SAE INTERNATIONAL®

SURFACE VEHICLE STANDARD	J537™	SEP2023
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(R) Storage Batteries

RATIONALE

Traditional internal combustion engine (ICE) vehicles comprise the vast majority of the global car parc in operation today. While new vehicle production is migrating to more advanced drivetrain configurations, including start-stop, the ratings and test procedures developed for the 12 V batteries supporting the traditional ICE architecture are often still applicable to the more advanced systems. Furthermore, maintenance of standards related to batteries for traditional ICE vehicles is critical to support the full life of those vehicles through multiple rounds of maintenance and component replacement. Other documents have been, and are being, developed to provide more specific guidance regarding batteries utilized within more advanced drivetrain systems, such as SAE J3012. The procedures detailed within this document were primarily developed to support traditional ICE vehicle operation but are often more widely applicable.

1. SCOPE

This SAE Standard serves as a guide for testing procedures of automotive 12 V storage batteries. The information contained herein was originally developed based on traditional ICE operation but can be more broadly applicable to other vehicle architectures. Although the test procedures contained herein are written from the standpoint of a 12 V nominal battery, they can be scaled for batteries with different nominal voltages.

1.1 Ratings Compliance

The reserve capacity and cold cranking at -18 °C ratings submitted for battery performance capability are to be based on procedures described in this document. The ratings submitted shall be of a level that when any subsequent significant sample size is tested in accordance with this document, that at least 90% of the batteries are expected to meet the ratings. The choice of 90% compliance recognizes that batteries consist of many plates requiring chemical-electrical formation procedures, and small variations in test conditions and procedures can measurably affect the performance of individual batteries.

1.2 Applications

This document applies to lead-acid types of storage batteries used in motor vehicles, motorboats, tractors, and starting, lighting, and ignition (SLI) applications that use regulated charging systems. This standard was originally developed based on traditional ICE usage, thus other applications or usage profiles could require alternate or additional testing.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J240 Life Test for Automotive Storage Batteries

SAE J1495 Test Procedure for Battery Flame Retardant Venting Systems

SAE J1715/2 Battery Terminology

SAE J2185 Life Test for Heavy-Duty Storage Batteries (Lead Acid Type only)

SAE J2801 Comprehensive Life Test for 12 V Automotive Storage Batteries

SAE J2981 Starter Battery Identification and Classification

SAE J3012 Storage Batteries for Start-Stop Operations

SAE J3060 Automotive and Heavy Duty Storage Battery Vibration

2.1.2 Battery Council International (BCI) Publications

Available from Battery Council International, 330 North Wabash Avenue, Suite 2000, Chicago, IL 60611, Tel: 312-644-6610, www.batterycouncil.org.

BCIS-04 BCI Battery Technical Manual - BCI Recommended Storage Battery Specifications Starting, Lighting and Ignition Types

2.1.3 European Committee for Electrotechnical Standardization (CEN) Publications

Available from CEN-CENELEC Management Centre, Rue de la Science 23, B-1000, Brussels, Belgium, www.cencenelec.eu.

EN 50342-1:A1:2018 Lead-acid starter batteries - Part 1: General requirements and methods of test

2.1.4 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60095-1 Lead-acid starter batteries - Part 1: General requirements and methods of test

3. ELECTRICAL TESTING PROCEDURE

Individual battery performance values are to be determined by the procedures outlined under Sampling, Conditioning, and Sequence of Tests.

3.1 Danger of Exploding Batteries

Batteries contain sulfuric acid and they can produce explosive mixtures of hydrogen and oxygen. Because self-discharge reactions generate hydrogen gas even when the battery is not in operation, make sure batteries are stored and worked on in a well-ventilated area. ALWAYS wear safety goggles and a face shield when working on or near batteries. When working with batteries:

a. Always wear proper eye, face, and hand protection.

b. Keep all sparks, flames, and cigarettes away from the battery.

c. Do not remove (unless specified as removeable by manufacturer and removal is authorized per test sequence) or damage vent caps.

d. Make sure work area is well-ventilated.

e. Never lean over battery while boosting, testing, or charging.

3.1.1 Temperature Measurement

Thermometers and other instruments used for measuring temperature shall have an appropriate range, and the value of each scale division shall not be greater than 1 °C (2 °F). The accuracy of the calibration of the instruments shall be 0.5 °C (1 °F) or better.

Flooded batteries with electrolyte access, or that have holes added to access electrolyte, should preferentially have temperature measured by placing a temperature measuring device directly into the electrolyte. Electrolyte temperature shall be measured above the plates in an intermediate cell (not an end cell).

