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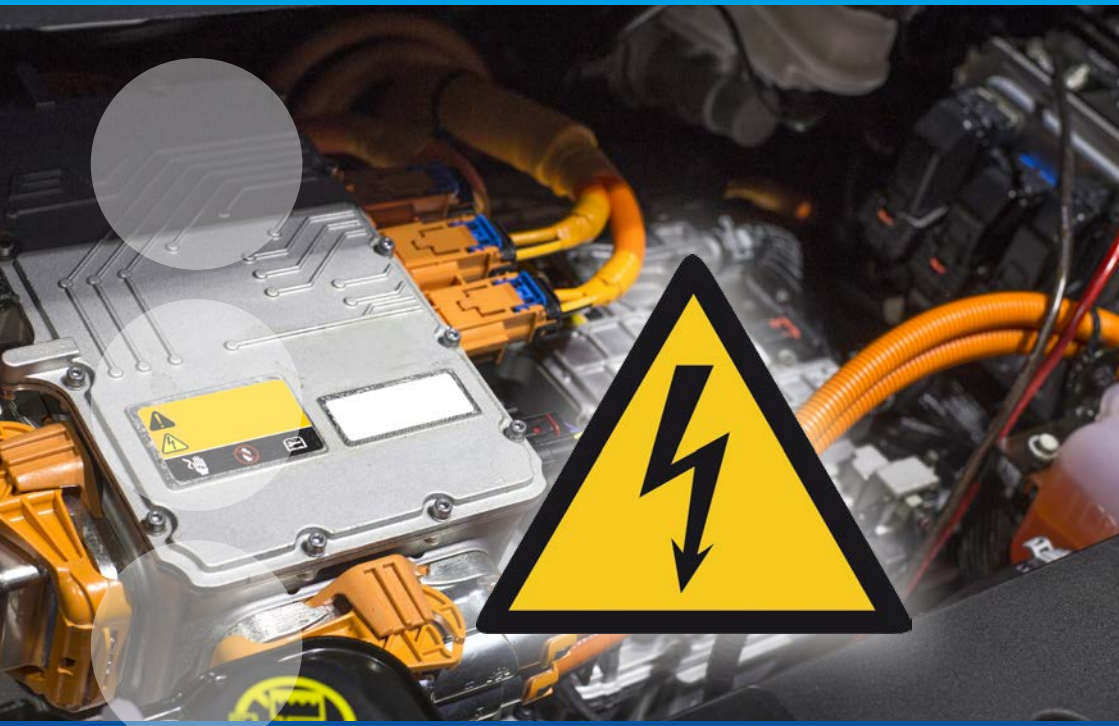

Training for work on vehicles with high voltage systems

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Training for work on vehicles with high voltage systems

Compared to the download version published in July 2021 of the present document, the following amendments were made in **cl. 5.1.4 Qualification Level 2S: Fachkundige Person (FHV):** more information regarding the skilled occupations where the necessary knowledge can be obtained as well as regarding the qualification necessary to obtain Level 2S.

Compared with the last version from 2012, the following essential changes were made:

- Editorial amendments
- New DGUV number assigned (formerly 200-005)
- Scope specified, e. g. this document does not apply to training for electrotechnical work on
  - track guided vehicles
  - mounted or fixed equipment in accordance with the European Machinery Directive
  - low voltage electrical equipment on vehicles
  - vehicles permanently connected to the electrical supply during use
  - watercraft and aircraft
- New definitions introduced:
  Fachkundige Person Hochvolt, FHV (a person who possesses the expertise and specialist knowledge to perform a special task on high voltage systems)
  Fachkundig unterwiesene Person, FuP (a person who has received instructions by an FHV)
- Introduction of the level model for qualification measures to be applied also in the service sector

Contents

page

page

Foreword

The automotive technology increasingly uses high-voltage systems. Wherever work is performed on vehicles equipped with such systems, one must always expect electrical hazards in the form of electric shock or arcing. The present DGUV Information contains instructions for the employer on how he or she can organize safe working on vehicles equipped with high voltage systems on the basis of the risk assessment and determine the need for training for work on vehicles equipped with high voltage systems.

The present Information is subdivided into the following sections:

- Organizational requirements for safe working (red tab)
- Need for training in research, development and production (green tab)
- Need for training in service workshops (orange tab)

Remarks:
According to stipulations of DGUV Regulations 3 and 4 „Electrical installations and equipment", electrical work (erection, modification and maintenance) may only be performed by electrically skilled persons or under their responsibility and supervision. The skilled person for work on non-live HV systems (Fachkundige Person Hochvolt, FHV) described in the following is an electrically skilled person in accordance with DGUV Regulations 3 and 4 in the field of high voltage systems.

1 Scope

The present DGUV Information governs the training of persons carrying out work on vehicles equipped with high voltage systems and on the components of such vehicles. This also includes work on mounted or fixed equipment directly connected to the HV system and sharing the protective measures.

This DGUV Information does not describe the training for work on

- track guided vehicles (e.g. trains, trams, trolley buses),
- mounted and fixed equipment of vehicles and working equipment falling under the scope of the European Machinery Directive and requiring protective measures in accordance with DIN EN 60204-1 (VDE 0113-1) against electrical hazards in the form of electric shocks and fault arcing,
- low-voltage electrical equipment on vehicles falling under the scope of VDE 0100 (e. g. 230 V sockets in omnibuses),
- vehicles permanently connected to the electricity supply during use (e. g. earth-moving machinery and similar equipment),
- watercraft and aircraft.

This document may offer guidance for work on vehicles that do not fall under the scope of this DGUV Information, i.e. that are not covered by the definition of vehicles in cl. 2 no. 14 (e.g. recreational watercraft).

In addition to the training for work on HV systems specified in the present document, further training requirements may exist (e.g. specialist knowledge for work on gas-powered vehicles, limited specialist knowledge P1 for pyrotechnical restraint systems, or expert knowledge for air conditioning systems).

2 Definitions

1. **High voltage (HV)**
   In the automotive sector, particularly in hybrid and fuel cell technology and on battery electric vehicles, high voltage comprises voltages > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC, as specified in UNECE R100.
2. **HV component**
   An HV component provides a voltage in accordance with the definition of „high voltage“in vehicles, or is operated with this voltage.
3. **HV system**
   An HV system consists of at least two HV components.
4. **Fachkundige Person Hochvolt (FHV)**[1]
   An FHV is a person who possesses the expertise and specialist knowledge necessary to perform a special task on a high voltage system. The requirements relating to the specialist knowledge depend on the respective type of task.
5. **Expert supervisor**
   The expert supervisor assumes both technical and managerial responsibility. He or she must be competent in his or her field of responsibility and must be charged in writing by the employer.
6. **Control and supervision**
   Control and supervision encompass all tasks required for the safe and proper performance of work on high voltage systems by employees who do not possess the knowledge and experience of an FHV. The control and supervision of work on high voltage systems may only be assumed by at least an FHV.
7. **Sensibilisierte Person**[1]
   A Sensibilisierte Person is a person who has been instructed regarding the intended use relating to the operation of HV vehicles and components.
8. **Fachkundig unterwiesene Person (FuP)**[1]
   An FuP is a person who has been instructed and, if necessary, trained on the job by an FHV regarding the work with which she or he is tasked and who has been familiarized with the necessary protective equipment and protective measures.

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[1] To avoid any misunderstanding and confusion caused by translation of the designations for the Fachkundige Person Hochvolt (FHV) into English, a translation is not attempted.

9. **Operation of vehicles**
   The operation of vehicles encompasses all tasks which are necessary to operate a vehicle, including the connection of the vehicle to charging devices and the refill of operating materials.
10. **Work**
    In the context of this DGUV Information, work is any form of electrotechnical or non-electrotechnical work on vehicles or HV components during which the possibility of an electrical hazard exists.
11. **Work in the non-live state**
    In the context of this DGUV Information, work in the non-live state is any work on or with HV components or in their hazardous area, e.g. trying out, maintenance, replacing, modifying, expanding, installing and testing, which have been set safely to the non-live state for the duration of the work.
12. **Work on the live HV system**
    In the context of this DGUV Information, work on live HV systems is any work on the HV system during which an employee may come into contact with HV components or parts with his or her body or with items (tools, devices, equipment or apparatus) if the non-live state is not ensured and an electrical hazard cannot be excluded.
13. **SoP (Start of Production)**
    Start of production represents the beginning of series production of vehicles where they are assembled in accordance with standardized work procedures. The development phase and manufacture of prototypes and pilot series vehicles has been completed at this stage.
14. **Vehicles**
    Vehicles in the meaning of the present DGUV Information are land vehicles which are moved operationally by machine force or are towed.
    Examples of land vehicles are motor cars and trucks, buses, trailers, agricultural machinery, excavators, loaders, non-track guided excavation machinery, mobile cranes, industrial trucks, ground vehicles used in aviation such as tractors, transport vehicles, vehicles for the loading and unloading of aircraft, supply and waste disposal vehicles, and two-wheeled vehicles.
15. **TP (teaching period)**
    A teaching period in this context has a duration of 45 minutes.

3 Organizational requirements for safe work on HV vehicles

3.1 Responsibility

In particular, the following laws and regulations specify the responsibility of employers with regard to safe working:

- Arbeitsschutzgesetz (ArbSchG, German Safety and Health at Work Act)
- Betriebssicherheitsverordnung (BetrSichV, German Industrial Safety and Health Ordinance)
- DGUV Regulation 1 „Principles of Prevention“

Entrepreneurial action
The primary and highest duty of accident prevention in a company always rests with the employer.

The employer is responsible for e.g.:

- Provision of and decisions concerning funds
- Selection of suitable employees
- Fundamental decisions concerning safety policy, safety organization, safety facilities

Examples of the employer’s duties regarding safe work on HV vehicles include:

- Producing risk assessments and defining protective measures
- Ensuring that only adequately qualified personnel work on the HV systems of vehicles
- Generating work instructions for work on HV systems
- Providing regular instructions for the employees
- Organizing structures and processes
- Specifying the scope of tasks and competencies of the personnel in consideration of the tasks to be performed

Section 7, concerning competence for tasks, of the DGUV Regulation 1 „Principles of Prevention“ states as follows:

(1) When assigning tasks to insured individuals, the employer shall consider whether the insured individuals are able to comply with the safety and health rules and measures applicable to their specific tasks. The employer shall also take into consideration the required qualifications for specific tasks.

(2) The employer must not assign to insured individuals tasks that they are clearly unable to perform without causing risk to themselves or others.

In order to verify competence, employers may consider vocational qualifications, vocational experience already gained, other evidence (certificates, etc.), knowledge and particular training and instruction. Whether competence is up to date must also be reviewed at regular intervals.

Regarding issues of fitness, employers may consult a doctor specialized in occupational medicine. Where the corresponding legal basis exists, the employer may charge these occupational doctors to carry out an assessment of aptitude.

The employer may commission in writing reliable and qualified persons to take on the tasks resulting from his or her duties (§ 13 ArbSchG).

