INDUSTRY STANDARD

- safe handling of high-voltage systems in electric vehicles









Industry Standard

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1 Introduction

This Industry Standard has been developed by BIL Sweden, the Swedish Association for Motor Retail Trades and Repairs (MRF) and the Swedish Vehicle Workshop Association (SFVF). SEK Svensk Elstandard and the National Electrical Safety Board have also been involved, providing support and acting as referral bodies. Furthermore, the Industry Standard is based on requirements and recommendations from vehicle manufacturers, importers and other actors active in the automotive industry.

Some of the methodology of this Industry Standard is based on Swedish standard SS-EN 50110-1:2013, issued by SEK Svensk Elstandard and approved on 9 October 2013. This is the Swedish version of European standard EN 50110-1:2013 produced by CENELEC.

SS-EN 50110-1:2013 is intended for electrical installations, whereas this Industry Standard has been adapted and concerns personal safety in respect of high-voltage systems when working with electric vehicles.

The Industry Standard applies as recommended minimum requirements in Sweden. Where laws, rules, manufacturer's instructions or other regulations impose requirements that differ from or are more stringent than the requirements of this Industry Standard, these other requirements shall take precedence.

Procedures, training, technical solutions and the correct level of protective equipment can help prevent accidents and mitigate their consequences, should an accident nevertheless occur.







This Industry Standard is continuously being updated. The latest version of the Industry Standard is available at elbilsinfo.se or on BIL Sweden's, MRF's or SFVF's website.

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3 Scope and application

This Industry Standard is aimed at companies that carry out maintenance, servicing and repairs on electric vehicles. The term "electric vehicles" is intended to apply only to those passenger cars, lorries and buses in series production and registered for use on roads that contain high-voltage propulsion systems according to type approval ECE R100.

This Industry Standard only addresses the electrical safety aspects of electric vehicles.

Furthermore, the Industry Standard is designed to supplement the manufacturer's instructions that apply to specific vehicles and shall be applied in a professional and safe manner.

Please note that several major actors in the automotive industry have chosen to define the concept of high voltage as voltage that normally exceeds 30 V AC or 60 V DC. This Industry Standard follows the industry's initiatives and defines "high voltage" in Section 4.1.2.

4 Terms and definitions

In this Industry Standard, the following definitions apply. For terms not defined below, please refer to the International Electrotechnical Vocabulary (IEV), <u>https://www.electropedia.org/</u>.

4.1 General

4.1.1 Electric vehicle

Refers to all types of passenger cars, trucks and buses in series production and registered for use on roads, powered by a high-voltage system, such as EV (Electric Vehicle), HEV (Hybrid Electric Vehicle), PHEV (Plug-in Hybrid Electric Vehicle), FCEV (Fuel Cell Electric Vehicle).

4.1.2 High voltage

Voltage used for the propulsion of electric vehicles (including connected auxiliary systems) which normally exceeds 30 V AC or 60 V DC and is below 1000 V AC or 1500 V DC (note that high voltage in this sense is a concept specially defined for the automotive industry).

In addition to the propulsion of electric vehicles, high voltage can be used for e.g. AC compressors, interior heaters, etc., and is also referred to as "operating voltage".

4.1.3 Extra low voltage

Voltage not normally exceeding 30 V AC or 60 V ripple-free DC between conductors, or to earth. For example, 12 V or 24 V electrical systems in vehicles.

4.1.4 Operating voltage

The same definition as for high voltage.

4.1.5 High-voltage system

Refers to all parts of electric vehicles designed to use voltage levels corresponding to high voltage, as well as functions that influence these systems (including energy sources such as batteries, capacitors and all other sources of stored electrical energy).

4.1.6 High-voltage component

Refers to a part of a high-voltage system.







4.1.7 Electrical energy storage system

Component which has an electrochemical composition and which stores electrical energy for later use, such as a high-voltage battery.

4.1.8 Risk

The combination of the likelihood and degree of potential injury to or ill health of a person exposed to one or more hazard sources.

4.1.9 Risk identification

A fairly simple initial assessment of the risk of electrical hazard in a specific job. If there is uncertainty about an electrical hazard, a risk analysis shall be undertaken.

4.1.10 Risk analysis

A risk analysis is a documented systematic assessment of the risks that may occur in a specific job.

4.1.11 Electrical hazard source

Source of potential personal injury or ill health caused by electrical energy.

4.1.12 Electric arc/arcing

A continuous heavy electrical discharge through air, where the electrical voltage has ionised the air, so that the air becomes electrically conductive.

