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Hot Application Cycle Life Test for Automotive Storage Batteries

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ABSTRACT

The current SAE standard for an accelerated laboratory test, J240b, does not comprehend the high under hood operating conditions of modern automobiles. The SAE Automotive Storage Battery Standards Committee commissioned a Task Force to develop a new test standard. Their objective was to develop a test that produced failure modes found in high temperature service and that took less time, A test development strategy was developed and carried out by members of the Task Force. The results indicated that running the current test, J240b, at a higher temperature, 75°C produced good results for batteries constructed with book mold cast grids but not others.

INTRODUCTION

To shorten product development time and to support continuous improvement, the automotive industry requires accelerated testing methodology that allows reliable evaluation of changes in component design and technology. The current accelerated laboratory SAE test standard for automotive storage batteries, J240b, was established in 1972 and modified in 1982. At the time this test was established, the negative impact of high temperature service on battery life was well documented by studies such as the BCI Failure Mode Study [1]. However, in general high temperature service was typically associated at that time with high temperature climate geographical regions and not automotive service environments. The designs of today's automobiles have significantly higher under hood temperatures at which the automotive storage battery must operate. The J240b life test is run at 40°C. This temperature does not represent today's under hood temperatures. The failure modes resulting from J240b at 40°C do not mirror those found in actual service.

Automotive companies and battery manufacturers have been aware of the inability of the J240b standard to be used to evaluate battery design and technology changes for improved high temperature service durability. They have investigated modifications to J240b and even established their own internal tests in some cases. Several companies have found that J240b run at 75°C gives good results. Changing the J240b test standard operating temperature from 40°C to 75°C was proposed to the SAE Automotive Battery Standards Committee. This change was accepted as an alternative test by the committee. There was disagreement on how applicable this test was to all battery design technologies, and there was dissatisfaction on the length of time the test took to complete. To address these problems, the Standards Committee commissioned a Life Cycle Task Force in September 1994. (See appendix for Task Force membership.) The objective for the task force was to develop a life cycle test that would produce the failure modes found in high temperature service for all current commercial lead-acid battery design technologies and that would be shorter in duration than the current test.

This paper will establish the basis for the development of a battery durability test by relating the history of SAE battery life tests. The test development strategy used by the Task Force will be described. The results of battery testing and the analysis of the test data will be presented. The findings of the Task Force and the recommendation to add an option to run J240b at 75°C will be presented.

SAE BATTERY LIFE TEST HISTORY

The automotive and battery industries have recognized the need for an accelerated laboratory life test which would indicate how long a battery would operate in typical service conditions, The SAE battery life test standard has existed in three forms since a life test for automotive storage batteries was first established over sixty years ago. Changes in the life test standard have been in response to changes in typical service condition as the automobile has evolved. The following is a brief description of each of these tests and the service condition that necessitated the test.

CYCLING LIFE TEST (CONSTANT CURRENT) – The first life test standard for automotive storage batteries subjected the battery to deep cycling constant current charge and discharges. For 12 volt batteries rated below 80 amp-hour capacity at the 20 hour rate, the test was as follows:

1. Discharge at 20 amps (constant current) for a total of 20 amp-hours at 110±5° F.
2. Recharge at 5 amp (constant current) for 5 hours for a total of 25 amp-hours at 110±5° F.
3. A complete capacity discharge test is made each week to determine the condition of the battery. The test is run at a 20 amp rate and is complete when the battery equivalent cell voltage is 1.70 volts.
4. The test is complete when the battery fails to achieve 40% of the ampere-hours equivalent of the ampere-hours rated by the manufacturer at the 20 hour rate.

A graphical representation of the test cycle is shown in Figure 1.

The failure mode of this test was the shedding of active positive plate material.

This was probably a meaningful test when it was introduced as a standard. At the time this standard was adopted, most states had the requirement that cars parked on the street overnight must have their parking lights "on". As the automobile evolved and parking light requirements were eliminated, this test no longer represented typical service conditions for the automotive storage battery. Finally, this test was eliminated from the SAE standards and was used only for the development of internal components of the battery. [2]

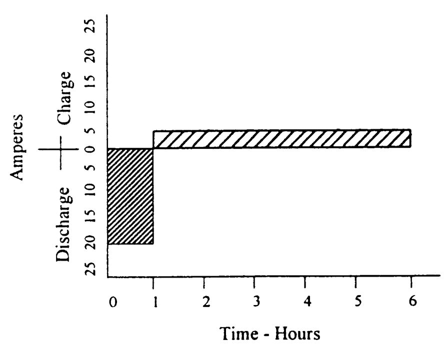

Figure 1. SAE Cycling Life Test – Discharge/Charge Cycle

OVERCHARGE LIFE TEST – After the SAE cycling test was deleted from the SAE standards, the SAE Overcharge Life Test was adopted. The basis for adopting this test was the experience with automobile charging systems of that era. These systems consisted of DC generators and mechanical voltage regulators. These systems were apt to cause overcharging of conditions to the battery. In fact, studies made by the Technical Committee of the Battery Council International showed that the major failure mode of automotive storage batteries was overcharge damage.