VRLA batteries or flooded batteries without electrolyte access (and without added access holes) should have temperature approximated in ambient air by an appropriate measuring device centrally mounted on the long side of the battery and well insulated from the ambient surroundings. This method may be used to verify battery has returned to room temperature (27 °C), to correct capacity, voltage, or specific gravity measurements to 27 °C, or to control charging to temperature limits. See 3.9.1 for temperature control in cold cranking testing.

Temperature measurement of batteries is not required for charging or capacity testing batteries in a circulating water bath maintained at 25 °C ± 3 °C (72 °F ± 82 °F). Testing has determined that departure from the internal temperature target of 27 °C (80 °F) is minimal and measurement of battery internal temperature is not required. Batteries should be immersed to a level corresponding to the tops of the plates, or 2.5 to 4.0 cm below the base of the terminal posts (or just below the terminals for side-terminal types) to assure adequate heat transfer to maintain desired temperatures. Temperature monitoring is recommended when charging used batteries or batteries suspected of being defective.

3.2 Sampling

Compliance determination samples shall be selected from normal production. Batteries tested should be new, unused, and not less than 14 and not more than 60 days from date of manufacture. Obtaining batteries within 60 days of manufacture may not be possible when sampling at the retail level; battery date codes, and ship codes should be recorded and included with test results for all batteries.

3.3 Battery Conditioning and Charging

3.3.1 Preconditioning, Recharging, and Manufacturer Recommendations

3.3.1.1 Preconditioning

For new, untested batteries, it is customary to conduct a preconditioning charge prior to the start of a testing sequence, utilizing the guidelines provided within 3.3. The primary purpose of this preconditioning charge is to ensure all batteries begin testing under similar conditions. This preconditioning charge can also serve to accelerate the stabilization, or break in, of new batteries. It is possible to omit preconditioning from a test sequence, but such a procedure should be clearly reported as lacking preconditioning (testing as received) in the test report.

3.3.1.2 Recharge

Unless otherwise specified in the test procedure, any test event that ends with battery in a discharged state, whether partial or full discharge, should be followed with a recharge utilizing the guidelines provided within 3.3.

3.3.1.3 Manufacturer Recommendations

Continued lead acid battery development necessitates the adoption of flexible charging guidelines. Manufacturer recommendations for charging procedures should be followed when available. The manufacturer recommended charge time shall be no greater than 24 hours to ensure smooth test lab operation. The additional recommendations regarding charging provided within 3.3 serve as a guide for testers that do not have manufacturer recommendations available to them (or for manufacturers considering establishing their own guidelines).

3.3.2 Flooded (Wet) Batteries

3.3.2.1 Charging Temperatures

Unless directed by the specific test procedure, charging shall not be started if electrolyte temperature is below 16 °C (60 °F), and during charge the temperature shall be maintained between 16 °C and 43 °C (60 °F and 110 °F). When charging is conducted in ambient air, electrolyte temperature shall be measured above the plates in an intermediate cell, or optionally according to 3.1.1. Battery temperature measurement is not required for charging procedures conducted in a circulating water bath.

3.3.2.2 Electrolyte Strength

Batteries shall be tested with the electrolyte as supplied by the manufacturer. Water replenishment may be permitted during testing in accordance with test procedures and manufacturer recommendations.

3.3.2.2.1 Corrections to Specific Gravity

Electrolyte specific gravity readings are to be corrected to a standard temperature of 27 °C (80 °F). Specific gravity decreases as liquid temperature increases, and vice versa. Test measurements made at other temperatures (T) shall be corrected to the standard temperature using the following equations:

$$\text{Specific gravity at 27 °C} = \text{measured value} + 0.0007\,(T-27) \quad \text{(Eq. 1)}$$

where:

T is in °C

$$\text{Specific gravity at 80 °F} = \text{measured value} + 0.0004\,(T-80) \quad \text{(Eq. 2)}$$

where:

T is in °F

3.3.2.2.2 Corrections to Voltage

When constant current charging, the on charge terminal voltage is to be corrected to a standard temperature of 27 °C (80 °F). It shall be reduced with increased temperature and vice versa, using the following equations:

$$\text{Terminal voltage at 27 °C} = \text{reading} + (0.0378[T-27]) \quad \text{(Eq. 3)}$$

where:

T is in °C

$$\text{Terminal voltage at 80 °F} = \text{reading} + (0.021[T-80]) \quad \text{(Eq. 4)}$$

where:

T is in °F

Corrections do not need to be made to open circuit voltage readings or to voltages measured during discharge.

3.3.2.3 Constant Current Charging

Unless otherwise specified by the manufacturer, the constant current rate for charging is to be set within the nearest 0.5 ampere of 0.5% (1/2%) of the -18 °C cranking performance rating [amperes] (unless the ratio of cold cranking rating [amperes] divided by reserve capacity rating [minutes] is less than 5.0, in which case the constant current is to be set within the nearest 0.5 ampere of 0.75% (3/4%) of the -18 °C cranking performance rating).

