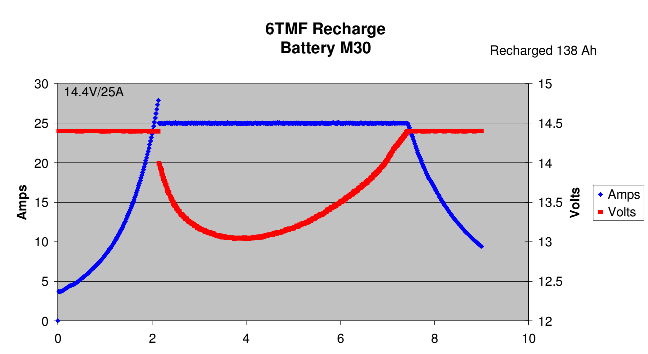

Figure 3: Battery Recovery

When the user selects the "Diagnostic Charge" mode, everything happens automatically. The charger is looking for the battery SOH and a minimum SOC to determine how it will begin to charge. The diagnostic charger will continually update the measured conductance, voltage, charge acceptance and load response during each charge session. If no structural or capacity faults are detected while charging, the high amp output will bring even badly discharged batteries back in a relatively short period of time. The actual maximum charge session limit has been establishes at five hours. This means batteries that have very low charge acceptance will still have a chance to respond and be recovered if practical. By the same token, if any battery is not coming up to necessary performance levels during a charge session, the charging process will terminate and the operator will be alerted.

The algorithms that have been developed will properly guide the diagnostic charger to be patient if they need to be, and to run at high output when a battery can accept more current. These algorithms will get batteries back into condition in as quickly as possible. In the end, only the batteries that demonstrate high enough recovered CCA values, good load performance and have recovered to approximately 90% SOC or more will pass the charger test. Now the war fighter gets the only decision they really need regarding each battery, it will either be called ***– good or bad!***

Safety First

By using combinations of complex measurements, a true diagnostic picture of the battery is composed. This technique will identify battery faults that could pose a safety risk for personnel who may be close by. If a battery fault is detected, the charge session is automatically stopped and the operator will get both a visual and audible indication of that charge status. The fault could be a broken internal weld, a shorted cell, or badly corroded plate structure, any and all possible failure will be found. The field personnel are much more likely to be good technicians rather than trained battery chemists. The work has been done by a dedicated engineering team to develop a modern tool that will give the war fighter the most advance way possible to analyze and properly charge recondition the heart of every vehicle, the battery.

Local success story

Apparently there have been some constraints on battery availability in some military supply channels. As a part of the work associated with this extensive study, a number of reclaimed batteries were delivered to a National Guard center near Chicago. Because this NG unit was unable to obtain needed batteries for some of their vehicles through normal channels, our recovered battery cores came in very handy. With the inventory of batteries we collected, every battery we tested and recovered were delivered to the NG center and put back into service. More than seventy 6-TMF and ArmaSafe batteries were returned to this local unit for their vehicles. Returns were only provided with batteries that were less than two years old based on the manufacture date code and that performed at or above 100% of their rated Reserve Capacity and CCA ratings. The value of these batteries alone amounts to a local saving of about $7,000.00. Not much in most military budget terms, but it is hard to ignore the potential savings if these charge and recovery techniques are applied on a wider scale.

Summary

Significant numbers of the vehicle battery returns found in the field have been badly discharged and subsequently discarded. It has also been demonstrated that across a wide sample of returned batteries, they could also be reconditioned and brought back to serviceable condition when exposed to the appropriate diagnostic charge regiment. Significant dollar savings are available with better products combined with consistent methods and procedures for handling vehicle batteries. In conjunction with the development of the GR1 240 US battery charger hardware and software, new training materials are also being prepared to support the war fighter with the initiatives represented by the work already completed.

Acknowledgements

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{1} Technical Summary Report, Passivation in Military 6-TMF Batteries, Doc No. DAA-IM-146 J. Klang