Accordingly, these persons may be responsible for:
- Performance of OSH measures
- Generation of OSH-related instructions
- Motivation to observe OSH
- Supervision and monitoring
- Reporting to the next senior superior
- Aversion of hazards on a case-by-case basis

The regular instructions of employees as stipulated in § 12 German occupational health and safety Act and § 4 DGUV Regulation 1 „Principles of Prevention“ must be provided by a superior. Where this person does not possess the necessary knowledge, he or she must seek the support of a skilled person.

Within the framework of their duty of care, superiors must make sure that employees are both physically and technically able to perform the intended task.

For electrical work on HV systems, the employees must be familiarized with theoretical electrical principles. Digital media, e.g. e-learning, may be used to support the communication of knowledge. In addition, the employees should be equipped with the practical skills required for work with the relevant HV components, tools and auxiliary materials.

Figure 1
Example of equipping employees with practical skills in work with the HV systems

The necessary training of the employees must be performed by persons with the requisite knowledge in the area of instruction concerned, teaching ability, and experience in the training of adults. During training, suitable training materials must be provided and practical exercises performed. Successful completion of the training measure must be documented by the body providing the training in a verifiable manner with statement of the topics covered. Training and educational measures may be performed in the form of in-house training or by external training providers. Accident insurers do not provide certification of training courses or educational institutions.

Responsible supervision in the HV area

Responsible supervision in the HV area is necessary wherever, in addition to the work on HV systems, further tasks are required, such as:

- Planning, engineering, design
- Organization of work
- Definition of working procedures
- Selection of suitable workers and supervisors
- Communication and explanation of the relevant safety regulations
- Specification of the tools and equipment to be used
- Performance of necessary training measures
- Monitoring of operations by random inspections or verification of success

Expert supervision must be assumed by a person with technical and managerial responsibility. The company management decide within the framework of the transfer of duties on who will assume technical and managerial responsibility for FHV.

Fachkundige Person Hochvolt (FHV)

Persons who are to work on HV systems must be qualified for these tasks. The scope of training depends among other things on the level of the electrical hazards present during the work and on the prior knowledge. The qualified employees must be able to assess the tasks assigned to them, to

recognize potential hazards and to apply the necessary protective measures.

When employing FHV, attention must be paid to whether these persons are qualified for work within the framework of the project planning and development process (prior to SoP), assembly of the HV system or for service work on series production vehicles (after SoP). The individual evidence of qualification and certificates indicate the working field in which the skilled persons may work (model certificate ⇢ see Annex 8).

An FHV can also assume managerial and supervisory tasks. This means assuming specialist and managerial responsibility, in particular for the following tasks:

- Training and instructing persons who have received expert instructions
- Monitoring the proper construction, modification, and maintenance of HV systems
- Ordering, implementing, and verifying the safety measures necessary for the respective work, including providing safety equipment
- Carrying out the safety measures necessary for the respective work; where appropriate, implementing safety measures and verifying safety measures implemented.

Fachkundig unterwiesene Person (FuP)
Persons who have received expert instruction are not allowed to work independently on high voltage systems and components. They are allowed to perform only those tasks for which they have received an instruction (model certificate ⇢ see Annex 7). When performing these tasks, they must apply the measures and behavioral rules they have been taught. The FuP may perform work on non-live high-voltage systems only under control and supervision of an FHV (see above).

3.2 Risk assessment

Under the German Safety and Health at Work Act, the employer is obliged to ensure and, if necessary, improve the protection of employees' safety and health. The risk assessment is an important step in this context (§§ 5 und 6 ArbSchG).

A risk assessment is a repetitive process for identifying hazards and evaluating the associated risks. Assessment of the hazards is a precondition for the taking of effective OSH measures relevant to the company.

Risk assessment consists of:
- Systematic identification and evaluation of relevant hazards
- Definition of appropriate OSH measures
- Monitoring the effectiveness of the measures defined

One source of hazards is unsuitable qualification of and instructions to the employees.

All OSH measures must comply with the general principles of hazard prevention set out in the German Safety and Health at Work Act.

Measures are classified as follows:
- Technical measures, e.g isolation, fixed shrouding (Figure 2: Basic protection by isolation and shrouding)
- Organizational measures, e.g. marking of HV vehicles in the workshop (Figure 7: Examples for marking of HV vehicles in the workshop), observance of specified waiting times to allow for the dissipation of voltage
- Personal measures, e.g. personal protective equipment (insulating gloves, helmet with visor, protective clothing against the thermal hazards of fault arcing, ...), instruction.

Figure 2 Basic protection by insulation and shrouding

A combination of these measures is also possible. Technical measures are to be given priority over organizational or personal measures.

A model risk assessment for an automotive workshop can be found in **Annex 1**.

3.2.1 Electrical hazards on HV systems

Hazards caused by electric shock are excluded if contact with live parts is not dangerous. This can be assumed if one of the following conditions is fulfilled on exposed parts:

- The voltage is max. AC 25 V or DC 60 V for frequencies up to 500 Hz and complies with the requirements for SELV (safety extra low voltage) or PELV (protective extra low voltage) as specified in HD 60364-4-41.

- For voltages with frequencies up to 500 Hz over AC 25 V or DC 60 V, the current generated does not exceed AC 3 mA effective or DC 12 mA due to a non-inductive resistor of 2 kΩ.
- The discharge energy does not exceed 350 mJ.

However, a risk is present if the above-mentioned values are complied with in normal operation but exceeded in the event of a failure or fault occurring.

In addition, all anticipated risks must be considered; where appropriate, measures to minimize hazards must be taken, e.g. the hazard of arcing caused by an accumulator, the risk of high discharge energy generated by a condenser.

!

Due to higher system voltages and increased electrical energy provided by the HV system, there is a so far non-existent level of electrical hazard for the vehicle area. There is the danger of irreversible physical damage or death by electric shock or arcing.

3.2.2 Protective measures against electrical hazards

Work on the HV system may not be started until protective measures have been taken against electric shock, short-circuits and fault arcs.

In general, work may not be performed on live parts of electrical systems and equipment. For this purpose, these systems and equipment must be set to the non-live state prior to and for the duration of the work.

This is achieved by the observance of five safety rules.

!

Five safety rules
Prior to starting work

1. Disconnect completely.
2. Secure against reconnection.
3. Verify that the installation is de-energized.
4. Carry out grounding and short-circuiting.
5. Provide protection against adjacent live parts with covers or barriers.

These five rules for safe work are vital. The rules must generally be observed in the order stated.

The first three rules must always be applied during work on the HV system. Whether the fourth and fifth rules must also be applied must be determined on a case-by-case basis.

In a given case, the requirement for application of the five safety rules on vehicles with HV systems can for example be met as follows (as determined by the manufacturer):

Rule 1: Disconnect completely

- Switch off the ignition.
- Withdraw the service plug/switch off main battery switch.
- Remove fuses.
- Trigger the disconnecting device by withdrawing plug for interlock/pilot/monitoring circuit.
- Disconnect the 12 V on-board electrical system battery.
- Disconnect from the stationary grid (e.g. charging plug).
- Guided isolating procedure via diagnostic device.

Figure 3 Various service plug types

Rule 2: Secure against reconnection

- Remove the ignition key and prevent unauthorized access to it.
- Store service plug against unauthorized access/safeguard main battery switch against reconnection, for example by means of a lock or lockable cover.
- Observe further internal company provisions and the manufacturer's specifications.

Figure 4 Example of safeguarding against reconnection

Rule 3: Verify that the installation is de-energised

- Use a suitable voltage tester to verify the non-live state (e.g. two-pole voltage tester).
- Residual charges (for example voltages in intermediate circuits) may be present even when the HV voltage has been disconnected.

!

The non-live state of the HV system must always be verified before work is begun!

The provisions of the vehicle manufacturer must be observed for verification of the non-live state. Suitable voltage testers or test apparatus specific to the manufacturer must be used. Test apparatus is suitable in particular when it has been tested against the necessary criteria by a test body and found to be suitable. Multimeters are not suitable.

Figure. 5
Verification of the non-live state

Other mobile measuring instruments are suitable for verifying the non-live state if they also satisfy the provisions for voltage detectors to DIN EN 61243-3 (VDE 0682-401) „Live working – Voltage detectors – Part 3: Two-pole low-voltage type“. Where voltage testers are used, ensure that they are suitable for the type and level of voltage to be measured and that they are fully serviceable. The non-live state must be verified on all conductive parts which could be live. Until the non-live state has been verified, the system is to be assumed to be live.

Rule 4: Carry out grounding and short-circuiting
Vehicles are usually isolated against earth potential. In such a case, **grounding** of active parts does not reduce the hazard.

Energy storage devices must not be short-circuited!

As chemical energy storage devices are frequently used, this document explicitly warns against **short-circuiting**. If this type of energy storage device is short-circuited, there is the risk of the energy storage device being irreparably damaged and even bursting. Energy storage devices are therefore usually not earthed and not short-circuited.

!

Vehicle-specific information of the manufacturer must absolutely be observed!

Rule 5: Provide protection against adjacent live parts with covers or barriers
The HV system usually is completely isolated before working on the HV components. However, where work on live HV components should be necessary (e.g. for troubleshooting), the exposed live parts not concerned by the work must be covered, for example with shrouds in accordance with DIN EN 61112 (VDE 0682-511).

Figure 6
Example for the covering of adjacent live parts

Completion of the work
Once the work has been completed, the safety rules are lifted in reverse order. All tools, auxiliary material and other equipment must first be removed from the site of work and the hazard area. The intended safe condition must be restored observing the manufacturer's specifications.

3.2.3 Examples of protective measures

The protective measures implemented in the high voltage systems differ from one manufacturer to another. The protective measures are such that no single fault alone poses electrical hazard to persons. A selection of protective measures which may be implemented in various HV systems is listed below:

- Disconnection of the entire HV system by means of an isolating facility (such as service disconnect, maintenance plug, switching device in the energy storage device)
- Plug-and-socket arrangement for all cable connections
- Safety loop (interlock, pilot line) for all HV components and plug-and-socket connections with at least single-fault tolerance
- Emergency stop device
- Shrouds of parts that are live and not protected against direct contact can be removed only by means of tools or by destroying them
- Disconnection of the system voltage by means of early-breaking plug contacts when plug-and-socket connections are broken, to prevent fault arcs (so-called "pilot line")
- Disconnection of electrical circuits when covers are opened, possibly including the engine cover
- Mechanical arrangements for the removal of components/opening of covers and shrouds requiring a time greater than the discharge time for the residual voltages
- Permanent, built-in facility for determining the non-live state of the HV system

- Uniform, clearly identifiable marking of all HV components, for example by orange conductors, warning labels on HV components,
- Creation of an electrical system which is not earthed and which is isolated against the vehicle earth and the individual conductors (HV system)
- Monitoring of insulation of the live conductors against vehicle earth
- Deliberate discharge of residual energy from the electrical energy storage components, such as capacitors
- Connection of all exposed conductive vehicle parts which might be live under fault conditions by potential equalization to prevent the formation of different potentials

A suitable combination of technical measures may be sufficient to ensure complete protection against electric shock and arcing from the HV system.

