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ENSURING LIFETIME COMPLIANCE OF ELECTRIC VEHICLES WITH SAFETY AND SUSTAINABILITY REQUIREMENTS.

- REVISION 01

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EXECUTIVE SUMMARY

Due to regulatory moves[1], technology advances and changing consumer behavior, electric vehicle (EV) adoption is rising considerably in most major automotive markets. With EVs claiming an ever-increasing share of the vehicle fleet, it is crucial to ensure that safety and environmental performance requirements are met through the vehicle's lifetime compliance. The term 'EV' in this document refers to vehicles that have an electric drivetrain, whether or not this is combined with a traditional combustion engine as in hybrid vehicles.

While compliance with many, but not all, of these requirements is checked at type approval, the function of relevant systems and components may deteriorate due to ageing, damage or tampering over the use phase of the vehicle.

CITA is convinced that ensuring the safe use of EVs and a proven positive impact on reducing emissions is an enabler of EV adoption rather than a roadblock. At the same time, current PTI (Periodical Technical Inspection) criteria do not yet address the specifics of EVs. A task force consisting of international PTI and EV experts has been formed to elaborate a set of recommendations which at the same time:

- Ensure vehicle safety and environmental performance compliance over the entire vehicle life;
- Consider cost/benefit[2] and convenience aspects from the user's perspective, and
- Keep investment for PTI service providers – and thus the cost to those who pay for or fund PTI – at a manageable level[3].

PTI remains essential and must be quickly adapted for EVs. This White Paper summarizes CITAs recommendations along with four subgroups:

1. General safety.
2. Electrical safety inspection (electric elements and resistance/isolation).
3. Rechargeable Energy Storage System (REESS) and Battery Management System (BMS).
4. Electric energy consumption.

[1] Stricter emission targets for vehicle manufacturers and subsidies for EV buyers/users
[2] In terms of both, monetary and time aspects for users
[3] As high investment would, in turn, drive PTI prices up

Several prerequisites for an effective PTI-adaption for EVs need to be given. These include, but are not restricted to:

- A mandate for relevant items to become part of the type approval requirements,
- Open access to relevant OEM data for PTI organizations in a legally standardized form, in a centralized way and on a non-discriminatory basis, and
- Relevant equipment needs to be available at the place where PTI is conducted, and inspectors must be appropriately trained for HSE (health, safety, environment) purposes and in order to achieve consistent outcomes.

It is currently unknown to which extent the condition of the EV battery affects the reliability and durability of the vehicle over time. The appropriate techniques to undertake an impartial assessment of condition of the battery should be developed in a separate study. The aim should be to enable the PTI inspector to assess all safety relevant battery data at PTI and not be limited to simply reading out the State of Health (SoH) status, which is only partially relevant.

CITA remains committed to working closely with relevant policymakers and industry stakeholders to ensure an effective adaptation of PTI for EVs.

BACKGROUND AND CONTEXT

Definition of Electric Vehicles

For the purposes of this paper, Electric Vehicles (EV) include Battery Electric Vehicles (BEV) and Hybrid Vehicles (HEV). Their high voltage components and systems are defined according to the UNECE Regulation No. 100. In light of this definition, EVs with electric components and/or systems, which only use voltages below 60V DC or 30V AC, are not within the scope of this paper. While the main focus is on light vehicles (including cars, vans and motorcycles) and heavy vehicles (including trucks and busses), the recommendations given in this paper should be considered to all BEV and HEV that meet the characteristics described above. Micro mobility is not in the scope of this paper but is being addressed in CITA papers "The inclusion of personal light electric vehicles in road traffic"[4] and Safe Function for Road-Going Micro-Mobility"[5].

Key differences in EV vs ICE[6] vehicle layout with relevance to PTI

Directive 2014/45/EU establishes minimum requirements for a regime of periodic roadworthiness tests of vehicles used on public roads. While the Directive provides a comprehensive framework for PTI, the specifics and associated safety risks and environmental aspects of EVs are not yet being addressed.

Comparing BEVs to ICE vehicles, the most obvious differences are in the engine and drivetrain. There are, however, less obvious differences resulting from the vehicle layout, including a higher curb weight (due to the battery), regenerative braking, battery charging functionality and additional focus on aerodynamics in the body and underbody work. A good number of publications deal with the differences between ICE vehicles and EVs. This paper, therefore, focuses on aspects relevant in the PTI context, which include:

- Electrical system: Risks of electrical hazard from damaged, malfunctioning, or tampered high voltage battery pack, inverter;
- Converter, on-board charger, charging socket, BMS, EVMS (Electric Vehicle Management System) and high voltage wiring;
- Traction batteries: Risk of thermal runaway, hazard due to ageing;
- Cooling system: Proper function of the complex cooling system needs to be ensured at any time to prevent the risk of overheating, fire or explosion (see above);
- Regenerative braking system, potentially leading to "sleeping" friction brakes;

[4] https://citainsp.org/wp-content/uploads/2020/11/CITA_Position-Micromobility.pdf
[5] To be released shortly
[6] ICE: Internal Combustion Engine

- Higher curb weight, resulting in higher stress for suspension, steering, friction brakes, and tires (which are also affected by the higher and directly available torque);
- Increased focus on aerodynamic efficiency: Structures, brake-, fuel- and electric lines, potentially even suspension and brakes may be less visible, therefore more complex to inspect, and
- Charging cable: While often overlooked, it can be a serious hazard if damaged or in poor condition.

