U. S. Department
of Transportation
Federal Railroad Administration

Safety of High Speed Magnetic Levitation Transportation Systems

Office of Research
and Development
Washington, D.C. 20590

High-Speed Maglev Trains; German Safety Requirements RW-MSB

(Translation of German Regelwerk Magnetschnellbahnen Sicherheitstechnische Anforderungen)

DOT/FRA/ORD-92/01
DOT-VNTSC-FRA-92/1

January 1992

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RW MSB	**Magnetschnellbahnen** Sicherheitstechnische Anforderungen	

Magnetschnellbahnen; Sicherheitstechnische Anforderungen

High-Speed Maglev Trains; Safety Requirements

Trains magnétiques à grande vitesse; spécifications de sécurité

Arbeitskreis Regelwerk Magnetschnellbahnen

Technical Report Documentation Page

1. Report No. DOT/FRA/ORD-92/01	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle High-Speed Maglev Trains; German Safety Requirements RW-MSB (Translation of German Regelwerk Magnetschnellbahnen-Sicherheitstechnische Anforderungen		5. Report Date January 1992
		6. Performing Organization Code DTS-701
7. Author(s) RW MSB Working Group*		8. Performing Organization Report No. DOT-VNTSC-FRA-92/1
9. Performing Organization Name and Address U.S. Department of Transportation Research and Special Programs Administration John A. Volpe National Transportation Systems Center Cambridge, MA 02142		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Research and Development Washington, DC 20590		13. Type of Report and Period Covered Translation March 1991
		14. Sponsoring Agency Code RDV-30

15. Supplementary Notes

*This group is composed of representatives of German Federal Railways (DB), Testing and Planning Company for Maglev Systems (MVP), Industry, Institute Railway Technology (IFB), TÜV Rheinland, and TÜV Hannover and sponsored by the German Federal Ministry of Research and Technology.

16. Abstract

This document is a translation of technology-specific safety requirements developed for the German Transrapid Maglev technology. These requirements were developed by a working group composed of representatives of German Federal Railways (DB), Testing and Planning Company for Maglev Systems (MVP), industry, Institute Railway Technology (IFB), and safety experts of TÜV Rheinland and TÜV Hannover headed by TÜV Rheinland and sponsored by the German Federal Ministry of Research and Technology.

Topic areas covered include: levitation, propulsion, energy and control systems, load assumptions and vehicle and guideway stability, design, production and quality assurance of mechanical structures, switches, lightning protection, electromagnetic compatibility, electrostatic discharge, fire protection and rescue plan.

The original document is in German. This unofficial translation has been completed by a contractor for the U.S. Department of Transportation's Federal Railroad Administration. The edition of this translation is March 1991. The translation has been formatted such that changes to this body of regulations can be changed on a page-for-page basis in either language.

17. Key Words maglev, magnetic levitation, transportation, safety, Federal Railroad Administration, high speed ground transportation, maglev safety regulations, Transrapid, German regulations		18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VA 22161	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 282	22. Price

Form DOT F 1700.7 (8/72) Reproduction of this completed page authorized

German High-Speed Maglev Train

Contents

Safety Requirements

The safety engineering requirements of high-speed maglev trains are established in these regulations, which consist of the following chapters:

Edition 1, March 1991

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES 0 1 2 3 4 5 6 7 8 9 10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

REGULATIONS FOR HIGH-SPEED MAGLEV TRAINS

Chronology - Chapter 0

"Regulations for High-Speed Maglev Trains"

Edition	**Revision**	**Date**	**Comment**
1	0	09/88	
1	1	12/88	Enlargement
1	2	12/88	Enlargement
1	3	01/89	Enlargement
2	0	03/89	Enlargement
2	1	05/89	No change
2	2	06/89	Change
2	3	08/89	Change
2	4	09/89	No change
2	5	10/89	Change
3			missing
4	0	09/90	Change
4	1	11/90	Expansion

Regulations for High-Speed Maglev Trains

1. Preface

This technical regulation contains safety-engineering requirements for high-speed maglev trains. This regulation includes the experiences gained by the participating groups in Germany during the development, construction, and testing of the operation of high-speed maglev trains up to the current state of the art. In this process, it has been found in particular that specific properties of this transportation system are not covered by the existing technical regulations.

The intention is that this regulation, insofar as it describes the current state of the art in safety engineering for high-speed maglev trains, be accorded the status of a recognized engineering standard.

2. Start of Validity

This safety regulation applies as of March 1, 1991.

3. Area of Application

The area of application of these safety-engineering requirements extends to high-speed maglev trains using electromagnetic levitation technology (EMS technology) with long-stator propulsion of the "TRANSRAPID" type. The characteristic feature of this transportation system is the integrated, no-contact levitation, guidance, and propulsion function in autonomous functional units of the levitation/guidance system.

High-speed maglev trains employing other linear motor variations will be covered separately at the proper time.

Operational and special vehicles, e.g., for assembly purposes or for towing the high-speed maglev train away in the event of propulsion failure or during initial commissioning, are not covered here. The standard construction and operating regulations and the professional association work safety provisions apply to these vehicles.

4. Purpose

At the time this regulation was published, more than thirteen years of experience in safety-oriented design of magnetic levitation trains were available, especially through the setup and operation of TRANSRAPID 05, 06, and 07. The vehicles noted and the guideways, operating systems, and other stationary installations for each of them were released by the competent supervisory authorities as demonstration or experimental facilities for operation involving persons not connected with train operations.

The prerequisite was the successfully completed assessment, by independent institutions, of the study of safety proofs, the expert inspection of all other safety-relevant subsystems and installations, as well as the establishment of the transportation and operational safety of the entire system.

In these regulations, special explanations are provided concerning those safety-engineering requirements that specifically pertain to maglev trains and that demand special clarification.

Accordingly, the purpose of these regulations is to describe from functional viewpoints all the safety-relevant mechanisms/subsystems or requirements/properties, especially with respect to the special circumstances associated with magnetic levitation engineering which are not covered in existing railroad engineering regulations.

5. Terms

The following terms are subdivided into definitions that specifically relate to high-speed maglev trains and other definitions that essentially relate to safety engineering.