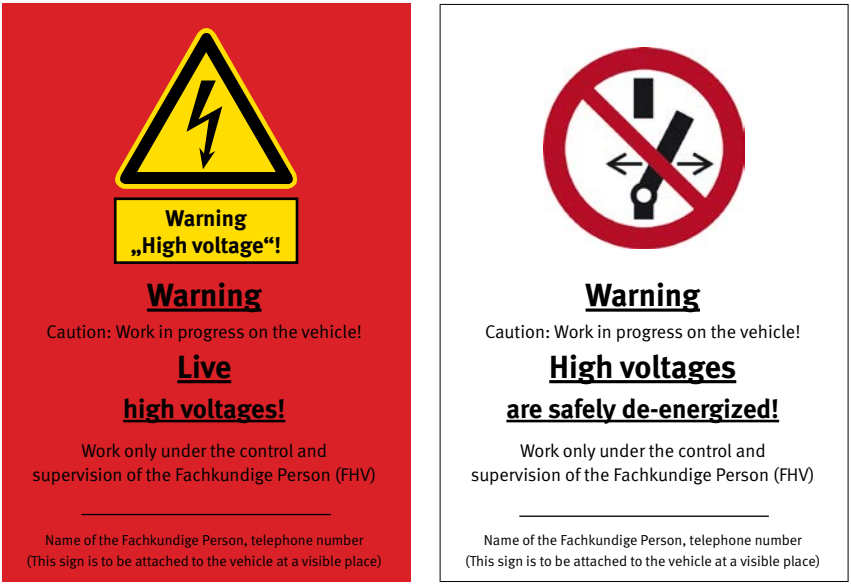


Figure 7 Examples for the marking of HV vehicles in the workshop

4 Training for work on high voltage systems in research, development and manufacture

4.1 Qualification levels for work to be performed prior to the start of production

4.1.1 General

The necessary training (topics and duration) must be determined on a case-by-case basis, in consideration of the hazard, the work to be performed and the prior qualification of the employees concerned. The topics of training listed serve only as an example and must be adapted to the specific requirements of the tasks. Training must be concluded by theoretical and practical examination demonstrating the skills and knowledge acquired. The demonstration of this acquisition must be documented.

The following level model shows the required qualification as a function of the work to be performed:

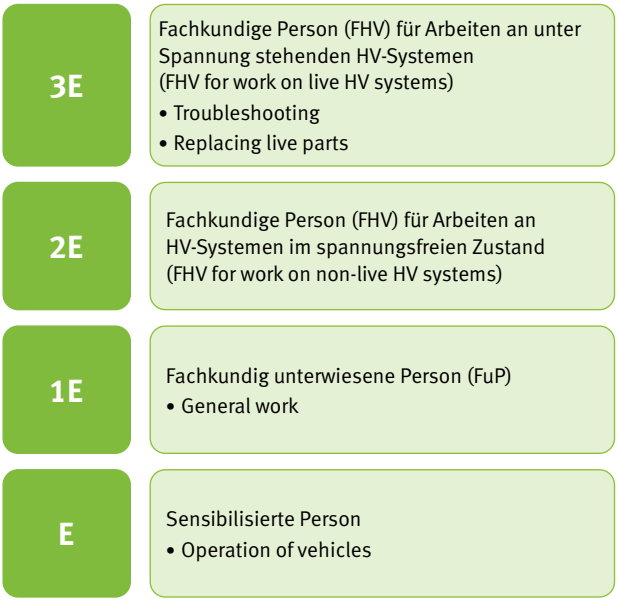


Figure 8
Qualification levels for work prior to start of production

Level E describes an employee's familiarization for the handling of HV vehicles. Essential elements include e.g. operating, cleaning, particularities of the vehicle's performance and the procedure to be followed when charging the vehicle.

Level 1E describes all non-electrical work which is required on a vehicle equipped with HV systems, e.g. wheel change, oil change. The employees must be informed of the possible electrical hazards presented by the HV system and of the intended use of the vehicle.

Level 2E describes the expertise required for work on non-live HV systems. This training level includes all work performed on HV systems in the non-live state. This requires decommissioning and recommissioning of the HV systems in accordance with manufacturer's specifications, or application and performance of at least the first three of the "Five Safety Rules".

A precondition for **Level 3E** training is successful completion of Level 2E training as well as safe performance of the associated practical tasks. Training for work on live HV systems qualifies the employee for all work on the HV system.

If it is found during the production development process that components are fitted which satisfy the safety standards of series production, they can be assigned to a post-SoP training level. The corresponding decision must be taken by the responsible expert supervisor.

The flow charts in Annex 2 and Annex 3 provide support in determining the requisite scope of training.

Figure 9 FHV working on HV components in the development area

4.1.2 Qualification Level E: Sensibilisierte Person

For the operation of HV vehicles, it is sufficient for employees to be made familiar with the intended use and the particular aspects to be observed. This also applies to service work, which is comparable to operation by the driver in terms of the electrical hazard. Examples of such work are:

- Replacement of windscreen wiper blades, refilling of screen wash
- Preparation of the vehicles for test drives
- Use of familiar filling points (e.g. for motor oil or coolant)
- Use of control bearing new symbols and danger labels or new connections (e.g. charging device on the vehicle)

Operation of the vehicles includes interior and exterior cleaning. However, care must be taken to ensure that all service lids and bonnets are closed as they may cover HV components which represent a hazard when damaged. There is a risk of the HV components being damaged due to improper cleaning using high water pressure.

In the event of accidents or damages occurring, or the vehicle being recovered or towed, additional hazards may occur. Drivers must be instructed about these hazards. In addition, drivers must be briefed about additional control elements, e.g. an emergency switch located at the driver's workplace.

!

The information provided by the development department must be observed for any operational action!

4.1.3 Qualification Level 1E: Fachkundig unterwiesene Person (FuP)

Instruction by an FHV is required for all general work to be performed on the HV vehicle.

This instruction is intended to provide training in the handling of HV systems to enable employees to work safely on the vehicle. The objective is for employees to be able to operate the vehicles equipped with HV components safely, to understand their structure and principles of operation, and to be familiar with the markings of the components. The topics covered by the instruction must also include the fact that work on HV components is permitted. Failure to observe these requirements may lead to electric shock or arcing.

The topics of this instruction must include:

- Electrical hazards and protective measures
- Operation of vehicles and the associated equipment (e.g. test rigs)
- Performance of general tasks which do not require isolation of the HV system
- Location and marking of the HV components and lines in and on the vehicle
- Performance of all mechanical tasks on the vehicle (but: "Don't touch orange!")

- Isolation of the HV system by actuating the service disconnect/the emergency-off switch as additional safeguarding measure
- Impermissible work on the vehicle
- Stopping the work in the event of uncertainty, and consulting the responsible FHV
- Organizational procedure for electrical work on HV components that is performed under the control and supervision of an FHV.

Instruction in Level 1E must last for at least 2 teaching periods, depending on type and scope of the work.

4.1.4 Qualification Level 2E: Fachkundige Person (FHV)

Employees must have an electrical qualification of Level 2E for any work to be performed on the HV systems.

Training for Level 2E must take account of the particular electrical knowledge already acquired by the employee:

!

After successful qualification, the acquired technical knowledge must be kept up to date by means of regular participation in training courses!

The following qualification topics serve as examples and must be adapted to the specific requirements of the work. The flow chart in Annex 2 provides support in determining the requisite scope of training.

Introductory course A: Persons without prior electrical knowledge but with technical training

Topics covered by the training:

- Basic electrical knowledge
- Electrical hazards and first aid
- Measures for protection against electric shock and against fault arcs
- Organization of safety and health for electrical work on HV components
- Specialist and people management responsibility
- Employee qualifications in the area of electrical engineering vs. high voltage technology
- Use of HV systems in the vehicle
- Structure and functioning of electrical systems in vehicles

A specification of the topics covered by the training can be found in Annex 4.

Depending on nature and scope of the work to be performed, the duration of the qualification must encompass at least 100 TP (including at least 16 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented.

Introductory course B: Persons with prior electrical knowledge in the automotive sector, e.g. car electricians, automotive mechatronics electricians, car mechanics, mechatronics electricians for agricultural and construction machinery.

Topics covered by the training:

- Electrical hazards and first aid
- Measures for protection against electric shock and against fault arcs
- Organization of safety and health for electrical work on HV components

- Specialist and people management responsibility
- Qualification of employees in the area of electrical engineering vs. high voltage technology
- Use of HV systems in the vehicle

A specification of the topics covered by the training can be found in Annex 4.

Depending on nature and scope of the work to be performed, the duration of the qualification must encompass at least 48 TP (including at least 16 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented.

Introductory course C: Electrically skilled persons, e.g. industrial electronics specialists, electrical fitters, electrical engineers

Topics covered by the training:

- Specialist and people management responsibility
- Qualification of employees in the area of electrical engineering vs. high voltage technology
- Use of HV systems in the vehicle
- Structure and functioning of electrical systems in vehicles

A specification of the topics covered by the training can be found in Annex 4.

The topics must be adapted to the participants' current level of knowledge.

Depending on nature and scope of the work to be performed, the duration of the qualification must encompass at least 24 TP (including at least 16 TP

of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented.

Introductory course D: Persons with prior theoretical electrical knowledge

As far as employees are concerned who for example have completed an engineering or scientific degree and therefore possess prior theoretical electrical knowledge, the required qualifications must be determined on a case-by-case basis.

Depending on nature and scope of the work to be performed, the duration of the qualification must be determined on a case-by-case basis and must encompass at least 16 TP of practical exercises. The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented.

4.1.5 Qualification level 3E: Fachkundige Person für Arbeiten an unter Spannung stehenden HV-Systemen

Employees possessing a qualification for work on live HV components may perform troubleshooting on live HV components if it is not possible to place the vehicle in the non-live state or if it is not possible to determine the non-live state. The same applies to work on live energy storage devices and to work with corresponding hazard potential, e.g. high voltage test according to working instruction.

Figure 10
Working on live HV components

Any work on the HV system during which an employee may come into contact with HV components or parts with his or her body or items (tools, devices, equipment or apparatus) is considered to be live work on HV systems if the non-live state is not assured and an electrical hazard cannot be excluded.

Verification of the non-live state is not considered to be work on live HV components if work procedure and work equipment exclude an electrical hazard.

Work on live HV components constitute a hazard potential for employees which is higher than for work on components in the non-live state. Further qualification is required in order to enable the employee to perform this work safely. The following individual preconditions must be fulfilled to obtain this further qualification.

Prior to the training measure, the person to be qualified must provide proof that he or she

- possesses at least a level 2E qualification,
- has a minimum age of 18 years,
- has successfully completed training in first aid including cardiopulmonary resuscitation (9 TP as stipulated in DGUV Information 204-022 “Erste Hilfe im Betrieb” (governing first aid in companies).

Furthermore, it must be ensured that the person to be qualified does not have any health issues (e.g. implant carriers, epilepsy, ...) which might result in hazards during work on live HV components (see also § 7 DGUV Regulation 1 „Principles of Prevention“).

The employer must observe the applicable legal bases (individual or collective agreements) when carrying out evaluations of aptitude relating to driving, steering or monitoring activities (see also DGUV Information 250-010 “Eignungsuntersuchungen in der betrieblichen Praxis” (governing aptitude tests in plant practice)). The evaluations must be handled separately from the preventive occupational medical care. Where legal bases applicable to an aptitude examination exist, the respective current recommendations of DGUV relating to occupational health advice and checks may be used for this aptitude examination as well. This occupational health advice provides guidance for conducting aptitude evaluations in order to assess aspects of the health-related aptitude of employees with regard to the tasks and activities they are intended to perform.

