Methods of test for lead-acid starter batteries used for motor vehicles and internal combustion engines

ICS: 29.220.10
Methods of test
for lead-acid starter batteries used for motor vehicles
and internal combustion engines
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Foreword

GCC Standardization Organization (GSO) is a regional Organization which consists of the National Standards Bodies of GCC member States. One of GSO main functions is to issue Gulf Standards /Technical regulations through specialized technical committees (TCs).

GSO through the technical program of committee TC No(3) " Gulf technical committee for Electrical and Electronic Products Specifications Sector " has updated the GSO Standard No: GSO 35/1984 " Methods Of Test For Lead-Acid Starter Batteries used for Motor Vehicles and Internal Combustion Engines". The Draft Standard has been prepared by (Kingdom Of Saudi Arabia).

This standard has been approved as a Gulf Standard by GSO Technical Council in its meeting No.(12), held on 13-14/9/1428h (25-26/9/2007) , The approved standard will replace and supersede the GSO standard No. GSO 35/1984
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METHODS OF TEST FOR
LEAD-ACID STARTER BATTERIES USED FOR
MOTOR VEHICLES AND INTERNAL
COMBUSTION ENGINES

1- SCOPE AND FIELD OF APPLICATION
This standard is concerned with the methods of test for 6V and 12V lead-acid batteries, used primarily as a power source for starting, lighting auxiliary equipment and ignition current of internal combustion engine used in vehicles.

It covers the methods of tests for the batteries covered in the standard mentioned in Sub-clause 2.1.

2- COMPLEMENTARY REFERENCES
2.1 GSO 34/2007 “Lead-Acid Starter Batteries Used for Motor Vehicles and Internal Combustion Engines”.
2.2 GSO 886/1997 “Water for Lead-Acid Batteries”.
2.3 GSO 479 “Sulphuric Acid”.

3- MEASURING INSTRUMENTS
3.1 Electrical measuring instruments
The range of instruments used shall be appropriate for the magnitude of the voltage or current to be measured.

For analogous instruments the readings shall be taken in the top third of the scale.

3.1.1 Voltage measurements
The instruments used for measuring voltages shall be of high impedance type and accurate to the second decimal or better. The resistance of the voltmeters used shall be at least 300 Ω/V or a digital voltmeter with an accuracy of 0.5%.

3.1.2 Current measurements
The instruments used for measuring current shall be of accuracy class 1 or better.

3.2 Temperature measurement
The thermometers used for measuring temperatures shall have an appropriate range, and the value of each scale division shall not be greater than 0.5 K. The accuracy of the calibration of the instruments shall be not less than 0.5 K.

3.3 Specific gravity measurement
The specific gravity of the electrolyte shall be measured with hydrometers furnished with a graduated scale, the value of each division of which is equal at most to 0.005. The accuracy of calibration of these instruments shall be to 0.005 or better.

3.4 Time measurement
The instruments used for measuring time shall be graduated in hours, minutes,
3.5 **Dimensions measurement**

The instruments used for measuring dimensions shall be vernier calliper, measuring tape and the like. They shall have an appropriate range and accuracy for the values to be measured.

4. **GENERAL TEST CONDITIONS**

4.1 **Condition of battery samples**

All tests shall be carried out on new battery samples. Samples shall be considered as new not later than:

- 30 days after shipment date of the manufacturer in case of filled batteries;
- 60 days after shipment date of the manufacturer in case of dry-charged batteries.

4.2 **Preparation of batteries prior to test - definition of a fully-charged battery**

All tests, except those in Clauses 10 and 16, shall commence with fully charged batteries.

Batteries shall be considered as fully-charged if they have undergone one of the two charging procedures of Sub-clauses 4.2.1 or 4.2.2 carried out at (27 ± 5)°C.

4.2.1 **Charging at constant current**

The battery is charged with $2 I_{20}$ (where $I_{20} = C_{20} / 20$) until a voltage of 2.4 V/cell is achieved. Then the charging is carried out with $2 I_{20}$ for additional 5 h.

After a rapid discharge capacity test at low temperature, the same charge is applied, however the residual charging time after reading 2.4 V/cell will be only 3 h with $2 I_{20}$.

4.2.2 **Charging at constant voltage**

The battery is charged at 2.667 V/cell ± 0.1 V for a period of 22 to 30 h, the current intensity being limited to $5 I_{20}$ or as specified by the manufacturer.

A reduction of total charging time to 16 h is admissible after a rapid discharge capacity test at low temperature.