The test subjected a 12 volt battery to a constant current charge of 4.5 amperes for 495 ampere hours at a temperature of 100±5°F. The test was ended when the battery could not sustain a constant current 150 ampere discharge to an end voltage of 1.2 volts per cell for 30 seconds.

The intent of this test was to evaluate the capability of a battery design to withstand overcharge service. Because the test was constant current, it did not represent the actual service condition in the voltage regulated automotive charging system. The result was that the test measured the corrosion rate of the grid rather than the service life of the battery. The rate of grid corrosion was the main failure mode and a key factor in the service life of a battery but not the only one. The value of the test was in grid development, i.e., component development to extend battery life, but not in evaluating the impact of battery design on battery life.

SHALLOW CYCLE TEST - J240B – In 1971, a SAE Battery Life Test Task Force developed a new SAE Life Test. This work was reported in a 1977 SAE paper, "New Rating Standards for Automotive Batteries" by Roger L. Bennett [2] as summarized in the following.

The need for this new life test was driven by the changes in the automobile over the preceding two decades. In addition as previously stated the constant current over charge test did not represent actual service conditions.

The significant changes in this new test were that it was a shallow cycle test and that the voltage during the charge cycle was limited to a set voltage. The charge-discharge cycle for this test is shown in Figure 2.

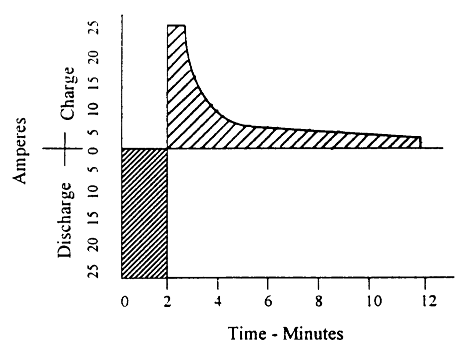

Figure 2. SAE J240a Life Test – Discharge/Charge Cycle

The discharge cycle was established to be representative of the cycling a battery receives in city and slow traffic driving. In these driving conditions, the output of the alternator can not meet the demand of the electrical system and the extra required current is supplied by the battery. The discharge current for the test, 25 amperes, was representative of the intermittent battery output required in these driving conditions. The discharge cycle of the test was then defined to be a 25 ampere constant current discharge for 2 minutes or 0.83 ampere hours. In contrast to 20 ampere hours of discharge for the earlier SAE cycle life test.

The charging current for the test was limited to a maximum of 25 amperes. This was typical of alternator output less the automotive electrical system load with the engine running at a cruising speed under favorable conditions. The charge time was set at 10 minutes. The maximum regulated voltage was set at 14.8 volts. This was higher than typical service. It was increased to accelerate the test. (Testing had shown the failure mode had not changed when the charge voltage was increased to 14.8 volts.)

The test was run at 105±5°F (40.6±2.8)°C.

The battery is given a weekly room temperature discharge at its (0°F, 17.8°C) cold crank rate in amperes. If it does not maintain a minimum voltage of 1.2 volts per cell for 30 seconds, the battery has completed the test.

Figure 3 shows how a typical battery design (antimony alloyed cast grids) of that era failed on the J240, shallow cycle test. In this graph, percent overcharge and check rate voltage (voltage after 30 seconds at 0°F cranking rate) are plotted against J240 cycles. Initially, the discharge voltage is normal and overcharge is very low. As the test proceeds, the battery CEMF decreases with a corresponding increase in overcharge. Finally, the battery is severely overcharged and fails. The internal battery failure mode was found to be severe positive grid oxidation due to overcharge. When testing batteries designed with antinomy alloyed cast grids, this failure mode correlated with service experience.

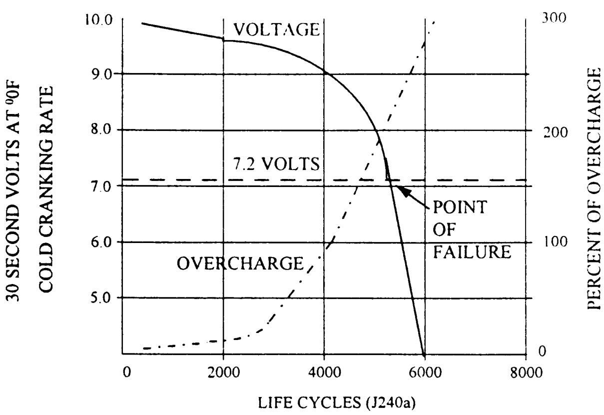

Figure 3. Illustration of battery failure on J240a Life Test

After the shallow cycle life test was developed, maintenance free design technology (calcium alloyed grid material) was introduced to the automotive industry. The inherent higher CEMF of this technology prevented the overcharge effect on the shallow cycle test that resulted in failure for the standard design technology (antimony alloyed grid material). The failure mode for batteries made using one implementation of this design technology (wrought lead grid material) was failure of the battery to recharge. This failure was attributed primarily to the shrinkage of negative plate material. The shallow cycle test when used on these batteries required excessive lengths of time to complete. Increasing the discharge time accelerated the test without changing the failure mode. Subsequently, the discharge time was increased from two minutes to four minutes for batteries with capacities less than 180 minutes. When this modification was made to the test in 1982, the standard was designated J240b. Over the next decade, the automotive industry shifted from antimony alloyed grid batteries to calcium based grid alloy batteries. During this same time period, the temperatures in the engine compartment of automobiles continued to rise. These two factors caused the SAE Life Test standard, J240b, as enacted in 1982 to be of little value. Typically, the test resulted in failure modes not found in service and was of little use in the evaluation of design changes made to improve battery life.