5.1 Definitions Specifically Relating to High-Speed Maglev Trains

Operating brake system:	Device for generating thrust reversal in order to operationally brake the vehicle by means of the linear motor. (See also the note at the end of the section "Definitions Specifically Relating to High-Speed Maglev Trains")
Bending switch:	Guideway element to enable a change of track using horizontal elastic deformation of the corresponding portion of the guideway.
On-board control system:	The on-board control system comprises all functions and installations of the operational control system and of vehicle control that are located on the vehicle.

EMS technology: Electromagnetic levitation technology. Both the levitation and guidance functions are performed by virtue of magnetic direct current fields--whose intensity can be controlled--with an attractive effect between levitation magnets or guide magnets and their reaction surfaces on both sides of the guideway.

[Illustration]

Guideway-based components

1 Sliding surfaces
2 Lateral guide rail
3 Long-stator components

Vehicle-based components

1 Bearing and set-down skid
2 Guide magnet
3 Levitation frames
4 Levitation/exciter magnet with linear generator winding

EMS technology: Corresponding components of guideway and vehicle

Guideway:	Part of the stationary installation, consisting of foundation, guideway pillar, and guideway girder.
Guideway element:	In the sense of operational control, the smallest unit of the guideway network that can be distinguished in terms of safety engineering.
Guideway pillar	Structural element on which the girders of the guideway are positioned and which transmits the introduced forces to the foundation.
Guideway girder:	Beam-shaped, discretely positioned structural element of the guideway for levitation and guidance and thus for track guidance of the vehicle.
Vehicle:	Collective term for units that can run independently and technically safeguarded.
Vehicle operating console:	Control installation in the vehicle for piloting same.
Parking brake system:	Installation for fixed positioning of the hovering or set-down vehicle (see also the note at the end of the section "Definitions Specifically Relating to High-Speed Maglev Trains").

Escape velocity:	Minimum limiting speed at which the vehicle can reach the next stopping point even during the maximum conceivable breakdown or emergency situation.
Guide magnet:	Transverse flux magnet with massive core for generating and absorbing magnetic guidance forces.
Speed range:	Location-dependent range of speed in which the vehicle must run during normal operation.
Slide surface:	Sliding surface of the guideway which absorbs the mechanical forces from the bearing skids.
Stopping point:	Track segment for stopping the vehicle, either as a station or as a stopping place with installations for evacuating passengers and allowing access to rescue personnel.
Stopping place:	Stopping point located outside stations for stopping the vehicle through application of emergency braking. The length of this track area is based on the vehicle length and the dispersion of the braking path.

Step-up chopper: Voltage converter to supply the on-board power network from the linear generator.

Linear generator: Installation for vehicle-based inductive generation of electrical energy from the kinetic energy created by vehicle motion.

MBO: Maglev Construction and Operating Regulation, Draft, status as of December 12, 1988.

Motor winding: Cable winding to generate the traveling field, inset in the stator pack grooves.

Emergency: Situation that can threaten personal safety.

Nutstein: Mounting element for the stator pack.

Primary spring suspension: Spring/shock absorber system between levitation and guide magnets and the corresponding levitation bogies.

Switching segment: Actively switchable line segment of long stator supplied from the corresponding converter.

Switch station: Switching element for activating the respective switch segment.

Levitation frame: Smallest complete functional unit of the levitation and guidance system.

Lateral guide rail: Functional surface on guideway girder which acts as reaction rail for the magnetic field generated by the guide magnets and which absorbs the necessary portion of the lateral forces required to carry out the guide function. It is also used as a reaction rail to absorb forces from the auxiliary brake and as a slide surface to absorb the mechanical forces from the guide skids.

Secondary spring suspension: Spring/shock absorber system between the levitation bogies of the levitation/ guidance system and the coach body.

Safe hovering: Preservation of levitation function even in the event of maximum conceivable breakdown and/or emergencies for limited and short-term continued operation.

SIAB: Safety shutoff of the propulsion

Safety braking system: Installation for performing emergency braking after the emergency stop instruction is triggered (see also the note at the end of the section "Definitions Specifically Relating to High-Speed Maglev Trains").

Station:	Stopping point for operational boarding and deboarding, which is also a stopping point for stopping the vehicle when emergency braking is performed. A station has a boarding/deboarding platform corresponding to the length of the train, with due regard for positioning accuracy, as well as additional installations in both planned approach directions for evacuating passengers and allowing access to rescue personnel. The length of this track area results from the maximum acceleration and braking deceleration distance in the event that the vehicle, due to a breakdown situation, has not achieved escape velocity after starting out, but instead emergency braking is applied.
Stator pack:	Element of the long stator, attached to the guideway girder, for holding the motor winding. With an integrated levitation and propulsion function in EMS technology, the stator packs constitute the reaction elements of the levitation magnets.
Breakdown:	Breakdown is a disturbance of regular operation which can lead to an emergency.
Chopper:	DC chopper converter to generate controllable direct currents.

Levitation/guidance chopper: DC chopper converter to generate controllable direct currents for the levitation or guide magnets.

Levitation/guidance system: Vehicle subsystem in which the levitation, guidance, and vehicle-related part of the propulsion function is generated.

Levitation magnet: Heteropolar magnet for generating and absorbing the magnetic levitation forces and, in case of integrated levitation and motor function, the motor forces.

TVE: TRANSRAPID Test Facility in Emsland.

Programmed braking: Vehicle braking for stopping at a stopping point.

Emergency braking: Vehicle braking effected by the safety braking system in order to stop at a stopping point that can be reached safely after an emergency stop instruction is triggered (see also the note at the end of the section "Definitions Specifically Relating to High-Speed Maglev Trains").