4.1.13 Incident

An event that could have led to, but did not result in, an electrical injury.

4.1.14 Electrical hazard

Risk of bodily injury due to electrical energy.

4.1.15 Electrical injury

Personal injury or death due to electric shock, electric burn, electric arc, fire or explosion initiated by electrical energy.

4.1.16 Electrical consequential damage

Damage caused to something other than a person initiated by electrical energy. For example, a vehicle fire and property or environmental damage.

4.1.17 Non-live

With voltage equal to, or close to zero. That is, without voltage and/or charge (no electrical potential between two points in an electrical circuit).

4.1.18 Disconnected part

Part of a high-voltage system confirmed as non-live after disconnection.

4.1.19 Live part

Part of a high-voltage system that has not been confirmed as non-live.

4.2 Personnel, organisation and communication

See Annex 1 for an illustration of organisation and roles.







4.2.1 Role

The responsibility and authority assigned to a person by virtue of a task or position.

4.2.2 Competence

Level of education/training, skill(s) or other acquired knowledge. Competence for a particular task is acquired through specific training or experience of doing the task.

4.2.3 Responsibility

The obligation to be responsible for an activity or thing. Only one person may be responsible for an area of responsibility at any one time. Responsibility can be delegated.

4.2.4 Technician

Person with sufficient training and experience to carry out professional repairs on vehicles.

4.2.5 Electric vehicles safety officer

Person who has been given the responsibility to ensure that handling of electric vehicles is carried out safely by, among other things, ensuring compliance with rules and working procedures.

4.2.6 Electric vehicles supervisor

A person designated by an *electric vehicles safety officer* whose duty it is to ensure that the person performing work on or who is near an electric vehicle is not exposed to electrical hazards.

4.2.7 Electric vehicles specialist

Technician with specific knowledge and experience allowing them to perform certain types of work on an electric vehicle. There are several levels of *electric vehicles specialist*.

4.2.8 Technician instructed in electric vehicles

Technician who has received appropriate instruction in order to avoid hazards that can result from electricity and to safely carry out certain types of work.

4.2.9 Person informed about electric vehicles

A person who has been informed in order to avoid hazards that can result from electricity and who can safely be present in premises where work on electric vehicles takes place.

4.3 Workspace

4.3.1 Place of business

Can be an establishment, workshop, a number of workplaces within the same organisation or out in the field.

4.3.2 Workplace

The place or places where work is to be carried out, is being carried out or has been carried out.

4.3.3 Danger zone

Area in which a person is at risk of coming into contact with live parts, e.g. through a part of their body, tools or other equipment, and where the person is at risk of electrical injury.







4.4 Work

4.4.1 High-voltage work

Work on or near a live high-voltage system, as well as work where there is uncertainty as to whether there is an electrical hazard.

4.4.2 Disconnect

Disconnection aims to change the electrical status of the electric vehicle by completely separating all high-voltage sources from other high-voltage components and securing against accidental connection.

4.4.3 Connect

Connection aims to change the electrical status of the electric vehicle by reconnecting the high-voltage system to its high-voltage sources.

4.5 **Protective devices**

4.5.1 Shielding

Insulated or uninsulated device used to prevent encroachment on equipment or part of high-voltage systems where there is an electrical hazard.

4.5.2 Insulating material

Material that prevents electric current from passing through it. Used to cover live components or those that have not been confirmed as non-live, in order to prevent accidental contact. Also used as a casing on tools to prevent electric current from reaching the user.

4.5.3 Voltage tester

Apparatus used to reliably determine the presence or absence of high voltage.

4.5.4 Insulation tester

Apparatus used to reliably take an insulation measurement between a high-voltage component or cabling and a frame or casing.

4.5.5 Cordon/barriers

Marking that clearly prevents an unauthorised person from entering a particular location or area.

5 Roles

The following describe the responsibilities and competence requirements for all roles (Sections 7 and 8 describe when each role is to be applied). The need for the various roles may vary depending on the work on electric vehicles carried out or the business engaged in. The same person may hold multiple responsibilities.

5.1 Electric vehicles safety officer

Description:

The *electric vehicles safety officer* is appointed to ensure an appropriate work environment at the place of business and to ensure compliance with frameworks and rules so that work on electric vehicles can be undertaken safely. The *electric vehicles safety officer* may be responsible for several workplaces. The person in question may be a workshop manager, master technician or other designated person with clear powers as below.