These aspects are, in CITA's view, not yet sufficiently addressed in the above-mentioned Directive[7] and should be addressed very soon. Inspection procedures[8] of many (mainly mechanical) parts are sufficiently defined in the current regulations (for vehicles with traditional powertrains) for EVs and will therefore not be covered in this document. The focus of this document is on EV specifics which are in our view not yet sufficiently covered in current regulations.

PHEVs are a special case, combining both the conventional ICE and BEV components, which both need to be inspected.

Similarly, Fuel Cell Hybrid Electric Vehicles (FCHEV) have additional hydrogen-related components which need to be inspected besides EV components and which are not included in the scope of this paper.

Batteries degrade over time. Their capacity gets reduced, internal resistance increases and vehicle performances, like the charging time, are impacted. As set out in this document, the in-vehicle safety and control devices must work properly even with deteriorated traction batteries over its total lifetime. However, the effect on emissions should also be studied. For example, the gradual degradation of the EV battery impacts the range of the vehicle in EV mode. Consequently, the remaining energy of battery could influence CO2 emissions of xHEV and hence the potential benefits of such vehicles in reducing Greenhouse Gases.

Because of the above, it is essential to have an impartial methodology to assess the conditions of EV batteries. An independent assessment of the safety effect of increased battery ageing over the vehicles lifecycle should be established in a separate study. A productive approach would be to collaborate with the manufacturer to set up conditions, data provision requirements and objectives for this study.

[7] With the potential exception of the effects of higher curb weight

[8] This affects 9 main inspection elements and their associated 29 deficiencies from chapters 6. "Chassis and chassis attachments", and chapter 8. "Nuisance" of the Directive 2014/45/EU

RECOMMENDATIONS

The following overview provides a summary of our recommendations on how PTI should be adapted to cover EVs appropriately. For a more detailed description, please refer to Annex 1.

1. General Safety

In respect to the General Safety regulation as well as common sense measures, a basic knowledge of EVs and high voltage should be a requirement for the PTI inspector. Not all PTI inspectors need to be trained in EVs from the start. However, if an EV is presented for inspection at a PTI center, only specially trained PTI inspectors should be testing it. The PTI inspector should be checking low and high voltage wiring and connector points to protect the safety of the driver and prevent electrical shock or fire hazards.

Visual checks will need to be conducted to check presence of labels and protective shields. There will also be a difference in brake testing, where it must be ensured that it is the mechanical safety brakes that are tested at PTI – without any interference from the regenerative brakes. In addition, the Acoustic Vehicle Alerting System (AVAS) must be checked, which can easily be done on the inspection lane itself. The 'Active driving possible mode' as well as 'State of drive indicator' should also be checked, which can also be accomplished on the inspection lane.

2. Electrical Safety Inspection

Currently, only visual inspections are defined in the UNECE Rule 4. Most safety relevant irregularities of high-voltage components cannot be recognized by a visual inspection only.

Therefore, for all components:

- Visual inspections are recommended, but need to be supported by further measures, like functional test for High Voltage (HV) components,
- Reading On Board Diagnostics (OBD) information from all safety relevant control units, especially hardware and software versions, readiness codes and defined error-codes, and
- Verifying the electric safety by measurements, as already defined in common harmonized standards, like equipotential bonding and isolation resistance.

The additional recommended tests should include:

- Verification of the vehicle inlet charging connection,
- Ensuring right equipotential bonding of the vehicle,

- Verification of the isolation resistance between the vehicle and HV components, and
- Charging cable test: all EVs should include an emergency charging wire/cable as part of the vehicle inspection.

For the implementation of a PTI for electric vehicle it is necessary to:

- Remove designated covers in conspicuous cases, if a disassembling-free inspection is not requested by type approval requirements,
- A regulated marking of all HV components including manufacturer, type and version (as is it the case for tires), which is freely visible without the need for disassembly free visible, would validate the eligibility of the components,
- Read data from OBD, while regulated and standardized OBD data link connector as communication layers, will dramatically decrease the costs for this safety check.

Most of the testing items are easily implementable into the PTI workflow. It is expected that these measures are comparable to emissions testing including pipe exhaust measurement, but of course time and effort will verify with the detailed requirements.

Why check the isolation resistance?

To ensure the electrical safety of an electric vehicle, the live parts shall comply with the protection against direct and indirect contact. The vehicle cabin and surroundings need to be monitored for losses of isolation resistance to avoid any hazard to the vehicle´s occupants or environment. Therefore, most vehicles on the market are already equipped with an on-board isolation monitoring device. During PTI, the correct function of the isolation monitoring device as well as the correct isolation resistance of the HV components that are not monitored by it must be tested.

Why an equipotential bonding testing?

In case of isolation faults within HV components, the equipotential bonding prevents different voltages between different vehicle components, or the vehicle and the vehicle environment, which can lead to an electric shock.

Additional Requirements:

- Tool-less accessible measurement points for checking safety-relevant components are required by type approval to be available for PTI,
- Opening covers without tools,
- Obligation to have an isolation monitoring device for each galvanically decoupled HV system in the vehicle architecture. For the PTI an

interactive measurement routine or a dedicated measuring point to verify the proper functionality of the isolation monitoring,

- Measurement points to be defined and be accessible for PTI activities for the equipotential bonding,
- The charging cable is a mandatory vehicle part and must be present during the vehicle PTI, and
- Installation of a standardized OBD data link connector for all vehicle types, including EV or future technologies (not included in Regulation (EU) 2018/858).

3. Rechargeable Energy Storage System (REESS) and Battery Management System (BMS)

For testing the BMS and REESS management system, CITA recommends focusing on the following items:

- Vehicle charging immobilization interlock,
- Charging communication test, and
- Charging test.