3.3.2.3.1 Batteries which are similar in design and which have been discharged to approximately the same extent may be series connected for recharge up to the voltage capacity of the charger unit.

3.3.2.3.2 Charging at appropriate constant current shall be continued until the criteria establishing full charge are achieved.

3.3.2.3.3 Two basic criteria may be used to recognize when a battery is fully charged using constant current charging:

1. When the temperature-corrected specific gravity of the electrolyte is constant (within ±0.002 between two hourly measurements or ±0.003/hour over three successive hourly intervals), or alternatively, for recharge events following a discharge, by charging to the specific gravity achieved in the full charging event prior to that discharge.

   or

2. When the temperature-corrected on-charge terminal voltage at the constant current does not change by more than 0.048 V per hour over three successive hourly intervals.

An alternate recharge regime using constant current is to recharge to a set amp-hour amount based on the prior discharge. Recharge after an RC test can be recharged up to 140% of the amp-hours removed using the recharge current noted above. Correspondingly, recharge after a CCA test can be recharged up to 200% of the amp-hours removed using the recharge current noted above. Contact the manufacturer to confirm the preferred amp-hour return levels.

NOTE: Battery vents that are removed for any specific gravity measurements or level checking/adjustments shall be reinstalled on the battery before any additional testing is conducted. Vents shall be firmly reinstalled and seated to their original position to avoid excessive water loss on subsequent testing/charging.

NOTE: In batteries which operate with excess liquid electrolyte, but without access to electrolyte, provisions to measure specific gravities and temperatures can be made by carefully cutting holes through the cover in locations recommended by the manufacturer. These holes shall be capable of being closed when not actively used for those measurements to retain integrity of the venting system. Adjustments to electrolyte strength or volume in such batteries are not permitted during preparation or testing.

NOTE: If requested by the originator, water may be added to batteries following, or during, electrical testing if subsequent testing (life, etc.) is planned. Any water additions shall be conducted using either distilled or de-ionized water. No use of tap water is allowed as it may introduce impurities which will adversely affect battery performance. Water addition amounts shall be limited to the level prior to the start of battery testing and should not be overfilled. Contact the battery manufacturer to confirm initial/factory electrolyte levels if necessary. A short mixing charge should be conducted following any water additions (3.3.2.4.4).

3.3.2.4 Constant Voltage Charging

3.3.2.4.1 Voltage

Constant voltage charging is authorized, but not recommended unless the correct applied voltage for the battery is known. When available, manufacturer recommendations should be followed, but in general, the applied voltages will usually be selected between 14.4 and 16 V, as battery chemistries and designs differ. When the correct applied voltage is not known, testing laboratories should request information on charging voltage from the battery manufacturer along with current and charging time limits.

3.3.2.4.2 Charging Current

In lieu of the battery manufacturer's recommendation, the maximum charging current limit shall be $5 \times I_{20,n}$ or 0.15×RC[Minutes] amperes with a power supply current maximum limited to 25 amperes (per battery when charging batteries in parallel [or per string of series connected batteries in a pack, e.g., two strings of two 6 V series connected batteries used in a 12 V application = 50 A limit]). Consequently, for constant voltage charging, the charger output shall be capable of at least 25 amperes per battery [or string] or, if less, the manufacturer's recommended current level per battery [or string] when parallel connected battery units are charged.

NOTE: $I_{20,n} = C_{20,n}/20$ = 20 hour current, nominal (rated), A.

3.3.2.4.3 Charging Time

Charge time shall be 24 hours, optionally 16 hours after cold cranking test, unless specific instructions are provided by the battery manufacturer. The manufacturer recommended charge time shall be within the range 14 to 24 hours.

3.3.2.4.4 Finish Charge

Unless otherwise specified by the manufacturer, a mixing charge at a constant current rate no greater than 0.5% (1/2%) of the -18 °C cranking performance rating [amperes], and for a fixed time period and in accordance with recommendations of the battery manufacturer is allowed to promote electrolyte mixing and to ensure complete recharge.

3.3.3 Valve Regulated Batteries (VRLA)

No provision for directly reading of electrolyte specific gravities or temperature can be made on batteries using electrolyte in gel form or absorbed in separators. Charging of valve regulated batteries should be carried out in accordance with the recommendation of the manufacturer or provisions in Section 3.

3.3.3.1 Temperature Control

Battery temperature shall be controlled by either:

1. Circulating water bath maintained at 25 °C ± 3 °C, or

2. Air ambient maintained at 20 to 25 °C with the provision that measured battery case temperature T_{Batt} shall be less than 35 °C, which if exceeded shall result in termination of charging until battery temperature $T_{Batt} \leq 30$ °C before charging is resumed. T_{Batt} can be measured according to 3.1.1.

