

# New mandatory safety testing requirements for electric vehicle batteries under R100



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White paper

## Abstract

UNECE Regulation No. 100 details safety requirements for the electric power train of road vehicles. The recently published Revision 2 of the Regulation includes a number of new requirements for rechargeable energy storage systems (RESS) used in battery electric vehicles. This white paper offers an overview of R100 and the new safety requirements for rechargeable battery packs.

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# Introduction

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The recently published Revision 2 of UNECE Regulation No. 100 will impose a number of additional tests on manufacturers of rechargeable energy storage systems (RESS) designed for use in motor vehicles manufactured, sold or operated in the European Union and other countries. These tests are intended to ensure the integrity and safe operation of such systems under anticipated operating conditions, as well as to provide a higher level of safety for vehicle drivers and passengers. Although this additional

testing will increase the compliance burden for battery manufacturers, it will also ease the acceptance and use of battery packs with type approval, thereby broadening the market for manufacturers.

This white paper will provide a summary of the new testing requirements, and the benefits likely to accrue to battery manufacturers.



# World Forum for the Harmonisation of Vehicles

The creation of global standards for motor vehicles, including electric vehicles and RESS, fall under the purview of the World Forum for the Harmonisation of Vehicles. Originally formed in the 1950s, the Forum is today a permanent working party (WP 29) operating under the auspices of the Transport Division of the United Nations Economic Commission for Europe (UNECE). The primary objective of the Forum is to establish globally harmonised regulations for motor vehicles in order to remove barriers to international trade, promote road safety and protect the environment.

The work of the Forum has its legal basis in the so-called 1958 Agreement, formally known as the "Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions." Under the terms of the Agreement, signatory countries agree to comply with a common set of technical specifications and requirements in connection with motor vehicles produced within their countries, and to allow the

importation, sale and use of motor vehicles from other countries that meet these specifications. At present, nearly 60 countries worldwide are signatories to the 1958 Agreement.

Specific technical requirements for motor vehicles are documented in approximately 130 separate UN Regulations (formerly known as "UNECE Regulations" or "ECE Regulations"). Individual regulations address topics as diverse as vehicle components like lighting and instrumentation, and operational characteristics including crashworthiness and environmental compatibility.

In order to demonstrate compliance with UN Regulations, manufacturers must submit vehicle products and components to an authorised third-party ("Technical Service") for type approval evaluation. Reports of these evaluations are then submitted by the Technical Service to the type approval authority in the signatory country, which issues the actual type approval certificates and authorizes manufacturers to apply the E-mark to their products. Type approvals issued in one signatory country are deemed legally equivalent to those issued in other signatory countries.

Accordingly, vehicles and components that have received type approval in one signatory country must be accepted for importation, sale or use in all other signatory countries.

Notably, the U.S. is not a signatory to the Forum's 1958 Agreement, and does not recognize UN regulations type approvals. Instead, manufacturers seeking to sell motor vehicles in the U.S. must meet U.S. Federal Motor Vehicle Safety Standards (FMVSSs) that address the design, construction, performance and durability of motor vehicles and motor vehicle components. However, unlike type approval requirements in Forum signatory countries, compliance with U.S. motor vehicle safety standards is demonstrated by a manufacturer's self-certification, and independent verification is not required prior to vehicle sale, importation or use.

# UN Regulation No. 100

UNECE Regulation No. 100 is officially titled “Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train.” Also referred to as R100, the Regulation addresses the safety requirements specific to the electric power train of road vehicles, as well as those high voltage components and systems that are “galvanically connected” to the high voltage bus of the electric power train.

R100 was originally published in 1996 under the terms of the Forum’s 1958 Agreement. A revised version of the Regulation (Revision 1) was issued in March 2011 to ensure that the Regulation kept pace with new automotive technologies, and minor amendments were issued in 2012 and 2013. However, since its inception, applications for type approval under R100 have been limited exclusively to entire motor vehicle assemblies. Evaluations of the safety and performance of vehicle components, such as drive trains and battery packs, were conducted as part of a total vehicle assessment, and limited in scope and depth.

Because R100 type approvals covered an entire vehicle, vehicle manufacturers seeking type approval were subject to a complex and time-consuming testing and evaluation process. More problematic, the “whole vehicle” approach to type approval meant that vehicle manufacturers were unable to change



individual systems or components, or to substitute components from one sub-manufacturer with those from another, since any changes to the originally approved design would require a new type approval application for the complete high voltage electrical powertrain.

