

6

Safety Standards for Stationary Batteries and Battery Installations

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6.1 INTRODUCTION

In Germany the generally acknowledged technical regulations are specified in the DIN standards (German Institute for Standards, Deutsches Institute für Normung). Specifically safety related standards must be observed providing for the protection of persons with reference to health and safety at work. In Germany safety related standards are classified as VDE regulations. The best known DIN VDE regulation for the “Erection of Electrotechnical Installations in Buildings” is DIN VDE 100, which has a “pilot function” and must be observed in general.

For batteries and battery installations DIN VDE 0510 applies ([Figure 6.1](#)). This VDE regulation includes the protective measures for avoidance of hazards and risks when installing and operating batteries. These practices are common in the following fields of application:

- Stationary battery installations.
- Traction batteries for electrical vehicles.
- Starter batteries in cars.
- On-board batteries in watercraft, rail, and road vehicles.
- Batteries for use in portable appliances.

6.2 SAFETY STANDARD DIN VDE 0510: “ACCUMULATORS AND BATTERY INSTALLATIONS”

In general the required measures specify how to avoid hazards and risks caused by

- Electricity.

GERMAN STANDARD		<i>Draft</i>	November 1996
	Secondary Batteries and Battery Installations Part 1: General	DIN VDE 0510-1	
DK 621.355-182.2		GERMAN STANDARD	July 1986
	Secondary Batteries and Battery Installations Stationary Batteries	DIN VDE 0510 Part 2	
DK 621.355:620.1:629.11-83		GERMAN STANDARD	November 1989
	Secondary Batteries and Battery Installations Traction Batteries for Electric Vehicles	DIN VDE 0510 Part 3	
GERMAN STANDARD		<i>Draft</i>	November 1996
	Secondary Batteries and Battery Installations Part 4: Starter Batteries in Motor Vehicles	DIN VDE 0510-4	
DK 621.355:629.11/.12:629.4		GERMAN STANDARD	<i>Draft</i> July 1991
	Secondary Batteries and Battery Installations Batteries Used in Ships, Rail and Road Vehicles	DIN VDE 0510 Part 5	
none		part 6	
DK 621.355		GERMAN STANDARD	August 1988
	Secondary Batteries and Battery Installations Application of Portable Batteries for Use in Equipment	DIN VDE 0510 Part 7	

Figure 6.1 List of published standards DIN VDE 0510.

- Electrolyte.
- Explosive gases.

resulting in

- Electrical protective measures, e.g. protection against direct and indirect contact.

Table 6.1 Survey of hazards and risks when operating batteries.

Hazard, risk	Potential of hazard
Electricity	High voltage and current, risk of short circuit
Electrolyte	Creeping currents (risk of fire), corrosion, caustic effects
Explosive gases	Hydrogen concentration >4% H ₂ vol. in air is explosive, sources of ignition

- Protective measures against corrosive and caustic effects of the electrolyte, e.g. sulfuric acid (H₂SO₄) in lead-acid batteries and potassium hydroxide (KOH) in NiCd batteries.
- Requirements regarding ventilation of rooms, cabinets, and enclosures where batteries are located.

Table 6.1 summarizes which individual measures must be taken in relation to stationary lead-acid batteries.

6.3 DIN VDE 0510 PART 1 (DRAFT): “GENERAL”

Part 1, “General”, precedes the safety standards for the different areas of battery application, specifying basic, generally applicable requirements, for example,

- Nominal voltage of commonly used primary and secondary battery systems (Table 6.2).
- Preferred areas of application of different battery designs.
- Charge characteristics, limit values for charging currents, recharge time periods.
- Modes of operation (Figure 6.2).
- Electrical protective measures including cross-reference to pilot document DIN VDE 0100 Part 410.
- Reference values for currents and voltages for charging equipment relevant to the specific charging characteristics (Table 6.3).

Table 6.2 Nominal voltage of commercial secondary battery systems.