Examples of tasks:

- be responsible for the introduction of correct work instructions and processes
- plan and ensure that risk analyses are carried out
- ensure that all personnel at risk from electrical hazards receive appropriate training so that they may safely avoid electrical injury
- ensure that all technicians carrying out high-voltage work have appropriate training for the work they are to carry out
- ensure access to appropriate tools and protective equipment and that these are kept in good condition
- ensure that operations, working procedures, checks and follow-up are updated as necessary, e.g. in the case of a reported electrical hazard source or incident
- be responsible for ensuring compliance with rules, working procedures and other safety regulations for the handling of electric vehicles

Competence requirements:

Documented sound knowledge of electrical theory, risks of high-voltage systems, legislation, rules, regulations and Industry Standards covering the part of the business related to the handling of electric vehicles.

5.2 Electric vehicles supervisor

Description:

An *electric vehicles supervisor* is designated by the *electric vehicles safety officer* for each electric vehicle on which high-voltage work is to be carried out. *Electric vehicles supervisors* have been given the task of ensuring that the person performing work on, or who is near an electric vehicle, is not exposed to electrical hazards. Furthermore, they shall ensure that the person carrying out work on the electric vehicle has the appropriate competence for the work that is to be carried out. The tasks of *electric vehicles supervisors* may relate to several electric vehicles.

Examples of tasks:

- undertake a risk analysis and plan the work on electric vehicles
- choose the correct working method in accordance with Section 8
- lead and direct the work
- ensure that the person carrying out the work has sufficient knowledge to avoid risks
- check and verify work that has been completed
- ensure that electrical hazard sources are marked and cordoned off if necessary

Competence requirements:

Documented sound knowledge of electric vehicle technology, electrical theory and risks of high-voltage systems, plus basic knowledge of legislation, rules, regulations and Industry Standards covering the part of the business related to the handling of electric vehicles. Furthermore, the person shall have sound knowledge of the operations for which they are responsible.

5.3 Electric vehicles specialist

Description:

An *electric vehicles specialist* is a technician with specific knowledge and experience allowing them to carry out certain types of work on an electric vehicle. At a basic level, an *electric vehicles specialist* shall have undergone in-depth training in the operation and design of electric vehicles and possess sufficient







knowledge and experience to analyse risks and avoid potential hazard sources resulting from electricity.

Examples of tasks:

- participate in and be able to perform risk analyses, and, where needed, risk identifications
- design and secure the workplace to minimise the risk of electrical injury
- carry out inspection and measurement, such as voltage insulation measurement
- perform disconnection and connection of high-voltage sources
- secure against accidental connection
- carry out servicing and repairs of non-live high-voltage systems
- report electrical hazard sources and incidents to the electric vehicles safety officer

Competence requirements:

The relevant person shall have undergone in-depth training (both theoretical and practical) and achieved a pass grade in electric vehicle technology, electrical theory and risks of high-voltage systems, as well as having a sound grasp of this Industry Standard. Furthermore, the person shall have completed training in, or have sound knowledge of the specific model in respect of the operations for which they are responsible.

5.4 Electric vehicles specialist with advanced competence

Description:

An *electric vehicles specialist with advanced competence* is basically an *electric vehicles specialist*, but with additional competence in one or more of the following tasks:

- work on or near a connected high-voltage system
- work on electrical energy storage systems
- risk analysis of crash-damaged vehicles

Competence requirements:

In addition to meeting the competence requirements for an *electric vehicles specialist*, an *electric vehicles specialist with advanced competence* shall have undertaken and obtained a pass grade in specific tailored training in order to carry out the above tasks.

5.5 Technician instructed in electric vehicles

Description:

A technician instructed in electric vehicles may carry out extensive and complex work on an electric vehicle provided there is no risk of electrical injury. To make this assessment, a *technician instructed in electric vehicles* shall possess the knowledge necessary to understand immediately when an operation cannot be carried out safely and shall immediately cease work and report to the *electric vehicles supervisor*.

A technician instructed in electric vehicles may also carry out work on or near high-voltage systems that have been disconnected, confirmed as non-live and secured against accidental connection by an *electric vehicles specialist*.

Examples of tasks:

- participate in and be able to perform risk identification







- carry out servicing and repair work on or near a non-live high-voltage system after the highvoltage system has been disconnected and secured against connection by an *electric vehicles specialist*
- carry out extensive and complex work in electric vehicles where the manufacturer has not indicated disconnection and where there is no electrical hazard

Competence requirements:

The relevant person shall have completed basic training in electrical theory, electrical safety and electric vehicle technology and obtained a pass grade. This is to ensure that they have adequate knowledge of and are able to work safely on electric vehicles.