REQUIREMENTS FOR A NEW SAE LIFE TEST

The increased under hood temperatures of today's automobile require an automotive storage battery accelerated life test that represents this service condition. The test must be useful for the automotive industry to make decisions in selecting batteries to meet their charging system design requirements and the quality and reliability expected of today's automobiles. The following is a list of requirements that the new test must meet to be of value.

- differentiate improvements between similar designs.
- differentiate the effect of battery size (capacity) on durability.
- produce a reasonably narrow range of results and be repeatable.
- run in a reasonable time (accelerated over actual field tests),
- preferably be run on available equipment.
- represent the results of both moderate and extreme temperature service.
- result in failure modes that represent the same life time distribution experienced in the field for a given battery design technology.

This last requirement is an important issue in developing an accelerated life test. For an accelerated test to produce valid results, unrealistic failure modes cannot be introduced. Unrealistic failure modes are ones that do not appear in field service or ones that significantly change lifetime distribution. [3]

Successfully developed, the new test would meet the following proposed scope statement for a new SAE battery life test standard.

PROPOSED SCOPE STATEMENT FOR SAE BATTERY LIFE TEST – This recommended practice applies to 12V automotive storage batteries at 180 minutes or less reserve capacity. This test simulates automotive service for the evaluation of battery durability in a voltage regulated charging system. It subjects the battery to charge and discharge cycles and an environment that produces and accelerates the failure modes found in actual service. While this test cannot be used to define the service life of an automotive storage battery, it can identify durability improvements in battery design and battery sizing which result in service life improvement. Other performance and dimensional information is contained in the latest issue of SAE J537,

TEST DEVELOPMENT STRATEGY

The starting point for the development of a new life cycle test was selected to be the current J240b run at 75°C. The basic format of the J240b test as developed still represents the cycling that an automotive battery would receive in normal service - shallow discharge cycle and constant potential charge. In addition several automotive companies and battery companies had been using the 75°C test with good success in developing batteries more resistant to increased temperature service. Ford Motor Company's experience using the 75°C test lead it to include it in its battery specification as a key life test. [5] However, even though J240b at 75°C was being used with success, it was found to produce incorrect failure modes primarily for batteries designed with wrought calcium alloyed positive grid. In addition, the test could take up to 12 weeks to complete depending upon the capacity of the battery. Automotive manufacturers desired a more accelerated test.

The development strategy decided upon was to modify J240b at 75°C such that the test could be accelerated and that it could be used for all commercial battery design technologies. The criteria for acceleration improvement was to reduce test time from the current J240b testing. The criteria for use on all commercial battery design technologies was to produce the failure modes found in service both in type and life time distribution for each technology.

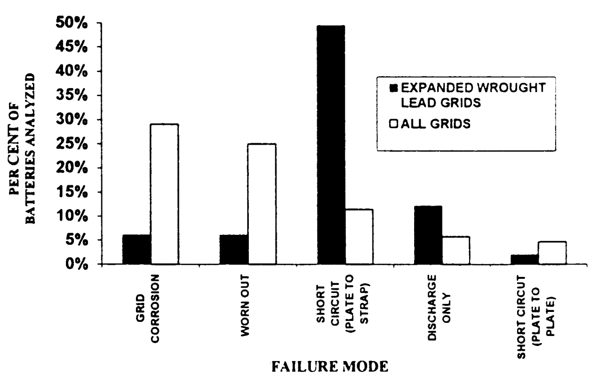

Figure 4. Comparison of failure modes for different positive grid technologies

FAILURE MODES – Automotive storage batteries that contain no life shortening defects i.e., manufacturing defects, and that have not been abused in service will eventually fail by a failure mode driven by service life. The life ending failure mode for a battery is dependent upon service conditions, the design technology, and the quality of the manufacture of the battery (In this case, quality means building the battery consistently to the design intent.) The influence of design technology on the life ending failure mode is illustrated by Figure 4. This graph shows the results of a "junk bin" study by Delphi to provide data for the 1995 BCI Failure Mode Study. The primary failure mode for batteries made using expanded, wrought calcium alloyed lead strip for positive grids was positive grid growth. (The actual failure for the battery is plate to strap shorting, but the root cause is the growth of the positive grid) This failure mode was only the third most likely when all battery design technologies were considered.