As work on live HV components is, in general, hazardous work in accordance with § 8 DGUV Regulation 1 “Principles of Prevention“, a second person must usually be present. This person must have at least received expert instruction (FuP) and must be trained in first aid.

In addition, employees must have at least one year of practical professional experience in the field of automotive technology or electrical engineering shortly before beginning the Level 3E training. This precondition is fulfilled by e.g. a vocational training undergone in motor vehicle mechatronics.

Employees having a Level 2E qualification without having undergone a vocational training in the field of automotive technology or electrical engineering do not necessarily possess the suitable level of sound theoretical and practical knowledge and skills in electrical engineering which is necessary for work on live HV components. Therefore, the competence of the employees must be verified to decide which additional knowledge and skills are necessary to fulfil the preconditions for a qualification for Level 3E.

Topics covered by the training

- Safe work methods for work on live HV systems
- Types, structure, specific features and risk potential of HV energy storage devices
- Work on live HV components

A specification of the topics covered by the training can be found in Annex 4.

The duration of the qualification must encompass at least 24 TP of classroom training (including at least 16 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented.

!

After successful qualification, the specialist knowledge must be kept up to date by regular participation in training courses!

4.2 Training for work relating to production and commissioning during the manufacturing process

4.2.1 Assembly

Assembly work is often of a repetitive nature; it can be performed by an FuP. This work is to be assessed in accordance with the criteria set out in section 3.2, and corresponding protective measures must be derived. This necessitates the implementation of technical measures and the formulation of binding work instructions. Review of the standardized work instructions for their technical correctness is the task of an FHV. The responsible superiors may assume control and supervision of assembly on the basis of these standardized working procedures.

The topics covered by the work instruction must be communicated to the employees by familiarization (for example in the course of product training) or instruction. The employees must have understood the material.

The relevant superiors are responsible for sustained integration of the standardized work procedures into the production process, generation of the requisite documentation, and monitoring of the implementation.

4.2.2 Commissioning (Finish)

Once the HV system has been commissioned by connection to the power source, the hazard potential increases. Depending on the task to be performed on the vehicle, this may necessitate further training measures for the employees. The following distinctions, which take account of differences in hazard potential, must particularly be made in this context:

4.2.2.1 *Commissioning of batteries with full protection against accidental contact and arcing*

Commissioning is adequate if performed in accordance with standardized work procedures (as described for assembly) by an FuP.

4.2.2.2 *Commissioning of batteries without full protection against accidental contact and arcing*

Protection against electric shock and fault arcs is not assured by technical means alone. Such work may be performed only by employees qualified to Level 3E in accordance with the level model.

4.2.2.3 *Reworking without faults in the HV system*

Should reworking not require intervention in the HV system, this work may be performed in accordance with standardized work procedures by FuP (as described for production-line assembly).

This includes work on the conventional vehicle electrical system up to 30 V AC and 60 V DC.

4.2.2.4 *Reworking with faults in the HV system*

Should electrical work be required on the HV system, its non-live state must be assured. This work requires an employee qualified to Level 2E in accordance with the level model. These provisions also include work on the conventional vehicle electrical system up to 30 V AC and 60 V DC if components of the HV system are affected.

Live work may be necessary for troubleshooting on the HV system. In this case, qualification to Level 3E in accordance with the level model is required.

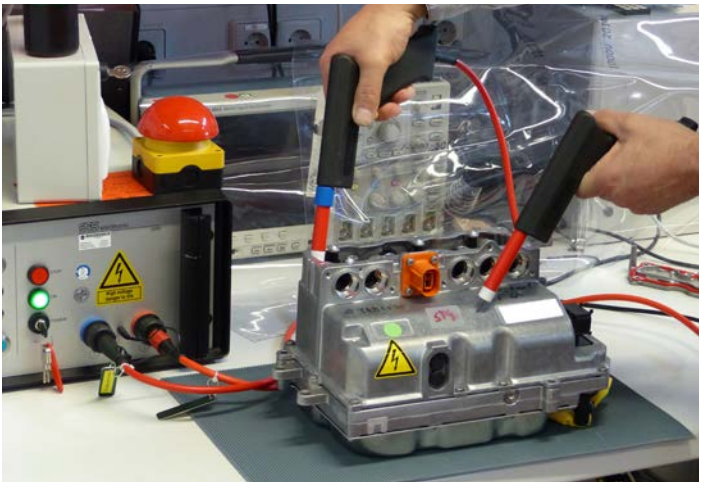


Figure 11 Voltage testing on an HV component

4.2.3 Electrical tests

Where electrical tests are performed in the manufacturing/assembly process, e.g. tests of the continuity of the potential equalization, insulation tests, voltage tests, etc., the requirements of DIN EN 50191 (VDE 0104) and of DGUV Information 203-034 „Errichten und Betreiben von elektrischen Prüfanlagen“ (governing the installation and operation of electrical test facilities) must be observed. In addition, the following distinction must be made regarding the required qualification:

- Where it is not possible to ensure the non-live state, employees having a Level 3E qualification must be tasked.
- In case of testing with full protection against accidental contact and arcing
  - a Level 2E qualification is required if the measuring result must be validated,
  - a Level 1E qualification is required if it is not necessary to validate the measuring result.

5 Training for work on series production vehicles

5.1 Qualification levels

5.1.1 General

Under common circumstances, HV components installed in series production vehicles do not pose electrical hazards. However, it is not possible to exclude contact with live parts during repair or service work. This danger is even higher in the case of accident vehicles equipped with HV components.

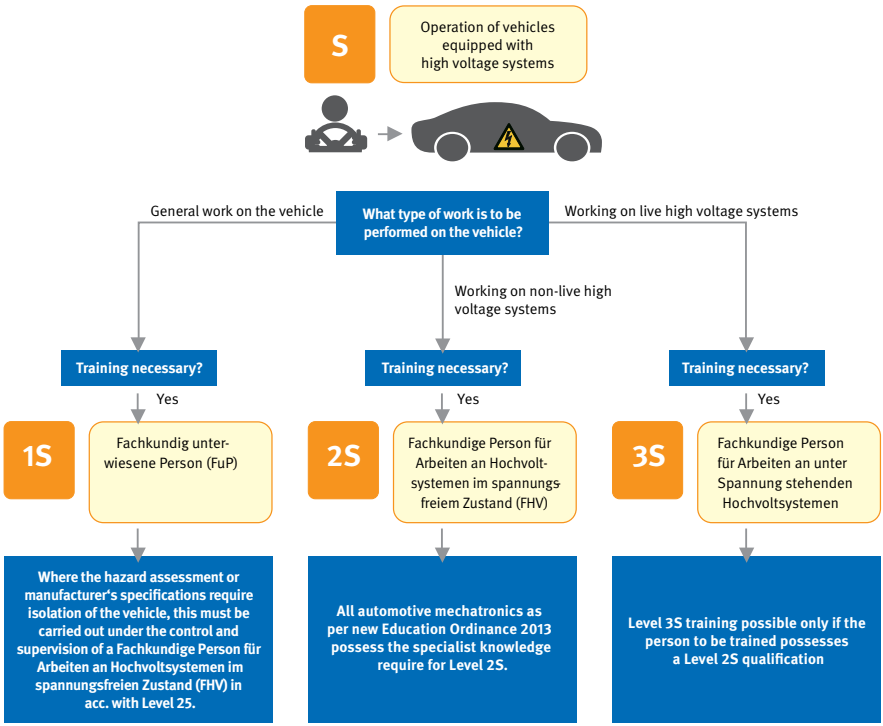


Figure 12 Classification for work on series production vehicles in the automotive area

Employers or the managers mandated by them are responsible for occupational safety and health. They must ensure that only skilled persons are employed for work on HV components who are able to correctly assess the dangers posed by vehicles equipped with high voltage systems and to determine the required protective measures (see Figure 12: Classification for work on series production vehicles in the automotive area).

FHV may instruct further persons regarding the hazards caused by high voltage systems. These instructions are to be conducted if work is to be performed on new vehicle types or vehicles equipped with new HV systems or components. The instructions must always be provided and documented by an FHV. The expertise for work on HV systems is classified into the following levels, depending on the work to be performed on the HV vehicle:

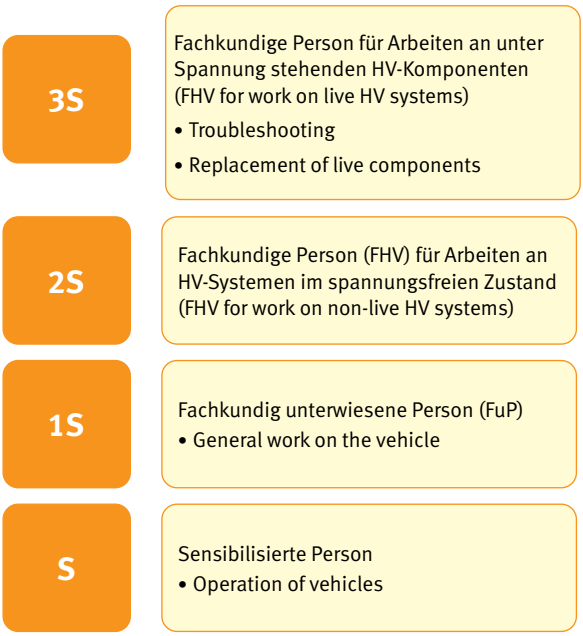


Figure 13
Qualification levels for work on series production vehicles

5.1.2 Qualification Level S: Sensibilisierte Person

For the operation of vehicles, it is sufficient for employees to be made familiar with the intended use and the particular aspects to be observed. This also applies to service work, which is comparable to operation in terms of the electrical hazard; examples of such work are:

- Replacement of windscreen wiper blades, refilling of screen wash,
- Special procedures for retrospective equipping of the vehicles (e.g. preparation of the vehicles in transport companies),
- Use of familiar filling points (e.g. motor oil, coolant),
- Use of controls bearing new symbols and hazard markings or new connections (e.g. charging device on the vehicle).

Operation of the vehicles includes interior and exterior cleaning. However, when performing cleaning work, care must be taken to ensure that all service lids and bonnets are closed as they may cover HV components which represent a hazard when damaged. There is a risk of the HV components being damaged due to improper cleaning using high water pressure. Manufacturer's specifications must always be observed.

In case of accidents, damage, and when recovering/towing the vehicle, additional hazards may arise (⇢ see VDA Leaflet „Unfallhilfe und Bergen bei Fahrzeugen mit Hochvolt- und 48-Volt-Systemen" governing accident assistance and recovery of vehicles equipped with high voltage and 48 V systems). Drivers must be made familiar with these hazards. In addition, they must be made familiar with additional controls, such as e.g. emergency off switch at the driver's workplace.

Familiarization may be conducted by the employer or a suitable person, e.g. an FuP.