A technician instructed in electric vehicles should, as a minimum, possess the following competences:

- basic knowledge and training in electricity, electric vehicles and associated risks
- knowledge of the hazard sources that may arise during the work and the safety measures to be taken
- ability to determine at any time whether or not it is safe to continue the work

Recommendation:

All personnel carrying out servicing, maintenance and repairs on electric vehicles should, as a minimum, be *technicians instructed in electric vehicles* or have an equivalent level of knowledge.

5.6 Person informed about electric vehicles

Description:

A *person informed about electric vehicles* has been given sufficient instructions to avoid electrical hazards and can safely be present in premises where high-voltage work may be taking place.

Competence requirements:

The person in question has knowledge of the electrical risks of an electric vehicle and how to avoid them (for example, by paying attention to cordons/barriers, warning text and warning signs).

All personnel who are present unattended in premises where high-voltage work may be taking place should as a minimum be *persons informed about electric vehicles*.

6 Requirements for general handling of electric vehicles

The following general requirements apply to all handling of electric vehicles, regardless of the work to be carried out.

All handling of electric vehicles shall be carried out in a safe manner. The competence requirements and the necessary safety measures to be taken depend on the type of work to be carried out. The conditions may also change during the work, in which case the competence requirements and necessary safety measures can also be changed accordingly.

General handling of electric vehicles can take place where there is no electrical hazard. Before starting work, its degree of difficulty shall be determined to allow the appropriate personnel to be selected for the relevant tasks.







Work on an electric vehicle is subdivided into general handling of electric vehicles (this section) and high-voltage work (see Sections 7 and 8).

Work that can be undertaken during general handling of electric vehicles is:

Connected high-voltage system:

- easily managed work that does not take place near the high-voltage system and where there is clearly no electrical hazard
- work carried out near the high-voltage system where the risk identification clearly shows that there is no electrical hazard

Disconnected high-voltage system:

- work carried out after disconnection, which can therefore be carried out without risk of electrical hazard, such as working on a disconnected part of a high-voltage system or other mechanical work

Clarification:

- note that disconnection and connection are high-voltage work to be handled in accordance with the requirements applicable to such
- in situations where disconnection is not possible (e.g. when the high-voltage system has sustained external damage or indicates a fault), the requirements for a connected high-voltage system apply

6.1 Risk identification

Risk identification is an initial assessment of whether or not there is a risk of electrical hazard during a specific job. If the risk identification indicates that there may be a risk of electrical hazards, the work shall be considered high-voltage work and a risk analysis shall be carried out (see Section 8). As a minimum, risk identification shall be carried out by a *technician instructed in electric vehicles*.

In order to reliably identify risks during the work, manuals or instructions from the manufacturer or equivalent should be used.

For operations performed more than once, risks need only be identified initially and the operations can then be performed several times over, unless new risks can be identified. However, where work is carried out near the high-voltage system or there is uncertainty as to whether an electrical hazard is present, risk identification shall be undertaken on each occasion. ("Near" means that the high-voltage system is within physical reach of the position work is carried out)

where the work is carried out.)

6.2 Competence requirements

Personnel handling electric vehicles should, as a minimum, be *technicians instructed in electric vehicles*. This is to be able to identify and determine whether the work involves electrical hazards (risk identification) and to avoid electrical hazards. Please note that even work that e.g. according to a manufacturer's instructions can be carried out without risk of electrical hazard may involve hazardous operations due to the human factor, external influences (damage to the electric vehicle) or incorrect actions previously carried out on the electric vehicle.







6.3 Personnel

Personnel working with electric vehicles are obliged to wear clothing appropriate to the workplace and the prevailing conditions there. This may mean, for example, tight clothing, personal protective equipment or not wearing metal items, such as watches and jewellery, if these are likely to pose a risk. Employers are responsible for clearly informing personnel about regulations regarding the use of protective clothing and/or personal protective equipment.

Personnel who wear electromedical devices (e.g. pacemaker, insulin pump, hearing implants) or who, for other health reasons, wish to object to working with electric vehicles, are responsible for informing the employer accordingly. The employer shall then undertake risk identification and take measures to eliminate any risks.

Personnel who, for safety reasons, deem the work to be hazardous are responsible for informing the employer accordingly. In such a situation, after a risk identification has been completed, the employer shall take whatever measures are required.

Where a job, e.g. during training, requires technical knowledge or experience to prevent electrical hazard or injury, the person carrying out the work shall be in possession of the required knowledge or experience, or be adequately supervised by a person who has the appropriate competence.

6.4 Place of business

All personnel working on, with, or near a high-voltage system shall be provided with training and information sufficient to give appropriate first aid in the event of electrical injury.