Designation	Electrodes +/-	Electrolyte	Nominal voltage	Gassing voltage
Lead-acid battery	Pb/PbO ₂	H ₂ SO ₄	2.00 V	~ 2.40 V
Nickel-cadmium battery	NiOOH/Cd	KOH NaOH (gas tight)	1.20 V	~ 1.55 V
Nickel-iron battery	NiOOH/Fe	KOH	1.20 V	~ 1.70 V
Silver-zinc battery	AgO/Zn	KOH	1.55 V	~ 2.05 V

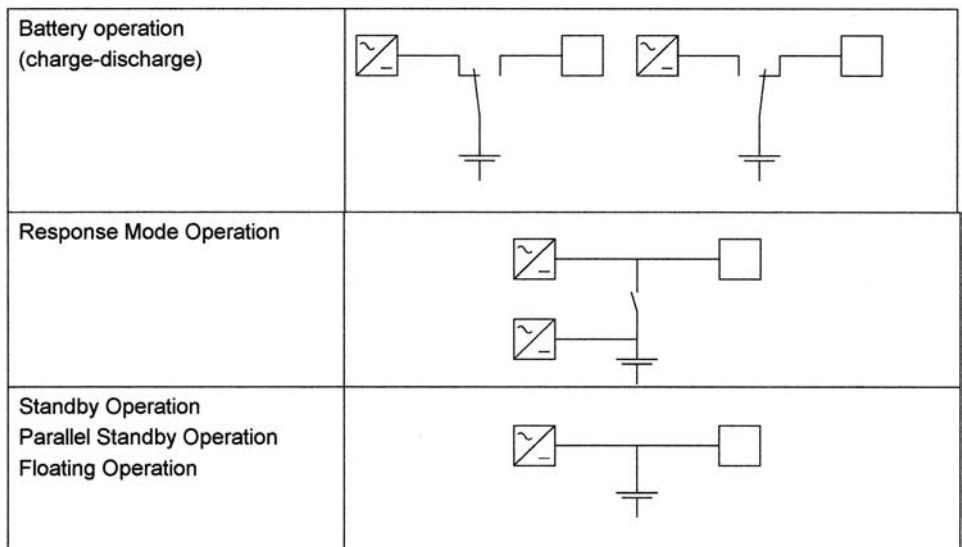


Figure 6.2 Modes of operation.

6.4 DIN VDE 0510 PART 2: “STATIONARY BATTERIES AND BATTERY INSTALLATIONS”

Some measures will be explained, e.g. in the case of stationary batteries providing an effective protection against hazards and risks during erection and operation of battery installations.

6.4.1 Hazards Caused by Electricity

Protective measures against direct and indirect contact (electric shock) are required depending on the battery nominal voltage and the chosen ground system of the electric network (Table 6.4). In the case of a system short circuit an effective protection can be achieved by incorporating a system with protective conductor and associated protective devices. In battery installations mainly an IT network or TN network is used.

Safe separation from the incoming mains supply by use of protection or isolation transformers is characteristic of a reliable DC power supply system and an effective protection measure (Figure 6.3).

A safe power source provides safety in case of failure of the transition of the AC voltage of the mains to the DC power side (Table 6.5).

Uninterruptible power supply (UPS) systems with galvanic connection to the incoming mains are an exception. In this case AC voltage against ground can be measured on the battery poles at the DC voltage side. (Recommendation: disconnect the entire UPS system for maintenance purposes.)

Electrostatic charge of the floor or of the clothing of personnel represents a specific risk when maintaining battery systems (Table 6.6). The energy of discharge sparks is sufficient to ignite battery charging gases (explosion!).

Table 6.3 Reference values for currents and voltages.
DIN VDE 0510 Part 1
Lead-acid batteries-Reference and limit values for currents and voltages applicable for charge equipment in dependance on the charger characteristic.
All currents are related to 100 Ah at nominal temperature.