The publication in 2013 of the second revision of R100 introduced significant changes in the overall type approval process applicable to RESS like electric vehicle batteries. For the first time, the Regulation has provided a

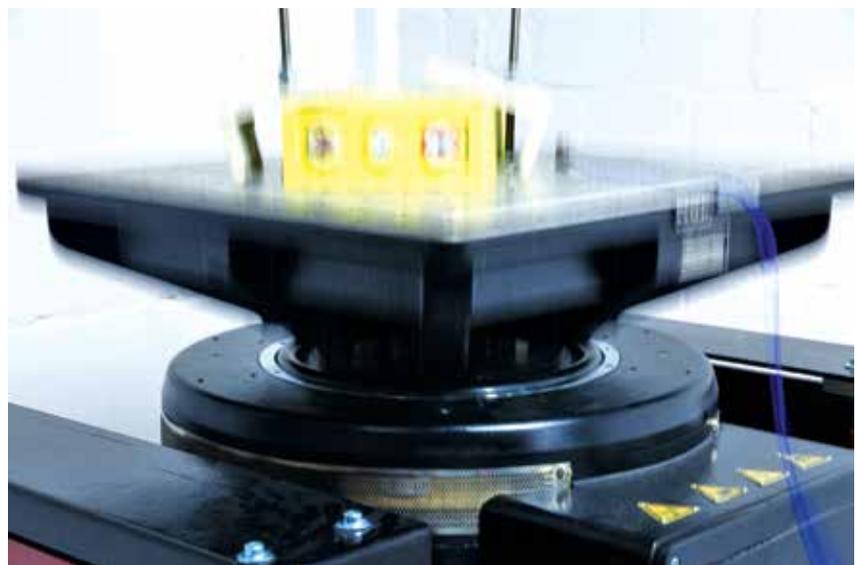
separate approval path for RESS and rechargeable battery packs, along with an expanded set of specific tests exclusively applicable to these systems. With the introduction of these new testing requirements, which become mandatory in July 2016, the responsibility for obtaining type approval for a given RESS may also shift from the vehicle manufacturer to the manufacturer or supplier of an RESS.

# Testing requirements in the second revision of R100

The essential requirements in the second revision of R100 applicable to RESS and rechargeable battery packs are categorized as Part II requirements, and can be found in Section 6 of the Regulation. Annex 8 provides detailed information on the specific testing procedures applicable to RESS and rechargeable batteries identified in Section 6 of the Regulation. As specified in this annex, R100 required assessments for RESS and rechargeable battery packs now include testing for:

- **Vibration** – The vibration test is intended to verify the safety performance of an RESS under vibration conditions similar to those likely to be experienced under normal vehicle operations. The device under test is subject to a vibration having a sinusoidal waveform with a logarithmic sweep between 7 Hz and 50 Hz and back to 7 Hz in the span of 15 minutes. This sweep is repeated 12 times for a total test period of three hours. At the completion of the vibration testing, the device is subject to a standard discharge followed by a standard charge, and then observed for one hour.

NEW TEST REQUIREMENTS
Vibration
Thermal shock and cycling
Mechanical shock
External short circuit protection
Mechanical integrity
Fire resistance
External short circuit penetration
Overcharge protection
Over-discharge protection
Over temperature protection

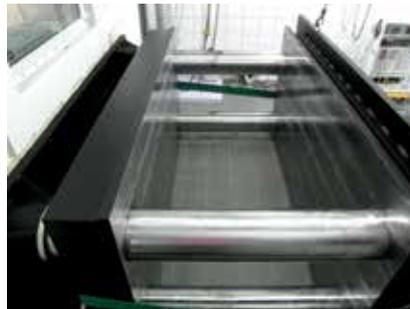


Battery pack undergoing vibration test.

- **Thermal shock and cycling** – The thermal shock and cycling test is intended to verify the resistance of an RESS to sudden changes in temperature similar to those likely to be experienced in actual environmental conditions. The device under test is first stored for at least six hours at approximately 60°C, followed by six hours of storage at approximately -40°C, with a maximum time between temperature extremes of not more than 30 minutes. This cycle is repeated five times, followed by storage of the device at ambient temperatures for 24 hours. At the completion of the thermal shock and cycling test, the device is subject to a standard discharge followed by a standard charge, and then observed for one hour.

- **Mechanical shock** – The purpose of the mechanical test is to verify the safety performance of an REESS under inertial loads that may occur in vehicle crash conditions. The device under test is accelerated or decelerated at speeds specified

in the tables accompanying the regulation, and the actual gravitational force is compared with the values specified in the tables. Upon the completion of the mechanical shock test, the device is observed for one hour.



Device used to test for mechanical integrity.

- **Mechanical integrity** – The mechanical integrity test is intended to verify the safety performance of an RESS under the kinds of contact loads that might be experienced in vehicle crash conditions. The device under test is crushed between a resistance plate and a crush plate with a force of least 100 kN with an onset time of less than three minutes and a hold time of between

100 milliseconds and 10 seconds. At the completion of the mechanical integrity test, the device is observed for one hour.