The life ending failure modes used in the development of the new life test in the order of life distribution were

1. positive grid corrosion/positive grid growth*
2. positive active material shed
3. negative densification
4. separator oxidation
5. water loss

   * Positive grid growth for those design technologies that have a life ending failure mode of shorts due to grid growth.

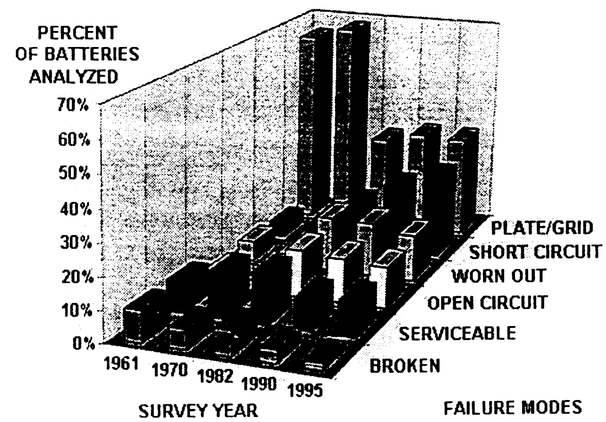

Figure 5. Failure Modes by Survey Year (BCI Failure Mode Surveys [4])

These failure modes were selected based on the failure mode studies and warranty analysis experience of Task Force members. The findings of a typical failure mode study for automotive storage batteries (in the United States) is illustrated in Figure 5. The chart in Figure 5 contains results found in the study presented to the BCI Convention in 1995 and in prior studies.[4] This chart also documents the change in failure mode distribution from 1961 to 1995. A change in the key failure modes is shown by this chart. This change was due to both changes in service stresses and battery technology as was previously discussed. From 1970 to 1982, plate/grid failures significantly decreased as more batteries were made with increased resistance to overcharge induced corrosion. During the same period, short circuits became a major failure mode because of batteries that failed by grid growth. The rate of grid growth failures can be seen to increase from the 1982 study to the 1995 study. This increase follows the increasing service temperatures to which automotive batteries have been subjected.

TEST CONTROL FACTORS – The following test control factors were selected to be varied in the development of the new life test. Each of these factors represents a stress or condition that influence the life of an automotive battery in normal service.

Control Factors

- open circuit stand
- discharge cycle
- charge cycle
- operating temperature
- equalization charge

The equalization charge was added as a test control factor to provide a method of reducing electrolyte stratification during the test. [6,7] In actual automotive service, the motion of the automobile eliminates stratification in the electrolyte.

NEW LIFE TEST PROCEDURE – The matrix of failure modes and test control factors in Figure 6 was used to select modifications to the J240b test procedure.

Test Control Variable

Failure Mode	Add open circuit stand at temperature	Increase depth of discharge	Decrease charge voltage	Add equalization charge	Decrease operating temperature
Positive grid corrosion	↑		↓	↑	↓
Positive grid growth	↑		↓		↓
Positive A.M. Shed		↑		↑	
Negative densification		↑			↓
Separator oxidation					↓
Water loss			↓		↓

Arrows indicate increase ↑ or decrease ↓ in the failure mode by change of control factor.

Figure 6. Matrix of failure modes and test control variables

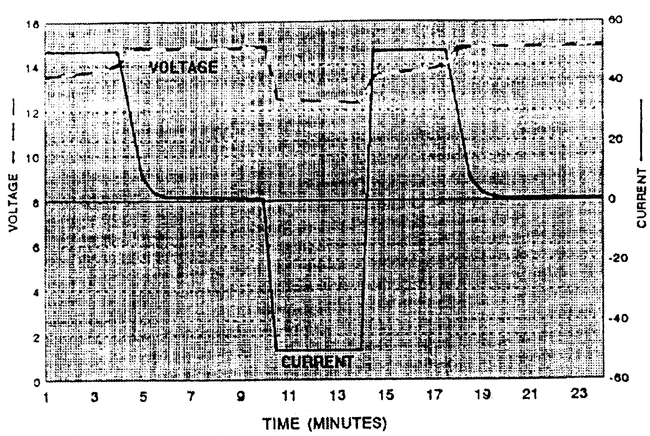

Figure 7. New life test charge/discharge cycle

The following modifications were selected to be made to establish the new life test procedure.

- test temperature 65°C
- discharge 4 minutes at 50 amperes
- charge 10 minutes at 14.8 volts with 50 ampere limit.
- weekend open circuit stand at 65°C after last discharge
- after weekend stand, recharge for 10 minutes at 50 amperes.
- then 4 hour at 3 ampere equalization charge

The entire modified test procedure is included in the appendix. A typical charge/discharge cycle for this test is illustrated in Figure 7.

LIFE TEST DEVELOPMENT

The following section of this paper reports the testing, analysis of test results and additional modifications made during the work done to develop a new life test.

EVALUATION OF THE PROPOSED NEW LIFE TEST – Members of the Task Force ran batteries to the new procedure to determine if it could be easily run on current laboratory equipment, if any anomalies occurred and if it met test development objectives, The following summarizes that testing and the results.