Following a cold cranking test, battery charging may begin after the battery has either soaked in a 25 °C ± 3 °C circulating water bath for 4 hours, stood in ambient air of 20 to 25 °C for 12 hours, or $T_{Batt\ Internal}$ has been confirmed to be greater than 16 °C when measured in air ambient according to 3.1.1. Because of the rapid temperature increase following a cold cranking test, it is recommended that the external case temperature T_{Batt}, measured under air ambient conditions using an insulated sensor, be allowed to attain 20 °C to assure a minimum internal temperature of 16 °C.

3.3.3.2 Voltage

Applied voltage shall be 14.8 V ± 0.1 V unless specific instructions are provided by battery manufacturer. The manufacturer recommended voltage will generally be within the range 14.0 to 15.0 V.

3.3.3.3 Charging Time

Charge time shall be 24 hours, optionally 16 hours after cold cranking test, unless specific instructions are provided by battery manufacturer. The manufacturer recommended charge time shall be within the range 14 to 24 hours.

3.3.3.4 Current

Unless otherwise specified by the manufacturer, current limit shall be $0.25xC_{20,n}$ ($5\times I_{20,n}$) or $0.15\times RC_{(Minutes)}$ amperes.

3.3.3.5 Finish Charge

Optionally, a constant current finish charge may be applied. Unless otherwise specified by the manufacturer, a finish charge [amperes] of 4 hours at $I=2.5\%\times C_{20,n}$ ($0.5\times I_{20,n}$) or $0.015\times RC_n$ may be applied.

NOTE: $C_{20,n}$ = Twenty hour discharge capacity, nominal (rated), Ah

$I_{20,n}$ = $C_{20,n}/20$ = Twenty hour current, nominal (rated), A

RC_n = Reserve Capacity (rated), Minutes

3.3.4 Dry Charged or Similar Batteries Which Need Electrolyte to Activate

If an activation test is required, refer to customer specifications; otherwise, fill according to the battery manufacturer's instructions, charge and condition according to 3.3.2 through 3.3.3, and then test as any other filled and charged battery according to 3.4.

3.4 Sequence of Tests

3.4.1 Perform tests according to the sequence in Table 1.

Table 1 - Sequence of tests

	Standard Test Sequence	Minimum Required to Conduct any Optional Tests (Event 9)
1. Dry Charge Battery Activation (if required) - 3.3.4	X	X
2. Preconditioning - 3.3	X	X
3. Reserve Capacity Test - 3.6	X	X
4. Rechargeability and Charge Rate Acceptance Test - 3.8	X (1)	
5. Cold Cranking Test at -18 °C or -29 °C (0 °F or -20 °F) - 3.9.1	X (2)	X
6. Reserve Capacity Test - 3.6	X (3)	
7. Cold Cranking Test at -18 °C or -29 °C (0 °F or -20 °F) - 3.9.1	X (2)	
8. Reserve Capacity Test - 3.6	(3)	
9. Optional Tests		
a. Cold Cranking test at -18 °C or -29 °C (0 °F or -20 °F) - 3.9.1	(2)	
b. Twenty Hour Capacity (C_{20}) - 3.7		
c. Cranking Characterization - 3.9.2		
d. SAE J240 - 3.10.1		
e. SAE J2185 - 3.10.2		
f. SAE J2801 - 3.10.3		
g. SAE J3060, Vibration - 3.10.4		
h. Stand/Rechargeability Test - 3.11.1		
i. Gassing Rate Characteristic - 3.11.2		
j. SAE J1495 - 3.11.3		

(1) Test event 4 is optional, to be agreed upon between requester and tester.
(2) The selection of test temperature for test event 5 shall be made prior to the start of testing. If test event 5 is not successfully achieved, the same temperature should be utilized for test event 7. If the same temperature is used for test events 5 and 7, test event 9 can be utilized to run the other temperature, if desired. Test event 7 is optional if only one cold cranking test temperature is desired, successful results are achieved in test event 5, and test event 8 is not planned/required.
(3) Test events 6 and 8 are not required, but may still be conducted, if Reserve Capacity and Cold Cranking were successfully achieved in a preceding test. If test event 7 is to be run, test event 6 shall be run. If test event 9 is to be run as a cold cranking test, test event 8 shall be run. Test events 6 and/or 8 may be changed from Reserve Capacity to Twenty Hour Capacity (3.7) if Reserve Capacity was successfully achieved in a preceding test.

3.5 New batteries may require extra conditioning, not afforded by test event 2, in determining their true reserve capacity and cold cranking capability; therefore, the highest test value obtained for each battery in test events 3, 6, and 8 for reserve capacity and test events 5 and 7 for cold cranking shall be used as the reported performance of that battery. In rare cases, primarily limited to deep cycle battery designs, batteries may require more than these five test cycles to reach maximum capacity, and in such situations, amended test procedures to determine true battery capability should be agreed upon by customer and supplier. Statistical use of the data generated by this reserve capacity and cold cranking capability testing shall be agreed upon by customer and supplier.

