29
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Safety in electric and hybrid vehicles

IN THIS ISSUE

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INTRODUCTION

The increasing accumulation of CO_2 in the Earth's atmosphere is the cause of the greenhouse effect that, together with the solar radiation, produces the global warming that has been observed in recent decades. Its consequences, such as climate change, are more and more evident, which alters the balance of ecosystems and thus threatens biodiversity and the continuity of life on Earth.

The international agreements that have been adopted to break and reverse this trend require the progressive reduction of CO_2 emissions, a great part of which are caused by the use of fossil fuels as energy sources.

This reduction requires the transition towards renewable energies and the increase of the energetic efficiency of consumers to comply with the goals of decarbonisation agreed upon for the different sectors of production. Transport is one of the most relevant sectors due to its direct and almost absolute dependency on oil derivatives.

In recent years, electrification has established itself as the only viable option in the long run to reduce CO_2 emissions required by the automotive sector, boosting the development of hybrid-drive or fully electric systems and the electrical energy storage or production that allow their mobility. All these vehicles, including hydrogen cell vehicles, share a common technical feature directly related to the performance and operating range required for their marketing and distribution: they are fitted with a high-voltage electrical system.

Regulation nº 100 of the United Nations Economic Commissions for Europe establishes the certification criteria regarding specific requirements for the electric drive trains to reduce the risks inherent to the high electrical voltage in the scope of normal usage of these vehicles.

According to this regulation, potential differences higher than 60V in direct current and greater than 30V RMS in alternating current are considered high voltage. Nowadays, operating voltages of electrical propulsion systems for passenger cars are between 150 and 800 volts, being 400 V the most common value.

Sales of electrified vehicles are increasing year after year, which is boosting the proportion of these vehicles on the roads and their presence in maintenance and repair workshops. Operations on hybrid and electric vehicles require specific actuation protocols to minimise the risk of electrocution inherent to the existing electrical potential, which may lead to extremely serious work accidents and even death if proper precautions are not taken.

It is obvious that maintenance, diagnostic and repair procedures cannot be considered normal use of the vehicle and, in many cases, require the direct manipulation of the high-voltage system components. However, as of today, there is not any common directive that contemplates the safety precautions needed to perform these operations.

In this legal loophole, manufacturers, standardisation bodies, and government entities have developed their directives. Currently, French standard **NFC 18-550** and German standard **BGI 8686** are the reference documents for the safety at work on hybrid and electric vehicles at the European level. Their development establishes the criteria for training, accreditation, working competencies, and protocols related to these high-voltage systems on motor vehicles up to 1000 V CA RMS and 1500 V CC.

Electrocution risk is concentrated on the components that work or conduct the high voltage and operations that require intervention in their surroundings. On hybrid vehicles, there is an additional risk derived from the operating temperature of the thermal engine and, on fuel cell vehicles, there are risks related to hydrogen as a chemical element and others derived from its storage at very high pressure.

ELECTRIC CURRENT AND HUMAN BODY

The electrical potential difference is imperceptible to our senses. Electricity is invisible and inaudible, it has no smell or taste and cannot be touched. And it should not.

The human nervous system and its entire activity, including the brain one, is based on carrying small electric currents or pulses that control vital functions, transmit sensitive information, and conduct orders, consciously or not, to the different organs of the body.

Excessive confidence in electricity increases its danger. Its presence in our daily life is as wide as the lack of knowledge about it and its effects on the human body.

The protective systems installed in the domestic supply networks prevent fatal accidents day after day, hiding the serious consequences that the circulation of electrical current through the organism can cause.

In the automotive repair and maintenance field, particularly, handling and repair of low-voltage wiring (12V) are usual, which generates a sense of safety that does not exist in high-voltage systems, and which is completely opposite.

The fuses placed in high-power electric propulsion systems protect components and circuits, but under no circumstances reduce the risk of electric shock. The working currents and voltages, together with the requirements imposed by mobility and circulation, make impossible the installation of differential switches or similar ones to reduce the risk of possible electrocution. It would imply reducing one risk and creating a new one.

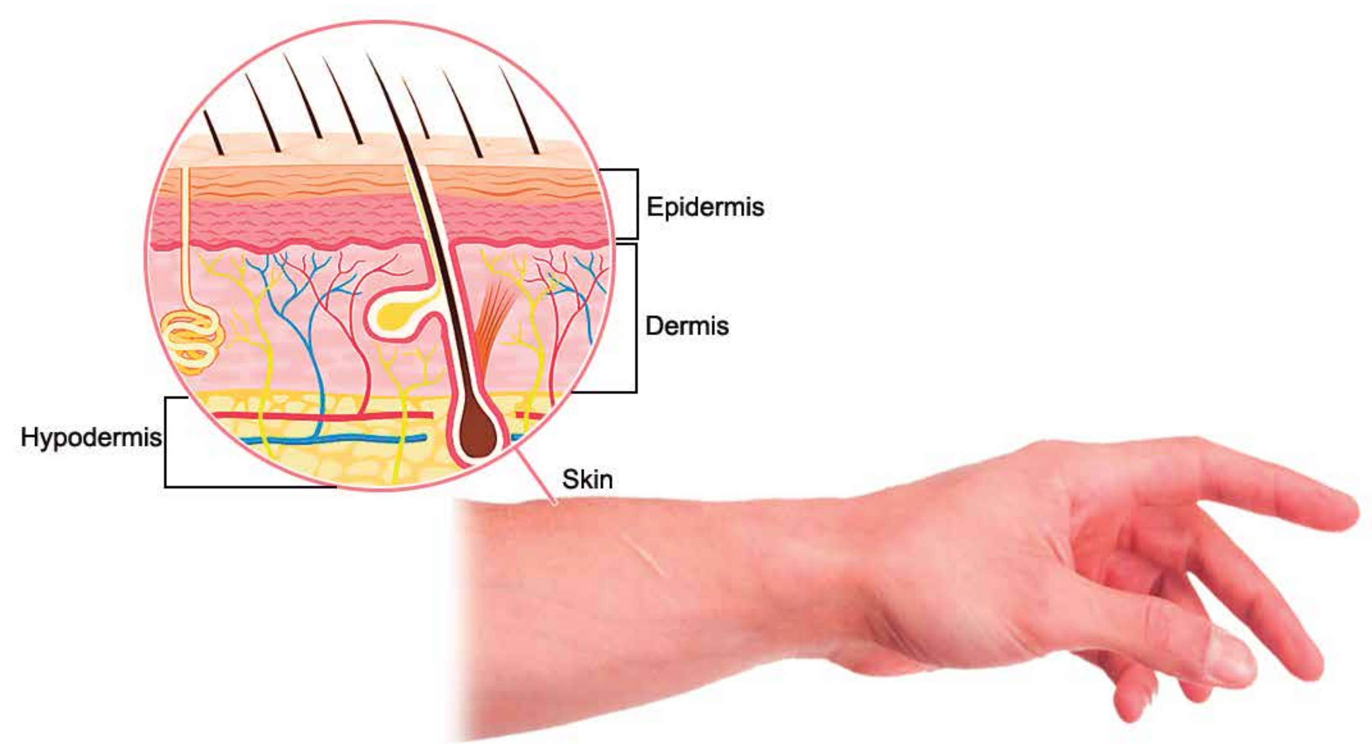
Electrocution is an electric shock or accident in which the circulation of electric current through the body of a human being or animal causes injuries. Electric currents are used, for example, for medicinal purposes and the recovery of muscles and nervous tissues. However, in this application, the current is controlled and does not cause damage to individuals.