The tests on these three checkpoints will detect in a very short time the major defects that could cause safety concerns relating to the vehicle and its occupants. In particular, malfunction or manipulation causing cable rips need to be avoided. Equally, wrong software updates, user manipulation or faulty communication between the EV and the charging station could damage parts or cause fire.

Additionally, CITA recommends an OBD connection to verify information focusing on safety and efficiency. This requires the creation of a regulated and standardized data access to control/check safety relevant state and subfunctions of the battery system, like malfunctions, failure modes, soft- and hardware versions.

4. Electric energy consumption

Regenerative braking, the use of kinetic energy to charge the HV battery when braking, is environmentally relevant and should be inspected as part of the PTI, including a short test drive if possible.

Drive efficiency and energy consumption should be inspected using the vehicle interface because failures and wrong software may lead to an environmental non-compliance.

PREREQUISITES

To enable effective inspection of EVs, several prerequisites need to be fulfilled. These start during the type approval or post-registration vehicle conversion process, include standardized access to vehicle / BMS data, and address safety and environmental aspects during the inspection.

The ability of relevant items to be inspected should become part of the type approval requirements.

Some of the inspection items proposed in this White Paper require interfaces at/to the vehicle and access to specific data. The ability for such inspections to be performed during PTI should be a type approval prerequisite. Please refer to Annex 2 for a detailed overview of relevant items for type approval and standardization.

Access to data for independent organizations in a legally standardized form, in a centralized way and on a non-discriminatory basis.

Relevant vehicle and BMS data can come in different forms and each OEM has its "own language". To efficiently facilitate access to and interpretation of relevant data, standardization of data access and data format is needed. As a minimum requirement, CITA proposes unrestricted, non-discriminatory access to the following groups of data in a standardized format (for details, please refer to the CITA paper "Future EU Legal Framework for Access to in-vehicle data" of January 2022[9]).

- Basic communication information:
  - Location of diagnostic connector and connector details (e.g., pin assignment).
  - Bus type and protocol information, general communication parameters (e.g., baud rate), including any additional hardware or software protocol information, parameter identification, transfer functions, 'keep alive' requirements, error conditions, or specification of ECU-specific communication parameters.
- Fitment information:
  - An unequivocal vehicle identification.
  - Component and diagnosis information.
  - Details on how to obtain all component and status information, time stamps, pending DTC and freeze frames.
  - The software calibration identification number (checksum) and its integrity information.
- Basic system information:
  - Service handbooks.
  - Technical manuals.
  - Component and diagnosis information.
- System condition inspection methods:
  - Results of the condition inspection method must include the defective components.
  - Diagnostic trouble codes (including manufacturer specific codes)
  - Details on how to obtain and interpret all fault codes of the relevant systems.
  - Details on how to obtain and interpret all hardware- and software versions of the relevant systems.
- System functional inspection methods:
  - A list of all available live data parameters, including scaling and access information.
  - A list of all available functional inspections including device activation or control, and the means to implement them.

[9] https://citainsp.org/wp-content/uploads/2022/01/CITA-Position-Paper-Access-to-Data-20220126.pdf

- A description of inspections to confirm its functionality at the component or in the harness.
- Inspection procedure including inspection parameters and component information.
- Connection details, including minimum and maximum input and output values and driving and loading values.
- Values expected under certain driving conditions, including idling
- Electrical values for the component in its static and dynamic states
- Failure mode values for each of the above scenarios.
- Failure mode diagnostic sequences, including fault trees and guided diagnostics elimination.

As needed, standardization efforts can/should be initiated via the relevant regulatory/industry working groups. Where applicable, existing international standards should be utilized.

Relevant equipment needs to be available at the place where PTI is conducted, and inspectors must be appropriately trained.

The places where PTI for EV takes place need to fulfil several requirements in terms of layout and equipment. In most cases, PTI takes place at PTI centres. In some countries, including Germany (as a "mobile service"), Austria, the UK and the Netherlands, PTI is also performed in car garages. Keeping economic aspects in mind while ensuring inspection of safety and environmentally relevant items can appropriately be performed, we believe the following equipment is needed as a minimum:

- PTI scan tool (mandatory in the EU at latest from 20 May 2023 on);
- Tool to measure isolation resistance in the vehicle charging inlet;
- Tool to measure isolation resistance between the HV electric system and chassis (a multi-meter is not sufficient); not necessary if interactive measurement routines have been implemented and components are integrated and validated in the vehicle;
- An isolation resistance measurement device, according to the IEC 61851-1, also capable of measuring PE contact and conducting ICCB Tests;
- Equipotential bonding device to verify the equipotential bonding (PE earth connection) as defined in the UNECE R100, using test currents as defined in ISO6469-3 (at least 200mA recommended 1A, test time >5s not relevant for PTI), and
- Charging tester, which is capable of varying the charging parameters, e.g., PWM and resistances (to ensure correct charging communication), to measure the resulting charging currents, and to guarantee that the maximum current is maintained; also, for use to test the "active driving possible mode".

Note: *Any of the above devices may be combined into an unique device or separated if this does not affect the accuracy of each device.*

Some of the recommended inspection items are recommended to be inspected using the vehicle interface. It can be foreseen that the PTI providers will not need other scan tools than they use today. However, updated software/data will be required.

Interacting with EVs means dealing with high voltage. So, inspectors need to be aware of this, be well trained in how to work safely in these environments and have access to relevant personal protective equipment.

OUTLOOK

CITA aims to initiate a constructive and target-oriented dialogue with relevant policymakers and key industry stakeholders to adapt PTI where needed for EVs. We strongly believe that for EVs to play out their full potential in terms of achieving sustainable and safe mobility while ensuring user acceptance over time, the items as laid out in this document must be regularly inspected over a vehicle's lifetime.