5.1.3 Qualification Level 1S: Fachkundig unterwiesene Person (FuP)

Persons who have (only) received electrical instruction may carry out general work on the vehicle which do not immediately touch the HV system. This may be e.g. panel work, oil and wheel changes, work on the brake system in the proximity of wheel hub motors, work in the proximity of the HV lines on the steering system, combustion engine, axles, etc., and electrical work on the conventional vehicle electrical system (up to 30 V AC and 60 V DC). Employees may be exposed to an electrical hazard during this work owing to human error or faults. They must be made familiar by FHV with these hazards, the protective measures and the codes for behaviour. The topics and duration of instruction must be geared to the nature of the work to be performed and to the anticipated hazard potential associated with it.

More comprehensive mechanical work which may be performed in the proximity of HV components, such as welding, drilling and grinding work, requires knowledge of the precise location of the HV components. Employees' awareness must be raised of the hazards which may arise during the use of tools and other equipment in the proximity of the HV system. They must be familiar with the markings of the components. The instruction must include making them aware that work on the HV components is not permissible. Inadvertent damaging, kinking or crushing of HV lines must be reported to the responsible skilled person for work on HV components. Failure to observe these requirements may lead to electric shock or arcing.

The instructions must be documented (example → see Annex 7).

These topics of this instruction must include:

- Electrical hazards and protective measures,
- Operation of vehicles and the associated equipment,
- Performance of general tasks which do not require isolation of the HV system,

- Location and marking of the HV components and lines in and on the vehicle,
- Performance of all mechanical tasks on the vehicle (but: „Don't touch orange!"),
- Isolation of the HV system as specified by the manufacturer, serving as an additional safety measure,
- Impermissible work on the vehicle,
- Stopping the work in case of an unclear situation and information of the responsible FHV,
- Organizational procedure for electrical work that is performed under the control and supervision of an FHV.

Depending on nature and scope of the work, the duration of the instruction must encompass at least 2 TP.

5.1.4 Qualification Level 2S: Fachkundige Person (FHV)

Successful completion of training according to this level equips the skilled persons to work independently and safely on high voltage systems. Work on non-live HV systems include all work on non-live HV systems and components or work in their hazardous area, e.g. measuring of isolation resistance, repair, replacement, modifying and testing.

Employees need a FHV qualification for any work on HV systems in the non-live state. The FHV must be able to place vehicles or systems into the non-live state in accordance with the "Five safety rules" and the manufacturer's specifications.

Work on non-live HV systems may be carried out only by an FHV or under control and supervision of an FHV!

The scope of training depends upon the scale of the electrical hazards occurring during the work and upon the employee's prior knowledge. The spe-

cialist knowledge and expertise must be kept up to date by regular participation in training courses.

Depending on the respective framework curricula, the training professions in the motor vehicle sector teach basic knowledge of electrical engineering both in the theoretical and in the practical area. In addition, both the inter-company and the in-house vocational training teach measuring of electrical values and work on electrical units and systems of the conventional electrical systems up to 30 V AC/60 V DC by way of practical exercises. Since 2002, the apprenticeship trades for car body maintenance mechanics and for car body construction and vehicle manufacturing technology focusing on

- vehicle body maintenance technology
- auto body construction technology and vehicle manufacturing technology

teach these skills as well.

Persons having successfully completed the education in the field of motor vehicle mechatronics, with focus:

- passenger car technology
- commercial vehicle technology
- motorcycle technology
- car body technology

in accordance with the German Ordinance on vocational training for motor vehicle mechatronics technician (Verordnung über die Berufsausbildung zum Kraftfahrzeugmechatroniker und zur Kraftfahrzeugmechatronikerin) dated 14 June 2013 possess a specialist knowledge degree of Level 2S.

Persons having successfully completed the vocational training in the field of car body construction and vehicle manufacture focusing on

- vehicle body maintenance technology
- auto body construction technology and vehicle manufacturing technology

in accordance with the German Ordinance governing the vocational training for car body construction mechanic and vehicle manufacture mechanic as well as for car body and vehicle body mechanic (Fahrzeugbaumechaniker-ausbildungsverordnung – FzMechAusbV) dated 10 June 2014 and having completed a one-week inter-company training with subsequent successfully passed knowledge examination in the field of "high voltage technology" are equally qualified for Level 2S.

Persons having successfully completed a vocational training in the field of passenger car mechatronics with the focus area "system and high voltage technology" already possess a Level 3S qualification.

!

After successful qualification, the acquired technical knowledge must be kept up to date by means of regular participation in training courses!

The topics listed in the following covered by the training serve as examples only and must be adapted to the specific requirements of the tasks. The flow chart in Annex 5 provides support in determining the necessary scope of training.

Introductory course A: Persons without electrical knowledge but with technical training

Topics covered by the training: :

- Basic electrical knowledge
- Electrical hazards and first aid
- Measures for protection against electric shock and against fault arcs
- Organization of safety and health for work on HV components
- Specialist and people management responsibility
- HV concept and vehicle technology
- General practical procedures
- Structure and function of electrical systems in vehicles

A specification of the topics covered by the training can be found in Annex 6.

Depending on nature and scope of the work, the duration of the qualification must encompass at least 80 TP (including at least 8 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented (an example is shown in Annex 8).

Introductory course B: Persons with prior electrical knowledge in the automotive sector, e.g. car electricians, automotive mechatronics technicians, car mechanics, or mechatronics electricians for agricultural and construction machinery

Topics covered by the training:

- Electrical hazards and first aid
- Measure for protection against electric shock and against fault arcs
- Organization of safety and health for work on HV components
- Specialist and people management responsibility
- HV concept and automotive technology
- General practical procedures
- Structure and function of electrical systems in vehicles

A specification of the topics covered by the training can be found in Annex 6.

Depending on nature and scope of the work, the duration of the qualification must encompass at least 16 TP (including at least 8 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented (an example is shown in Annex 8).

Introductory course C: Persons with theoretical electrical knowledge

The requisite qualification necessary for persons who, due to their education and training, possess theoretical electrotechnical knowledge, must be determined on a case-by-case basis.

Depending on nature and scope of the work, the duration of the qualification must be determined on a case-by-case basis and must encompass at least 8 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented (an example is shown in Annex 8).

5.1.5 Qualification Level 3S: Fachkundige Person für Arbeiten an unter Spannung stehenden HV-Systemen

Employees possessing a qualification for work on live HV components may perform troubleshooting on live HV components if it is not possible to place the vehicle in the non-live state or if it is not possible to determine the non-live state. The same applies to work on live energy storage devices and to work with corresponding hazard potential, e.g. high voltage test according to manufacturer's specifications.

Any work on the HV system during which an employee may come into contact with HV components or parts with his or her body or items (tools, devices, equipment or apparatus) is considered work on live HV systems if the non-live state is not assured and an electrical hazard cannot be excluded.

Verification of the non-live state is not considered work on live HV components if work procedure and work equipment exclude an electrical hazard.

Work on live HV components constitute a hazard potential for employees which is higher than that for work on components in the non-live state. Further qualification is required in order to enable the employee to perform this work safely. The following individual preconditions must be fulfilled to obtain this further qualification.

Prior to the measure, proof must be provided that the person to be qualified
- possesses at least a Level 2S qualification,
- has a minimum age of 18 years and
- has successfully completed a first aid training including heart-lung resuscitation (9 TP in accordance with DGUV Information 204-022 „Erste Hilfe im Betrieb“ governing first aid in companies).

Furthermore, it must be ensured that the person to be qualified does not have any health issues (e.g. implant carriers, epilepsy, ...) which might result in hazards during work on live HV components (see also § 7 DGUV Regulation 1 „Principles of Prevention“).

The employer must observe the applicable legal bases (individual or collective agreements) when carrying out evaluations of aptitude relating to driving, steering or monitoring activities (see also DGUV Information 250-010 “Eignungsuntersuchungen in der betrieblichen Praxis” governing aptitude tests in plant practice). The evaluations must be handled separately from the preventive occupational medical care. Where legal bases for an aptitude examination exist, the respective current recommendations of DGUV relating to occupational health advice and checks may be used for such an aptitude examination as well. This occupational health advice provides guidance for conducting aptitude evaluations in order to assess aspects of fitness of employees with regard to the tasks and activities they are intended to perform.

As work on live HV components is, in general, hazardous work in accordance with § 8 of the DGUV Regulation 1 „Principles of Prevention“, a second person must usually be present. This person must have at least received expert instruction (FuP) and must be trained in first aid.

In addition, employees must have gained at least one year of practical professional experience in the field of automotive technology or electrical engineering shortly before beginning the training for Level 3E. This precondition is fulfilled by e.g. a vocational training undergone in motor vehicle mechatronics.

Employees having a Level 2S qualification without having undergone a vocational training in the field of automotive technology or electrical engineering do not necessarily possess the suitable level of sound theoretical and practical knowledge and skills in electrical engineering which is necessary for live work on HV components. Therefore, the competence of the employees must be verified to decide which additional knowledge and skills are necessary to fulfil the preconditions for a qualification for Level 3S.

Topics covered by the training:

- Safe working procedures for work on live HV systems
- Types, structure, specific properties and hazard potential of HV energy storage devices
- Work on live HV components

A specification of the topics covered by the training can be found in Annex 6.

The duration of the qualification must encompass at least 24 TP (including at least 16 TP of practical exercises). The organization of the qualification measure must allow for all participants to perform practical exercises.

The knowledge acquired must be demonstrated in a test and documented.

Figure 14 Example for the safeguarding of the work area for work on live HV components

!

After successful qualification, the acquired technical knowledge must be kept up to date by means of regular participation in training courses!

5.2 Accident assistance

Where vehicles have suffered minor damage in an accident, the accident recovery services repair it on site in order to restore the vehicles to working order without delay, if possible. More major damage is always repaired in the workshop. However, it is necessary to take into account whether this work is general work on the vehicle or work on the HV system of the vehicle.

Accident assistance on vehicles equipped with HV system requires a qualification in accordance with Figure 13: Qualification levels for work on series production vehicles and at least a qualification for Level 1S.

When towing vehicles, the vehicle manufacturer's specifications must be observed. As an additional measure, the HV system of the vehicle can be deactivated by actuating the service disconnect/emergency off switch, if need be (→ see *VDA Leaflet „Unfallhilfe und Bergen bei Fahrzeugen mit Hochvolt- und 48-Volt-Systemen" governing accident assistance and recovery of vehicles equipped with high voltage and 48 V systems*).

When working with a crane or rope winch, care must be taken to prevent any HV component from being damaged. If the vehicle is passed to third parties, it is recommended to inform about the measures implemented and to demand a confirmation.

5.3 Accident assistance and vehicle recovery

The HV components are fitted in the vehicle in such a way as to protect them against damage in the event of an accident. Despite this, parts of a damaged vehicle could be live following an accident. The safety of the emergency service personnel must be assured in any case. Guides providing corresponding information on particular vehicles to deactivate the vehicle's HV system are available for emergency service personnel.

!

Where airbags and belt tensioners have been actuated due to an accident, the HV system usually is automatically deactivated. However, this is not an isolation in accordance with cl. 3.2.2.

Where vehicles have been damaged so severely by external influences that there is an increased fire risk, the accident recovery service has the task of safeguarding the danger zone and to alarm the fire brigade (→ see FBFHB-024 „Instructions for lithium-ion battery firefighting in vehicle fires").