*NOTE: If neither complete knowledge of the battery construction nor a specification from the manufacturer is available, then charge according to this Sub-clause (4.2.2).*

4.3 **Activation of dry-charged (charge-conserved) batteries**

Dry-charged batteries shall be filled with the appropriate electrolyte (1.28 ± 0.01) to the maximum level indicated by internal or external marks or according to the manufacturer’s instructions.

4.4 **Fully charged battery**

4.4.1 The batteries subjected to test shall be filled and charged in accordance with the manufacturer’s instructions. The level and specific gravity of the electrolyte in each cell shall be checked and adjusted after the charge on standard batteries only.
4.4.2 Condition of full charge

4.4.2.1 For charging at constant current

Two basic criteria may be used to recognize when the battery is fully charged:

4.4.2.1.1 When the specific gravity of the electrolyte is constant within ± 0.005 over three successive hourly intervals, or

4.4.2.1.2 When the on charge terminal voltage at the constant current does not change by more than 0.008 volts per cell per hour over three successive hourly intervals.

The readings must be corrected to 27°C (=80°F) to eliminate the effects of changing temperatures.

4.4.2.2 For charging at constant voltage

Two basic criteria may be used to recognize when the battery is fully charged:

4.4.2.2.1 When the specific gravity of the electrolyte is constant within ± 0.005 over three successive hourly intervals, or

4.4.2.2.2 When a constant current (± 1%) is observed over three successive hourly intervals at a constant terminal voltage.

4.4.3 The specific gravity of electrolyte measured by means of the hydrometer shall be corrected as follows:

For each 1°C above 27°C, add 0.0007 to the hydrometer reading;
For each 1°C below 27°C, deduct 0.0007 from the hydrometer reading.

4.4.4 For sealed battery designs, electrolyte specific gravity and temperature shall be measured by carefully drilling a hole in the top of the battery, per the manufacturers directions, to gain access to the electrolyte. This hole shall be blocked with a rubber stopper during all test times.

4.4.5 Any adjustment to the electrolyte, amount or specific gravity, throughout this procedure is NOT applicable for sealed batteries designs.

5- VISUAL INSPECTION

The batteries shall be inspected visually to ensure that they are free from any remarkable deformation, crack or any other defects.

6- CHECKING OF MATERIALS, CONSTRUCTION, PACKING AND MARKING

The batteries shall be checked for conformity with the relevant requirements of the materials, construction, packing and marking.

7- CHECKING OF DIMENSIONS

Dimensions of the battery shall be checked for their conformity with the relevant requirements.

8- CHECKING THE SPECIFIC GRAVITY OF THE ELECTROLYTE

The specific gravity of the electrolyte is checked by means of the hydrometer on a fully-charged battery.

For inspection purposes only, a provision of inspection holes of the batteries of

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sealed design can be carefully cut through the cover outside the venting channels. These inspection holes have to remain sealed during battery testing.

9- CHECKING OF RATED CAPACITY “C₂₀” (SLOW DISCHARGE RATE CAPACITY)

9.1 The C₂₀-test shall start within a period of 2 to 24 h for standard batteries and 8 to 96 h for MF batteries, from the end of the charge in accordance with Sub-clause 4.13 of the standard mentioned in Sub-clause 2.1.

9.2 Throughout the duration of the test the electrolyte temperature shall be maintained at a temperature between 25°C and 29°C. For this purpose the battery may be placed in a water-bath or in air cooled chamber. The upper surface of the battery shall be at least 15 mm but no more than 25 mm above the level of the water. If several batteries are in one water-bath, then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

9.3 The battery shall be discharged at a continuous current of I₂₀ = \( \frac{C_{20}}{20} \) kept constant at ±2% of the nominal value until the terminal voltage has fallen to 1.75 V/cell i.e. to 5.25 V in the case of a 6 V battery and 10.50 V in the case of a 12 V battery.

The temperature of the electrolyte during the test shall be maintained between 25°C and 29°C.

9.4 During discharge, the following values shall be checked and noted at suitable intervals:

a) the battery terminal voltage;

b) the discharge current;

c) the temperature of the electrolyte or the temperature of the water bath.

When the voltage at the battery terminals has fallen below 1.90 V per cell (average) the voltage shall be checked at half-hourly intervals and when the voltage at the battery terminals has fallen below 1.80 V per cell (average) the voltage shall be checked at 15 minutes intervals.

If the option of automatic recording is not available, only voltage variations should be recorded.