ANNEX 1: DETAILED OVERVIEW OF RECOMMENDATIONS

General safety

Description	Method	Why does this need to be inspected?	Main reasons for Rejection	Recommendation
Ensure that EV PTI is carried out correctly and safely	Follow safety guidelines for Electrical and high voltage systems	For Health and Safety reasons, both for the vehicle user and the PTI inspector	N/A	Basic knowledge of EVs and high voltage should be a requirement for the PTI inspector. Not all PTI inspectors need to be trained in EVs from the outset, however if an EV is presented for inspection at a PTI center, only specially trained PTI inspectors should be testing it. Update Directive 2014/45/EU to specify training requirements equal to Dutch regulation NEN 9140 or German DGUV 209-093[10]
EV electrical hazard marking as defined by UNECE R100	Visual inspection of high voltage electrical hazard marking without disassembling	To prevent electric shock and fire hazards	(a) Incomplete or illegible (b) Missing or not found (c) Not firmly fitted (d) Not in accordance with vehicle records	Visual checks to check the presence of labels and protective shields. The marking needs to be visible and placed where the hazard can occur on the vehicle. This must first be included in the *Type Approval*, as well as the obligation for the OEM to provide information on where the markings are located on the vehicle
Mechanical foundation (safety) brakes	Brake test in bench without interference from blended braking / regenerative brakes	The mechanical safety brakes get less use on EVs with regenerative brakes. This can result in reduced functionality over time as brake callipers or cylinders get stuck, etc	Brakes do not meet the requirements	The mechanical foundation brakes are the only safety brakes. It must be ensured that these are tested in isolation from the regenerative brakes. This requires: A switch on dashboard or via OBD to disable regenerative brakes or a model-specific OEM confirmation that regenerative brakes do not kick in at the 5 kph brake bench testing speed

[10] https://publikationen.dguv.de/widgets/pdf/download/article/3982

Description	Method	Why does this need to be inspected?	Main reasons for Rejection	Recommendation
AVAS where mandatory	Functional (noise) inspection during short test drive, i.e., on the PTI lane	To make sure that pedestrians and other road users can hear the EV approaching	Alerting noise absent or not in accordance with requirements	Perform acoustic check - conspicuousness test similar to exhaust loudness. Can be checked when driving the vehicle onto the test lane. Amend Directive 2014/45/EU No additional time required
UNECE Rule 4 Low and High Voltage wiring	Visual inspection with vehicle over a pit or on a hoist, including inside the engine compartment (if applicable) Check of operational readiness function of the systems by an applicable interface (OBD)	The aim of these checks is to protect the safety of the driver and prevent the risk of electrical shock or fire	(a) Wiring insecure or not adequately secured (b) Loose fixings, touching sharp edges, connectors likely to be disconnected (c) Wiring likely to touch hot parts, rotating parts or the ground, connectors[11] disconnected (d) Wiring slightly deteriorated (e) Wiring heavily deteriorated (f) Wiring extremely deteriorated (g) Damaged or deteriorated insulation (h) Likely to cause a short-circuit fault (i) Imminent risk of fire, formation of sparks (j) Readiness of safety relevant systems (e.g., isolation monitoring system, BMS)	Test method involving OBD needs to be provided by OEM in a standardized way (*Type Approval* requirement) Amend Directive 2014/45/EU

[11] relevant parts for braking, steering, etc

Description	Method	Why do we need to check this at PTI	Main reasons for Rejection	Recommendation
“Active driving possible mode” indicator and associated information signal if driver leaves vehicle in active driving possible mode (as defined by UNECE R100) if fitted / required	Visual inspection and by operation when possible. With the charging cable connected, and the driver’s weight lifted out of the seat, the vehicle shall not be able to move	Prevent the vehicle from driving away with the charging cable connected or with the driver absent	(a) Indicator / information signal not fitted in accordance with the requirements (b) Indicator / information signal not functioning correctly (c) vehicle can move while being charged or with no driver present	Visual inspection and functional test to be adopted by Directive 2014/45/EU
“State of drive direction” indicator (as defined by UNECE R100) if fitted / required	Visual inspection and by operation	Road safety	(a) Indicator not fitted in accordance with the requirements (b) Indicator not functioning correctly	Visual inspection and by operation Short test drive, a few meters Amend Directive 2014/45/EU

Electrical safety inspection (electric elements and resistance / isolation)

Description	Method	Why do we need to check this at PTI	Main reasons for Rejection	Recommendation
Vehicle inlet charging connection	Visual and functional testing of the vehicle inlet charging connection Check of operational readiness function of the systems by an applicable interface (OBD)	Identification of possible manipulation, damages in the charging connection or inlet cover that could cause a risk to the user	(a) Cover of the inlet damaged (b) Foreign matter, removal, and effective surface marking (c) Not dry or clean on the inside of the socket (d) Insecure or loose connection	Visual control of the charging inlet including verification of the cover and locking functionality
Isolation resistance of the vehicle charging inlet	Measurement of the isolation resistance of the vehicle's charging port Measurement of equipotential bonding	Ground continuity is checked between charging inlet ground pin and any ground point on the vehicle Isolation testing information about the current safety status of the vehicle	(a) Isolation of the HV components is not given (b) The double of the isolation resistance limits as defined in UNECE R100 or predefined values from the vehicle manufacturer is not given (c) Enclose protection (d) Equipotential bonding not in accordance with the requirements as defined in the ISO6469-3	Isolation resistance measurement of the vehicle charging inlet AC and DC depending on the built-in charging port by using an appropriate tool (multi-meter not allowed) Verification of the equipotential bonding (PE earth connection) as defined in the UNECE R100