Risks of electric current circulation through the human body are classified according to the nature of the factors that intervene in its development, particularly in its intensity.

Factors Attributable to the Human Body

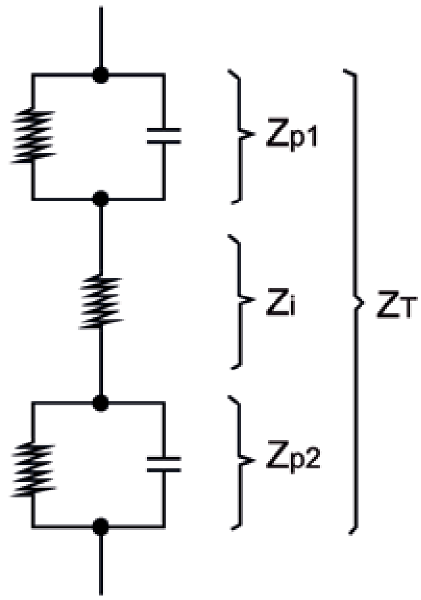
The human body has a complex electrical conductivity. It is not considered an insulator or a good conductor, as its tissues offer a variable impedance to the passage of electrons, mainly depending on the voltage difference.

Its initially low electrical conductivity can be compared with the one of the dielectric materials. The first layers of **the skin**, and more specifically the epidermis and dermis, insulate the body from the external environment, also at the electrical level.



The **impedance** of the organism towards the electric flow is caused by the combination of the capacitive and resistive effects of the elements that form the different parts of the body (blood, musculature, skin…). The total body impedance (Z_T) is the sum of the three impedances in series:

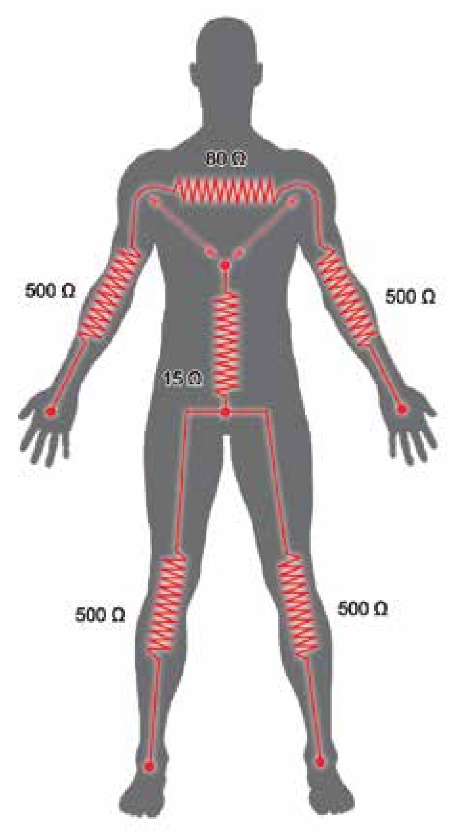
- Z_i = Internal body impedance (trunk and/or extremities).
- Z_{p1} = Skin impedance in the input area.
- Z_{p2} = Skin impedance in the output area.



Internal impedance is due to the organs and tissues that are situated under the skin, in the trunk and/or extremities, and it depends on the way the initial contact with the potential difference is produced. Lower impedance corresponds to the trunk, while extremities (arms and legs) are the ones that offer the highest impedance. The impedance of the head corresponds to one fifth of a limb (approx. 100 Ω)

Skin impedance is represented as a capacitor in parallel with a resistor to indicate the capacitive behaviour of the dermis and the resistive effect of the epidermis.

A thick and dry skin represents a resistance of up to 1,000,000 Ω, while for moist and thin skin, the ohmic value is reduced to 1,000 Ω. If the most superficial layer is worn or damaged, the value can be reduced to approximately 500 Ω, increasing the risk of electrocution as the internal elements are more unprotected. The blood, lymph and the other liquids that impregnate the internal tissues offer a higher conductivity than the skin.



The capacitance of the skin tissue is reduced with moisture and with the intensity of the electrical flow. Since the skin can be easily pierced by the electric current, the subjacent impedance of the capacitive effect of the dermis is usually not considered and the average resistance of the human body for hypothetical or theoretical calculations is fixed at approximately 1000 Ω.

The **resistance of the contact points** with the difference in electric potential (current input and output) depends on highly variable factors. The electrical contact in sweating conditions or through a wet surface will offer lower resistance than if it is produced with dry skin and clothes. Likewise, the larger the contact surface, the lower the initial resistance. This phenomenon becomes less relevant with the increase of the voltage difference.

Factors Attributable to the Power Supply

The seriousness of the injuries in an electric accident depends on the current intensity that circulates through the body and its path.

According to **Ohm's law**, the intensity of the electric current is the result of the difference of potential or voltage depending on the resistance that the matter offers to the circulation of electrons. Taking into consideration the resistance of the constant body, the higher the voltage difference, the greater the current intensity and the higher the probability of injuries or their seriousness.

Intensity = Voltage / Resistance

The magnitude of the current that circulates through the human body is always approximate, as it depends on the physiology of each organism and the type of current. Current values referred to as normal are valid statistical parameters for most people.

The nature of the electric current itself, direct or alternating, is a determining factor when talking about the danger of an electric accident. Skin impedance towards the direct current is greater than the one toward the alternating current, which influences the frequency as well.

High-frequency currents **are less dangerous than low-frequency ones.** For example, for frequencies above 100,000 Hz, the affectation on the body is limited to the heating of the skin (by the Joule effect) without any alteration on the nervous system, since the electrical conduction is more frequently produced through the skin than inside the body due to its capacitive behaviour.

For frequency currents lower than 10,000 Hz, the danger is comparable to that of a direct current of the same intensity. However, **alternating currents of very low frequency are considered 4 times more dangerous than direct currents of the same power.**

Without going any further, the current of the electrical network in Europe is 50 Hz (60 Hz for the American continent), being this frequency in combination with the domestic supply voltage of 220V potentially fatal due to the alteration produced on the drive system and the activity of the heart in case of electric shock. Luckily, differential switches, which are obligatory in all legal distribution facilities, cut the current when the intensity of the current phases does not correspond to the neutral phase.

The risk in hybrid and electric vehicles is more related to direct current rather than alternating current. The accumulation of electric charges is only possible using differences in the potential of constant polarity, and recovery is always in the form of direct current. Energy storage in batteries is the only viable option for free mobility vehicles, being even necessary for fuel cell vehicles. The capacity and output voltage of high-voltage automotive batteries are in all cases enough for producing lethal currents.