- **Fire resistance** – The purpose of the fire resistance test is to verify the resistance of an RESS to exposure from a fire originating outside of a vehicle, in order to provide a driver and passengers with sufficient escape time. The test can be conducted either as a vehicle-based test, in which a device is mounted to simulate actual mounting conditions in a vehicle, or as a component-based test without vehicle mounting. The device under test is then subject to both direct and indirect exposure to a flame that has been produced by burning commercial fuel. At the completion of the fire resistance test, the device is observed for a period of three hours, or until it has cooled to ambient temperature, whichever is less.

- **External short circuit protection** – The external short circuit protection test is intended to verify the performance of a device's short circuit protection system, intended to limit consequences associated with short circuits. The device under test is subject to an intentional short circuit by connecting the positive and negative terminals of the device, using a connection with



Battery module being prepared for a mechanical shock test.

a resistance of not more than 5 mΩ. The short circuit condition is continued until the function of the short circuit protection can be confirmed, or for at least one hour after the temperature measured on the device casing has stabilized. At the completion of the external short circuit protection test, the device is subject to a standard discharge followed by a standard charge, and then observed for one hour.

- **Overcharge protection** – The purpose of the overcharge protection test is to verify the performance of a device's overcharge protection system. When conducting the overcharge protection test, the device under test is charged until the device automatically interrupts or limits the charging, or until the device is charged to twice its rated capacity. At the completion of the overcharge protection test, the device is subject to a standard discharge followed by a standard charge, and then observed for one hour.

- **Over-discharge protection** – The over-discharge protection test is intended to verify the performance of a device's over-discharge protection system. During the over-discharge protection test, the device under test is discharged until it interrupts or limits the discharge, or when the device is discharged to 25% of its nominal voltage level. At the completion of the over-discharge protection test, the device is subject to a standard discharge followed by a standard charge, and then observed for one hour.

- **Over-temperature protection** – The purpose of the over-temperature protection test is to verify the performance of a device against internal overheating during operation, even when the device's cooling function fails. When conducting the over-temperature protection test, the device under test is first repeatedly charged and discharged with a steady current, so as to increase the

temperature of cells as rapidly as possible. The device is then placed in a convection oven or climatic chamber, and the temperature of the oven or chamber is gradually increased to a pre-determined level. The test is concluded when the tested device inhibits and/or limits the charge and or discharge to prevent the temperature increase, or when the temperature of the tested device is stabilised.

- It is important to note that testing values that differ from those presented in Annex 8 of the Regulation may be applied in coordination with the technical service, depending on the requirements or preferences of the manufacturer of an RESS or the vehicle.

# The impact of second revision R100 testing on RESS manufacturers

As previously noted, the testing requirements applicable to RESS and rechargeable batteries under the second revision of R100 are far more extensive than previous versions of the Regulation. More important, vehicle manufacturers can shift the responsibility for obtaining the required RESS type approval to the RESS manufacturer or distributor. Therefore, RESS manufacturers should initiate the changes necessary to comply with the new type approval requirements ahead of the July 2016 effective date.

Although the second revision of R100 can shift compliance and testing requirements to RESS manufacturers,

the Regulation's new approach to type approval may also provide them with increased market opportunities. Vehicle manufacturers will now have the ability to evaluate type-approved rechargeable battery systems and components during the vehicle design process, and to select those systems that best match their specific requirements. Vehicle manufacturers will also be able to more easily modify or change RESS in production vehicles without the need to resubmit their vehicle for a full type review. These conditions are likely to create a more level playing field for all manufacturers, and foster technical innovation through increased competition.

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# Conclusion

The second revision of R100 introduces significant testing requirements for manufacturers of RESS and rechargeable batteries for electric vehicles. At the same time, the Regulation also modifies the current type approval scheme, a change that is likely to increase competition in the RESS marketplace. Manufacturers can take advantage of the changing market landscape by taking steps now to evaluate the performance of their current RESS

and rechargeable battery systems against the requirements of the new suite of tests, ahead of the July 2016 transition. TÜV SÜD can assist manufacturers in the testing and type approval of RESS such as rechargeable batteries for electric vehicles for compliance with the requirements of the second revision of R100. TÜV SÜD is equipped to run pre-tests to identify where RESS are subject to failure, or where redesign might be required, thereby saving

valuable time and expense. In addition to safety testing, TÜV SÜD also offers a broad portfolio of endurance and lifetime testing services and a worldwide network of testing facilities that enable manufacturers to meet their testing requirements close to home.



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