There shall be first aid equipment at the place of business. The equipment shall be tailored to the risks involved in the business.

It is recommended that defibrillators are present and that all employees have undergone CPR training, and that training sessions are kept up to date according to current recommendations.

6.5 Workplace

The workplace shall be clearly defined. Furthermore, there shall be sufficient space for the work, the requisite equipment, a free access route and adequate lighting in the workplace. Combustible materials should not be stored near the workplace.

6.6 Temporary interruption

Procedures to avoid electrical hazards during handover of work shall be in place. An example of this is handover of work that is taking place on a disconnected vehicle. If there is uncertainty in such a case, disconnection shall be confirmed or carried out again before the work can proceed further.

6.7 Emergency measures

Appropriate procedures for emergency measures in the event of an incident, electrical injury or electrical consequential damage shall be in place.

The *electric vehicles safety officer* should consider the risks associated with the handling of electric vehicles and, if necessary, develop and implement the measures appropriate to take in an emergency. Based on a needs analysis and the size of the organisation, these may include some or all of the following emergency measures:







- the *electric vehicles safety officer* shall ensure that information has been produced on the measures to be taken in the event of accidents or incidents involving electric vehicles, and that this information is directly available
- a procedure shall be established for documenting and reporting electrical accidents and incidents to the Swedish Work Environment Authority or National Electrical Safety Board
- depending on the scope of the business, cooperation with the emergency services should be considered, e.g. as regards storage parking of damaged electric vehicles
- in the event of an accident, the person ultimately responsible for the place of business shall be informed. The emergency services shall also be informed if necessary
- after an incident or electrical injury, appropriate measures shall be taken to keep the workplace safe and to prevent, as far as possible, further damage to the site. The aim is to facilitate investigation of the accident scene. This may be carried out by inhouse personnel, or, in special circumstances, by the police, an authority or an insurance company







7 Specific requirements and guidelines for high-voltage work

In addition to general requirements and guidelines for general handling of electric vehicles (Section 6), there are additional requirements and guidelines for high-voltage work as below. High-voltage work thus places higher demands on e.g. the organisation, the level of education/training and the safety measures to be taken.

A job is considered high-voltage work when:

- it takes place on a non-disconnected high-voltage system
- it takes place near a non-disconnected high-voltage system where there is uncertainty as to whether there is an electrical hazard

Work on electrical energy storage systems and live systems is also included in high-voltage work. These are dealt with in more detail in Section 8.3.

7.1 Risks of high-voltage work

Technicians working on a connected high-voltage system may be exposed to hazard sources arising from conduction of electric current through the body (electric shock/electrocution) or electrical arcing.

When current is conducted through the body, electrons in the tissue are affected during the time the body is in contact with electrical voltage. It can be difficult to determine what is actually the input and output when the body becomes part of the circuit. The current often flows from hand to hand, but can also flow between other body parts and lead to serious electrical injury.

Electric arcs rarely occur. Reliable protection is still needed because it cannot be excluded that arcs might occur, especially since they can be caused by the actual work itself. Electric arcs not only occur as a result of short circuits; they can also occur when live parts are separated without special measures (cable connections, connectors, fuses, etc.).

The effects of an arc depend, inter alia, on the transmission and exposure ratio, the design of the installation and the distance to the arc.

Arcs can occur in many ways where the gases in the air are broken down and ionised into a plasma that can reach temperatures of over 4,000°C. Harmful arcs can occur at various voltage levels. The person exposed to electrical injury does not necessarily need to be in contact with the arc, but can be seriously injured even at a distance by:

- thermal radiation
- shards and splinters
- pressure waves
- flying fragments
- intense electromagnetic radiation (visible light and UV radiation) that can lead to permanent damage to the skin and eyes
- shock wave (bang)
- toxic gases (copper dioxide) and particles caused by molten, vaporised material in or adjacent to the arc

If the risk analysis indicates a risk of current being conducted through the human body or consequences of an electric arc, and no other safety measures can be taken to eliminate these risks, appropriate personal protective equipment shall be used, see Section 7.13.







7.2 Organisation

An *electric vehicles safety officer* shall be designated for each place of business that engages in high-voltage work. In addition, *electric vehicles supervisors* shall be designated for each vehicle on which high-voltage work is to be carried out. These roles and responsibilities can be delegated. The same person may hold multiple roles/responsibilities.

7.3 Risk analysis

If high-voltage work is carried out at the workplace, a risk analysis for all aspects of the work shall be completed. Before starting a specific high-voltage job, *the electric vehicles supervisor* shall carry out a risk analysis.