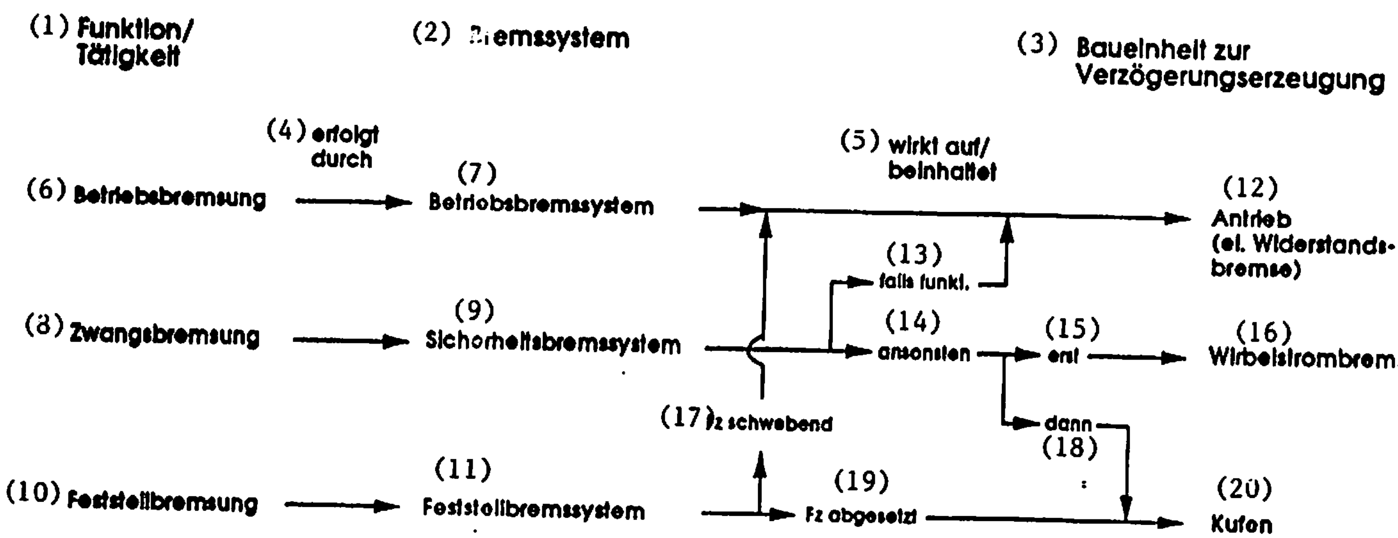
<u>Exception:</u> If the escape velocity is not achieved after restarting at a stopping place, the emergency stop then initiated leads to stoppage of the vehicle outside a stopping point.

Emergency stop: Emergency braking effected by operating personnel, by means of safety-engineering installations or on the basis of technical breakdown/failures, until the vehicle is stopped at a stopping point that can be reached safely.

Exception: See "Emergency braking."

[Key to figure, Page 13]

(1) Function/activity
(2) Braking system
(3) Component for generation of deceleration
(4) Effected by
(5) Affects/covers
(6) Operational braking
(7) Operational braking system
(8) Emergency braking
(9) Safety braking system
(10) Block braking
(11) Block braking system
(12) Propulsion (el. resistance brake)
(13) If functional
(14) Otherwise
(15) First
(16) Eddy current brake
(17) Vehicle levitating
(18) Then
(19) Vehicle set down
(20) Skids



Note: Braking plan for the TRANSRAPID 07

5.2 Safety-Engineering and Other Terms

Operational control system:	Functions and installations whose purpose is the safety, control, and guidance of vehicle operations, as well as intercommunication between them.
BLT:	Operational control system
BOStrab:	Ordinance on the Construction and Operation of Streetcars (Streetcar Construction and Operation Ordinance - BOStrab), BGBl [Federal Legal Gazette] I, 1987
DB:	German Federal Railroad
EBO:	Railroad Construction and Operating Regulation, BGBl II, 1967. First Ordinance Amending the Railroad Construction and Operating Regulation (EBO), BGBl II, 1969. Second Ordinance Amending the Railroad Construction and Operating Regulation (EBO), BGBl I, 1981.
EVU:	Power company.
Highly reliable:	See safe life.

Safe life:	During the anticipated service life, neither the product as a whole, nor any of its critical subfunctions may fail (see VDI [Association of German Engineers] 2244, May 1988).
MSRUe:	Relating to process measurement, control, and monitoring technology.
Redundancy:	Presence of more functionally capable means in one unit than would be necessary to perform the required function (see DIN 40 041, December 1990).
Fail-safe:	Ability of a technical system to remain in a safe state or to immediately switch to another safe state in the event of certain types of breakdown (see VDI/VDE [Association of German Engineers--Association of German Electrical Engineers] 3542, Chapter 1, Dec. 1988).
Safety:	A situation in which the risk is no greater than the tolerated risk (see DIN VDE 31 000, T 2, Dec. 1987).
Availability (momentary):	Probability of encountering a unit at a given time within the required service life in a functionally capable state (see DIN 40 041, Dec. 1990).

Availability (stationary): Average operating time between two failures divided by the sum of the average operating time between two failures and the average length of breakdown (see DIN 40 041, Dec. 1990).

Reliability: Condition of a unit with regard to its suitability for meeting the reliability requirements during or after predetermined intervals under given service conditions (see DIN 40 041, Dec. 1990).

SYSTEM PROPERTIES, ESPECIALLY "SAFE HOVERING"

Chronology - Chapter 1

System Properties, Especially "Safe Hovering"

Edition	Revision	Date	Comment
1	0, 1, 2		missing
1	3	01/89	
2	0	03/89	Changes
2	1	05/89	Enlargement
2	2	06/89	Changes
2	3	08/89	Changes
2	4	09/89	Changes
2	5	10/89	Changes
3			missing
4	0	09/90	Changes
4	1	11/90	Changes

System Properties, Especially "Safe Hovering"

1. Preface

The most essential feature of a high-speed maglev train is no-contact levitation and guidance by magnetic forces. In the course of developing magnetic levitation technology, it has been seen that this property is increasingly preserved even in the event of breakdown: The TRANSRAPID 05 set down uncontrolled in emergency braking. The TRANSRAPID 06 was able to set down only in a controlled manner. If this set-down process had to occur safely in all conceivable cases of breakdown, then it is a logical step to now extend the phase of this ensured characteristic to the entire running operation, i.e., to be able to levitate in a consistently safe manner. This "safe hovering"--in conjunction with the running and braking concept and the resulting requirements--is the property that defines the system, has consequences for almost all subsystems, and to that extent is the first property to be described here.