3.6 Reserve Capacity Test

Unless otherwise agreed to, prior to starting the test, batteries should have been fully charged according to 3.3. After charging, allow it to stand at room temperature for 4 to 96 hours.

During the stand period, regulate battery temperature so that electrolyte temperature, measured above the plates in an intermediate cell, or alternately as described in 3.1.1, is stabilized at 27 °C ± 3 °C (80 °F ± 5 °F) before the start of the discharge.

Discharge the battery at 25 A ± 0.1 A. During discharge, using any convenient method, maintain electrolyte temperature within the range 24 to 32 °C (75 to 90 °F). Results will not be considered valid if electrolyte temperature moves outside this range before the end of the discharge. In accordance with 3.1.1, battery temperature measurement is not required for capacity testing conducted in a circulating water bath maintained at 25 °C ± 3 °C.

End the discharge when the voltage across the battery terminals has fallen to 10.5 V ± 0.05 V, noting the discharge duration in minutes and the electrolyte temperature at the cut-off point. In accordance with 3.1.1, battery temperature measurement is not required for capacity testing conducted in a circulating water bath maintained at 25 °C ± 3 °C. If temperature measurement is required, correct the discharge duration for final temperature, if different from 27 °C (80 °F), using the following equations and record the corrected time as the Reserve Capacity achieved.

$$M_c = M_r[1 - 0.009\ (T_{final} - 27)] \quad \text{(Eq. 5)}$$

where:

M_c = minutes corrected to 27 °C (80 °F)

M_r = minutes actually run

0.009 = temperature correction factor

T_{final} = temperature of electrolyte above the plates in an intermediate cell at end of discharge, °C or in air ambient, when measured according to 3.1.1

For T_{final} in °F use:

$$M_c = M_r[1 - 0.005\ (T_{final} - 80)] \quad \text{(Eq. 6)}$$

where:

0.005 = temperature correction factor

Unless the next test to be performed in the test sequence specifies otherwise, recharge the battery according to 3.3.

3.7 Twenty Hour Capacity (C_{20})

This optional test can be run according to EN 50342-1 or IEC 60095-1. Running this test at any point during the test sequence is to be done as a reference only. To fully understand C20 capability of a given battery and determine ratings, EN50342-1 (or similar standard such as IEC) shall be followed in its entirety.

3.8 Rechargeability and Charge Rate Acceptance

This test determines the battery capability to accept charge at low temperature when fully discharged, and to determine the rate at which the battery would accept the charge from a voltage regulated charging system which has adequate current capacity.

The charging equipment used in this test should be capable of a minimum current output in amps equivalent to 50% of the rated reserve capacity value in minutes.

Use caution when including this test within a battery test sequence. Inclusion of this test in a test sequence can have significant impacts on subsequent testing.

3.8.1 Using the same battery discharged, but not yet recharged, through the reserve capacity test (3.6) (discharged to 10.5 V at the reserve capacity rate per 3.6), place the battery in a cold chamber until electrolyte temperature above the plates in an intermediate cell has stabilized at 0 °C ± 1 °C (32 °F ± 2 °F), or optionally, when measured according to 3.1.1.

3.8.2 With the battery in a cold chamber, at 0 °C ± 1 °C (32 °F ± 2 °F) ambient, charge it at a constant potential of 14.40 V ± 0.07 V. Measure the current input and record the value after 10 minutes of charging.

3.8.3 Continue to charge for a total duration of 120 minutes ± 0.05 minute. Discontinue the charging, remove the battery from cold chamber and raise the battery temperature until the electrolyte temperature above the plates in an intermediate cell has stabilized at 27 °C ± 3 °C (80 °F ± 5 °F), or optionally, when measured according to 3.1.1.

3.8.4 Discharge the battery at 25 A ± 0.1 A. During discharge, using any convenient method, maintain electrolyte temperature within the range 24 to 32 °C (75 to 90 °F). Results will not be considered valid if electrolyte temperature moves outside this range before the end of the discharge. In accordance with 3.1.1, battery temperature measurement is not required for capacity testing conducted in a circulating water bath maintained at 25 °C ± 3 °C.

End the discharge when the voltage across the battery terminals has fallen to 10.50 V ± 0.05 V, noting the discharge duration in minutes and the electrolyte temperature at the cut-off point. In accordance with 3.1.1, battery temperature measurement is not required for capacity testing conducted in a circulating water bath maintained at 25 °C ± 3 °C.

If temperature measurement is required, correct the discharge duration for final temperature different from 27 °C (80 °F) using the equations from 3.6.