A risk analysis is a documented systematic assessment of the risks that may occur in a specific job. A risk analysis is undertaken using available information (e.g. manufacturer's instructions) so that the work can be performed in a way that is safe for the person carrying out the work and for anyone who approaches the electric vehicle. The document shall be available to the technicians who will be working on the vehicle in question.

The risk analysis shall assess the risk of incident, electrical injury and consequential electrical damage arising from electric current being conducted through the human body, fire or the consequences of arcs.

If necessary, a risk analysis shall be carried out on an ongoing basis, as conditions may change while the work is in progress.

To perform a risk analysis, the manual or instructions from the manufacturer or equivalent should be used.

7.4 Competence requirements

High-voltage work requires special competence and may only be carried out by an *electric vehicles specialist* or *electric vehicles specialist with advanced competence*, based on the type of work to be carried out.

A training programme tailored to the company shall be in place in order to develop and maintain competence to carry out high-voltage work. This programme shall be tailored to the specific requirements and guidelines applicable to high-voltage work and shall be based on theoretical and practical exercises.

7.5 Personnel

Personnel who, for safety reasons, consider that a specific high-voltage job cannot be carried out safely (for example due to changes in operations or substandard instructions) shall inform the *electric vehicles safety officer* accordingly. In such a case, after an updated risk analysis, the *electric vehicles safety officer* shall take the necessary measures to ensure that the work can be carried out without risk.

7.6 Place of business

Personnel who are present without supervision in premises where high-voltage work may be in progress and where there may be a risk of electrical hazard shall, as a minimum, be *persons informed about electric vehicles*.

Where persons who have not completed training in the electrical hazards of electric vehicles are permitted or may be present in premises where high-voltage work is in progress, safety measures shall







be taken. An unattended electrical hazard shall then be adequately prevented by ensuring prevention of electrical injury (through e.g. contact with live parts) by means of shielding or insulation.

7.7 Workplace

Electric vehicles supervisors are responsible for ensuring that workplaces where there may be electrical hazard sources are marked and cordoned off.

7.8 Temporary interruption

Where the work is interrupted, appropriate protective measures shall be taken to prevent electrical hazards, e.g. by ensuring that uninsulated live parts cannot be touched accidentally. If necessary, *electric vehicles supervisors* shall be informed of such interruptions.

Procedures to avoid electrical hazards when taking over responsibility and/or work shall be in place and followed on handover, e.g. when another technician takes over an area of responsibility and/or job started by someone else.

Electric vehicles supervisors determine whether an interruption is of such a nature that a risk analysis shall be carried out and/or additional safety measures shall be taken, or the work partly or completely redone from the beginning.

7.9 Emergency measures

Appropriate procedures for emergency measures shall be in place in the event of electrical injury or incidents involving electricity. See Section 6.7.

7.10 Protective measures and planning their implementation

On the basis of a risk analysis, electric vehicles supervisors shall:

- choose the working method
- decide on protective measures, such as protective equipment, work clothes, tools and a cordon/barriers
- plan implementation with regard to knowledge level requirements
- ensure that sufficient on-site personnel are familiar with emergency procedures
- ensure that the necessary instructions are given to the technician who will carry out the work, before they start work
- inform those involved in the work of any reasonably predictable hazards that are not immediately apparent to them
- before the work is started, and while it is in progress, ensure compliance with all applicable rules and instructions

7.11 Adverse weather conditions

Appropriate protective measures shall be taken or restrictions implemented to ensure safety in adverse conditions, e.g. if work has to be carried out outdoors, during thunderstorms, high humidity or heavy rain.

7.12 Communication (communication of information)

Before a job is started, the *electric vehicles safety officer* shall be informed of the planned work by the *electric vehicles supervisor*.







All necessary information on the electric vehicle and the nature of the work shall be available to all the roles involved, in a language mastered by the role in question.

In order to ensure understanding and comprehension in a workplace where the personnel speak different languages, an agreement shall be reached in advance on a language which the parties concerned understand.

7.13 Tools, equipment and protective devices

As a minimum, protective devices shall comply with IPXXB requirements and be labelled with the W012 electrical hazard symbol described in ISO 7010 and the W042 arc flash hazard symbol described in ISO 7010.