Lead-acid battery	Nominal capacity	Ia characteristic current (A)		IU characteristic			IUla characteristic			Wa characteristic			WoWa characteristic		
		With autom. disconnect when fully charged	Limit value for 72 h charge period	Initial charge current I (A) (reference value) ^a	Voltage limitation U (Vpc) ^d	Final charge current (A) (typical value) ^a	Initial charge current I (A) (reference value) ^a	Voltage limitation U (Vpc) ^d	Max. current, when fully charged I (A) (limit value)	At 2.0 Vpc	At 2.4 V/pc (limit value)	At 2.65 Vpc (limit value)	Initial charge current (A) at 2.0 Vpc (reference value) ^a	Switchover voltage U (Vpc) (0)	Current of taper characteristic (A) (limit value)
Traction battery GiS/PzS	C ₅	5	2	20 to 30	2.4	2	20 to 30	2.33 to 2.4	5	16	8	4	20 to 30	2.4	8 at 2.4 Vpc 4 at 2.65 Vpc
Traction battery PzV ^c	C ₅	–	–	10 to 20	2.23 to 2.4	0.1 to 1.5	10 to 20	2.3 to 2.4	1.5	–	–	–	–	–	–
Stationary battery OGi, OPzS, GroE	C ₁₀	5	2	10 to 20	2.23 to 2.4	0.05 to 1.0	10 to 20	2.23 to 2.4	5	14	7	3.5	–	–	–
Stationary battery OGiV, OPzV ^c	C ₁₀	–	–	10 to 20	2.23 to 2.4	0.1 to 1.5	10 to 20	2.23 to 2.4	1.5	–	–	–	–	–	–
Starter battery	C ₂₀	10	2	50 ^b 20 ^c	2.4	2	–	–	–	24	12	6	–	–	–
Battery for portable equipment GiV ^c	C ₂₀	–	–	20	2.27 to 2.4	0.1 to 1.5	–	–	–	–	–	–	–	–	–

^a Current I is not limited when below gassing voltage. Specified values are valid for recharge periods of 8 to 14 hours, when IUla, Wa, and WoWa characteristic is applied.

^b For quick charge only.

^c For traction purposes.

^d After recharge is completed switch over to float charge or disconnect time-delayed (observe manufacturer's instructions!).

^e Observe manufacturer's instructions.

Table 6.4 Hazardous voltages.

Voltage	Potential of hazard	Protection measure
<60 V	No risk	No specific protection measures required
>60 V	Hazardous	Protection against direct contact
<120 V		
>120 V	Lethal	Protection against direct contact and indirect contact

Table 6.5 Additional hazards caused by effects of the current.

Hazards	Measures
High currents (short circuit)	Limitation of short-circuit current by fuses or circuit breakers Short-circuit safe installation of leads
Corrosion	Keep insulation clean Prevent leakage current
Electrostatic charge	Prevent electrostatic charge of floors and cloths
Disturbed function caused by superimposed AC currents	During float charge: $I_{\text{eff}} \leq 5 \text{ A}$ per 100 Ah During charging: $I_{\text{eff}} \leq 20 \text{ A}$ per 100 Ah

Table 6.6 Prevention of electrostatic charge by certain conductivity.

Conductivity of surfaces/floors	
$R < 10^5 \Omega$	Conductive
$10^5 < R < 10^8 \Omega$	Not defined, surfaces conditionally conductive
$R > 10^8 \Omega$	Insulating, electrostatic chargeable

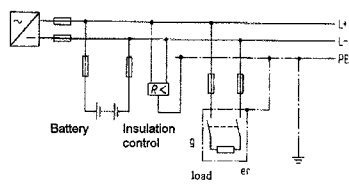
6.4.2 Hazards Caused by the Electrolyte

Lead-acid batteries contain the electrolyte sulfuric acid (H_2SO_4). NiCd batteries contain mostly the electrolyte potassium hydroxide (KOH). Both electrolytes create burns and can cause injury to the skin. In the event of electrolyte entering the eyes burns of the cornea with permanent damage are possible (Table 6.7). For first aid wash with plenty of water and obtain medical attention.