Unless the next test to be performed in the test sequence specifies otherwise, recharge the battery according to 3.3.

3.8.5 Acceptance Criteria for These Tests

3.8.5.1 Charge Rate Acceptance

Current input after 10 minutes ± 0.1 minute of charging (3.8.2) shall be at least 3% of the battery -18 °C cold cranking rating.

3.8.5.2 Rechargeability

The percent ratio of the discharge time in minutes (3.8.4) as obtained after 120 minute recharge (3.8.3) to the original reserve capacity value (3.6) shall be at least 50%.

3.9 Cold Temperature Power Characterization

3.9.1 Cold Cranking Test

The following test is a measure of the cranking capability of a battery at the rating temperature.[1]

3.9.1.1 Prior to starting the test, batteries should have been fully charged according to 3.3. After charging, allow it to stand at room temperature for 8 to 96 hours. Place the battery in an ambient environment held at the rating temperature (-18 °C or -29 °C (0 °F or -20 °F)) until the electrolyte above the plates of an intermediate cell has stabilized at the rating temperature ±0.5 °C (±1 °F) (typically 16 hours). In the case of a starved or gelled electrolyte battery, place the battery in ambient held at the rating temperature until the core temperature of an element in an intermediate cell has stabilized at the rating temperature. The time required to achieve this is generally accepted as a minimum of 24 hours but can be determined in separate thermal response testing.

[1] Rating temperature for purpose of this test is either -18 °C or -29 °C (0 °F or -20 °F).

3.9.1.2 With the battery in an ambient environment at the rating temperature,[1] discharge the battery at the rating current for 30 seconds (different temperatures should have different ratings). The rating current shall be held constant ±2 A throughout the discharge. Measure battery terminal voltage under load at the end of 30 seconds ± 0.2 second.

NOTE: If a battery being tested for CCA has terminals (L or flag, etc.) which prevent a solid connection or the connection quality and resistance is uncertain, it is acceptable to use voltage probes (taps/spikes) in the terminal burn area to eliminate the error due to high resistance test connections. For batteries that require a “false” terminal to be used to match with test equipment leads (side and stud terminals) the voltage drop through the false terminal shall be validated as to have no effect on the test outcome. Alternatively, voltage probes (taps/spikes) may be used to by-pass the false terminal.

The acceptance criterion for this test is that the battery terminal voltage at 30 seconds shall be 7.2 V or greater.

Unless the next test to be performed in the test sequence specifies otherwise, recharge the battery according to 3.3.

3.9.2 Cranking Characterization Test

3.9.2.1 Following completion of the minimum required test sequence for conducting optional tests, conduct a reserve capacity test according to 3.6. Recharge per 3.3. Repeat the reserve capacity test and recharge per 3.3. (The battery will then have gone through the sequence preconditioning, Reserve Capacity, Cold Cranking, Reserve Capacity, Reserve Capacity.) Allow each battery to stand at room temperature for 8 to 96 hours. Subsequent discharge tests are to be conducted without further capacity tests.

3.9.2.2 To avoid potential hysteresis effects, the test sequence shall be varied across multiple samples. At least three different batteries, each receiving a different test sequence, shall be used to evaluate cranking characterization. Additional samples may be tested, but sample size shall always be in increments of three to maintain balance between the three different test sequences. Each test sequence consists of a battery sample tested at three cranking discharge rates, high, medium, and low. The order of the discharge rates (high, medium, and low) is detailed in Table 2 for each separate sample.

Table 2 - Sequence of cranking characterization tests

Battery Sample Number	Test Sequence Order Number Discharge - High Rate	Test Sequence Order Number Discharge - Med Rate	Test Sequence Order Number Discharge - Low Rate
1	1	2	3
2	3	1	2
3	2	3	1
4	1	3	2
5	3	2	1
6	2	1	3
7-9, 10-12, etc. Repeat sequence above.			

Discharge the battery at three current rates and temperature(s) ±0.5 °C as agreed to by battery manufacturer and customer. Temperature control procedures and timing should be consistent with the procedure described in 3.9.1. Typical nominal test temperatures include -18 °C and -29 °C. Measure terminal voltage as a function of time for each discharge current rate and record voltage at 2, 5, 10, 15, 20, 30 seconds, or until the voltage declines to 7.2 V. If discharged to 7.2 V, record the time to 7.2 V. Plot voltage as a function of time as shown in Figure 1. Following each discharge, recharge batteries per 3.3 and then proceed to the next discharge rate. After the final discharge, unless the next test to be performed in the test sequence specifies otherwise, recharge the battery according to 3.3.