Batteries Tested – The technologies tested were hybrid and maintenance free (calcium/calcium - cast grids and expanded grids). The battery sizes were in the range of 460 - 650 CCA and 80 -150 RC.

Test Results – The test could be run on current laboratory equipment.

There were no major anomalies found in the testing.

The equalization charge increased specific gravity 0.010 to 0.030.

Failure modes found were positive active material shed, mossing shorts, water loss and negative plate shrinkage.

Cycles to failure ranged from 800 to 2200.

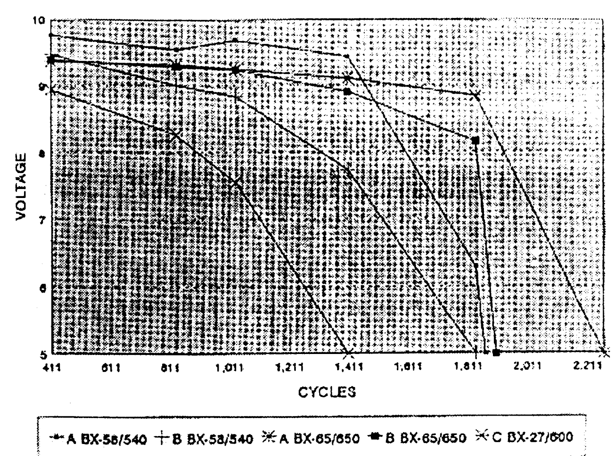

Figure 8. Illustration of failure of batteries run on proposed new life test

The check rate voltage for a set of batteries tested at Ford Motor Company in Figure 8 illustrate how batteries failed on this proposed test.

Analysis of Results – The test accelerated wear out rate for the batteries tested. The failure modes produced by the test do not represent the life ending ones found in field service for at least the three commercial battery design technologies tested. Therefore, the test procedure as proposed was considered unacceptable.

MODIFICATIONS TO PROPOSED NEW LIFE TEST – The results of the evaluation testing on the proposed new life test procedure indicated a major gap still existed between the proposed test and the main requirements for a life test - correct life ending failure modes, valid for all commercial battery design technologies and accelerated results. In order to accelerate the test development process, the task force decided to establish four modifications to the proposed test and evaluate them concurrently. Each of these modifications would be tested at one test site. In order to reduce variations due to types of batteries tested, the test batteries would be made to similar specification by three producers and three batteries from each producer would be provided to each test site.

Test Batteries – The batteries for the evaluation of the test procedure modifications met the following requirements.

- Design - O.E. Specifications
- CCA 520 -550
- RC 90 - 100

All three sets of batteries represented designs developed to improve high temperature service. All designs were maintenance free technology - calcium alloyed lead both negative and positive. Two designs used book mold cast positive grids and one used expanded wrought lead positive grids.

Four Test Modifications – Analysis of the evaluation testing data on the proposed test led to the discharge cycle, charge cycle and operating temperature as being the variables to be modified. The four modifications are shown in Table 1.

In addition, the following change was made in the check rate procedure. In paragraph 9., the discharge rate was changed to ½ of 0°F cold cranking rate. As part of the development process, during the check rate the 15 second voltage was to be monitored and recorded. These changes were made to obtain performance test conditions that were thought by task force members to better mirror end of life failure in the field and test procedures used in the field.

Table 1. Four Test Modifications

Modific'n	Temp.	Dischar Current	Dischar Time	Charge Current	Charge Time
A	66°C	20 amps	6 min.	25 amps max.	12 min.
B	66°C	35 amps	4 min.	35 amps max.	10 min.
C	75°C	20 amps	6 min.	25 amps max.	12 min.
D	75°C	35 amps	4 min.	35 amps max.	10 min.

Preliminary testing to these four modifications indicated that water loss experienced during the running of modifications C and D was a concern. The magnitude of the water loss was great enough that erroneous failure modes could be introduced. To address this concern, an additional set of batteries were run for modifications C and D with the charge voltage set at 14.4 volts. In addition, tests were run at 14.4 volts with and without the addition of water to determine the impact of water loss.

Results of Testing to the Four Modifications – The test results for each modification are presented in the following. The three different batteries used in the testing are designated as battery type "A", "B", or "C". The basic design of each of these battery types is given in Table 2. All of the batteries were built to original equipment specifications.

Table 2. Battery Designs

Battery Type	Group Size	CCA	RC	Positive	Negative
A	58	540	100	Cast-Ag/Ca/Pb	Expanded - Ca/Pb
B	58	540	100	Cast-Ag/Ca/Pb	Expanded - Ca/Pb
C	75	525	90	Expanded Wrought Sn/Ca/Pb	Expanded Wrought -Ca/Pb

Test Results Modification "A" – The results of testing to modification "A" are summarized Table 3.

Table 3. Test Results Modification "A"

Battery Type	Average Cycles to Failure	Water Loss (Kg)	Primary Failure Modes
A	4970	1.03	PAM Shed, Positive Grid Corrosion, NAM Shrinkage
B	5193	1.16	PAM Shed, Positive Grid Corrosion, NAM Shrinkage
C	2968	0.46	PAM Shed, Positive Grid Corrosion, NAM Shrinkage

Test Results Modification “B” – The results of testing to modification “B” are summarized Table 4.