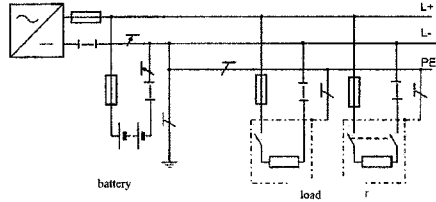
Metal is corroded by sulfuric acid. Therefore metallic battery stands or cabinets must be protected by suitable paint or plastic coating. Potassium hydroxide is just as dangerous and attacks many organic materials. Use alkali-resistant paint.

Depending on the type and size of the installation use floor coverings resistive to the electrolyte or place in suitable trays. The warning sign WS2 according to DIN 40008 Part 3: “Warning for Hazards from Batteries” must be provided (Figure 6.4).

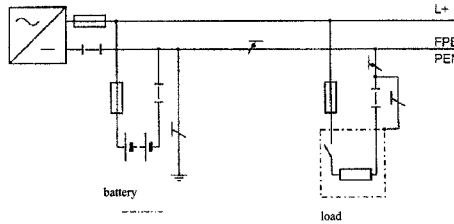
IT network



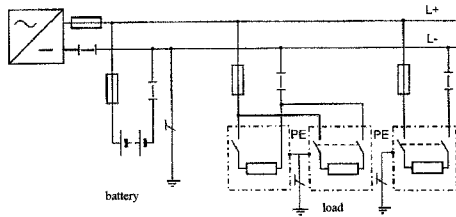
TN-S network



TN-C network



TT network



USV network

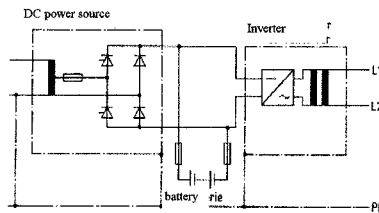


Figure 6.3 Network structures for DC power supply systems.

6.4.3 Explosive Charging Gases/Ventilation of Battery Rooms

When charging batteries hydrogen gas (H_2) and oxygen gas (O_2) are formed as a result of electrolysis of the water. A content of 4% hydrogen in air is explosive. Basically the measures listed in [Table 6.8](#) can be applied to prevent explosions. Dilution of hydrogen concentration is required by sufficient ventilation, because

Table 6.7 Effects from electrolyte.

Hazard	Measures
Burns of skin or eyes	Wear protective gloves and goggles. First aid measure: Wash with plenty of water. Medical attention required, especially in case of eye contact.
Corrosion of iron parts, concrete, a.s.o. due to spilled electrolyte	Electrolyte resistive floor or carpet. Electrolyte resistive paint. Limitation of spread of liquid electrolyte.
Sprayed electrolyte (aerosol)	Clean top of battery with water to prevent leakage currents. Use ceramic filter plugs.

generation of gases cannot be avoided when charging batteries. Spark-generating equipment in close vicinity of batteries is not permitted. (see [Tables 6.9](#) and [6.10](#).)

The ventilation requirements for battery rooms, cabinets, and enclosures result from the required dilution of the hydrogen generated during charging and from the safety factors covering the battery aging and risk of failures (worst-case condition) ([Figure 6.5](#)). Ventilation is required for both ventilated and valve-regulated batteries. Also valve-regulated batteries release excessive charging gases through the valves.



1. Warning sign W1 according to DIN 40008 part 3 "Dangerous electrical voltage" for classification of rooms for accommodation or locked accommodation with restricted access



2. Warning sign W2 according to DIN 40008 part 3 "Warning of hazards from batteries" for marking of a battery system



3. Prohibition sign "Fire, naked flames, smoking prohibited". Applies in the close vicinity of the battery.

Figure 6.4 Warning and prohibition signs.

Table 6.8 Measures to avoid explosion hazards.

Risk	Measure
Inflammable substances or mixtures of gases	Avoid these substances.
Sources of ignition	Dilute to noncritical concentration.
	Avoid sources of ignition.
	Sufficient distance.
	Protective encapsulation, “EX” protection.

Table 6.9 Sources of ignition for oxyhydrogen gas.