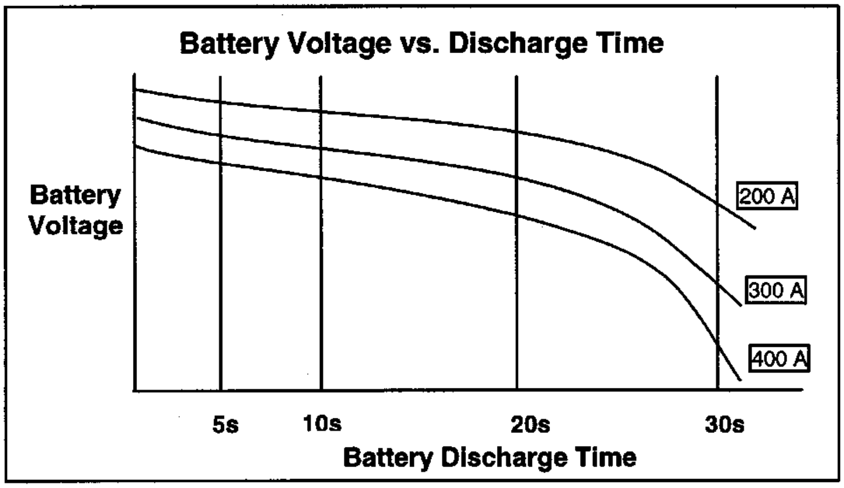

Figure 1 - Example - battery voltage versus discharge time plot

3.9.2.3 Plot mean voltage as a function of current (separate graph for each test temperature), for discharge times of 2, 5, 10, 15, 20, 30 . . . seconds to produce a plot as shown in the following example. At least three batteries are to be used to generate the curves (Figure 2).

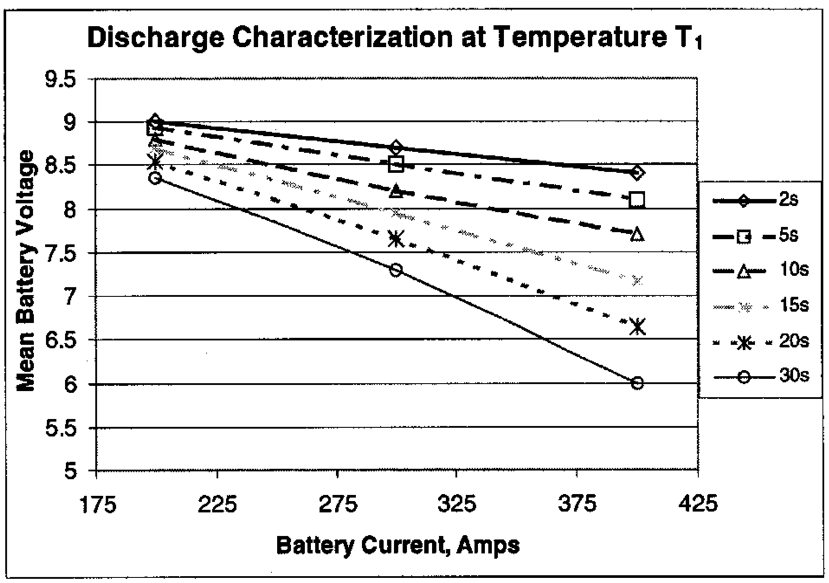

Figure 2 - Example - discharge characterization at temperature t_1

3.9.2.4 Plot mean voltage as a function of current (separate graph for each test time), for test temperatures of -18 °C and -29 °C, and any other appropriate temperature, to produce a plot as shown in the following example. At least three batteries are to be used to generate the curves (Figure 3).

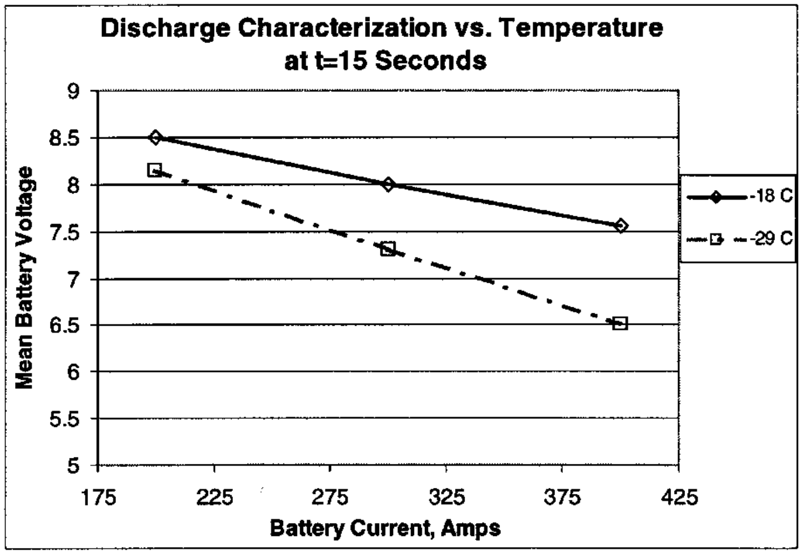

Figure 3 - Example - discharge characterization versus temperature at t = 15 seconds

3.10 Optional Durability Tests

The durability of an automotive storage battery is a function of the vehicle application and its use, of the environment in which it operates, and of the design and the technology used to build it. These factors interact in complex ways to influence the useful life of a battery. This section defines tests to measure the durability of vehicle storage batteries. The following life-limiting failure mode tests (life tests) may be conducted for scientific and durability evaluation of each battery design. Appropriate alternate testing that meets or exceeds the basic technological and demonstrated requirements of the testing listed below may be substituted by agreement between battery manufacturer and customer.