9.5 The duration of discharge expressed in hours (a), calculated from the commencement of discharge until the battery terminal voltage has fallen to 5.25 V in the case of a 6 V battery and 10.50 V in the case of a 12 V battery. The capacity, “C” in ampere-hours at a temperature “t°C” is equal to:

\[
C_{t°C} = a \cdot \frac{C_{20}}{20} \text{ Ah}
\]

Where:

t°C : the average value of the initial and final electrolyte temperatures measured in the central cell(s).

If the average value t°C differs from the reference temperature of 27°C during discharge, the capacity measured shall be corrected to its theoretical value at 27°C to which the rated capacity is referred by the use of the following formula:
The capacity in ampere hours measured at the temperature “t°C”,
the average of the initial and final temperatures during discharge,
the temperature coefficient of variation of capacity for temperatures
between 25°C to 29°C (this represents a capacity variation of 1%
per-degree Celsius of the temperature difference from 27°C).

10- RAPID DISCHARGE CAPACITY TEST OF A DRY CHARGED
BATTERY AT NORMAL TEMPERATURE (ACTIVATION TEST)

10.1 The battery shall be kept in a temperature of (27 ± 5)°C for at least 24 h.

10.2 The battery shall then be filled with electrolyte of specific gravity 1.28 ± 0.01.
The temperature of the electrolyte shall be (27 ± 5)°C.

10.3 Twenty minutes after the completion of filling, the battery shall be discharged at a
current of I = 3C20 A until the battery terminal voltage has fallen to a value of 3 V
in the case of a 6 V battery and 6 V in the case of a 12 V battery.

10.4 During the discharge the battery terminal voltage shall be measured and recorded.
The first voltage reading should be taken 5 to 7 seconds after the commencement
of the discharge. Thereafter, voltage readings shall be taken at suitable intervals
until the end of the test.

11- RAPID DISCHARGE CAPACITY TEST AT LOW TEMPERATURE

11.1 The fully charged battery, after a rest period of 1-5 h, shall be placed in a cooling
chamber with (forced) air circulation at a temperature of (-18 ± 1)°C for a
minimum of 20 h or until the temperature in one of the middle cells has reached
(-18 ± 1)°C. For sealed battery designs, electrolyte temperature should be
measured by carefully drilling a hole in the top of the battery, per the
manufacturer’s directions, to gain access to the electrolyte. This hole should be
blocked with a rubber stopper during all test times.

11.2 When this temperature has been reached, the battery shall then be discharged
continuously at a constant current, A, for a minimum discharge duration time of
30 s or until the battery terminal voltage has fallen to a value of 3.6 V in the case
of a 6 V battery and 7.2 V in the case of a 12 V battery.

11.3 During the discharge the battery terminal voltage shall be measured and recorded.
The first voltage reading should be taken 5 to 7 seconds after the commencement
of the discharge. Thereafter, voltage readings shall be taken at suitable intervals
until the end of the test.

12- RESERVE CAPACITY TEST (RC)

12.1 This optional test shall be carried out on the batteries rated in terms of reserve
capacity.

12.2 The discharge shall start within a period of 2 to 24 h for standard batteries and 8
to 96 h for MF batteries, from the end of the charge in accordance with Sub-clause
4.13 of the standard mentioned in Sub-clause 2.1.
12.3 During the stand period, regulate battery temperature so that electrolyte temperature, measured above the plates in an intermediate cell, is stabilized at \((27 \pm 3)\degree C\) \((80 \pm 5)\degree F\) before the start of the discharge.

12.4 Throughout the duration of the tests, the battery shall be placed in a water-bath maintained at a temperature of \((27 \pm 2)\degree C\). The upper surface of the battery shall be at least 15 mm but no more than 25 mm above the level of the water. If several batteries are in the same water-bath, then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

12.5 Discharge the battery at \((25 \pm 0.25)\) amperes. During discharge, using any convenient method, maintain the electrolyte temperatures within the range of 24°C (75°F) to 32°C (90°F). Results will not be considered valid if electrolyte temperatures move outside this range before the end of the discharge.

12.6 End the discharge when the voltage across the battery terminals has fallen to the equivalent of 1.75 volts per cell, noting the discharge duration in minutes and the electrolyte temperature at the cut-out point.

12.7 Correct the discharge duration for final temperatures different from 27°C (80°F) using the formula shown below and record the corrected time as the reserve capacity achieved.

12.7.1 Celsius correction:

\[
RC = rc \cdot [1-0.009 (Tc - 27)]
\]

Where:
- \(RC\) = minutes corrected to 27°C (80°F)
- \(rc\) = minutes actually run
- \(Tc\) = end of discharge electrolyte temperature (°C)

12.7.2 Fahrenheit correction:

\[
RC = rc \cdot [1-0.005 (TF - 80)]
\]

Where:
- \(TF\) = end of discharge electrolyte temperature (°F).