Naked flame
Flying sparks
Electrical, sparking equipment
Mechanical, sparking equipment
Electrostatic charge

Table 6.10 Measures to avoid explosions of oxyhydrogen gas.

Information for equipment in battery rooms
Sufficient natural or technical (forced) ventilation
No heaters with naked flames or glowing devices ($T < 300\text{ }^{\circ}\text{C}$)
Separated battery enclosures with separate equipment
Antistatic clothes, shoes, and gloves (DIN 4843) surface resistance: $< 10^8\text{ }\Omega$
Cable hand lamp without switch (Protection class II)
Resp. battery hand lamp (Protection class IP54)
Warning and prohibition signs

Depending on the building conditions “natural” or “technical” (forced) ventilation can be applied for the technical design of the battery room ventilation. Aspects that must be considered are given in [Tables 6.12](#) and [6.13](#).

At present, for stationary batteries, a safety distance of 0.5m is specified according to DIN VDE 0510 Part 2. Inside this area ignition of charging gasses is possible. This applies for both vented and valve-regulated batteries.

The future European Standard EN 50272-2 (replacing DIN VDE 0510 Part 2) will have a new definition of the safety distance d (see [Figures 6.6](#) and [6.7](#)).

A frequent argument is that vented batteries require special battery rooms, but valve-regulated batteries do not. Valve-regulated batteries can be accommodated as one likes; but in this sense it is not correct. DIN VDE 0510 does not require separate battery rooms. This is a requirement of the owner/user who wants to have specific protection of the supply system, e.g. in case of fire or unauthorized access. This is to ensure system functionality even in cases of crisis (see DIN VDE 0108: “Safety Power Supply Systems for Public Premises”, Regulations for Electrotechnical Installations in Buildings.)

Table 6.11 Reference values for current I (proposal for European standardization).

	Lead-acid battery vented type Sb < 3%	Lead-acid battery valve-regulated type	NiCd battery vented type
Gas emission factor f_g	1	0.2	1
Safety factor for gas emission f_s (includes 10% faulty cells and aging)	5	5	5
Float charge voltage U_{float} V/cell	2.23	2.27	1.40
Typical float charge current I_{float} mA pro Ah	1	1	1
Current (float) I_{gas} mA pro Ah (refers only to the calculation of the airflow when float charging)	5	1	5
Boost charge voltage U_{boost} V/cell	2.40	2.40	1.55
Typical boost charge current I_{boost} mA pro Ah	4	8	10
Current (boost) I_{gas} mA pro Ah (refers only to the calculation of the airflow when boost charging)	20	8	50

Table 6.12 Technical design of “natural” ventilation of battery rooms.

Air inlet and outlet is required
Minimum free area of opening: $A \geq 28 \cdot Q$ (A in cm ² , Q in m ³ /h) (assumption: air velocity $A_{ir} = 0.1$ m/s)
Amplification of ventilation by use of a chimney (air ducts)
Ventilation into the outside ambient (not to air condition systems or adjacent rooms)
Workplaces are considered to be sufficiently ventilated when the room volume exceeds $\geq 2.5 \cdot Q$

Table 6.13 Design of ventilation in battery rooms.

Forced ventilation with fan (exhauster)
Air exchange in accordance with air flow Q
Intake air must be clean
After-running of fan for 1 hour required when charging with plenty of gassing
Airflow = sum of Q when charging more than one battery in the room
Avoid ventilation short circuit by applying sufficient distance between air inlet and outlet

Ventilation air flow Q

$$Q = v \cdot q \cdot s \cdot n \cdot I \cdot \frac{C}{100 \text{ Ah}}$$

v = dilution factor = 96% air / 4% H_2 = 24

q = generated amount of hydrogen = $0.42 \cdot 10^{-3} \text{ m}^3/\text{Ah}$

s = safety factor = 5

n = no. of cells

I = current per 100 Ah

C = nominal capacity of battery

Combined factors:

$$v \cdot q \cdot s = 0.05$$

$$Q = 0.05 \cdot n \cdot I \cdot \frac{C}{100 \text{ Ah}} \quad (Q \text{ in m}^3/\text{h}, I \text{ in A})$$

Figure 6.5 Ventilation of battery rooms.