2. Definition of Terms and Purpose

The term "safe hovering" characterizes the property of the high-speed maglev train of being able to maintain its levitation function even in the event of the maximum conceivable breakdown and/or emergency at least to such an extent that limited and short-term continued operation is possible. "Safe hovering" thus means excluding set-down above a defined set-down speed, V_{ab}.

If the breakdown or emergency in question is not combined with a propulsion failure, then the vehicle will reach the next station or, if there are stopping places between stations, at least the next stopping place. If the breakdown or emergency is combined with a propulsion failure and the vehicle was previously running within the specified speed range (see Chapters 0 and 9), then, depending on the topography, it can still cover a relatively large distance while hovering (approx. 5 - 10 km), based on its high kinetic energy and due to its favorable aerodynamic design. Thus, it is possible, based on the property of safe hovering, to formulate a stopping place plan such that the vehicle, even under worst-case conditions, will reach the next stopping place if the vehicle was in a regular running state prior to the onset of the breakdown or emergency combined with the propulsion failure.

It must be determined individually for each application whether such a plan is to be realized or other supplemental strategies are to be pursued, especially in terms of the planned rescue measures (see Chapter 12).

In order to hover safely, the levitation function must thus have a safe life, since there is no reliable failure direction for this as a whole. Safe-life levitation thus means that the high-speed maglev vehicle must be able to accomplish each mission--i.e., the sum of all running times between the respective departure and stop--in a levitated state.

This safe hovering is generated by so-called active subsystems. On the other hand, these subsystems must have a safe failure direction, i.e., they must in principle have a fail-safe characteristic.

Starting with the operating situation, which is characterized by speeds of more than 400 km/hr, the initial safe state is safe hovering analogous to the airplane. The absolutely safe state--as in any transportation system--is the lowest state in terms of energy (parking with all energy turned off), to which the high-speed maglev train, however, in contrast to conventional wheel-on-rail technology, cannot be transposed through simple measures (conventional emergency braking).

The explanation for this, and thus the justification of the need for safe hovering, is a consequence of the running and braking plan, as well as of EMS technology in conjunction with high vehicle speeds. Furthermore, safe hovering permits a rescue strategy that can be executed through the stopping place system.

If the stopping place system--i.e., the absolute ability to reach defined stopping points--is to be realized on the basis of and/or enabled by safe hovering, then the vehicle must be able, from any point along the line, even in the event of failure of the force of propulsion, to utilize its momentum to keep running at least to a preselected stopping point where it can undertake programmed braking. In the event of breakdown or an emergency, the vehicle must be brought to a standstill at this preselected stopping point by initiating emergency braking.

The vehicle comes to a standstill outside a stopping point only if during the start-up phase from a stopping place the limiting speed for reaching the next stopping point (escape velocity) is not achieved, e.g., through propulsion failure, whereby the vehicle can be restarted or must be brought back to the starting point. Otherwise, it is not permissible in the stopping place concept to stop outside the stopping points in regular train operation with passengers. Exceptions to this rule, especially in order to change the direction of travel, require a special provision. Stopping points are stations or stopping places, in each case provided with facilities for passenger evacuation and access by rescue personnel.

Note: Setting down at the high cruising speed would--in addition to considerations of high dynamic stresses--require an auxiliary levitation/guidance system suitable for safely levitating and guiding the vehicle from its maximum speed to a stop, if possible without damage to the vehicle and guideway. Besides this, there would also have to be compliance with requirements of train safety engineering in this operating state, e.g., maintaining a given braking curve or coming to a safe stop before a danger point.

In past vehicle development efforts it has been seen that with EMS technology it is scarcely possible to meet all of the requirements for the auxiliary levitation/guidance system, so that the idea of safe hovering is further pursued instead. To be sure, here again it is necessary to meet essential safety-engineering requirements, which will be noted below.

3. Resulting Technical Requirements

To ensure the concept of safe hovering, the following occurrences must be ruled out with adequate probability; in the broadest sense they lead to untimely braking:

- loss of levitation/guidance function
- "racing," or magnet striking
- failure of programmed braking function. The following subsystems are required for the programmed braking function:
  - vehicle location
  - vehicle operational control system
  - safety braking system
- violation of clearance envelope

Such occurrences can have different causes, the possibility of which must be adequately ruled out.

3.1 Levitation/Guidance Function

The levitation/guidance function can be lost as a result of the following:

- loss of power supply
- faulty device control

- software defect
- loss of synchronism followed by set-down
- entry into stator short-circuit loop before the neutral point.

The first two factors can in turn result from the effect of fire, lightning, or insufficient electromagnetic compatibility of the electronic control and monitoring equipment.

3.1.1 Required Measures/System Structure

The required safe life property must be achieved through adequate reliability. The levitation/guidance function can be safeguarded by a large number of autonomous units, ensuring that--considering the maximum conceivable number of failed levitation/guidance units during a mission--the overall levitation/guidance function will nevertheless be maintained.

Loss of Energy Supply

It is necessary to ensure that the energy supply as a whole cannot fail, since in this case the vehicle would set down. However, since the possibility of individual failures in the electrical system cannot be ruled out with adequate certainty, there is an essential need for redundancy; i.e., for each section, an adequate number of mutually independent and electrically/mechanically safely separated power systems must be provided, so that, in the event of power system failures, levitation and track guidance are maintained without impairing the other as yet intact power systems. To increase availability, these power systems can be potential-free, i.e., not connected to the vehicle ground, so that they are not turned off in the event of a ground fault.

It is furthermore necessary to provide installations through which the output capacity of the power systems needed to maintain the levitation/guidance function is ensured during the mission.

Note: The current state of the art is characterized by 4 independent, battery-buffered central power networks per section which--starting at a vehicle speed of about 100-150 km/hr--cover their energy needs from vehicle motion, by way of linear generators and step-up choppers. In TR 07, there are 30 linear generators with subsequent step-up choppers for each section, from which in each case one of the 4 central power networks and a levitation/guidance chopper connected to that system are supplied directly and decentrally. At an adequate vehicle speed, the levitation and track guidance function is thus ensured, even without the involvement of the central power networks. Below the specified speed, i.e., during the acceleration and braking phase and during stationary levitation (without outside power feed), the power is supplied from the batteries.