Generally, high-voltage alternating currents in these vehicles are only used to supply and regulate the operation of traction electric motors and the actuation of the air conditioning compressor.

Indirect Factors Related to the Accident

The magnitude of the electrical risk is proportional to the seriousness of injuries in case an accident occurs. When they are predictably insignificant, the risk is low. If they can be serious, the risk is high. And if they are life-threatening, the risk is maximum.

The non-electrical factors that modify the risk are several. Variables such as the electricity's path through the body, the time of exposure, or the injuries resulting from the electric shock (blows, falls, loss of consciousness, etc.) increase the risk due to their influence on the consequences of the accident if it were to occur.

The **current path** through the body is decisive. Current will always follow the easiest circuit, this being the combination of the lowest resistance and path length.

Its effects will be more or less dangerous depending on the affected organs. The risk is higher when the left hand is an input or output point since the path usually affects the heart directly.

The **time of exposure** or current circulation through the body results in aggravated injuries, thus increasing the risk. It is calculated from the moment of contact with the electrical voltage difference until the circuit opening takes place (if it occurs). Depending on the current intensity and the affected muscle groups, the voluntary release and interruption of the electrical flow are not possible autonomously or reflexively due to the saturation of the nervous system and the contraction of fibres.

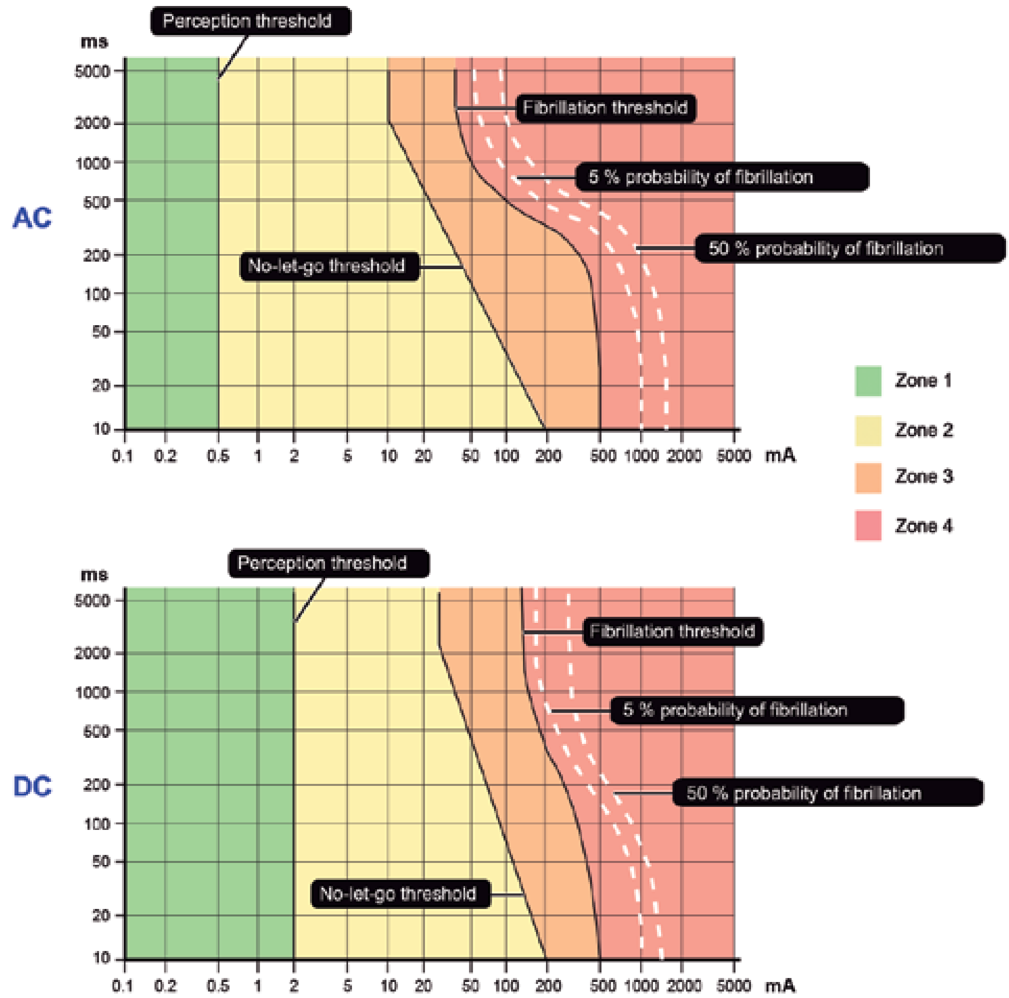
For an alternating current with an intensity of around 100 mA, heart fibrillation is produced causing arrhythmia or cardiac arrest if the time of exposure of the organ reaches 500 ms. In case the person survives, injuries are usually irrecoverable.

EFFECTS OF THE ELECTRIC CURRENT ON THE HUMAN BODY

Electric current effects on the human body range from the perception of a slight tickle to death due to several causes. Generally, they affect respiratory and circulatory functions caused by the overstimulation of the nervous system, being burns and internal bleeding also common.

A current higher than **30 mA** is enough to cause irreversible damage if the person is not helped in time. When the current reaches **50 mA**, it affects the heart and death is quite probable.

The danger of the electric current depends on the intensity, path and time of exposure to it. The next graphs show the effects of the alternating and direct current depending on the intensity and conduction time. They are divided into 4 zones delimited by physiologic thresholds.



- **Zone 1:** It is a safety zone where no sensation is perceived and no reaction is produced no matter how much time passes.
- **Zone 2:** It comprises from the perception threshold to the no-let-go threshold. Generally, there is no dangerous physiological effect directly related to the electrical current, although there are risks derived from or by the reaction.
- **Zone 3:** It starts from the no-let-go threshold and ends at the fibrillation threshold. Usually, it causes no damage to the organs. In direct current, with the increase of the intensity and time of exposure, there is a possibility of reversible alteration of the rhythmic operation of the heart. In alternating current, moreover, muscular contractions and breathing difficulty occur, with the possibility of atrial fibrillation and temporary cardiac arrest.
- **Zone 4:** It starts at the ventricular fibrillation threshold (due to the high risk of suffering from this phenomenon). Most of the effects of the third zone appear in direct current, including the possibility of severe burns that increase when time and intensity rise. As to the alternating current, the effects of the 3rd zone intensify, being particularly severe the cardiac and respiratory arrests, which in this case are irreversible without external stimulation.