Depending on the energy storage device type, leaking substances might possess hazardous characteristics. Any contact must be avoided. It cannot be excluded that, due to internal reactions, the energy storage device might even catch fire sometime later.

Recovery of severely damaged HV vehicles and separated HV energy storage devices must be carried out using suitable tools and appropriate personal protective equipment (face protection, if need be: respiratory protection, where necessary, protective gloves for work on live parts) (see VDA Leaflet „Unfallhilfe und Bergen bei Fahrzeugen mit Hochvolt- und 48-Volt-Systemen" governing accident assistance and recovery of vehicles equipped with high voltage and 48 V systems).

When handing over the accident vehicle to public officials, government representatives or recovery companies, it is recommended to provide information about the measures already taken. It is particularly important to provide information about possible hazards due to damaged HV components.

!

Rescue and recovery staff need at least an FuP qualification in accordance with 5.1.3. Wherever the situation is unclear or where it is not possible to exclude electrical hazards, an FHV must be consulted.

5.4 Scrappage/Reuse/Recycling

Consideration must be given to the electrical hazards presented by the HV vehicle when it is scrapped/reused/recycled. HV vehicles are not always identifiable externally as such. For this reason, vehicles must be examined prior to scrappage for the possible presence of HV components. The orange cables, the decals indicating high voltage and batteries marked with higher voltages than the conventional 12, 24 and 42 V are clear indications that the vehicle has an HV system. Under normal circumstances, the HV components fitted to series production vehicles do not present an electrical hazard. Should the cable insulation or the shrouding of the HV components be damaged or destroyed, however, there is a risk of arcing caused by short-circuits or of electric shock in the event of contact with the live parts.

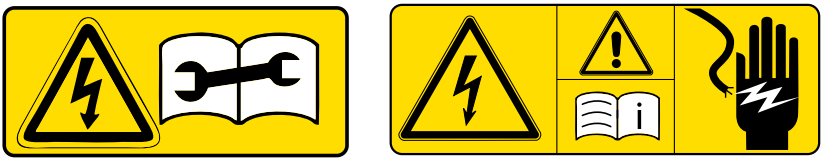


Figure 15 Examples for the marking of HV components

Prior to scrappage/reuse/recycling, the HV system must be safely isolated (see cl. 3.2.2) by an FHV with observance of the manufacturer's instructions for the specific vehicle; the HV components must be isolated from the vehicle's electric system and prepared for removal. The electrical energy storage devices (such as batteries, supercaps/EDLCs etc.) must then be removed in accordance with the manufacturer's instructions, and properly disposed of.

Where work must be performed on live HV components (e.g. disassembling the energy storage device), a Level 3S qualification is necessary.

Annex 1

Model risk assessment

Facility	Automotive workshop	**Sector:**	Automotive maintenance
Operational area:	Maintenance measures and service work	**Version:**	.....
Workplace:	Work on vehicles with HV systems	**Sheet no.**	.....

Hazards identified (description)	Risk ☺😐☹	Protective measure	Need for action		Effective	
			Who	Until when	Effective as of	Who
General Misconduct or errors due to insufficient expertise regarding handling of HV vehicles	☺😐☹	☐ Preparation of operating instructions regarding handling of HV vehicles on the basis of the manufacturer's operating manual ☐ Instruction of employees on the basis of the operating instructions prepared. ☐ Handling of accident vehicles must be considered separately. ☐ ...				

Hazards identified (description)	Risk	Protective measure	Need for action		Effective	
			Who	Until when	Effective as of	Who
Electric shock and fault arc (on HV systems)	☺😐☹	☐ Manufacturer's specifications must be observed when working on the vehicle. ☐ During non-electrical work on the vehicle, checking of whether HV components are fitted in the working area; if yes, place the HV system in the non-live state. ☐ Work on the HV system may be carried out only by employees who possess the necessary expertise, or under the control and supervision of such employees. ☐ Marking of vehicles equipped with HV components, e.g. sign with warning against hazardous electric voltage (e.g. W08 ⚠) ☐ Marking of the switching states of the HV components in accordance with DGUV Information 209-093. ☐ Marking of the working area during electrical work on the HV system. ☐ Visual inspection of the HV components for externally visible defects ☐ Working on the HV system only with the HV system placed in the non-live state and following application of the 5 safety rules Remark: The first three rules must always be applied; the decision on whether the fourth and fifth rule are to be applied must be taken on a case-by-case basis. ☐ Use of two-pole voltage testers in accordance with DIN EN 61243-3 (VDE 0682-401) to verify the non-live state				

Work sheet: Hazards and protection objectives						
		☐ Adjacent live components must be covered (e.g. with shrouds in accordance with DIN EN 61112 (VDE 0682-511) during troubleshooting. ☐ DGUV Information 203-077 „Thermal hazards due to electric fault arcing“ must be observed when selecting suitable PPE against fault arcing. ☐ ...				
Electric shock and fault arc (during work on the battery charging infrastructure)	☺😐☹	☐ Work on charging stations and similar equipment parts as well as on building installations is electric work which must not be performed by an FHV ☐ ...				
Fire and deflagration caused by improper handling	☺😐☹	☐ Handling and storage of lithium-ion batteries in accordance with manufacturer's specifications and in compliance with applicable fire protection regulations ☐ Safe parking area for accident vehicles with uncertain battery condition ☐ Preparation of a handling concept regarding batteries with uncertain condition ☐ ...				

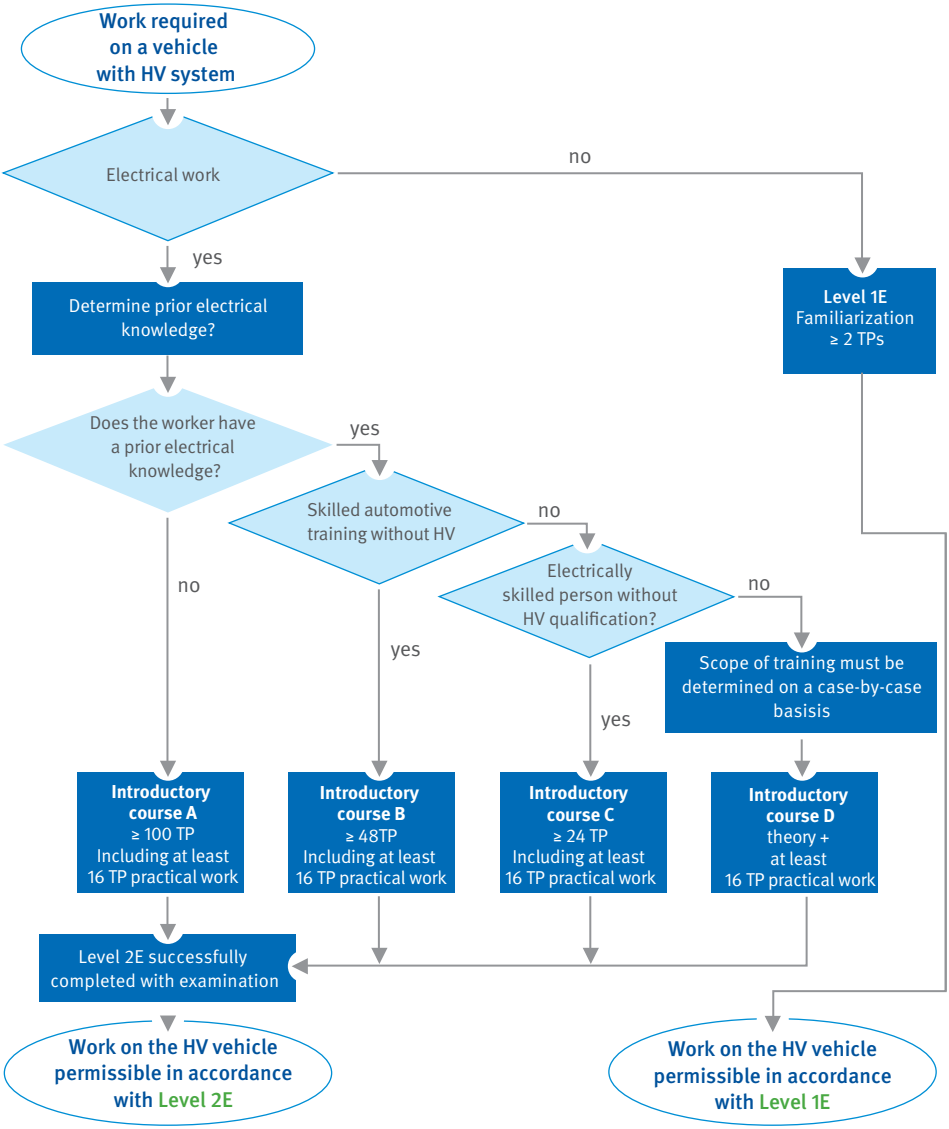
Applicable documentation:

☐ Operating instructions ☐ Instruction manual ☐ Where are these documents:

Assess the risk with the protective measures effective at the time of the assessment. Classification in accordance with hazard matrix in „low“ „green smiley symbol “ (Stage 1), „medium“ „yellow smiley symbol“ (Stage 2) and „high“ „red smiley symbol“ (Stage 3/ Stage 4) Version: 05.11.2019

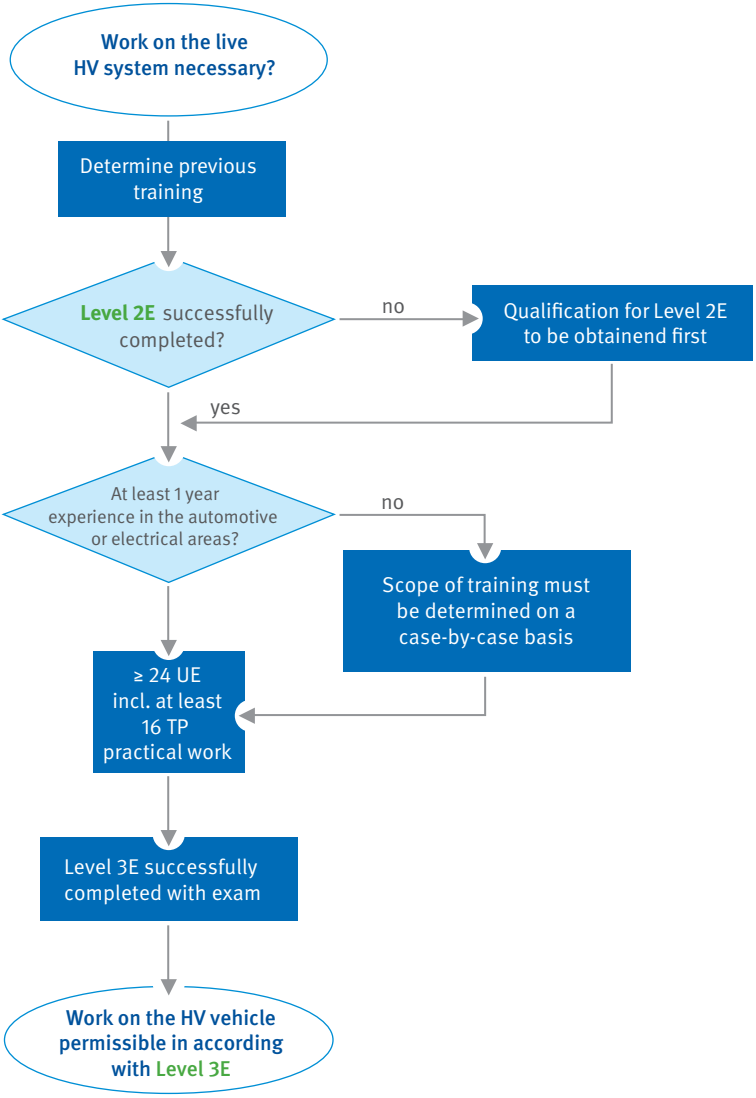
Annex 2

Flow chart: Need for training for work prior to SoP, requiring **Level 1E/2E**



Annex 3

Flow chart: Need for training for work prior to SoP, requiring **Level 3E**



Annex 4

Topics covered by the training for work on high voltage systems in development and manufacture

The topics indicated below serve as an example only and reflect the current state of the art of automotive HV technology. Topics irrelevant to the work to be carried out can be ignored. Other relevant topics must be added in their place if necessary.