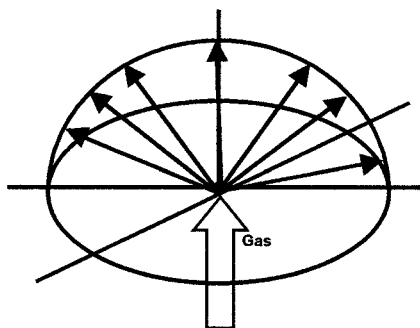
6.5 DIN VDE 0510 PART 3: “TRACTION BATTERIES FOR ELECTRIC VEHICLES”

Additional requirements for batteries in electric vehicles result from the legislation of the European Union, e.g. “Essential Safety Requirements of the Machinery Directive”. This results in requirements like battery marking and declaration of precise battery weight (because of the counterweight of the battery in forklift trucks). Ventilation is also required during vehicle operation due to residual gases after charging.

For more details see chapter 4.

6.6 DIN VDE 0510 PART 5 (DRAFT): “BATTERIES ON BOARD CRAFTS OR VEHICLES”

Many national and international regulations must be observed in the case of ships or watercraft. An important deviation from the other parts of DIN VDE 0510 is the increased safety factor for the air ventilation ($s = 10$), because of the solid steel walls of the crafts or vehicles, e.g. of ships. The exchange of air may be hindered by air-tight bulk heads. This applies also for ventilation in passenger rooms, e.g. in trains or street cars having batteries below the passenger seats. Any risk of oxygen/hydrogen explosion must be avoided in these cases.



Volume of a hemisphere

$$V_h = \frac{2}{3} \pi d^3$$

Required air flow for the dilution to 4 % in air of generated hydrogen H_2

$$Q_{gas} = 0,05 \cdot (n) \cdot I_{gas} \cdot C \cdot 10^{-3} \left(m^3 / h \right)$$

$$Q_{gas} = \frac{V_h}{t}$$

Required radius of hemisphere

$$d = 28,8 \cdot \left(\sqrt[3]{n} \right) \cdot \sqrt[3]{I_{gas}} \cdot \sqrt[3]{C} \quad (mm)$$

Figure 6.6 Calculation of the safety distance d .