Direct Effects

Direct effects are those that are directly produced by the electric current circulation through the body. They depend to a greater degree on the intensity than on the time of exposure, and can be classified in the following way:

Muscle and Nervous Effects

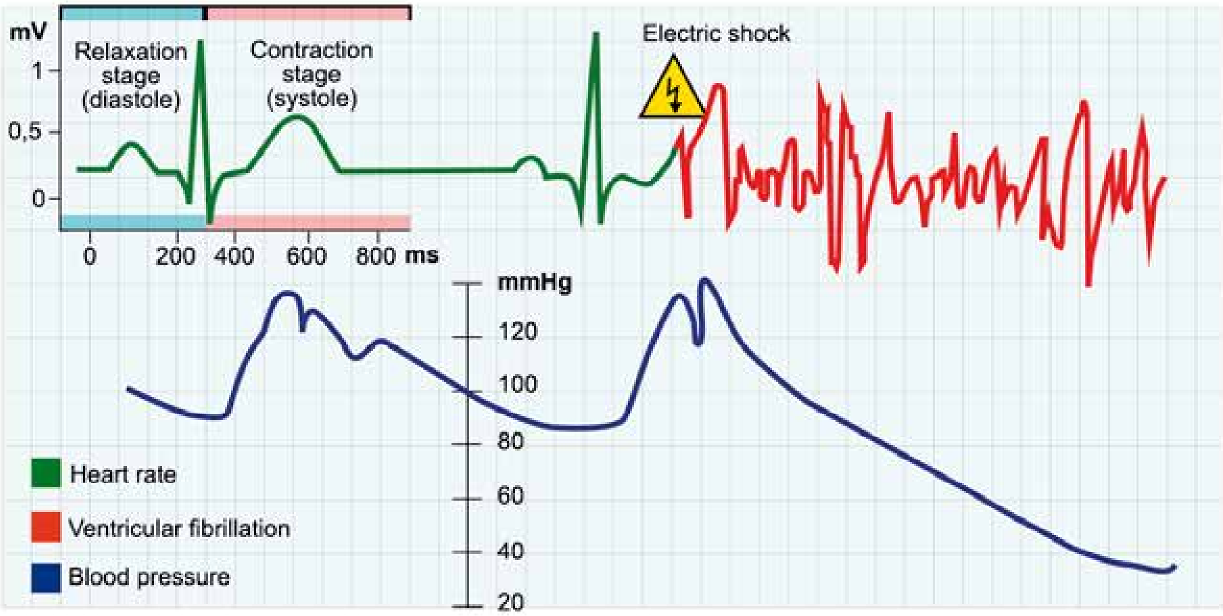
Tingling and cramps: These are sensations that can cause reflex movements due to their affectation on the nervous system when the current intensity is between 1 and 10 mA. In principle, there is no danger for the person and contact can be maintained without any problem.

Muscle entrapment or tetanisation: Body muscles react in an uncontrolled way due to the cellular overstimulation caused by the electric current. The forced and repetitive muscle contraction/relaxation induces after a short while a permanent contraction condition known as tetanisation. This stiffness results in total or partial motor disability, depending on the current path.

Respiratory arrest: Sensory alteration impedes the gas exchange in the alveoli of the lungs, in a way that the individual is not able to expel the CO_2 resulting from the cell activity, which leads to their accumulation in the lungs and blood. If this condition is prolonged, it causes loss of consciousness that may end in irreversible brain damage or death if the person is not helped in time. This condition is recognised by the bluish colour of the lips or mucosa (cyanosis) and the rapid and weak pulse.

Choking: It is the suspension or difficulty in renewing the air contained in the lungs that the passage of electric current generates (from 25 to 30 mA) through the thorax and which affects the muscle masses that are in charge of the breathing movements (mainly pectorals and large dorsal muscle). The tetanisation of the diaphragm also impedes the gas flow.

Ventricular fibrillation and heart failure: It occurs when the electric current passes through the heart's lower chambers and disturbs the heart rate. The disordered and poorly synchronised ventricular contraction and relaxation impede the pumping and blood circulation to the rest of the body, causing death if the person is not helped in time. The most common symptoms of ventricular fibrillation are brain collapse and loss of consciousness.



Cardiac arrest: The electric current passes through the heart, which impedes the nerve response of the organ and interrupts its activity as well as the blood flow circulation. Without immediate aid, it causes death, brain death first and absolute death later.

Thermal Effects

Burns: Part of the electrical energy is transformed into heat, by Joule's effect, when electrons of the electric current circulate through the outermost orbits of the conducting atoms. The excessive heating of the conducting tissue and its adjacent tissues causes burns.

These injuries can be external or internal and of different seriousness depending on the current/section ratio (mA/mm²) of the electric current and the time of exposure. Internal damage is mainly due to the predominant circulation of current through the nerves and blood vessels, which damages and destroys these tissues. External damage concentrates on the skin, which separates from its support due to dehydration.

Burns can also occur without contact, by an electric arc. Depending on the current energy, the damage can be extremely severe in the current input area.

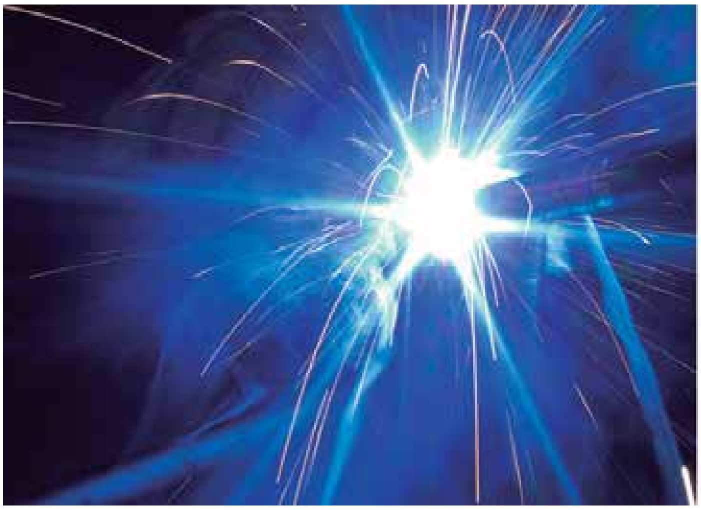
Other Effects

Electrocution, particularly if prolonged, may also cause secondary effects, some of them delayed. Circulatory problems (gangrenes) and kidney failure are frequent. The toxic effects of the burns reduce the metabolic capacity of the kidneys. There is also the possibility of suffering from brain damage or strokes due to the blockage of the blood vessels. On occasions, mental disorders of neurotic type appear after the accident.

Indirect Effects

Injuries that occur as a consequence of the electric accident, but which are not inherently caused by the current circulation through the body, are considered indirect effects.

Ophthalmological injuries by radiation, contusions and wounds derived from the reflex action or muscle contraction caused by the current, and fractures suffered from falls or blows are some of them. In the case of cars, if electrocution occurs while driving, this may lead to other road accidents, which are usually severe and with a high probability of affecting third parties.



ELECTRICAL AND CHEMICAL RISKS

The possibility of circulation of the electric current through the human body, which may cause injuries or damage is considered an **electrical risk**. The existence of risks depends on two types of constraints: the physical and the physiological ones.

The physical conditions required for the electric circulation to occur are:

- The existence of an electric circuit comprised of conductor elements.
- The circuit must be closed or there must be the possibility of being closed.
- The electric potential difference must be greater than zero.