Basic electrical knowledge

- Electric voltage
- Electric current
- Direct current, alternating current, three-phase current
- Calculations involving power of ten
- Power sources
- Electrical resistance
  - Ohm's Law
  - Connection in series
  - Connection in parallel
- Electric power
- Forms of power generation
- Power sources
  - Fuel cell, supercaps, batteries (lithium-ion, nickel-metal hydride)
- Coil
- Electric motor
- Three-phase asynchronous motor/three-phase synchronous motor
- Three-phase generator
- Transformer
- Semiconductors, diodes, bipolar transistors
- Design of a relay
- Design of a capacitor
- Use of a capacitor to smooth undulating voltage
- Instruments, measurement procedures and measurement methods:
  - Digital measuring instruments
  - Measurement of current, voltage and resistance
  - Measurement errors
  - Troubleshooting on vehicles
  - Diagnostics

- Reading off and use of measurement results is practised in order for measurement displays to be read and interpreted correctly.
- Measurement of V/R/I, use of voltmeters, ammeters and electronic boards
- Production/interpretation of V/I diagrams in preparation for the specialist module
- Estimation (by ratios) and calculation of voltages and resistances in series and parallel circuits
- Determining of potentials, voltage drops and currents in circuits
- Electrical power and electrical efficiency
- Reading of circuit diagrams, tracing of current paths

Electrical hazards and first aid

- Effects on the human being
- Stimulus thresholds
- Let-go threshold
- Cardiac fibrillation
- Burns
- Duration of the effect of current upon the human body
- Resistance of human body
- Hazardous body currents
- Maximum touch voltage
- General information on first aid, behaviour in the event of fire
- Accidents caused by electric current
- Measures to be taken in the event of an injury
- First aid in the event of injury caused by electric current
- Records of first-aid measures
- Reporting of accidents

Measures for protection against electric shock and fault arcs

- Classification of protective measures; key terms
- Protection against direct contact:
  - Protection by the insulation of live parts
  - Protection by shrouding or encapsulation

- Protection against direct and indirect contact (extra-low voltage)
- Protection against indirect contact (protection against hazardous electric shock in the event of a fault)
  - Protective insulation
  - Protective separation
  - Protection by disconnection:
    - Protective device
    - Mains systems
    - Protective measures in the IT system
- Function of potential equalization
- Protective measures:
  - Overload protective devices
  - Residual current devices RCD (ground fault circuit interrupter) in the charging infrastructure
- Tests based upon DIN VDE 0100-600:
  - Visual inspection
  - Measurements of the insulation resistance
  - Function test
- Organization and documentation of the tests.

Organization of safety and health for work on HV components

- OSH system
- International legislation (UNECE R100)
- German legislation (German Safety and Health at Work Act, German Industrial Safety and Health Ordinance with TRBS)
- DGUV Regulation 1 „Principles of Prevention“
- DGUV Regulations 3 and 4 „Electrical installations and equipment “
- Codes of practice (DIN, EN, ISO, VDE, further standards (e.g. DIN VDE 0105-100))
- Risk assessment and risk analysis
- Measures for accident prevention: The five safety rules
- Repair, commissioning, maintenance and service
- Assurance of safety by personal protective equipment and other equipment
- Informative safety technology, warning signs

Specialist and man-management responsibility
- Delegated responsibility of managers
- Responsibility of the Fachkundige Person (FHV)
- Legal consequences

Employee qualification in the area of electrical engineering vs. HV technology
- Who is permitted to carry out which work?
- Distinction between HV technology and electrical installations and equipment
- Instruction of electrical lay persons, tasking of workers

Use of HV systems in vehicles
- Introduction to the subject of “High voltage systems”
- Structure, function and mode of operation of
  - Fuel cell vehicles
  - Hybrid drives
  - Electric vehicles
- HV components: e.g. fuel cells, HV batteries, power electronics, DC/DC converters, three-phase, synchronous and asynchronous machines, other safety-critical components
- Requirements of the Federal Rule UNECE R100
- Federal Motor Vehicle Safety Standard 305 (FMVSS 305)
- Measures to ISO 6469-3 and DIN EN 61140 (VDE 0140-1) for protection against electric shock
- Calculation of body currents in the event of insulation faults; hazards of such body currents
- Risk assessment for high voltage systems
- Protection classes/degrees of protection
- Placing of high voltage systems in the non-live state
- Measurements on the HV system
- Replacement of installed components
- Commissioning with determining of the RISO of the HV system with/without faults in the HV system

- Measurements (voltage drop and potential) on high-resistance circuits on conventional vehicles in consideration of the Ri of the instruments
- Measurement exercises on HV vehicles: location of the components, connection and disconnection of the maintenance plug (service disconnect), checking of isolation, measurement of HV+ against HV- and against the vehicle earth
- Markings in accordance with vehicle standards/DIN VDE standards/DGUV regulations
- Conductors and cables:
  - Cable core arrangements, core and outer insulation
  - Core markings
  - Proper electrical connections
  - Preparation of fine and ultra-fine-stranded conductors

Structure and function of electrical systems in vehicles

Safe work methods for work on live HV systems (Level 3E)

- Competence of the employees
- Organization of work (e.g. supervision, assignment, work permit, ...)
- Tools and protective, testing and other equipment (e.g. PPE) to be used
- Safeguarding of the work areas
- Marking of the high voltage system

Types, structure, specific features and risk potential of HV energy storage systems (Level 3E)

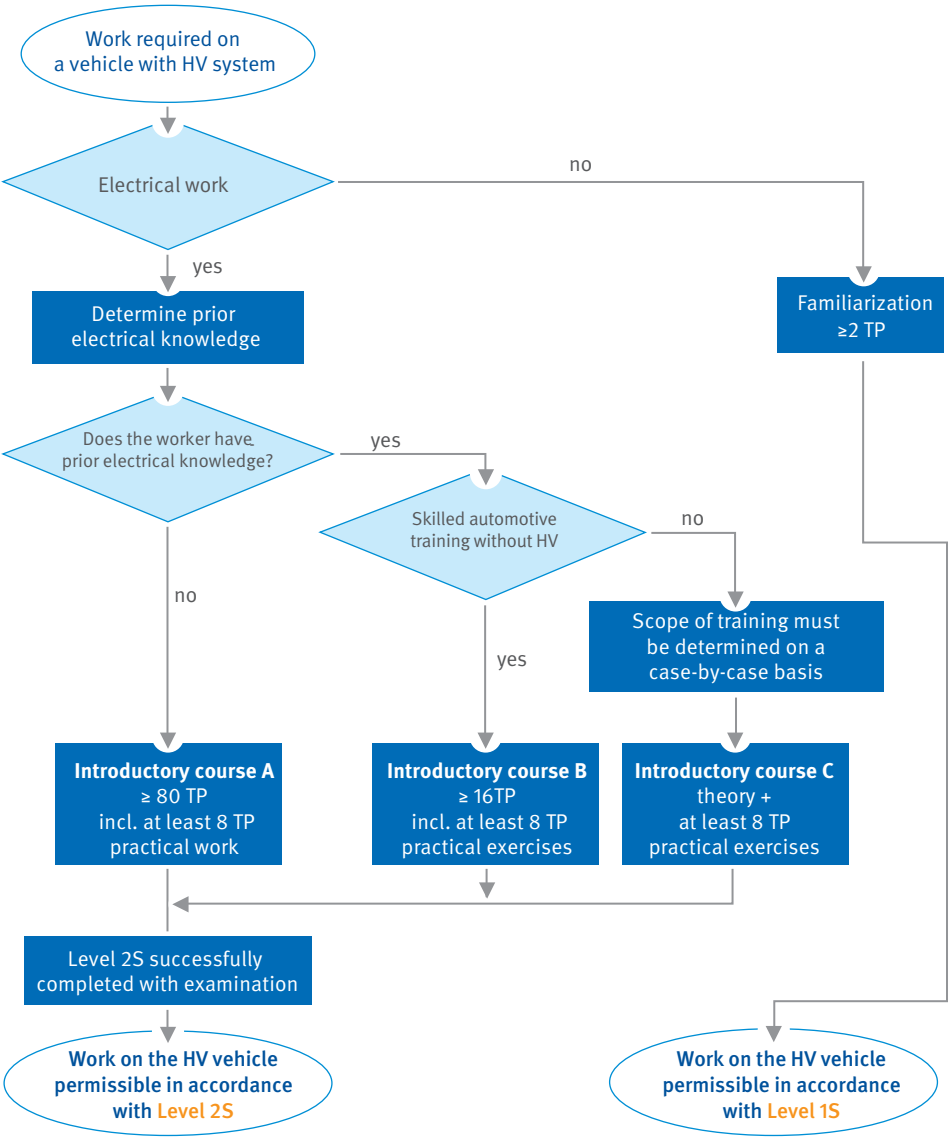
- Types of HV energy storage systems (e.g. Li-ion, supercaps, ...)
- Structure of HV energy storage units (e.g. cell structure, energy carrier, cooling, ...)
- Hazards caused by electrical energy
- Specific non-electrical hazards, e.g. chemical hazards, risk of fire and explosion, risk of falls from a height

Work on live HV components (Level 3E)

- Practical exercises with the diagnostics and measurement instruments, application of different measurement methods (e.g. measurement of voltage, troubleshooting on live HV components)
- Replacement of cells/components in the HV energy store

Annex 5

Flow chart: Need for training for service work requiring Level 1S/2S



Annex 6

Topics covered by the training for FHV for work on series production vehicles with HV systems

The topics indicated below serve as an example only and reflect the current state of the art of automotive HV technology. Topics irrelevant to the work to be carried out can be ignored. Other relevant topics must be added in their place if necessary.