NOTE: The temperature \(T\) must be within the range of (24 - 32)°C / (75.0 - 90.0)°F, otherwise the test is invalid.

12.8 Conversion from RC to \(C_{20}\)

Once the reserve capacity is determined, the 20 h capacity can be calculated using the following formula in order to carry out the other tests where the \(C_{20}\) value is referred:

\[
C_{20} = -133.3 + \sqrt{17778 + 208.3 \cdot RC}
\]

NOTE 1: This equation is not recommended for the batteries having \(RC\) ≥ 480 min \((C_{20} ≤ 200 Ah)\).

NOTE 2: The above equation is just for reference only and this may require modification to reflect the relationship between \(RC\) and \(C_{20}\) in most recent designs.

13- **CHARGE ACCEPTANCE TEST**
13.1 The battery shall be discharged at an ambient temperature between 0 and 30°C at a current \( I_0 = \frac{C_e}{10} \) for 5 h.

The value of \( C_e \) shall
- either be taken as the maximum \( C_{20} \) value of the three previous discharges according to Clause 9.
- or be calculated from the maximum reserve capacity “RC” value of the three previous discharges according to Clause 12 with the correlation formula of Sub-clause 12.8.

13.2 Immediately after the discharge, the battery shall be cooled for 20 h to 25 h at \((0 \pm 1)\) °C or until the temperature in one of the middle cells has reached \((0 \pm 1)\) °C.

13.3 At this temperature, the battery shall be charged at a constant voltage of \((14.4 \pm 0.1)\) V. After 10 minutes, the charging current \( I_{ca} \) shall be recorded.

14- CONSERVATION OF CHARGE TEST (SELF DISCHARGE - LOSS OF CAPACITY DURING STORAGE)

14.1 The fully charged battery, after a complete cleansing of the electrolyte from its surface, is stored undisturbed for a period of 21 days at a temperature of \((40 \pm 2)\) °C. No connecting clamps or cables shall be attached to the terminals.

14.2 After 21 days of storage, without prior charging, the battery is placed in a cooling chamber with (forced) air circulation at a temperature of \((0 \pm 1)\) °C for a minimum of 20 h or until the temperature in one of the middle cells has reached \((0 \pm 1)\) °C.

14.3 The battery shall then be discharged - either within or outside the cooling chamber - within 2 min after the end of the cooling with the rated current specified for the rapid discharge capacity test at low temperature. This current shall be kept constant to within \( \pm 0.5\% \) during the discharge. The 30 s voltage shall be recorded during discharge.

15- BATTERY LIFE TEST (ENDURANCE TEST)

15.1 Throughout the whole test period, with the exception of the rapid discharge test at the temperature 0°C (see Sub-clause 15.5) the batteries shall be placed in a water bath at a temperature of \((40 \pm 2)\) °C.

15.2 The batteries shall be connected to a device where they undergo a continuous series of cycles, each cycle comprising:

a) a discharge for 1 h at a current

\[ I = \frac{C_{20}}{4} \quad (A) \]

b) a recharge for 2 h at a constant voltage of \((14.8 \pm 0.05)\) V, the maximum current being limited to

\[ I_{max} = \frac{C_{20}}{2} \quad (A) \]
15.3 After a series of 32 cycles of discharge and recharge, in accordance with Sub-clause 15.2, the batteries shall be disconnected from the endurance circuit and allowed to remain on open circuit for a period of 72 h. They shall be recharged according to item b) of Sub-clause 15.2.

15.4 The whole sequence of 32 cycles, followed by the open-circuit period, constitutes one endurance test unit.

15.5 At the completion of six units (or nine units in case of heavy duty batteries) the batteries are submitted to another series of 32 cycles and an open-circuit period of 72 h. The batteries shall then, without recharge, removed from the water bath, be cooled to an electrolyte temperature of \((0 \pm 1) \, ^{\circ}C\) [measured in a central cell(s)] or for a minimum of 20 h and discharged at 0.6 of the rated current.

15.6 After 30 s of discharge the voltage across the battery terminals shall be measured. It shall be not less than 3.6 V in the case of a 6 V battery and 7.2 V in the case of a 12 V battery. The discharge shall then be terminated.