In this kind of configuration, the length of the startup and braking phase must be limited with regard to available battery capacity, or the battery capacity must be designed in accordance with the maximum startup and braking time.

The possibility of an untimely shutoff of all power networks necessary to maintain the levitation/guidance function during a mission--e.g., through activating the central total shutdown command--must be prevented by a suitable technical installation. A total shutdown command must be activated by an active signal and may take effect only while the vehicle is in a stationary and set-down position.

Faults or failures in the total shutdown control system must prevent total shutdown safely. Emergency shutdown installations must be provided for this possibility. Access to these emergency shutdown installations must be made so difficult that only trained members of the operations personnel can activate them.

Defective Controls

To be able to set the vehicle down, all levitation/guidance units must receive a set-down command. If this should occur during running operation due to a failure, then this would be as critical as an interruption of the entire power supply network. Thus, the set-down command must be generated as an active signal and be linked by a logical AND-operator to the autarchic device for determining speed present in each levitation/guidance unit. Only if the vehicle speed V is less than the permitted set-down speed V_{ab} may the set-down command take effect locally. In that case, there is a controlled set-down--either intentional or due to error, but in any event uncritical. If systematic faults are not present in the autarchic but structurally identical equipment for determining speed, then the required safety is ensured by the high level of redundancy of the levitation/guidance units.

Software Flaws

Systematic flaws, if present, especially affect the software for the safety-relevant process measurement and control and monitoring installations (MSRUe) of the levitation/guidance units. Single-channel software must be valid and correct, i.e., error-free in the mathematical sense. In the case of MSRUe structures with diverse software, the programs must be adequately low in errors.

Loss of Synchronism

If the vehicle speed differs from the speed of the long-stator traveling field, then asynchronism, or slippage, is experienced. The vehicle has fallen "out of sychronism." If the phase angle between the long-stator and the levitation magnet field fluctuates, then the result is oscillation. In both cases, depending on the geometry of the levitation magnets and of the long-stator, periodic forces can appear in the x and z direction which, depending on the speed, generate unacceptable stresses on the vehicle and the guideway and possibly force the vehicle into uncontrolled set-down. Thus, it must be ensured that this type of slippage/oscillation situation cannot occur or that it is demonstrably harmless in terms of its force effects, or that it is safely detected in time before unacceptable forces build up and result in motor shutdown.

Stator Short-Circuit Loop

If a short circuit develops in the long-stator winding such that a stator short-circuit loop is formed in combination with the neutral point, and if the vehicle enters this short-circuit loop, then--depending on the geometric conditions--the result will be unacceptable braking and vertical forces that can lead to a loss of the levitation/guidance property. This type of breakdown must be prevented through a corresponding design of the winding and/or through monitoring short circuits and ground faults in the long-stator winding.

3.2 Magnetic Gap Control

Electromagnetic levitation represents an unstable state requiring continuous control, during which a nominal gap size of about 10 mm must be maintained between the stator or guide rail and the levitation or guide magnets. As a result of failures in a chopper or the corresponding MSRUe unit, the magnetic force can increase to such an extent that the gap becomes 0. Because of the resulting excessive magnetic current, the relevant overcurrent protection unit will then turn the magnet off, but the the magnet striking prior to that results in the application of unacceptable local forces. If because of a systematic failure--in the software, for example--some or all of the magnets race in the manner described, meaning that all or part of the levitation/guidance system then impacts against the guideway, then this has destructive effects on the vehicle and the guideway. Therefore the possibility of magnet racing must be reliably ruled out.

3.2.1 Safe Magnetic Gap Monitoring

Establishing a tight upward and fast-acting current limitation cannot be considered as a measure to prevent magnet racing because the magnetic currents possess a large dynamic range. Still, sufficiently rapid shutoff or safe disconnection of the relevant magnet is the suitable fail-safe measure, since one cannot justify a failure exclusion, at least according to the current state of the art. Failures can occur in the output or MSRUe part of the chopper unit. There is a need to directly introduce the shutoff or disconnect process beginning at a minimum gap to be observed in order to preserve the no-contact property, through a suitable fail-safe monitoring device. If there is a failure in the monitoring device, then this too must lead to nullification of the magnetic field. The monitoring device must be allocated autonomously to each magnet and be unconditionally activated, free of outside influences, whenever the magnetic gap control system is turned on.

3.3 Clearance Envelope and Tolerances of Reaction Surfaces

The concept of safe hovering, as can be deduced from other requirements, requires compliance with the clearance profile and with the tolerances of the reaction surfaces. This requirement, in connection with safe hovering, is significant because unacceptable maladjustments and displacements on the guideway not only mechanically endanger the vehicle but can also lead to magnet shutoff and unacceptable vehicle braking.

3.3.1 External and System-Specific Influencing Factors

The possibility of obstacles on or along the guideway, through which the clearance envelope is violated, must be ruled out. This is done, for example, by elevating the guideway. The distance between the guideway and buildings or forestation must be determined as a function of the speed and the environmental situation.

The guideway girder as a whole, as well as the components of the guideway appurtenances for levitation and guidance, must not vertically and laterally exceed the permissible tolerance at the points of junction. This calls for reliable mounting, especially of the stator packs and the guide rails, to the guideway, as well as suitable positioning of the guideway girders.

3.4 Electromagnetic Compatibility/Electrostatic Charge/Lightning Protection/Fire Protection

In addition to the possible dangers for safe hovering which have been discussed so far and which are essentially inherent to the system, one must also deal with external factors which can influence this property. Special attention must be devoted here to electrical or electromagnetic influences, through which the function of the MSRUe installations can be disrupted or destroyed. The most basic effect of that type is caused by lightning.

Furthermore, safe hovering brings with it special requirements for fire protection.

3.4.1 Preservation of Levitation Function During Lightning Strike

In terms of safe hovering, there are no requirements regarding electromagnetic compatibility and electrostatic charges that go beyond the level of the standard measures described in Chapter 10.

As for lightning protection, what is dealt with here is not only the direct threat to persons in the vehicle when lightning strikes but also the indirect hazard caused from the secondary effect of lightning. This can cause a breakdown of MSRUe installations which affects running performance, levitation, and operation of the braking system; i.e., impairs safe hovering as a whole.