In order for the electric circulation through the human body to occur, the following physiological conditions must be met:

- The person or part of him/her must be a conductor element (if not protected).
- The body must be in contact with the circuit.
- The voltage difference between the points of contact with the body (input and output) must be higher than zero.

The contact with the electrical current is considered direct when it occurs on an element, which is predictable to be live and indirect when it occurs on an element that is usually not live (insulation fault or accidental derivation). The first case is considered negligence.

Hazards arising from electricity are excessive electric current, induction and electric arcs.

The **chemical risk on electrified vehicles** is mainly located in batteries, both high-voltage and low-voltage batteries. This is because they are manufactured with highly reactive chemical elements and because of the corrosive and flammable character of electrolytes. For safety reasons, it is convenient to perform a visual inspection of the condition of the batteries before manipulating them. The aim is to discard deformations, damage or losses. Risks associated with batteries are the emission of harmful gases, smoke, dust, the spill of corrosive fluids and explosions.

COLLECTIVE PROTECTIVE EQUIPMENT

When it is impossible to eliminate or contain the risks in their origin, in the propagation medium or at an organisational level, the implementation of preventive and protective measures is the only option to reduce risks. These measures are studied to prevent accidents and reduce their consequences. The objective of the collective protective equipment is to **protect individuals from risks** that are present at work, either because of the nature of the activity performed or the environment itself. Their application is essential to impede accidents in series, so they should be considered a priority. An example of collective safety measures and elements are the signalling of fire-fighting equipment to make its location easier, if necessary, the installation of protective railings on different-level floors to prevent falls or the arrangement of non-slip strips on the stairs.

Safety Signalling

Safety signs inform about the existence of a risk, the actions that can increase the risk or the actuation and the protective methodology against it. Five types of signs with different colours and shapes can be found:

1. **Warning:** These signs alert about the existence of a risk and indicate its typology and danger. For example, on an electrical panel or on a high-voltage battery, a warning panel is placed to indicate the electrical risk derived from the high voltage.
2. **Prohibition:** They indicate that certain actions that increase the risk are not allowed.
3. **Obligation:** These signs impose a particular behaviour or specific equipment in the zone, for example, the obligation of accessing the workplace with the required personal protective equipment (gloves, shoes, helmets, etc.).
4. **Rescue and relief:** They indicate safe exit routes and other relevant information in the event of an accident (first-aid kit, defibrillator, decontamination area, etc.)
5. **Equipment for emergencies:** They indicate the location or address where the emergency equipment is placed, such as the fire alarm button or fire hoses.

Signalling at the workplace must be kept in good condition and positioned according to specific regulations, seeking the maximum visibility of signs. The pictograms and colours used transmit a lot of information instantaneously, eliminate language barriers and can be read at a greater distance than text indications.

Fire Protection

Fire-fighting measures have the mission to detect and extinguish or limit the spread of fires in the work environment. The initiation of a fire requires three fundamental factors: a **fuel** (in liquid, solid or gaseous state), a **comburent agent** (the oxygen of the air) and a **heating source** (a spark, a burning cigarette, etc.). The work environment provides the first two factors and the possibility of sparkles or electric arcs is proportional to the voltage difference.

For a particular environment, the transfer speed of the fire depends on its temperature, and the time elapsed between the detection and the beginning of the extinction is essential to reduce fire potential and danger. It is important to have appropriate material components and the most efficient ones for the extinction, usually an extinguisher. Extinguishers must be placed in an accessible manner on fixed surfaces free of obstacles (the distance from the upper part to the ground must be between 80 and 120 cm). They must be placed near the zones of risk and evacuation exits.

The **extinguisher** is a piece of equipment that stores in its inside a substance under pressure (extinguishing agent) for its remote projection. The internal pressure is achieved by initial compression, chemical reaction or a mixture with additional gas. There are several extinguishing agents whose chemical composition is more effective against a specific type of fire or fuel.

Depending on the origin of the fire, 5 types of fire can be found:

- **Class A:** These are fires that involve solid materials like paper, cardboard, wood, plastic, textiles, etc.
- **Class B:** These fires are started by liquid flammable substances such as fuel, paint or oil. The use of water is prohibited to quench them. Carbon dioxide, dry powder or a specific type of foam must be used instead.
- **Class C:** These are fires that involve gaseous substances like butane, natural gas, methane…
- **Class D:** These are fires that involve metals like aluminium, sodium, magnesium, potassium, etc.
- **Class F:** These fires are started by cooking ingredients such as fats, oils, etc.

Extinguishers can be classified according to the agent used:

- **Water extinguishers:** Only suitable for class A fires.
- **Powder extinguishers:** There are three types: powder against reignition is effective against class A, B, and C fires, dry powder against class B and C fires and special powder against class D fires.
- **Foam extinguishers:** Mainly indicated against class B fires. Physical foam or chemical foam extinguishers can be found. They can be also used for solid materials such as wood, paper, textiles, etc.
- **CO_2 extinguishers:** Indicated against small class B fires and fires in electrical installations.

The **powder extinguisher** (hydrogenated sodium bicarbonate) and the **CO_2** extinguisher, also known as carbonic snow, are suitable for extinguishing flames in electrified vehicles.

Depending on the volume of the extinguisher, the impulse or work capacity is between 8 and 60 seconds. The correct working mode of the extinguisher can be found on its label, as well as some precautions that should be taken into account. Generally, the agent must be projected on the basis of the closest flames, maintaining sufficient continuity.

In any case, emergency services (fire department) should be called to extinguish the fire. In case of danger, move away in the opposite direction of the fire and the wind.

Insulated Tools

Tools are considered part of the work environment and part of the collective protective measures.

Insulating hand tools must be used when working on the high-voltage systems of electrified vehicles and their surroundings up to 50 cm (danger zone). They must have the corresponding approval marking according to **IEC 60900 standard**, which includes the **double triangle** symbol and a maximum voltage of **1000 V.**

It is convenient to visually inspect the insulated tools before using them, especially the lining of the handling surface to ensure their proper condition and operation.

The use of these tools does not exempt from using the necessary personal protective equipment (insulating gloves, work clothing, appropriate footwear, etc.). As far as possible, work should be carried out with no voltage.

Rescue Stick

The rescue stick is used in rescue operations for people in electric shock conditions or people that are still in the risk zone. The stick prevents the rescuer from chain electrocution during the rescue manoeuvre.

It must be located in a dry and easily accessible place. Moreover, it must be kept in a good state of conservation and free of bonded dirt, as it may reduce the insulation. The rescue without the necessary protection measures involves a high risk of becoming part of the electrical accident or suffering another accident derived from it.