3.10.1 SAE J240

This test applies to 12 V automotive storage batteries of 180 minutes or less reserve capacity using cast positive grid technology only. This life test simulates automotive service when a battery operates in a voltage regulated charging system. It subjects the battery to charge and discharge cycles comparable to those encountered in automotive service. This test is conducted at 75 °C and has also historically been conducted at 41 °C to produce failure modes that are common under applications with elevated application or environmental temperatures.

3.10.2 SAE J2185

This practice applies to 12 V storage batteries which operate in a voltage regulated charging system. It simulates heavy-duty applications by subjecting the battery to deeper discharge and charge cycles than those encountered in starting a vehicle.

3.10.3 SAE J2801

This practice applies to 12 V storage batteries, which operate in a voltage regulated charging system. It is a life cycle test that is designed to produce the failure modes found in service for the most common commercially available 12 V Starting Lighting and Ignition lead-acid battery manufacturing design technologies.

NOTE: The SAE J2801 test profile (charge/discharge/stand) that is programmed into the testing cycling equipment shall be reviewed carefully prior to testing to ensure all charge, discharge, rest, and end-of-test criteria are properly stated, sequenced, and looped. Verify this profile with the manufacturer.

3.10.4 SAE J3060

This test applies to 12 V automotive storage batteries and is used to determine the ability of a battery to withstand vibration similar to that encountered in on-road applications of passenger car and light truck vehicles without suffering mechanical damage, loss of capacity, or loss of electrolyte.

3.11 Other Test Procedures

This section defines tests to measure rechargeability after discharged stand, battery water loss rate, and the performance of the venting function.

3.11.1 Stand/Rechargeability Test

This test determines the battery capability to accept charge after standing for at least 30 days fully discharged at room ambient temperature.

3.11.1.1 This test is conducted after the battery has completed the standard test sequence. After the third reserve capacity test (3.6) has been completed, continue to discharge the battery at the rate specified in 3.6 until the terminal voltage is 6 V or below.

3.11.1.2 Upon achieving 6 V, immediately, short circuit the battery terminals with an 18-Ω resistor (±20%).

3.11.1.3 After 30 +2/-0 days at room temperature (27 °C ± 3 °C), remove the resistor.

3.11.1.4 Charge battery at a constant 15.8 V ± 0.03 V, for total charge duration of 120 minutes ± 0.5 minute.

The charging equipment used in this test should be capable of a minimum current output of 100 amperes.

3.11.1.5 Discharge battery per 3.6.

Unless the next test to be performed in the test sequence specifies otherwise, recharge the battery according to 3.3.

3.11.1.6 Acceptance Criteria

3.11.1.6.1 Charge Acceptance

Current input after 20 minutes ± 0.5 minute of charging (3.11.1.4) shall be at least 5 amperes.

3.11.1.6.2 Rechargeability

The percent ratio of the discharge time in minutes, as obtained after 120 minutes recharge (3.11.1.5), to the original reserve capacity value of the third reserve capacity test (3.6) shall be at least 50%.

3.11.2 Gassing Rate Characteristics (BCIS-04, BCI Recommended Storage Battery Specifications, Starting, Lighting, and Ignition Types - Gassing Rate Characteristic)

This test provides a basis for comparing flooded battery designs with respect to their ability to withstand service water losses. The gassing rate as measured by this test, in combination with the volume of electrolyte above the plates may influence battery life in specific applications.

3.11.3 SAE J1495

This standard details procedures for testing lead-acid SLI, Heavy-Duty, EV, and RV batteries, to determine the effectiveness of the battery venting system to retard the propagation of an externally ignited flame of battery gas into the interior of the battery under sustained overcharge conditions.

4. SPECIFICATIONS

This section, including appendix figure references, of prior revisions of this document "Type Designations and Markings" and "Terminal Polarity Identification" have been incorporated into SAE J2981.

5. BATTERY CONTAINER DESIGN FOR BOTTOM HOLD-DOWN

This section, including appendix figure references, of prior revisions of this document have been incorporated into SAE J2981.

6. NOTES

6.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE STARTER BATTERY STANDARDS COMMITTEE