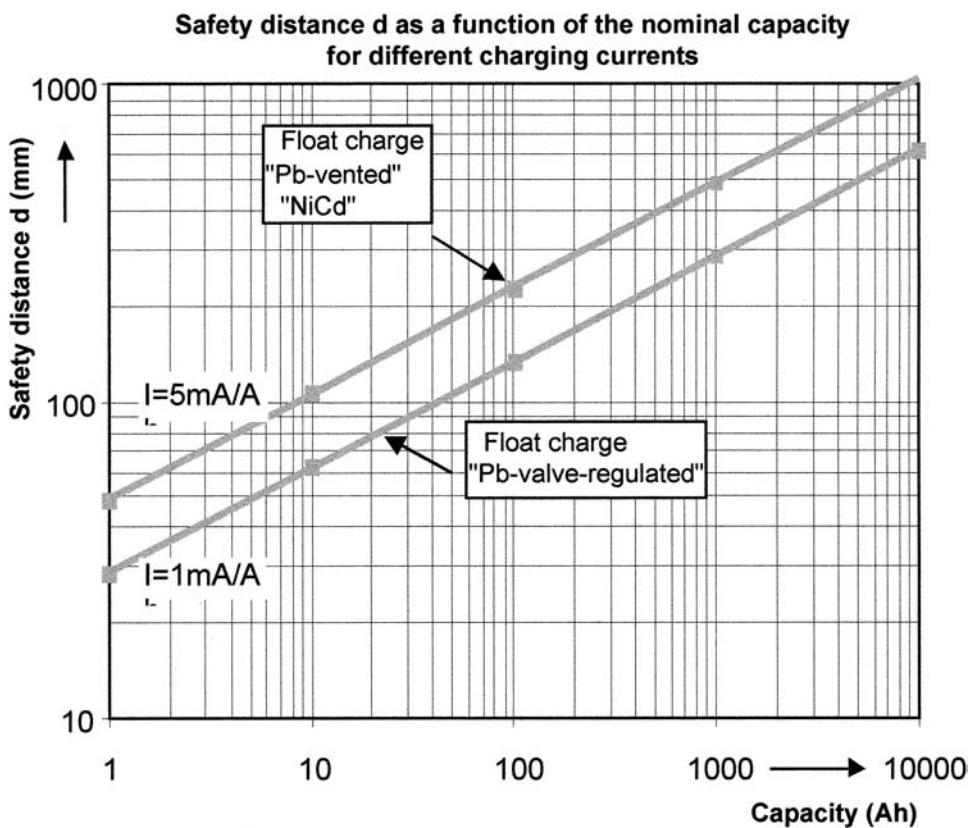


Figure 6.7 Safety distance d during float charge.

6.7 DIN VDE 0510 PART 6: “PORTABLE BATTERIES”

Small batteries are quite often an integral part of appliances, e.g. razors, mobile phones, computers, etc. Specific requirements must be observed, for example:

- Exchange with primary batteries.
- Marking of polarity, noninterchangeability.
- Ventilation of battery enclosures, which must not be hermetically sealed.
- Marking for protection of children, e.g. on button cells (swallowing hazard).

6.8 DIN VDE 0510 PART 4 (DRAFT): “SLI – STARTER BATTERIES”

These batteries are quite often used and charged outside cars. Repeated accidents are caused when jump-starting without expertise. The survey shown in Figure 6.8 gives information about the correct sequence for jump-starting.

1. Use the right “jump leads” for otto motors or diesel engines.
2. The capacity of the current supplying starter battery (e.g. 45 Ah) can be less than the capacity of the discharged battery.
3. Only batteries having identical nominal voltage (e.g. 12 V) should be interconnected by the “jump lead”.
4. No contact shall exist or be made between the car bodies.
5. Keep away sources of ignition, like naked flames, cigars and cigarettes, sparks from starter batteries (risk of explosion).
6. Don't lean over starter batteries (risk of burns). The electrolyte of a discharged starter battery stays liquid even at low temperature.
7. The discharged starter battery should not be separated from the associated on-board electrical system.
8. Switch off the ignition of the car before connecting the “jump leads”. Brakes must be pulled. Put gear stick into neutral, or park for automatics.
9. Attach the jump in such a way that they cannot be snagged by rotating parts of the motor.
10. Connect and disconnect the leads in the following order

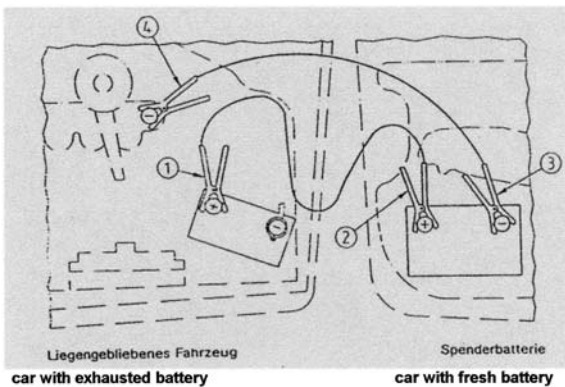


Figure 6.8 Information for the use of jump leads.

6.9 INTERNATIONAL STANDARDIZATION

The safety requirements shall be identical worldwide and must be standardized internationally. This is provided by the IEC (International Electrotechnical Commission). Within Europe national standards can form trade barriers, which must be harmonized. This work is done by CENELEC (European Committee for Electrotechnical Standardisation). Actually the safety standards for stationary batteries and battery installations are being drafted to become a European Norm. The norms for traction batteries and portable batteries will follow.

REFERENCES

1. CENELEC International Regulations, Parts 1–4.
2. DIN VDE 100 and DIN VDE 0510, German Institute for Standards.