Description	Method	Why do we need to check this at PTI	Main reasons for Rejection	Recommendation
Isolation resistance between the HV electric system and chassis	Visual inspection of the warning device and isolation resistance measurement. Check of operational readiness of the systems by an applicable interface (OBD). Measurement of the isolation resistance	The isolation resistance is the main indicator for the actual status of an electrified powertrain. This measurement is an indication of a possible defective part before an arc, damage or an accident occurs. The isolation monitoring device is responsible for monitoring the high voltage system to protect against electrical accidents and reduce the risk of fire.	(a) Isolation monitoring system shows malfunction (b) Isolation resistance between the electric high voltage buses and the chassis in accordance with UNECE R100 is not complied with.	Verification of the isolation resistance indicator in the dashboard. Verification of the isolation monitoring values in OBD operational readiness system signals. Measurement of the current isolation resistance between the HV electric system and chassis via the internal isolation monitor device if it is testable or via an isolation measuring device at defined HV access points.
Vehicle electrical chassis (protective earth) and inter-charging protective earth	Visual inspection with vehicle over a pit or on a hoist. Measurement of equipotential bonding.	Safety of the entire high voltage system: The resistance between the components is low enough to prevent a potential difference between high voltage components, which could result in a potential electric shock. The requirement for additional equipotential bonding is part of the ISO6469-3 and must be present under all operating conditions and over the entire operation life of the vehicle. It is a central element of safety in a high voltage system. To guarantee the proper operation of the integrated isolation monitoring device.	(a) Wiring insecure or not adequately secured (b) Loose fixings, touching sharp edges (c) Wiring likely to touch hot parts, rotating parts, or the ground (d) Wiring slightly deteriorated (e) Wiring heavily deteriorated (f) Wiring extremely deteriorated Equipotential bonding not in accordance with the requirements as defined in the ISO6469-3	Equipotential bonding test (PE earth connection) measurement according to UNECE R100 Test current as defined in ISO6469-3 at least 200mA recommended 1A, maximum applied Test voltage in case of too high resistance <5V, 4 wire measurement, test time >5s not relevant for PTI (to keep inspection time economic)
Description	**Method**	**Why does this need to be inspected?**	**Main reasons for Rejection**	**Recommendation**

Traction motor(s)	Visual inspection Check of operational readiness of the systems by an applicable interface (OBD) Measurement of equipotential bonding when possible	Inspection of the mounted traction motors, checking if it is deteriorated or severely damaged mounting. Loose or fractured mountings and check if any kind of modification / manipulations. Guarantee correct operation of the integrated isolation monitoring device	(a) Traction motor number not in accordance with vehicle documents (b) Shield is deformed, not in-place or damaged, or corroded (c) Warning marking missing or illegible (d) Connection of wiring harness insecure or corroded (e) Electrical insulation damaged or deteriorated (f) Fault readiness of the traction motor (g) Wrong version of type approved hardware and software not in accordance with the requirements as defined in the UNECE R100 (h) Equipotential bonding not in accordance with the requirements as defined in the ISO6469-3	The traction motor should be checked considering fixation, modifications, casing, connection, etc. as recommended in Rule 4 additionally inspection related to the cooling leaks to be observed. Verification of the Traction motors available OBD signals. Equipotential bonding test (PE earth connection) verification
Electronic converters, motor and inverter and wiring harness and connectors	Visual inspection Check of operational readiness of the systems by an applicable interface (OBD)	Change software or hardware for manipulation that could impact the type approval or insurance requirements Identify inadequately secured, corroded or otherwise faulty items with immediate risk of failing, short circuit of electrical shock	(a) Not in accordance with requirements (b) Inadequately secured (c) Damaged or corroded components (d) Shields not in place or damaged (e) Damaged or deteriorated electrical insulation (f) Fault readiness of the converter and inverter systems (g) Wrong version of type approved hardware and software	As in the traction motor case, motors, converter, and inverter should be checked considering fixation, modifications, casing, connection, etc. as recommended in UNECE Rule 4
Description	**Method**	**Why does this need to be inspected?**	**Main reasons for Rejection**	**Recommendation**

Service disconnect device	Visual inspection	The service disconnect is accessible and the compartment is not damaged. Protection against direct contact with live parts.	(a) Insecure or not adequately secured (b) Damaged or corroded components (c) Shields not in place or damaged (d) Damaged or deteriorated electrical insulation (e) Voltage presence (f) Warning marking missing or illegible	Visual inspection of the Service disconnect device
On-board charger	Visual inspection, by using electronic interface and by measurement Measurement of equipotential bonding	When the On-board Charger is not working correctly - danger to the user could ensue due to voltage difference between vehicle and charger When the On-board Charger is not working in the PHEV then the vehicle is not working accordingly to the homologation - CO_2 emission relevant	(a) Shield is deformed, not in-place or damaged, or corroded (b) Warning marking missing or illegible (c) Connection of wiring harness insecure or corroded (d) Electrical insulation damaged or deteriorated (e) Fault readiness of the On-board charger system Equipotential bonding not in accordance with the requirements as defined in the ISO6469-3	Visual inspection in accordance with Rule 4 is a prerequisite for the isolation resistance test in the charging port Equipotential bonding test (ground connection PE), limit as defined in the UNECE R100 100mOhm or lower value according to the values predefined by the vehicle manufacturer