16- **TEST FOR LEAKAGE OF AIR**

Check the sealing of each cell of the battery by compressed air at a pressure \(2 \, \text{N/cm}^2\). The volume of the tubes and auxiliary parts in connection with the cell under pressure shall not exceed 0.5 litre. Note air pressure in the cell 15 seconds after pressure supply has been disconnected. At the end of 15 seconds, record the pressure reading of the manometer connected to the cell.

The air pressure test shall be carried out in dry condition.

17- **WATER CONSUMPTION TEST**

This test is only done on maintenance free (MF) batteries.

17.1 Not later than one hour after the battery being charged according to Sub-clause 4.2, the battery shall be cleaned, dried and weighed to an accuracy of \(\pm 0.02\%\).

17.2 The battery shall be placed in a water bath maintained at a temperature of \((40 \pm 1) \, ^{\circ}C\). The upper surface of the battery shall be at least 15 mm but no more than 25 mm above the level of the water. If several batteries are in the same water bath then the distance between them and also the distance to the walls of the bath shall be at least 25 mm.

17.3 The battery, with tightly closed vent plugs, shall be charged at a constant voltage of \((14.4 \pm 0.05) \, V\) (measured across the battery terminals) for a period of 500 h (approximately 21 days).

17.4 Immediately after this overcharge period, the battery shall be weighed again under the same conditions as in Sub-clause 17.1 with the same scales.

17.5 The loss in weight, corresponding to the water consumption, during overcharge is calculated as:

\[
WC = \frac{WB - WA}{\text{Effective Capacity} \ (C_e)}
\]

Where:

\[
WC = \text{Water consumption in g/Ah or g/min}
\]
WB = Weight in g before water consumption test
WA = Weight in g after water consumption test

18- VIBRATION RESISTANCE TEST

18.1 The vertical vibration table must be able to generate a harmonic oscillation of (22 ± 2) Hz and accelerations of 6 G and adapted to the battery design and to field conditions.

18.2 The battery is subjected to rapid discharge at normal temperature (27 ± 2)°C, at a rated rapid discharge current. The terminal voltage at 30 s shall be recorded.

18.3 The battery is recharged and fixed to a vibration table and vibrated at vertical harmonic oscillation (22 ± 2) Hz.

Vibration duration:

a) heavy duty batteries : 20 hours at acceleration 6 G
b) other batteries : 2 hours at acceleration 3 G

18.4 After vibration, the presence of any crack on the container and/or cover and/or excessive overflow of electrolyte shall be checked and recorded.

18.5 The battery is again subjected to rapid discharge test in accordance with Sub-clause 18.2.

19- ELECTROLYTE RETENTION TEST

19.1 After charging according to Sub-clause 4.2 the battery shall be stored for 4 h on open circuit.

19.2 If necessary the electrolyte level of each cell shall be adjusted to the maximum with water conforming to the standard mentioned in Sub-clause 2.2. The external surfaces of the battery shall be cleaned and dried.

19.3 The battery shall then be tilted in either direction at intervals of not less than 30 s between each tilting as follows:

a) the battery shall be tilted through 45° from the vertical for a maximum period of 1 s;

b) the battery shall be maintained in this position for 3 s;

c) the battery shall be returned to the vertical position for a maximum period of 1 s.

19.4 At the end of the test, the presence of any overflow of electrolyte shall be checked and recorded.

20- TEST FOR LEAKAGE OF ELECTROLYTE (HEAT ENDURANCE TEST)

20.1 The battery, fully charged and filled with electrolyte, shall be maintained at a temperature of -10°C for 24 hours, at the end of this period, it shall be subjected to a temperature of 27°C for 30 minutes, after which it shall be stored either at a temperature of 50°C for 24 hours or at a temperature of 60°C for 10 hours.

20.2 At the end of either period, the container and the welding of connections and covers shall be inspected. Presence of any leakage of the electrolyte or liquefaction of the sealing material shall be recorded.
21- TEST FOR STRENGTH OF TERMINAL

21.1 The strength of terminal shall be examined in such a way that appropriate adapters are fitted to positive and negative terminals.

21.2 A torque shall be applied to the adapter using a torque wrench in the direction of rotation illustrated in Figure 1. The torque being 11.8 Nm for a thin type tapered terminal $T_1$, 14.7 Nm for a thick terminal $T_2$ and 4.9 Nm for a bolt and nut type terminal $T_3$. Check for any abnormality on the terminal part.

![Tapered terminals $T_1$ and $T_2$](image1.png) ![Bolt and nut terminal $T_3$](image2.png)

**FIGURE 1**

ARROW MARKS INDICATE DIRECTION OF ROTATION OF TORQUE WRENCH