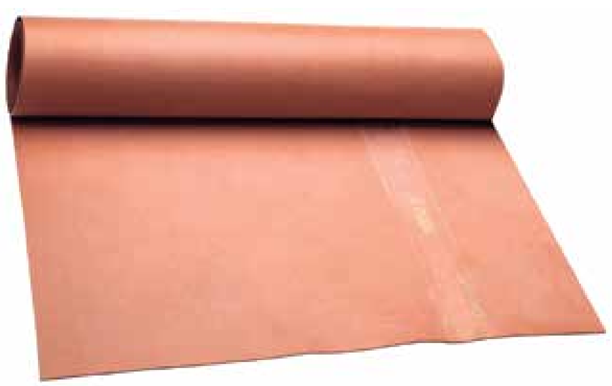
Insulating Bags, Mats and Shields

Insulating bags or covers, normally made of transparent polyvinyl, are used to cover high-voltage terminals and connectors during repairs. This prevents accidental contact with them and reduces the risk of electrocution.**Electrical insulation mats** are placed on the ground surface to insulate it from the earth's zero potential, which due to its enormous mass allows the conduction of electric current with great ease. They must comply with the requirements of the UNE- EN 61111 standard and have a protection voltage higher than the maximum voltage of the vehicle. They are obligatory if specific high-voltage footwear is not used.

Furthermore, they can be used to insulate tables and workbenches when used as a support for batteries or other components that can store high voltage.

Insulating shields or blankets are aimed at protection against accidental contact with high-voltage live parts or components. The recommended ones are class 0 with protection of up to 1500 Vcc and that comply with the UNE-EN 611112 standard.

The three above-mentioned elements reduce risks in the work environment and are part of the collective protection measures.



It is important to visually inspect insulating bags, mats and shields before using them so as to detect possible perforations, deformations or oil or acid contamination. Likewise, the manufacturer's recommendations for maintenance and conservation must be followed.

PERSONAL PROTECTIVE EQUIPMENT

Personal equipment protects the person wearing or holding it from one or several hazards, reducing the risks that may affect their safety or health. PPE's use is compulsory when preventive, technical and organisational measures cannot reduce or eliminate the risks that are present in the work environment.

The employer must provide the employee with the appropriate PPE when there are foreseeable risks in performing the assigned work, bearing in mind the following considerations:

- To identify the type of risk and the exposed parts of the body.
- To determine the PPE's required characteristics for the protection of the user, ensuring that the PPE does not hinder or is not an obstacle to the performance of the work and taking into account the magnitude of the hazard and the environmental conditions.
- Supplied PPE must comply with the existing approval regulations, it must be duly certified and not expired.
- To have in mind the features of the operator (physical and physical conditions, state of health, height, etc.).
- To take into account the job characteristics (if special or training skills or physical effort are required, etc.).
- If different PPEs must be combined, they must be compatible and risk efficient.

All PPE must have the manufacturer's information brochure where relevant information for the user is detailed (technical features of the equipment, storage, instructions for use, maintenance and cleaning, etc.)

The PPE that is valid within the EU territory has the CE marking, which certifies that they comply with the Regulation (EU) 2016/425 of the European Parliament and of the Council on personal protective equipment. Depending on the risk of exposure, PPE can be classified into three categories (I, II, III). The first one offers protection against non-serious risks, the second one protection against medium to high risks and the third category against very serious or even risks of death (in the event of the PPE aimed at high-voltage handling).

The PPE for complete protection against the high voltage of the electrified vehicles are as follows:

Insulating Gloves

They protect the operator up to the forearm from the high voltage. Their characteristics and selection depend on the maximum voltage of the system to be manipulated.

In automotive applications, beige class 00 insulating gloves, which protect up to 750 volts in direct current and 500 volts in alternating current, may be sufficient. However, for systems with higher voltage, red class 0 insulating gloves must be used. They are valid up to 1500 volts in direct current and 1000 volts in alternating current.

The gloves' suitability for high-voltage operations is determined by the presence of the double triangle on the insulating material, the class and maximum insulation voltage according to the regulation and the CE marking together with the identification code of the certifying body.

If possible, gloves should never be used as the only protective element. They must be worn over flame retardant gloves if there is a risk of an electric arc and whenever possible under the mechanical protection gloves to prevent damage to the insulating material.

Insulating gloves must be visually inspected before each use and manually checked for leaks in the following way:

1. Lay the glove flat on one side.
2. Roll the opening of the glove over itself three times and observe that the glove inflates progressively.
3. Fold the fold in half to ensure that the glove is airtight.
4. Bring the inflated glove close to your ear and press it with your hand to detect any possible air leaks.
5. If there is an air loss, the gloves must not be used and must be discarded.

Insulating Footwear

Insulating shoes protect against a possible electric shock caused by electrical conduction to the floor or ground, whose electric absorption capacity is considered maximum due to its enormous mass.

Like insulating gloves, the footwear required in the automotive sector can be class 00 or 0 and must meet the same measures of approval and identification. It differs from conventional safety footwear because of the non-metallic reinforcement and the other insulating materials used for its manufacture.

It is possible to wear insulating shoes or dielectric overshoes that, as their name suggests, are placed over the usual footwear.

Footwear must be kept free of moisture and dirt accumulation. Moreover, a periodic visual inspection must be performed to check its good condition, paying special attention to the integrity of the sole.

The use of specific footwear can be replaced with an insulating mat of a suitable size to sufficiently cover the surface of the work area. The characteristics of the electrical insulation and identification must be equivalent to those of the footwear, exceeding by themselves and separately the maximum working voltage of the vehicle electric system.

Insulating footwear

Dielectric overshoes

Arc-Flash Face Shield and Insulating Helmet

The aim of the **helmet and face shield** is to protect the operator against arc flash discharges or accidental contact with high-voltage systems when working. Both elements also comply with the protection against temperature and ultraviolet radiation burns.

Helmet use is imperative in the disassembly and repair procedures of the vehicle underbody when the high voltage has not been disconnected and particularly when the battery removal must be carried out from underneath the vehicle.

Work Clothes

In addition to being comfortable, work clothes must provide adequate thermal and mechanical protection. For operations on electrified vehicles, clothing must also offer enough resistance to electricity and fire. It is recommended to use cotton or man-made fibres resistant to flames. The fabric must not be acrylic and clothes must not contain metal parts, such as zips or buttons.

During operations, it is strictly forbidden to wear rings, pendants, earrings and personal metal objects that are in contact with the skin due to the risk of electromagnetic induction and electric arc.

LOCK-OUT TAG-OUT PROCEDURE FOR HYBRID AND ELECTRIC VEHICLES

By means of the lock-out tag-out procedure can be achieved a maximum reduction of electrical hazards. It basically consists in consigning the risk to the smallest space possible, in this case, the battery. It is an ordered procedure or sequence of actions, specifically designed for the maximum safety of the operator who carries it out and the working environment.

When it refers to motor vehicles, it comprises the following operations:

1. Identification
2. Signalling
3. Work area delimitation
4. Disconnection
5. Lockout
6. Verification

The lock-out tag-out procedure must be carried out on hybrid or electric vehicles only when it is possible and necessary, that is, as a previous step to the intervention in the vicinity of the high-voltage system, welding operations or if electrical type malfunctions are suspected, bearing in mind that diagnostic and check operations of the high-voltage system are not compatible with this procedure.

All operations must be performed by qualified, duly authorised personnel and under supervision at certain times.