Description	Method	Why does this need to be inspected?	Main reasons for Rejection	Recommendation
Charging Cables	Visual and functional testing Measurement of equipotential bonding	For the safety of the vehicle user and especially for other people passing by when charging. Guarantee electrical safety (isolation resistance, PE and ICCB Test). Guarantee the proper function of the cable: proximity circuit and control circuit. Avoid any risk of fire. Verification of the resistance coding to guarantee that the maximum current is maintained	(a) Not in accordance with requirements (b) Damaged or corroded components (c) Mechanical damage including strain-relief (d) Damaged or deteriorated electrical insulation (e) Damaged or deteriorated electrical insulation (f) Grounding line damaged or deteriorated electrical (g) Increased transmission resistance of lines (h) Resistor PE to PE not suitable for wiring harness (i) Trigger current of the ICCB too high (j) Trigger time of the ICCB too high (k) Interchange of wires (l) Equipotential bonding not in accordance with the requirements as defined in the ISO6469-3	Visual inspection of the charging cable, Isolation resistance measurement according to the IEC 61851-1 depending on the cable, PE contact measurement, ICCB Test (tripping residual current limitation, time). Verification of the resistance coding.

REEESS management system, BMS (safety protocol, charging test and information on state of health)

Description	Method	Why does this need to be inspected?	Main reasons for Rejection	Recommendation
Charging communication test	Accessing the vehicle charging inlet and using an interoperability test device	An incorrect charging communication affects the vehicles limitation of the charging current and can cause a fire hazard or damaged parts	Incorrect parameters of the charging interface	A charging test which emulates a charging situation while varying the charging parameters, e.g., PWM and resistances.
Battery information	Through the use of the electronic interface (OBD2) and with the help of an interoperability test device	Verification of the accuracy of information with a focus on safety	Detection of abnormalities, incorrect software updates	Regulated and standardized OBD2 connection to control/check state and safety relevant subfunctions of the battery system. Verification of the REESS available OBD signals related to the life state of the battery, i.e., the State of Certified Energy (SOCE), the State of Certified Range (SOCR), the total number of charges and quick charges, the total number of deep discharges or the internal resistance value) SW-number and -integrity should be included in ISO ePTI Standard

Description	Method	Why does this need to be inspected?	Main reasons for Rejection	Recommendation
REESS e.g., traction battery	Visual inspection Check of operational readiness of the systems by an applicable interface (OBD) Measurement of equipotential bonding	Ensure that the safety operation of the REESS Prove that the current REESS is in a mechanical integrity and the right bonding is given To avoid security risks related to manipulation/ tampering and events Guarantee correct operation of the integrated isolation monitoring device	(a) Shield is deformed, not in-place or damaged, or corroded (b) Leaking or unusual smell (c) Warning marking missing or illegible (d) Battery chemical type on the housing not illegible (e) Connection of wiring harness insecure or corroded (f) Electrical insulation damaged or deteriorated (g) Fault readiness of the REESS Battery Management System (h) Wrong version of type approved hardware and software of the Battery Management System (i) Not in accordance with the requirements as defined in the UNECE R100	Visual inspection of the component including leaking Verification of the REESS available OBD Equipotential bonding test (PE earth connection) verification

Electric energy consumption

Description	Method	Why does this need to be inspected?	Main reasons for Rejection	Recommendation
Electric regenerative braking system	Visual inspection of the indicator of the electric regenerative braking system, and using vehicle interface Visual inspection of the braking lights	Regenerative braking contributes to low CO_2 emission Safety (braking lights)	(a) Missing, or not in accordance with the requirements (b) Indicator malfunctioning (c) Indicator or vehicle interface shows system malfunction (d) Braking lights do not function when applying the regenerative brakes	In a first step, a qualitative test is recommended. This should include a short test drive where possible In future, more detailed inspections may become necessary: - standardized SW-tests; SW-number and -integrity (update of ISO ePTI Standard necessary) - regeneration functional- and efficiency test complete test (would need thresholds from the VM)
Drive efficiency test	Use of vehicle interface	Failures and wrong software may influence the drive efficiency and may lead to higher energy consumption and/or CO_2 emissions.	(a) Indicator or vehicle interface shows system malfunction (b) Software version or -integrity incorrect	SW-number and -integrity should be included in ISO ePTI Standard Note: A real-drive efficiency inspection (on-road, or on a test bench) was found not recommendable for PTI because of a too low cost-benefit-ratio

ANNEX 2: ITEMS RELEVANT FOR TYPE APPROVAL AND STANDARDIZATION

Type Approval

- Type Approval should require the following BMS functionality in order to ensure safe and sustainable operation throughout the life of the vehicle
  - Power management
  - Temperature control
  - Balancing of battery cell charge (uniform wear of cells), ...
  - This also avoids thermal runaways
  - Both for non-PHEV, and BEV, consumption of electric power should be monitored in OBFCM.
  - Requirement to have an isolation monitoring device in the vehicle architecture
- Type Approval must ensure that PTI can be carried out properly
  - Easy and safe to remove covers
  - Mandatory vehicle electronic interface for all EV
  - Ensure that PTI gets physical and electronic access to the vehicle's electronic interface
  - Ensure that PTI gets all related diagnostic data, thresholds, etc. free of charge for inspection
- For Isolation resistance and equipotential measurement
  - Define vehicle specific testing points, settings and thresholds
  - Measuring points accessible without tools for the inspection of safety-relevant components at PTI should be required in the type approval
- For Hybrid vehicles, additional information points must be implemented:
  - ICE must be able to start easily for emission testing
  - The information on how to start the engine must be available for PTI
- Regenerative/electrical brakes must not interfere with brake testing of mechanical brakes
  - Regenerative/electrical brakes must have a switch-off function, or
  - An OEM statement is needed to confirm that the two systems do not interfere while being tested on a braking bench.