Table 4. Test Results Modification “B”

Battery Type	Average Cycles to Failure	Average Water Loss (Kg)	Primary Failure Modes
A	6307	1.05	PAM Integrity Loss, NAM Shrinkage
B	5017	0.80	PAM Integrity Loss, NAM Shrinkage
C	1720*	0.34	PAM Shedding, NAM Shrinkage

* Two battery average. The third test battery failed early due to mechanical short.

Test Results Modification “C” – The results of testing to modification “C” are summarized Table 5. This data includes watered batteries and batteries run at 14,4 volts as well as 14.8 volts.

Table 5. Test Results Modification “C”

Battery Type	Average Cycles to Failure	Average Water Loss (Kg)	Primary Failure Modes
A	4025	0.83	Positive grid corrosion, PAM Integrity and Shedding, NAM Shrinkage
B	2740*	1.18	Positive grid corrosion, PAM Integrity and Shedding, NAM Shrinkage
C	1470*	0.61	PAM Shedding, NAM Shrinkage

* Two batteries each of this type failed when 10.5 volts was not sustained during 20 ampere discharge cycle.

Test Results Modification “D” – The results of testing to modification “D” are summarized Table 6. This data represents only batteries run on the test without watering and at 14.8 volts.

Table 6. Test Results Modification “D”

Battery Type	Average Cycles to Failure	Average Water Loss (Kg)	Primary Failure Modes
A	3692	0.67	Positive grid corrosion, PAM Integrity and Shedding, NAM Shrinkage
B	2695	0.63	Positive grid corrosion, PAM Integrity and Shedding, NAM Shrinkage
C	1035	0.20*	PAM Shedding, NAM Shrinkage

* Data from only one battery.

Results of Reducing Charge Voltage from 14.8 to 14.4 – Decreasing the charge voltage maximum limit from 14.8 to 14.4 volts was found to have no significant effect on cycles to failure or failure modes produced. See Table 7 for the data supporting this conclusion.

Table 7. Comparison of 14.4 to 14.8 Charge Voltage on Modification “D” Testing

Battery Type	Charge Voltage 14.4	Charge Voltage 14.8
	Cycles to Failure	Cycles to Failure
A	3362 Avg.	2744 Avg.
B	2799 Avg.	2291 Avg.
C	1006	1061

Results of Adding Water During Tests – The results of testing on all four modifications indicated that adding water to batteries during the tests had no significant effect on test results. These tests were run on the same battery design, but one different than those in comparing the four modifications. See Table 8 for the results of this testing.

Table 8. Testing With and Without Water Additions

Test Modification	Water Additions During Tests	Without Water
	Cycles to Failure	Cycles to Failure
A	3840	3840
B	4100	3690
C	2880	3520
D	2460	2460

Comparison of 15 second to 30 second voltage – Figure 9 shows check rate voltages at 15 seconds and 30 seconds for a battery run to test modification "D". There was not a significant difference in the end of life between the two measures.

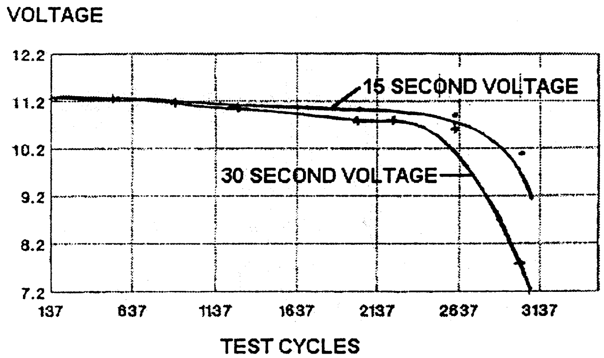

Figure 9. Comparison of 15 second and 30 second voltage check rates.

<u>Analysis of the Results of Testing to Modifications "A", "B", "C", and "D"</u> – None of the four modifications resulted in a test procedure that met all of the development objectives. Modifications "C" and "D" produced a more accelerated test than modifications "A" and "B"; however, there was no improvement in the test duration over the current J240b run at 75°C.

None of the modifications produced failure modes that mirror field experience on the batteries tested. The requirement of usefulness for all commercial lead-acid battery design technologies was not met. In general, batteries exhibited a greater degree of positive material (PAM) loss or degradation, greater negative active material (NAM) shrinkage, and greater water loss than is experienced in the field. This was especially true of modifications "C" and "D", the two tests run at 75°C. Failures of batteries with Ag, Ca alloyed positive book mold cast grids tested to modifications "C" and "D" more closely represented the type of failures experienced in accelerated field tests. [5]

The loss of positive active material in batteries run on modification "D" is illustrated in Figures 10, 11 and 12. This type of material loss is not typically found when failed batteries are analyzed. The extreme loss of PAM for batteries with expanded wrought, Sn, Ca alloyed lead positive grids (Figure 12) is not the primary failure mode for this type of battery and is rarely found in service. The primary life ending failure mode for this type of battery is grid growth shorts as was shown in Figure 4. The test modifications that produced extreme loss of PAM as the primary failure mode then can not be reliably used to evaluate service life and developments to improve service life for batteries made with expanded wrought , Sn, Ca alloyed lead positive grids.