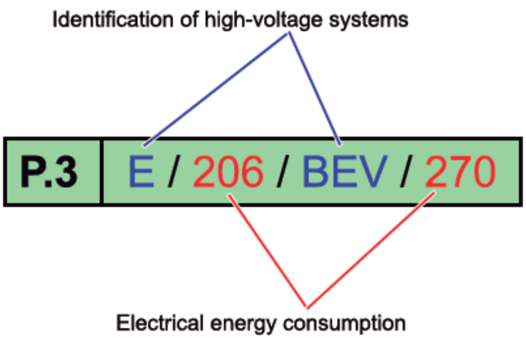
Identification

The existence of a high-voltage system in motor vehicles can be recognised directly or by consulting the vehicle registration certificate. Field P.3 of this document informs of the type of fuel or energy source for propulsion.

The vehicles fitted with high-voltage systems are identified by the letter E, followed by the electrical energy consumption in Wh/km. Additionally, by means of acronyms, the classification of the drive system can be shown. For example, **BEV** stands for battery electric vehicles, **REEV** for range-extended electric vehicles and **PHEV** stands for plug-in hybrid electric vehicles.

Visually, the presence of orange conductors under the front or rear hood and high-voltage warning signals are the most accessible elements of direct identification.

Código	Descripción
M.1	2700 / -------------- / --------------
M.4	------------------ /
L	2 / 4
L.0	- / ------------------
L.1	1 / delantero / no
L.2	4 · 205/55R16 86P-16X6 1/2J
P.5.1	Nissan
P.5	EM57
P.3	E / 206 / BEV / 270
P.1	0
P.1.1	------------------ / -
P.2	110
P.2.1	17.46
S.1	5
S.2	----------------------
U.1	----------------------
U.2	----------------------
V.7	----------------------
V.9	EURO AX



Signalling

After the vehicle has been identified as electrified, proof of it must be left, by placing the corresponding danger warning lights as visible as possible from all angles.

If there is an enabled or reserved area for this type of vehicle, it will be parked there. These operations allow to adopt specific measures in case of fire.

If the operations to be carried out require disconnection from high voltage, the work area must be delimited before performing them.

Work Area Delimitation

The purpose of delimiting the area surrounding the vehicle is to prevent access to this area by any unauthorised or duly qualified person, for their own safety and that of the operator who will disconnect the high voltage.

It consists in setting a perimeter of restricted access by using posts and chains of non-electrically conductive materials, leaving a sufficient separation with the vehicle to allow door opening and mobility around the vehicle.

The function of this perimeter is indicated by placing danger and prohibition warning signs that can be visible from any possible direction of approach.

It is recommended to have a rescue stick in the surroundings of the work area.

Disconnection

The existence of one or several easily accessible mechanical devices for the disconnection of the high-voltage accumulator is obligatory for high-voltage vehicles. The location of these disconnection devices can be consulted in the technical information from the manufacturer, in the vehicle rescue sheet (**http://www.rescuesheet.info/seite_3_es.html**) and in some cases in the user's manual.

Generally, in order to carry out the disconnection, the next sequence of steps must be followed:

- Disconnect the charging plug if the vehicle is connected to the network.
- Read and clear the fault codes of the vehicle related to the high-voltage system.
- Switch the ignition off. For vehicles fitted with a keyless access system, keep the transmitter in a place with exclusive access that is far away enough to avoid detection.
- Remove the negative cable from the service battery.
- Put on the PPE required for work with high voltage and request the supervision of a second operator before proceeding with the disconnection.
- Remove the service plug and, if possible, place a blind-off cap, insulating bag or mat in its position.

Download rescue sheet of various car makers here.

Lockout

The safety achieved after the disconnection must be maintained by protecting the high-voltage system against any accidental or unauthorised reconnection. For this purpose, the connector must be stored in a place with exclusive access for the person responsible for the lock-out tag-out or the required mechanical locking devices must be fitted and the key must then be kept using the same criteria.

Verification

After a reasonable period of time that is sufficient for the discharge of any possible residual currents, the absence of potentially dangerous voltages in the vehicle installation must be verified.

To do so, locate the control points specified by the manufacturer of the vehicle and perform the measurements indicated by it using an approved absence of voltage tester.

Generally, the required checks are as follows:

- Absence of dangerous voltage between the positive and negative terminals of the high-voltage accumulator connector.
- Absence of voltage between the negative terminal and the chassis of the vehicle.
- The same check on the positive terminal.
- Absence of dangerous voltage between the inverter output contacts.
- The same check must be performed between the inverter phase contacts and the chassis of the vehicle.

If necessary, these checks can be carried out with a conventional multimeter. However, always perform a previous and later check to ensure the correct measurement of the tool, both in alternating and direct current and check that a sufficient measuring range is selected.

After confirming that there is no voltage, it is recommended to indicate that the vehicle is in a safe condition, specifying the date and name of the person in charge of the lock-out tag-out procedure.

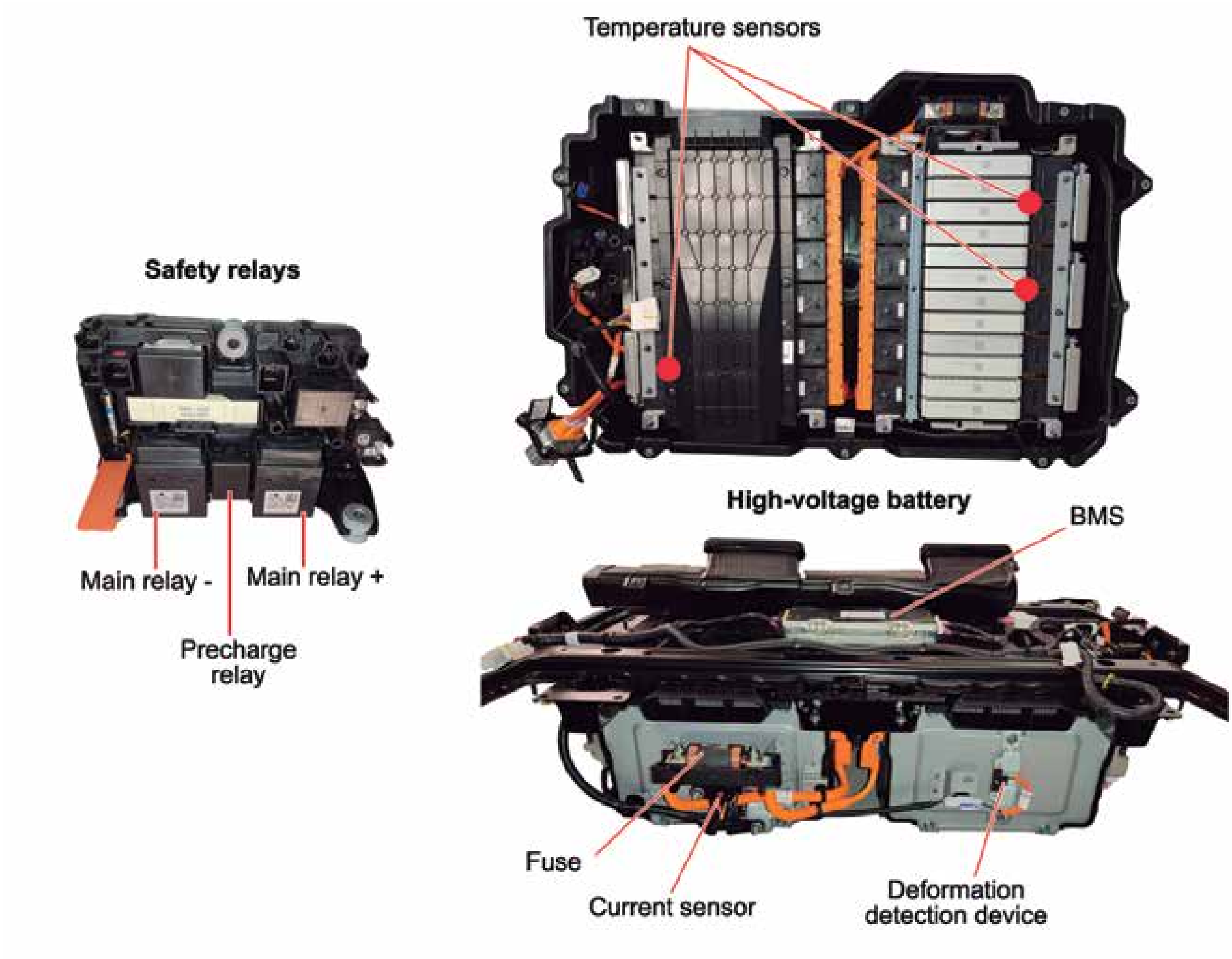
After this operation, the area delimiting elements can be removed and the vehicle will remain locked out and tagged out and ready for repair.