Standardization in ISO ePTI

- Standardization of diagnostic information to access relevant in-vehicle information
  - Any of the points described under "2 Type approval"
  - Operational readiness values and defect codes for all high voltage components
  - Information about the DTC

- Energy recovery
- Tests for sustainability (e.g., charging behavior, ...)
- Safety tests (e.g., thermal management)

Additional PTI information requirements

- Information regarding the homologated software / hardware version (checksum)
- Updated list of valid software / hardware list for checking (checksum)
- Information on homologated software updates (OTA)
- Integrate vehicle components, including charging port (Type) and on-board charger information
- Information about the allowed kind of charging for the vehicle
- Safety relevant information of (high voltage) components especially the REESS
- Instruction of the OEM on how to assess mechanical damages
- TA shall reference the ePTI standard.

Other requirements

CITA recommends that the EV battery supply chain be subject to regulatory standards with respect to socio-economic and ecological aspects, and that the batteries should be labeled accordingly. This labeling should be checked at the time of type approval.[12]

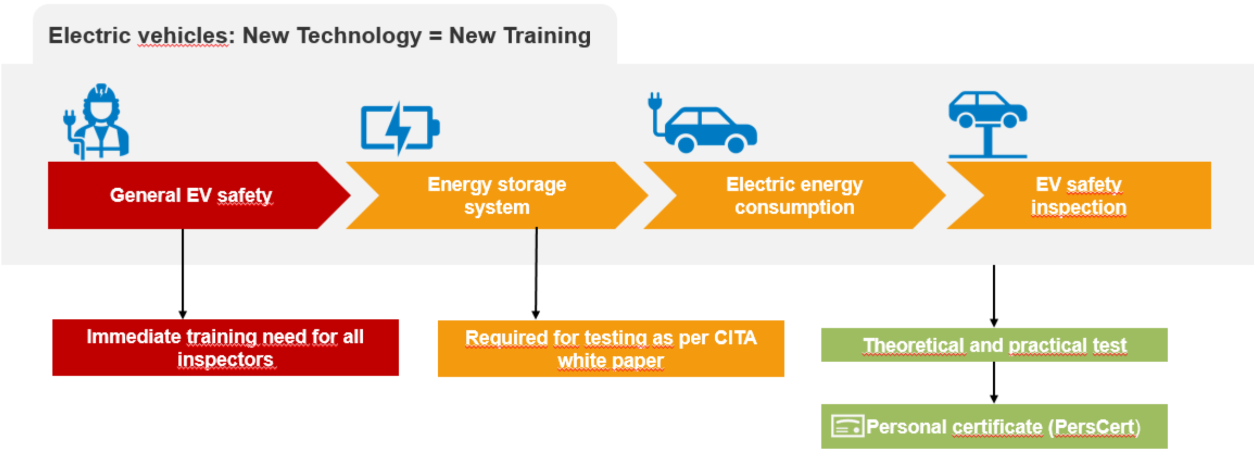
[12] Please also refer to the CITA Position Paper "CITA's proposal regarding the regulation for the batteries of electric vehicles" https://citainsp.org/wp-content/uploads/2021/12/20211217-CITA-Position-Paper-EV-batteries.pdf

ANNEX 3 - JUNE 2023: AMENDMENT WITH PRACTICAL RECOMMENDATIONS FOR TRAINING AND TESTING METHODS.

TRAINING OF PTI INSPECTORS

It should be appreciated that Electric Vehicles represent a new technology which must be understood and mastered in order to avoid safety hazards for EV users and inspectors.

In analysing the gap between current PTI inspector training curriculum and what is required to properly test EVs as set out by the CITA position paper above, it is clear items need to be added for the testing to be both efficient and safely performed. The requirements can be divided into stages as illustrated below:



The training curriculum should concentrate on the following items, which in turn can be delivered to the PTI inspectors through belended learning modules:

Introduction
- Moving a vehicle to perform a PTI
- Use of lifting device
- Design-related hazards with EVs
- Protection against electric shock
- Legal framework

Electrical hazards
- Forms of electrical hazards
- Influencing factors
- Significance of the current path
- Influence of exposure time and current intensity
- Significance of the type of current

Measurements in a simple circuit
- Measure current and voltage
- Performing measurements with a multimeter
- Meaning of potential difference
- Potential equalization

Safe handling of high-voltage vehicles in a de-energized state
- Voltage-free state of electrical systems
- Ensuring the de-energized state
- Five safety rules for working on electrical systems
- Measures to be taken before switching on again