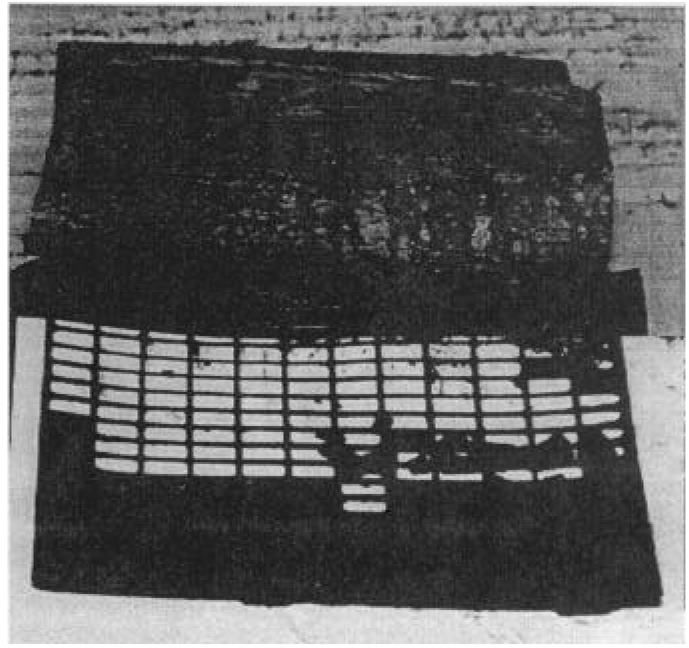

Figure 10. Positive active material shed for plate from battery type "A" run on modification "D".

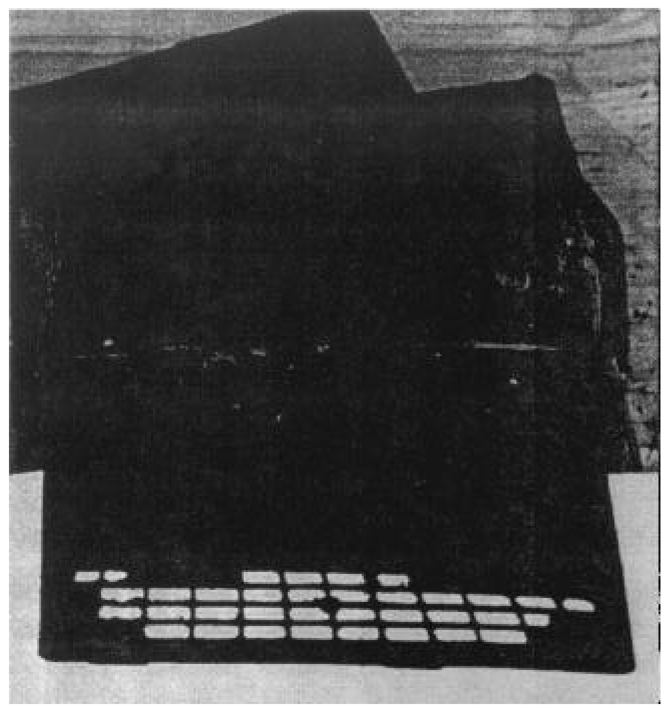

Figure 11. Positive active material shed for plate from battery type "B" run on modification "D".

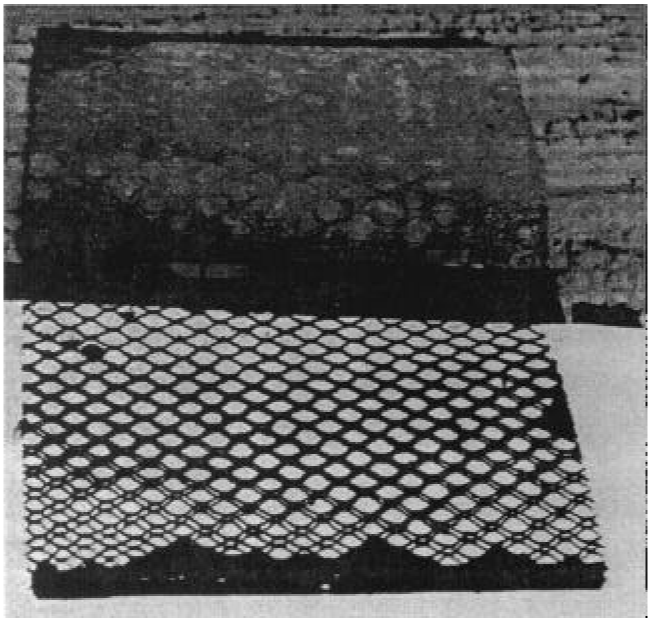

Figure 12. Positive active material shed for plate from battery type “C” run on modification “D”.