The basic requirement specifies that the lightning current be shunted off with the least possible resistance--i.e., with low dissipation--away from the coach body via the levitation bogies and the levitation/guidance magnets into the guideway, and from there to the ground. This calls for a highly conductive connection between the coach body structure and the levitation bogies and between the latter and the levitation/guidance magnets or bearing skids. Via the air gap, the lightning current is conducted into the guide rail, the long stator, or the slide surface. These guideway equipment elements must be included in the potential equalization measures, depending on the guideway construction. With a guideway top chord made of steel, this requirement is considered to have been met by virtue of the highly conductive connection. With a concrete structure, the guide rail or the steel slide surface is to be used as the path for the lightning current, and it must be connected to the ground arrestor with the corresponding potential.

If there are other narrow junction points between the vehicle and the guideway that are comparable to the levitation/guidance gaps, then the corresponding items of equipment must be given special electrical protection. What is desirable here is a defined junction for the lightning current between the levitation/guidance system and the guideway in order to provide a well-defined current path. This junction, or the device provided for that purpose should be easily accessible and therefore easy to check as well.

The guideway must be included in the lightning protection measures as a whole. The lightning current must be shunted off as resistance-free as possible from the top chord, which serves as the lightning impact surface or the junction element for the lightning current on the vehicle side.

With regard to secondary coupling into the interior of the vehicle, a threat to safe hovering must be avoided by means of consistent potential equalization, use of shielded lines (connect shields on both ends with reference ground), use of shielded equipment, and twisting of longer go-and-return lines. If necessary, overvoltage arrestors should be attached to those MSRUe installations that are directly responsible for the operation of safe hovering.

This is explained in greater detail in Chapter 10 of these regulations.

3.4.2 Preservation of Levitation During Fire in Vehicle

Preventive fire protection measures for the high-speed maglev train can be derived by analogy from DIN 5510, which applies explicitly to rail vehicles according to the EBO and the BOStrab. It is initially important to categorize the high-speed maglev train according to fire protection classes. The categorization criterion of the standard noted above is the underground mode of operation in conjunction with the distance between evacuation points or the presence of safety areas (e.g., emergency walkways). According to the MBO draft, safety areas must be provided if the threat to persons inside the clearance profile is not excluded by other measures.

Normally, in a single-track, elevated guideway there is no safety area between stations and/or stopping places. This is why a high-speed maglev train must be categorized in fire protection class 4 according to DIN 5510.

The requirements in DIN 5510 must be complied with accordingly, and compliance must be proven. As for safe hovering, the requirements in Chapter 1, Sections 3 to 3.2.1, of this body of regulations must also be complied with in case of fire.

The system-specific measures and installations required for this, insofar as that they go beyond the pertinent regulations, especially DIN 5510, are listed in Chapter 3 with regard to the requirements for on-board energy systems and in Chapter 11 with regard to other fire protection measures.

4. Resulting Operational Requirements

To ensure the concept of safe hovering, certain operational requirements must be met. These can be subdivided into environmental and organizational requirements.

4.1 Environmental Requirements

Environmental influences must impair neither the levitation/guidance function, and thus the levitation or running capacity, nor the braking capacity.

4.1.1 Effects of the Weather

Safe hovering must not be impaired by weather-related effects on the vehicle/guideway system.

This applies particularly to wintertime operation. Snow and ice on the guideway and on the functional elements must not cause any intolerable magnetic gap deviations. Damage to the vehicle, especially the levitation bogies and the underside of the vehicle, from loose pieces of ice or ice separated from the vehicle must be prevented by suitable coverings.

4.1.2 Settling and Earthquakes

Practical experience relating to the earthquake-proof design of the guideway or its safety-oriented design in areas with settling is not available at this time because high-speed maglev train systems in use thus far have not been subject to danger in this regard.

If a revenue service line is to be laid in such regions, then suitable precautions are to be taken.

1. Wherever possible, endangered areas should be bypassed during planning.

2. If it is impossible to bypass settling, subsidence and earthquake regions, then geological and hydrological maps, mining plans, and miscellaneous soil studies should be used to find solutions for the alignment whereby these regions can be crossed by the shortest possible distance. Double-track guideways must be divided into two separate guideways that are far apart enough that both guideways cannot be simultaneously affected given the possible subsidence.

3. In endangered areas, there must be constant monitoring of the guideways. Ground movements are most noticeable in their vertical components, i.e., in settling and subsidence. As long as no significant vertical changes in the guideway are ascertained, there is no need to count on any other changes here (sloping, horizontal shifts, dragging, or pressing).

   Note: Permanent monitoring can be done hydrostatically, for example, by installing liquid containers in the ends of the guideway girders. The two containers for a particular girder are connected with each other by a tube according to the principle of interconnected pipes. If the liquid levels in the containers are uneven--which can be determined electrically using a level transmitter--then there has been a change in the longitudinal inclination, which can then also be associated with slanting.

4.2 Organizational Requirements

4.2.1 Securing Mobile Guideway Elements

Mobile guideway elements, such as switches and transfer tables, not only require safety measures pertaining to operational control; they also demand special technical and/or operational installations or measures.

The possibility that a switch is set wrong or that the shunting will come to a halt outside the safe end positions cannot be ruled out. This means that all branching or junction points of switches, as well as all shunting points of transfer tables, must be secured so that the vehicle, if necessary, will come to a halt in a fail-safe manner before that type of guideway element (programmed braking). Depending on the position of the guideway element in question (track section or sidetrack system), stopping places with opportunities for evacuation must be provided at all the points noted above.

4.2.2 Guideway Inspection

The placement of the guideway girders as well as the fixture for the functional elements to the guideway girders must be checked regularly. The number and type of checks must be determined as a function of operational experience and the results of prior inspections. Time- and load-dependent inspections must be conducted until adequate operational experience is available.

Special attention must be devoted to the fixture for the stator packs and that of the guide rails. The test criterion and scope of the tests will depend on the structural shape of the guideway girder (steel, concrete, hybrid construction). The fixture installations for the above-mentioned functional elements must be easy to inspect and accessible.

5. Braking System

The characteristics of EMS technology place special demands on the braking system. This is why 2 independent brakes are required in the MBO. In the event of breakdown as well, safe programmed braking at stopping places before danger points, at stations, and --if available--at other stopping places is required.