SAFETY ELEMENTS AND SYSTEMS ON ELECTRIC VEHICLES

Several safety strategies and measures have been implemented on electrified vehicles.

The working voltage of all control units and systems of the vehicles that do not require high electrical power at low voltage (12V) and the integration of high-voltage components in compact construction units allow to simplify the high-voltage wiring to the bare minimum and thus reduce the risks.

The approval regulation requires a system for monitoring the insulation and disconnection of the potential of the high-voltage battery to the chassis of the vehicle, which keeps the high voltage contained inside the battery when the vehicle is parked and impedes its connection if the insulation of the high-voltage installation is not enough.



Two normally open relays connect the battery terminals to the high-voltage supply installation of the drive equipment and the charger only when the vehicle is in the Ready or Recharge mode. The BMS manages the operation of the relays by following logic programming of the inner temperature, detection of leakage current and compliance of high voltage components and connectors. The automatic disconnection after the initial compliance test is only permissible in the event of an accident, at the request of the airbag unit depending on the severity of the impact.

The existence of these relays and their control systems maintain the vehicle in a condition that is equivalent to “lock-out” when the Parking mode is selected, and thus reduce the risk of electrocution to the battery space. However, it is a theoretical condition that has not been proven. There is always a possibility of a mechanical failure of the relays, which may remain connected or a possibility of a failure in the control system itself, so the lock-out tag-out procedure must be carried out manually and the voltage absence must be checked in all cases.

It is logical not to perform maintenance or repair procedures as there is an electrical risk, while the vehicle is being charged, as the high voltage is maintained and some systems of the vehicle are active.

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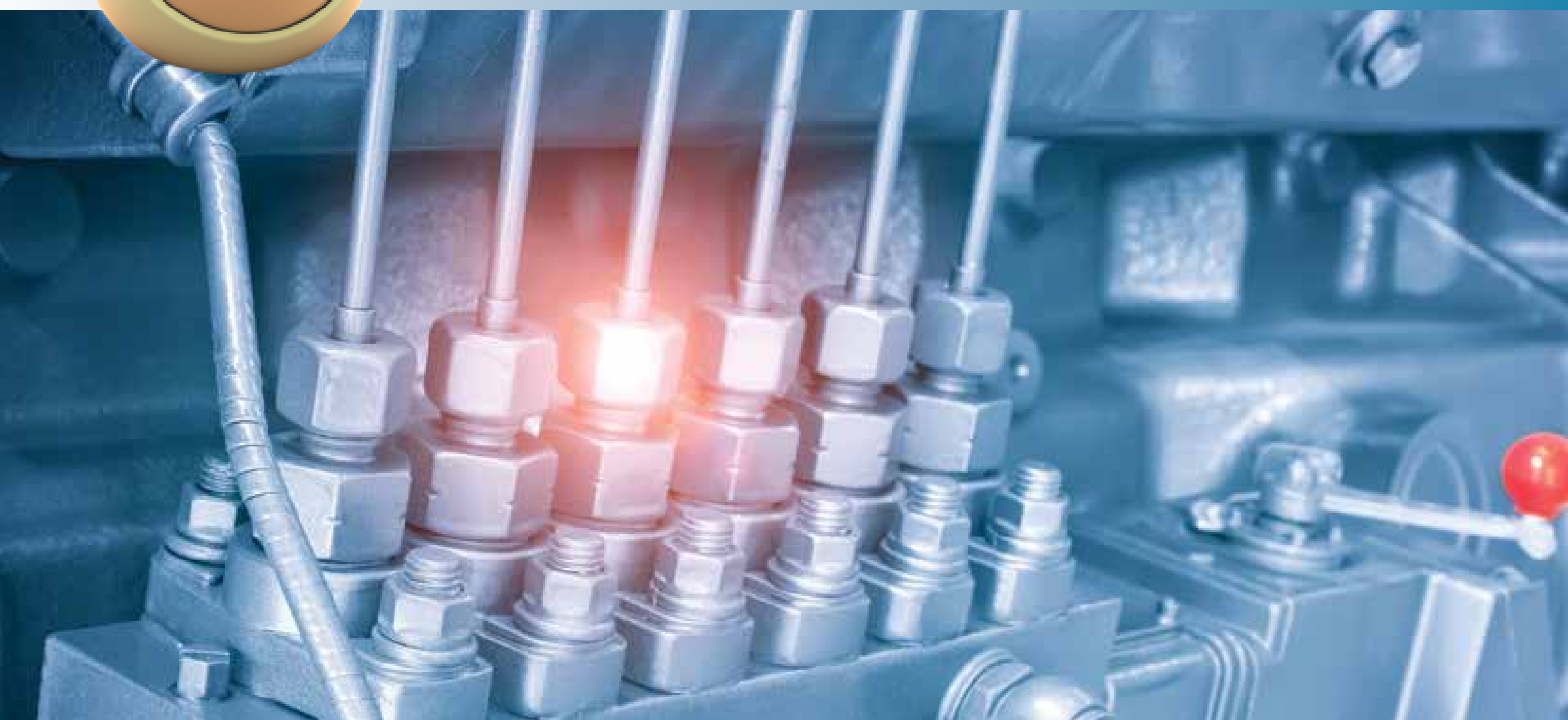

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