CONCLUSION

A two year study was made by a SAE Life Cycle Task Force to develop a life test to replace the current standard, J240b. Many variations in test conditions and parameters were explored. The following lists summaries them.

- Temperature (65° - 75°C)
- Depth of discharge based on time (4 - 10 minutes)
- Recharge based on time (6 - 12 minutes)
- Depth of discharge based on current (20, 35, 50 amperes)
- Recharge voltage (14.4 and 14.8)
- Watering - additions and no additions
- Boost charge (3 amperes for 3 hours)
- Check rate current (1/2 CCA and full CCA)
- Check rate discharge time (15 and 30 seconds)

Minor variations in these test parameters were found to not significantly effect the outcome of the test.

There was no significant improvement in the development objectives listed below in any of the test variations explored over running the current J240b standard at 75°C.

Development Objectives

1. Better correlation of test failure modes to field failure modes.
2. Universal test, i.e., one that works equally well on all lead-acid design technologies.
3. Reduction in the time required to run a life test.

The results of the Task Force’s work do not indicate any clear direction for future work to make improvements in these development objectives using the test development strategy described in this paper.

The current J240b test run at 75°C is as good as any of the test variations explored during the development process reported in this paper. However, this test discriminates against certain battery design technologies, i.e., test cycle life indicates shorter life than observed field life. (This is true primarily for batteries designed with wrought calcium alloyed lead positive grids. An accelerated test that results in grid growth shorts as the primary life ending failure mode needs to be developed for this design technology.)

The Task Force is recommending two courses of action. One is to support the SAE Automotive Storage Battery Standards Committee’s decision to add the paragraph as stated below to the current J240b standard. The other is to sponsor the on going study of life tests for automotive storage batteries and the development of a universal life test(s) that meets the listed development objectives.

ADDITION TO SECTION 3. OF SAE J240B

3.11 – Optionally, this test may be conducted with the water bath temperature maintained as high as 75°C ± 3°C (167°F ± 5°F) depending on the temperature and severity of the application. Shortening of time and of number of cycles to failure point can be expected. However, this test option may change the types and distribution of failure modes depending on the battery design technology. The battery supplier and the automotive user should concur that this test option will produce failure modes that correlate with application life and the temperature required to produce these failure modes.

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The following individuals reviewed this paper and provided the critical comments and corrections to ensure it accurately represents the work of the SAE Life Cycle Task Force: Jerry Crow - Delphi, Rick Johnson - Bolder Technologies, Karl Keckan - Ford Motor Company, Tim Moyer - East Penn Manufacturing Company, John Miller - GNB, Mike Greenlee - Exide, James Sarria - Ford Motor Company, Jaime Navarrette - Daramic, and Jennifer Rose - JCI.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

CEMF: counter-electromotive force, voltage produced within a battery mainly by electrochemical means.
NAM: negative plate active material
PAM: positive plate active material

APPENDIX

SAE LIFE CYCLE TASK FORCE MEMBERSHIP

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Rick Johnson	JCI/Bolder
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PROPOSED TESTING PROCEDURE

1. Cycle life testing shall begin within 60 days of the final nondestructive test as shown in Paragraph 3.7, SAE J537 (June 1982).
2. The battery is tested in a water bath maintained at 150 ± 5°F (65.6 ± 2.8°C).
3. Water level of the bath specified in 2 is to be maintained at a height equal to or greater than 75% of the overall height of the battery container or within 1/2 inch of the metal bushing of side terminal batteries.
4. The test cycle is performed as follows:

   Discharge: 4 min. ± 1 sec. at 50 ± 0.10 A.

   Charge: (a) Maximum voltage (at battery cable terminals): 14.8 ± 0.03 V.
   (b) Maximum rate: 50 ± 0.10 A.
   (c) Time: 10 min. ± 3 sec.
5. Battery is continuously cycled for 96 (+10.0) hours. A switching delay of not more than 10 seconds is permitted from termination of charge to start of discharge and termination of discharge to start of charge.
6. The battery is given a 60-72 hour stand on open circuit in the 150°F (65.6°C) water bath after the last discharge cycle.
7. Charge: (a) Maximum voltage (at battery cable terminals): 14.8 ± 0.03 V.
   (b) Maximum rate: 50 ± 0.10 A.
   (c) Time: 10 min. ± 3 sec.
8. After 7, to eliminate stratification, charge the battery as follows:
   (a) Time: 3.0 hours
   (b) Current: 3.0 ± 0.10 A
9. With the battery at the temperature obtained in paragraph 6, discharge at a rate equal to its 0°F (-17.8°C) cold cranking rate in amperes (see SAE J537) to 1.20 V per cell or a minimum discharge time of 30 sec., whichever comes first.
10. Replace battery on the life test without a separate recharge. Start on the "charge" portion of the cycle.
11. The life test shall be considered completed when the battery fails to maintain 1.20 V per cell for a minimum of 30 sec. on the manual discharge (paragraph 9) for two consecutive 96-106 hour test periods.
12. Water should be added as required during the cycling portion of the test except to those batteries described as maintenance free.