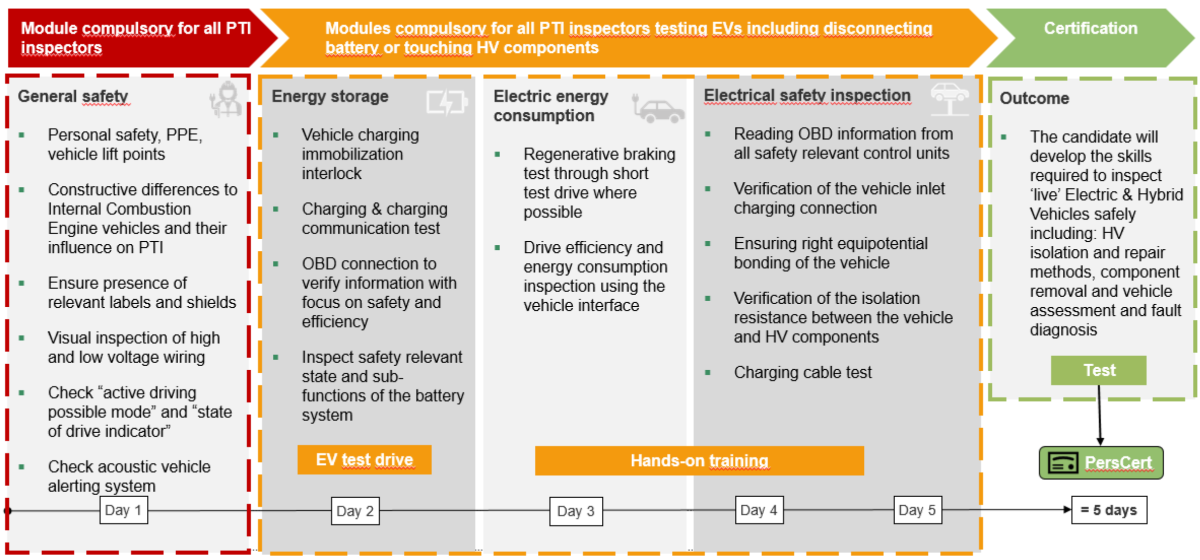
Intrinsic safety of high voltage vehicles
- Insulation monitor
- Service plug and test circuit
- Direct and indirect contact
- Protective measures during charging

Assistance in case of electrical accidents
- General principles
- Immediate measures in the event of electrical accidents
- Initiate rescue chain
- First aid measures

The objective of the training is to raise the PTI inspector's awareness of the HV systems, the associated risks and hazards and how to mitigate these dangers. And equally to explain the structure and basic principles of operation of EHV's in order to ensure that the inspector has the knowledge to safely operate these vehicles. Finally, the inspectors should understand that electrical interaction with HV systems requires specialist training and is not permissible for them until such training has been passed.

In practical terms it is envisaged that the training should be dlivered as a blended learning combination of self-study, distance learning and hands-on face to face training. The total duration of the training is estimated at 5 days.

The training in the red module below is considered urgent for all PTI inspectors. The training in the amber module should be compulsory for anyone testing EVs. The green module is the final element, which results in a personal EV certificate for the PTI inspector.



PRACTICAL TESTING METHODS FOR THE MOST PROMINENT EV PTI TESTS

The amendment below sets out practical testing propositions and lists examples of testing equipment that may be used for the purpose of the test step in question. Further details on each testing step may be found in the White Paper itself (above).

INSULATION RESISTANCE MEASUREMENT AT THE CHARGING PORT:

Measure the insulation resistance of the charging connection of the electric/hybrid vehicle

Protection against short circuit / damage to charging connection, check whether the insulation of the various connections of the electric vehicle are in good condition

Examples of Test Equipment

METREL: A 1507 3-Phase Active Switch, MI 3155 EurotestXD, A 1632 eMobility Analyser

Hella Gutmann: Mega Macs X + e-Mobility modul

GMC Instruments Profitest Emobility + Tester

AVL DiTEST HV-Safety/workSAFE

EQUIPOTENTIAL BONDING MEASUREMENT

Measurement of equipotential bonding on all components accessible without dismantling

ECE R100: resistance between two components < 100 mΩ, test current min. 200 mA (higher test current helps to detect conductor faults)

4-wire measurement technique required (Kelvin measurement)

Examples of Test Equipment

METREL: A 1507 3-Phase Active Switch, MI 3155 EurotestXD, A 1632 eMobility Analyser

Hella Gutmann: Mega Macs X + e-Mobility modul

GMC Instruments Profitest Emobility + Tester

AVL DiTEST HV-Safety/workSAFE

MEASUREMENTS ON THE CHARGING CABLE

The charging cable is not part of the type approval, but should be tested when present in the vehicle

Insulation resistance charging cable

Continuity of the charging cable's earth conductor

PP resistance measurement

If no cable is available, note this in the report, but do not declare as an error

Examples of Test Equipment

METREL: A 1507 3-Phase Active Switch, MI 3155 EurotestXD, A 1632 eMobility Analyser

Hella Gutmann: Mega Macs X + e-Mobility modul

GMC Instruments Profitest Emobility + Tester

IMMOBILIZATION AND LOCKING DURING CHARGING

Check that it is not possible to move the vehicle with the charging cable plugged

Check that the cable is locked by the vehicle, it must not be possible to remove the cable until unlocking has taken place

Examples of Test Equipment

Golden cable / emergency plug

Charging cable if available

FUNCTION OF SERVICE DISCONNECT

Perform visual inspection (see if it s broken, etc.)

Make sure that disconnection will be effective in case of intervention (e.g. in case of emergency)

ACOUSTIC VEHICLE ALERTING SYSTEM

An audible alert must be activated when vehicle is started and whenever vehicle is driven below 20 km/h

Check if the sound is audible when driving the vehicle to the test lane

AVAS (Acoustic vehicle alerting system) mandatory since 01.07.2019 should be checked for all vehicles approved after this date

BRAKE LIGHTS DURING REGENERATIVE BREAKING

Brake lights should illuminate during regenerative breaking

When the EV battery is almost full, the vehicle slows down very little and has no brake lights. Check charging condition if no lights are visible

Test equipment: Brake tester

READ OUT OBD-DATA

Read out error codes via OBD

Check if energy recovery system is working via OBD (on brake tester)

Test Equipment: OBD-reader, Brake tester

CONTACT DETAILS

CITA, the International Motor Vehicle Inspection Committee, is the worldwide not-for-profit association of government agencies and authorized private companies active in the field of vehicle compliance.

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