5.1 Safe Programmed Braking

In order to perform the required programmed braking, the vehicle must under all circumstances feature a controllable braking capability. Even in the event of breakdown, the attainable maximum value of the braking force for emergency braking must remain within established limits. The maximum attainable braking force value must be compatible with the load assumptions for the guideway and vehicle. The attainable minimum value of braking force must be in agreement with designed headways to danger points.

It is assumed that in future revenue service vehicles as well, the safety braking system will first act on the propulsion unit (thrust reversal). Only if this is no longer possible due to a breakdown a structural component based on a different principle must provide the necessary braking deceleration. Disruptions and breakdowns within this part of the safety braking system must not lead to a situation where the tolerance limits of braking deceleration are either not attained or are exceeded (safe-life design), nor must there be any restrictions on vehicle handling.

One technical consequence of this requirement is that the part of the safety braking system independent of the propulsion unit, according to the current state of the art, must be built up of mutually independent units, each of which is specially qualified and reliable. In the event of breakdown or failure, there is no preferred direction, but the existence of the breakdown must nevertheless be signalled to the conductor. If the breakdown or failure occurs within installations for controlling the safety braking system, then this should generate the same effect as if the control command had been operationally activated: The vehicle must be braked by the emergency system and must come to a stop at the next respective stopping point that can be reached (fail-safe design).

The current location and stopping point information must be redundantly available, i.e., three times over. If the availability of this information is reduced to only in two channels, emergency braking must be initiated, which can still be conducted safely in this way.

A simple redundant, i.e., 2-channel solution is also possible if emergency braking is initiated as soon as this information is available only in one place, due to breakdown or failure. The reliability of the information installations must be so high that there is no need to allow for the possibility that the location information will be lost by another flaw in the last channel before the vehicle reaches the stopping point (see DIN VDE 0831).

6. Rescue Plan

With a high-speed maglev train, as a ground vehicle, an opportunity for evacuation is in principle feasible for every place along the guideway. However, safe hovering opens up the possibility of optimal evacuation of the vehicle at these places through realization of the stopping place plan. On-board passenger safety must be ensured in keeping with the circumstances in question until these areas are reached. With regard to the rescue plan, the high-speed maglev train is thus rather comparable to an airplane, although the incendiary composition of the high-speed maglev train is considerably lower than that of an airplane, due to the absence of fuel.

This is why the measures noted in Chapters 11 and 12 for avoiding an evacuation, as well as the technical installations and organizational requirements for conducting the evacuation, closely follow airplane engineering regulations.

If the stopping place plan is to be realized, then the following requirements of the starting phase and of the line layout must be met.

The adequate short-term availability of the propulsion unit during the starting phase is first of all needed in order to bring the vehicle into the speed range that will ensure adequate kinetic energy in order to reach the desired stopping point in the event of propulsion failure after the starting phase (escape velocity).

The number, location, and length of stopping places (for fixed or predetermined stations) are based on the topography of the line layout and wind conditions. The distance between two stopping points on an uphill stretch must be calculated with due regard for the maximum conceivable wind force in the event of head wind, the most unfavorable permissible conditions for the vehicle and the guideway, and the particular track design parameters, as well as propulsion failure.

If the same line section is also used for travel in the opposite direction, then the part of the safety braking system independent of the propulsion unit must bring the vehicle to a halt at the preselected stopping point while moving downhill with a tail wind and propulsion failure. This braking capacity must be mathematically verified assuming maximum wind force and the most unfavorable permissible conditions for the vehicle and guideway in this particular case and for the gradient in question.

The requirements noted apply accordingly to line sections with tunnels as well. If necessary, auxiliary stopping places must be provided in tunnels as well.

Depending on the application of a high-speed maglev train and/or the local conditions, other rescue plans are also possible, which are explained in greater detail in Chapter 12.

7. Proofs/Tests

It is necessary to prove compliance with the safety-engineering requirements of this body of regulations.

To this end, it is necessary first of all to provide an overall system description in safety-engineering terms; this must explain fully and in adequate detail how all of the safety-relevant technical and operational requirements, as well as the rescue plan, are to be implemented according to this body of regulations. This requirements specification is also the basis for all tests and acceptance trials that must be performed during the development, production, construction, and initial commissioning phases, and must therefore also contain the processes or methods used for providing proof with respect to the respective subsystems.

This system description, together with the proofs mentioned in this body of regulations, represent in their entirety the safety proof.

The overall safety-engineering system description, whose structure should be based on that of this body of regulations, should consequently illustrate in a unified form compliance with safety-engineering requirements resulting from safe hovering.

What follows are the minimum requirements for the proofs to be provided on materials or components, passive systems, active systems and, operational requirements relevant to the property of safe hovering.

7.1 Materials/Components

Manufacturer certificates and/or test certificates are to be provided for all materials and components that have been identified as safety-relevant in terms of safe levitation, e.g., line material, switching equipment, etc.; these certificates must indicate suitability for the intended purpose. As an alternative, individual tests with the same information content as far as the results are concerned can be provided.

7.2 Passive Systems

Passive systems--e.g., fixture elements and equipment relevant to safe hovering--must, in keeping with requirements, be documented by specifications, design records, and production records, including all calculations and other items of proof, e.g., testing and acceptance records; they also require special quality assurance during construction of the vehicle, erection of the guideway, initial commissioning of the overall system, and during actual operation.

7.3 Active Systems

Active systems for safe hovering--e.g., all relevant MSRUe installations--must, with respect to the proof/tests, satisfy the requirements for passive systems accordingly. In addition, special safety proofs are required describing the desired system performance in case of an error.

If the fail-safe property is required, then a theoretical proof of failure leading in the safe direction and corresponding acceptance tests are required. The safety level demanded must correspond to the safety level customary in railroad engineering. This is characterized, for example, by DIN VDE 0831 or the German Federal Railroad Regulation MUe 8004 (see also Chapter 4).