The following tools, equipment and protective devices shall be available at places of business where high-voltage work is carried out:

- insulated and insulating tools according to standard SS-EN 60900
- voltage tester according to standard SS-EN 61243-3
- insulation meters, measuring instruments and measuring probes according to standard SS-EN 61557 and min. cat 4 1000V
- insulating equipment or materials for shielding SS-EN 61111, SS-EN 61112
- equipment that prevents accidental connection of the high-voltage system
- eye or face protection according to standard SS-EN166, 170, 171
- insulating gloves according to standard SS-EN 60903
- hearing protectors according to standard SS-EN 352-1, 352-2, 130087-7
- protective clothing according to SS-EN standards, EN ISO 11611, EN ISO 11612, EN ISO 14116, SS-EN 13087-7, EN 13034, EN 397, EN 388 and EN 61482-2:2020 (with cal/cm² as recommended by the manufacturer, but at least one layer of minimum 8–12 cal/cm²)

Instructions for the use, storage, maintenance, transport and inspection of the tools, equipment and protective devices shall be available at the place of business.

All tools, equipment and protective devices provided to ensure safe working with electric vehicles shall be fit for purpose, kept in good condition, used as intended and stored appropriately. Instruments and tools shall also be maintained according to the manufacturer's instructions, via e.g. calibration or servicing.

Note: "Kept in good condition" involves periodic visual checks and electrical testing to check the electrical and mechanical characteristics before and after use, as well as after repair or modification.

7.14 Manuals and instructions

Up-to-date manuals, instructions and diagrams applicable to each high-voltage job shall be available at the place of business.

7.15 Signs and barriers

Premises where high-voltage work may be in progress shall be marked with signs at all entrances, clearly showing that high-voltage work may be in progress and indicating which persons are permitted to be present on the premises.

Furthermore, workplaces shall always be marked with a barrier/cordon and appropriate warning signs if work is being carried out where electrical hazards may occur. The signs shall be executed in accordance with the ISO 7010 standard and the W042 arc flash hazard symbol described in ISO 7010.













7.16 Disconnection/connection

Disconnection and connection may only be carried out by an *electric vehicles specialist* in accordance with the manufacturer's instructions and using appropriate equipment.

The electric vehicle or its high-voltage component on which work is to be carried out shall be prepared by putting it into a defined status (disconnected or connected) which shall be maintained throughout the work.

If a change in status is required, the *electric vehicles supervisor* shall be informed.

7.17 Measurement

When measurements are carried out in a high-voltage system, appropriate and type-approved measuring instruments and probes shall be used.

If there is a risk of touching uninsulated live parts, the person carrying out the measurement shall use the correct level of personal protective equipment and take protective measures against electric shock/electrocution and the consequences of arcing.

7.18 Inspection

Once a job has been completed, it shall be inspected by *an electric vehicles supervisor* before the high-voltage system is connected.

In the case of extensive work (e.g. larger bodywork repairs, bodywork customisations, etc.) where *electric vehicles supervisors* cannot see the entire operation on a single occasion in order to carry out an inspection after completion of the work, ongoing inspection during the work may be needed. Documentation and photographs, etc., can also constitute supporting material for the inspection.

An inspection may include visual checks and measurement. The scope of the inspection shall be tailored to the work carried out. For example, an insulation measurement should be performed after replacing a component of the high-voltage system. The inspection shall be carried out on the basis of the manufacturer's instructions.

Deficiencies posing an immediate danger shall be remedied without delay. Failing this, faulty parts shall be immediately disconnected and protected against connection.

8 Working methods for high-voltage work

high-voltage work is divided up as follows:

- disconnect and connect (see Section 8.1)
- work on a connected high-voltage system (see Section 8.2)
- work near a connected high-voltage system where risk identification cannot exclude electrical hazards and a risk analysis is required (see Section 8.2)
- work on electrical energy storage systems (see Section 8.3)

8.1 Disconnect and connect

The operations relating to disconnection and connection of high-voltage sources shall be carried out in accordance with the manufacturer's instructions. As a minimum, the following operations shall be carried out in the specified order, unless there are overwhelming reasons to proceed otherwise.

Disconnection and connection may only be carried out by an *electric vehicles specialist* or *electric vehicles specialist with advanced competence* and only with insulated tools and/or insulated gloves.







8.1.1 Disconnection

Disconnection involves disconnection of all the electric vehicle's high-voltage sources from the rest of the high-voltage system and securing the system against accidental connection.

Disconnect from external voltage sources

The electric vehicle shall be disconnected from all external voltage sources (external charger, mains connection or similar), unless otherwise specified in the manufacturer's instructions.

Set the vehicle to the off position

Just as the ignition is switched off on a conventional vehicle, the electric vehicle shall also be set to the off position. This can be done e.g. by pressing the "START-STOP" button and removing any start keys/cards.