Basic electrical knowledge

- Electric voltage
- Electric current
- Direct current, alternating current, three-phase current
- Calculations involving power of ten
- Power sources
- Electrical resistance
  - Ohm's Law
  - Connection in series
  - Connection in parallel
- Electric power
- Forms of power generation
- Power sources
  - Fuel cell, supercaps, batteries (lithium-ion, nickel-metal hydride)
- Coil
- Electric motor
- Three-phase asynchronous motor/three-phase synchronous motor
- Three-phase generator
- Transformer
- Semiconductors, diodes, bipolar transistors
- Design of a relay
- Design of a capacitor
- Use of a capacitor to smooth undulating voltage
- Instruments, measurement procedures and measurement methods:
  - Measurement of current, voltage and resistance
  - Measurement errors
  - Troubleshooting on vehicles
  - Diagnostics

- Reading off and use of measurement results is practised in order for measurement displays to be read and interpreted correctly.
- Measurement of V/R/I, use of voltmeters, ammeters and electronic boards
- Production/interpretation of V/I diagrams in preparation for the specialist module
- Estimation (by ratios) and calculation of voltages and resistances in series and parallel circuits
- Determining of potentials, voltage drops and currents in circuits
- Electrical power and electrical efficiency
- Reading of circuit diagrams, tracing of current paths

Electrical hazards and first aid

- Effects on the human being
- Stimulus thresholds
- Let-go threshold
- Cardiac fibrillation
- Burns
- Duration of the effect of current upon the human body
- Resistance of human body
- Hazardous body currents
- Maximum touch voltage
- General information on first aid, behaviour in the event of fire
- Accidents caused by electric current
- Measures to be taken in the event of injury
- First aid in the event of injury caused by electric current
- Records of first-aid measures
- Reporting of accidents

Measures for protection against electric shock and fault arcs

- Classification of protective measures; key terms
- Protection against direct contact:
  - Protection by the insulation of live parts
  - Protection by shrouding or encapsulation

- Protection against direct and indirect contact (extra-low voltage)
- Protection against indirect contact (protection against hazardous electric shock in the event of a fault)
  - Protective insulation
  - Protective separation
  - Protection by disconnection:
    - Protective device
    - Mains systems
    - Protective measures in the IT system
- Function of potential equalization
- Protective measures
- Testing of the dielectric strength, for example by on-board or external diagnostics systems
- Visual inspection and function test
- Organization and documentation of the tests

Organization of safety and health for work on HV components

- OSH system
- International legislation (UNECE R100)
- German legislation (German Safety and Health at Work Act, German Industrial Safety and Health Ordinance with TRBS)
- DGUV Regulation 1 „Principles of Prevention“
- DGUV Regulations 3 and 4 „Electrical installations and equipment “
- Codes of practice (DIN, EN, ISO, VDE, further standards (e.g. DIN VDE 0105-100))
- Risk assessment and risk analysis
- Measures for accident prevention: The five safety rules
- Repair, commissioning, maintenance and service
- Assurance of safety by personal protective equipment and other equipment
- Informative safety technology, warning signs

Specialist and man-management responsibility
- Delegated responsibility of managers
- Responsibility of the Fachkundige Person (FHV)
- Legal consequences

HV concept and vehicle engineering
- Introduction to the subject of “High voltage systems”
- Structure, function and mode of operation
- Definition of high-voltage system
- HV batteries, power electronics, DC/DC converters, other HV components
- Fuel cell vehicles
- Hybrid drives
- Electric vehicles

General practical procedure
- Setting the high voltage system to the non-live state
- Measurements on the HV system
- Replacement of installed components
- Commissioning with determining of the RISO of the HV system with/without faults in the HV system
- Measurements (voltage drop and potential) on high-resistance circuits on conventional vehicles in consideration of the Ri of the instruments

Structure and function of electrical systems in vehicles

Safe work methods for work on live HV systems (Level 3E)
- Competence of the employees
- Organization of work (e.g. supervision, assignment, work permit, ...)
- Tools and protective, testing and other equipment (e.g. PPE) to be used
- Safeguarding of the work areas
- Marking of the high voltage system

Types, structure, specific features and risk potential of HV energy storage systems (Level 3E)

- Types of HV energy storage systems (e.g. Li-ion, supercaps, ...)
- Structure of HV energy storage units (e.g. cell structure, energy carrier, cooling,...)
- Hazards caused by electrical energy
- Specific non-electrical hazards, e.g. chemical hazards, risk of fire and explosion, risk of falls from a height

Live work on HV components (Level 3E)

- Practical exercises with the diagnostics and measurement instruments, application of different measurement methods (e.g. measurement of voltage, troubleshooting on live HV components)
- Replacement of cells/components in the HV energy store.

Annex 7

Model certificate: Fachkundig unterwiesene Person (FuP) Level 1S

Certificate of attendance

Mr. John Smith
E-Mobility Dealership, 17 Anystreet, 77777 Anytown

attended the following training with ..... TPs*
from (date) _____ to (date) _____

Fachkundig unterwiesene Person (FuP) Level 1S

The participant received instruction from a „Fachkundige Person Hochvolt (FHV)" (FHV) in the work on HV vehicles, in the possible hazards and in the necessary protective equipment and protective measures.

This instruction does not release the employer from the obligation to provide regular instructions in accordance with § 4 DGUV Regulation 1 „Principles of Prevention".

Subject of the training in accordance with DGUV Information 209-093:

- Electrical hazards and protective measures
- Operation of vehicles and associated equipment
- Performance of general tasks which do not require isolation of the HV system
- Location and marking of HV components and wiring in and on the vehicle
- Performance of all mechanical tasks on the vehicle (but: "Don't touch orange!")
- Isolation of the HV system as additional safety measure in according with manufacturer's specifications
- Impermissible work on the vehicle
- Suspension of work in the event of uncertainty and information of the responsible FHV
- Organization of procedures for work to be performed under the control and supervision of an FHV
- ...

Company: _____

Place	Date	Instructing FHV

* Teaching periods (equivalent to 45 minutes)

Annex 8

Model certificate: Fachkundige Person Hochvolt (FHV) Level 2S

Certivicate 2S

Ms. Jill Smith

E-Mobility Dealership, 17 Anystreet, 77777 Anytown

attended the following training course on DD.MM.YYYY until DD.MM.YYYY

Fachkundige Person Hochvolt (FHV) Level 2S

The participant followed the course of training and passed the examination.

The participant satisfies the primary conditions for successful participation by virtue of his or her comprehensive basic electrical knowledge obtained through his or her initial and further training in the automotive sector and demonstrated in a preliminary test.

Topics to be taught *(can also be stated on the reverse):*	TP*
Specialist and people management responsibility	
Electrical hazards and first aid	
Measures for protection against electric shock and fault arcs	
Organization of safety and health regarding electric work	
HV concept and vehicle technology	
Practical exercises: • Perform isolation procedure on vehicle • Enter here the specific HV systems, on which practical training was performed. • Diagnostics and measurement instruments, as well as their practical use for different measurement methods (e.g. insulation tests, tests of the continuity of the potential equalization) •	
Total scope of training	XX

This training measure equips the participant to work independently and safely on vehicles with high voltage systems. Such work includes application of the five safety rules, the replacement of HV components such as air-conditioning and oil pumps in the non-live state and troubleshooting on non-exposed HV components including the use of test adapters proof against electric shock hazards. The participant is able to assess the work with which he or she is tasked, to recognize possible hazards, and to take the protective measures necessary for the HV system concerned.
This training measure satisfies the minimum requirements of the DGUV Information 209-003.

Party responsible:

Place	date	Training Course

* **Teaching period (equivalent to 45 minutes)**

Regulations, codes, literature

1. Statutes, regulations, technical rules

Available from:
Bookshops, the Internet: e. g. www.gesetze-im-internet.de

- Arbeitsschutzgesetz (ArbSchG) (German Safety and Health at Work Act)
- Betriebssicherheitsverordnung (BetrSichV) (German Industrial Safety and Health Ordinance)
- Technische Regeln für Betriebssicherheit (TRBS) (Technical rules for industrial safety and health)

2. Occupational safety and health regulations, rules and informative documents

Available from:
Your responsible accident insurance institution
or from www.dguv.de/publikationen

DGUV Regulations

- DGUV Regulation 1 „Principles of Prevention“
- DGUV Regulations 3 and 4 „Electrical installations and equipment“

DGUV Rules

- DGUV Rule 109-009 „Fahrzeuginstandhaltung“
  (DGUV Rule governing vehicle maintenance)

DGUV Informative publications

- DGUV Information 203-002 „Elektrofachkräfte“ (DGUV Information governing qualified electricians)
- DGUV Information 203-034 „Errichten und Betreiben von elektrischen Prüfanlagen“ (DGUV Information governing installation and operation of electrical test facilities)
- DGUV Information 203-077 „Thermische Gefährdung durch Störlichtbögen“ (DGUV Information governing thermal hazards caused by fault arcs)
- DGUV Information 204-022 „Erste Hilfe im Betrieb“ (DGUV Information 204-022 governing first aid in companies)

Fachbereich AKTUELL

- Gasantriebsysteme in Fahrzeugen – Qualifizierung für Arbeiten an Fahrzeugen mit Gasantrieb“ (FBHM-099) (FBHM-099 governing vehicles with natural gas engines and qualification for work on vehicles with natural gas engines)
- „Instructions for lithium-ion battery firefighting in vehicle fires” (FBFHB-024)

3. Standards/VDE provisions

Available from:
Beuth-Verlag GmbH, Burggrafenstraße 6, 10787 Berlin or
VDE-Verlag, Bismarckstraße 33, 10625 Berlin

- DIN EN 50191 (VDE 0104): 2011-10
  „Erection and operation of electrical test equipment“
- DIN EN 60204-1 (VDE 0113-1): 2019-06
  „Safety of machinery – Electrical equipment of machines – Part 1: General requirements“

- DIN EN 60529 (VDE 0470-1): 2014-09
  „Degrees of protection provided by enclosures (IP Code)“
- DIN EN 61112 (VDE 0682-511): 2010-03
  „Live working – Electrical insulating blankets”
- DIN EN 61140 (VDE 0140-1): 2016-11
  „Protection against electric shock – Common aspects for installation and equipment“
- DIN EN 61243-3 (VDE 0682-401): 2015-08
  „Live working – Voltage detectors – Part 3: Two-pole low-voltage type“
- DIN VDE 0105-100 (VDE 0105-100): 2015-10
  „Operation of electrical installations – Part 100: General requirements“
- DIN VDE 0100-600 (VDE 0100-600): 2017-06
  „Low-voltage electrical installations – Part 6: Verification“
- DIN VDE 1000-10 (VDE 1000-10): 2019-12
  „Requirements for persons working in the field of electrical engineering“
- ISO 6469-3:2018-10
  „Electrically propelled road vehicles – Safety specifications
  Part 3: Electrical safety“

4. Literature

- Regulation No 100 of the Economic Commission for Europe of the United Nations (UNECE)
  „Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train“
- Motor Vehicle Safety Standard 305 (FMVSS No. 305)
  „Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection“, National Highway Traffic Safety Administration (NHTSA), Department of Transportation
- Leaflet of the German Association of the Automotive Industry (VDA)
  „Accident assistance and recovery of vehicles with 48V and high-voltage systems“

Notizen

Berufsgenossenschaft
Holz und Metall

Isaac-Fulda-Allee 18
55124 Mainz

Internet: www.bghm.de

Zentralverband Deutsches Kraftfahrzeuggewerbe (ZDK)

Zentralverband Karosserie- und Fahrzeugtechnik e.V.

Land Bau Technik Bundesverband