Check that the high-voltage system is non-live

The check to ensure it is non-live shall be carried out via measurement, as specified by the manufacturer. Measuring equipment for voltage checks shall be checked immediately before use and, if possible, after use. The equipment shall be designed for the purpose in question.

This step is carried out in order to check if the vehicle has been switched off and to detect any defects in the high-voltage system.

If voltage testers or voltage indication systems are used, these shall meet the requirements of SS-EN 61243.

Disconnect internal high-voltage sources

The electric vehicle on which work is to be carried out shall be disconnected from all internal voltage sources, as specified by the manufacturer. The disconnection may consist of an air gap (service connector) or equivalent disconnection system (e.g. pilot wire) to ensure that the disconnection point cannot be electrically bridged. It shall be possible to verify disconnection visually or via diagnostics.

Protect against connection (blocking)

The method for blocking connection of the internal high-voltage sources shall ensure that accidental connection is impossible, e.g. via locks. In the absence of a locking device, another appropriate method shall be used.

A sign prohibiting unauthorised tampering shall be posted. The sign shall contain information about who has locked/blocked the installation and indicate that work is in progress.

Check that the high-voltage system is non-live

Check and confirm again that the system is non-live before work is started on the electric vehicle.

This step is carried out in order to check that disconnection has been successful and to detect any defects in the high-voltage system.







Permission to start work after disconnection has been carried out

Written or verbal approval from the *electric vehicles supervisor* is required before work can begin after disconnection.

Work on a disconnected high-voltage system involves operations on or near a high-voltage system after disconnection has taken place, where work can be carried out without the risk of electrical injury.

8.1.2 Connection

Connection involves reconnecting the electric vehicle's high-voltage system to its high-voltage sources after the work has been completed.

After completion of the work, the work that has been carried out shall be inspected by an *electric vehicles supervisor*. The persons involved shall be informed that the work has been completed and that the high-voltage system will be connected.

The operation relating to connection of high-voltage sources shall be carried out in accordance with the manufacturer's instructions. As a minimum, the following operations should be carried out, in the order indicated, unless there are overwhelming reasons to proceed otherwise:

- check that all connections are correct and insulated (if they have insulation)
- carry out and document insulation measurement. The measured value must not be less than the specified value of the manufacturer
- remove connection protection (blocking)
- connect internal high-voltage sources
- delete any error codes and perform new diagnostic checks

The complete procedure for connection must be carried out by an electric vehicles specialist.

8.2 Work on or near a connected high-voltage system



Work on or near a connected high-voltage system involves work where contact with uninsulated live parts can occur or such parts can be reached within the danger zone.

Work on or near a connected high-voltage system may:

- be carried out where the nature of the work so requires, e.g. when measuring or testing the high-voltage system
- only be carried out with the special permission of the *electric vehicles safety officer*
- only be carried out by an *electric vehicles specialist with advanced competence*
- only be carried out with insulated tools and/or insulated gloves
- only be carried out with the correct protection level of protective clothing, if the risk analysis so requires

Work on or near a connected high-voltage system may also be carried out if disconnection is not possible, e.g. due to a technical fault in the vehicle.

Work on or near a connected high volt system is not allowed if disconnection has not been carried out due to e.g. lack of equipment or knowledge.

When working on or near a connected high-voltage system where contact with uninsulated live parts may occur, or where such parts can be physically reached within the danger zone via body parts, tools, equipment or other protective devices, a stable working position shall be ensured so that both hands are free.







8.3 Work on electrical energy storage systems

Work on electrical energy storage systems involves working on or in high-voltage batteries. The starting point for such work is that the battery is always live regardless of the charging status.



Working in a high-voltage battery involves a high risk of contact with uninsulated live parts. The highest possible protective measures shall be taken, such as shielding or insulation of live poles in the battery.

Work on or in a high-voltage battery may only be carried out:

- with the special permission of the *electric vehicles safety officer*
- by an electric vehicles specialist with advanced competence
- from a stable working position where both hands are free
- with insulating gloves and insulated tools
- with the right level of protective equipment to prevent electrical injury in the event of arcing, such as eye or face protection, hearing protectors and appropriate protective clothing

Please note that the above requirements and guidelines apply both to a battery fitted in a vehicle and where the battery has been removed from the vehicle.







9 Annexes



- 1. Electric vehicles safety officer
- 2. Electric vehicles supervisor
- 3. Electric vehicles specialist
- 4. Electric vehicles specialist with advanced competence
- 5. Technician instructed in electric vehicles
- 6. Person informed about electric vehicles
- A. Place of business
- B. Workplace
- C. Danger zone