If the <u>safe-life</u> property is required--i.e., if a residual probability of failure commensurate to the risk must not be exceeded, then a theoretical reliability proof concerning compliance with it (e.g., fault tree analysis) must be kept and supplemented by practical tests within the framework of acceptance tests. This residual probability of failure may not exceed the value $1.0 \cdot 10^{-6}$ after an assumed operating time (running and stationary operation) of one year.

<u>Software</u> must be valid and correct, i.e., it must be accordingly validated, verified, and documented. The extent of inspections is to be adapted to the safety level of railroad engineering.

7.4 Operational Requirements

Compliance with operational requirements for safe hovering must be documented by suitable descriptions and calculations.

7.5 Checking the Proofs

The overall system description concerning safety engineering and the proofs mentioned in this regulation (safety proof) must be checked in terms of theory and practice by an independent institution for completeness and correctness of content.

With regard to safe hovering, the pertinent part of the system description, in conjunction with the proofs noted in 7.1 through 7.4, constitute the safety proofs.

8. Equally Applicable Standards

There are no known specific standards relating to safe hovering. Other standards relevant to the high-speed maglev train are noted in Chapters 2-12.

PROPULSION INCLUDING ENERGY SUPPLY

Chronology - Chapter 2
"Propulsion Including Energy Supply"

Edition	Revision	Date	Comment
1	0	12/89	**Title:** Propulsion, Substation
1	1	01/90	Changes **Title:** Propulsion Including Energy Supply
2, 3			missing
4	0	09/90	Changes
4	1	11/90	No change

Propulsion Including Energy Supply

1. Object

Chapter 2 deals with the long-stator propulsion subsystem, with requirements to be met in terms of the electrical safety and reliability of the propulsion unit and the requirements to be met by the propulsion unit in terms of marginal conditions indicated by the vehicle and/or guideway and to be complied with in order to maintain "safe hovering."

The long-stator propulsion subsystem consists of the following subsystems:

1. Energy feed from the public power network - (interface to the EVU [electricity supply company])
2. Converter with power output and control section
3. Propulsion controls with data interfaces and transmission to other substations and subsystems
4. Feeder circuit with feeder cable and switches
5. Long stator with laminated pack and cable winding

Subsystems 2 and 3 together can be called the substation. Subsystem 1 (EVU substation) is not the subject of this regulation, although requirements must be established for the availability of the feed-in.

Under discussion here are requirements to be met by the electrical safety system and by the propulsion cut-off system in the event of breakdown, as well as by the ground-fault detection system, intended to minimize the risk of short circuits. In addition, the requirements to be met in terms of safe cable winding and safe stator pack mounting are noted.

2. General Safety Requirements

In the event of a breakdown there must be no danger to persons resulting from the propulsion system. To this end, all components and subsystems must be designed with adequate reliability in accordance with the rules of technology and the relevant regulations.

The higher-order safety plan brings with it the requirement that it must be possible to switch off the propulsion through the operational control system with a high degree of reliability.

The propulsion unit itself cannot be safely designed. However, in keeping with the requirements of the safety plan noted in Chapter 1, requirements must be made of the propulsion unit in terms of the performance data, redundancy, and reliability of individual functions.

The propulsion unit must feature a redundant design such that even in the event of a partial failure the necessary propulsion output can be made available. This reduced propulsion output must be dimensioned in such a way that even on ascending gradients the minimum speed to be indicated by the vehicle (battery charge) and/or rescue plan (position of the stopping points) is ensured. The higher of the speeds must be taken here as the basis for designing the propulsion output.

The requirement of propulsion redundancy also means that the motor winding must be designed redundantly as well. The two motor windings must be electrically independent of each other.

In the event that startup takes place with a reduced residual propulsion output or emergency braking is not elicited immediately upon failure of half of the propulsion output, the minimum acceleration must be great enough that the limiting speed at the determined location is safely achieved.

The performance design of the propulsion must take into account the requirements with respect to stopping points in both running directions of a track.

If the result of slippage and vibration is that the specified load assumptions of the guideway and/or vehicle are exceeded, then these fault states must be detected and the propulsion must be shut off with high reliability. Otherwise, they must be tolerated by the vehicle or guideway, so that there is no danger to persons, or its probability of occurrence is so small that the risk is acceptable.

Ground faults must be detected with high reliability. Safety-critical effects of short circuits must be prevented with high reliability or, if this is not possible, their effects must be taken into account when specifying the load assumptions.

The failure of the power supply through, e.g.,

- failure of the public power network
- tripping an automatic circuit breaker
- blockage or arc-through of the inverter

- non-acceptance of the braking energy

may not cause or facilitate a safety-engineering failure that cannot be overcome by the operational control equipment.

3. Electrical Safety

3.1 Protection Against Dangerous Body Currents

For system sections with nominal voltages up to 1000 V AC and 1500 V DC, all measures against dangerous body currents in keeping with DIN VDE 0100, Part 410 are permissible. For the system sections (e.g., feeder circuit, long-stator winding, substation in the power section) with nominal voltage greater than the voltages noted above, the stipulations of DIN VDE 0101 must be noted, with consideration to the higher and variable operating frequency, and for grounding systems those of DIN VDE 0141. In addition, DIN VDE 0160 applies to the operating equipment in the power electronics and other electronic operating equipment that has an impact on the propulsion system. For the converter section, moreover, the stipulations of DIN VDE 0558 must be observed, and here in particular the partial change 1a of 12/79 for protection against dangers arising from electrical voltage.

Protection against dangerous body currents through indirect contact in the sense of DIN VDE 0100, Part 410 must be ensured in telecommunication systems through special measures in accordance with DIN VDE 0800, Part 2, depending on the type of network for heavy current in question.

3.1.1 Recommended Protective Measures

3.1.1.1 System Elements With UN > 1000 V

The type of power network chosen must be IT networks, since only this type ensures adequate reliability of the propulsion and a limitation of fault effects. In keeping with DIN VDE 0101, a ground fault monitoring unit must be provided that immediately detects a ground fault - if necessary, the substitute measures according to DIN VDE 0141 apply.

Insulation of the operating equipment (except for power electronics) is to be designed for the highest voltage during a ground fault, and resonance effects with the corresponding voltage and current increases must be taken into account, e.g., through installation of an overvoltage arrestor, in keeping with the variable network configuration (e.g., loss of the double power feed).

Compliance with the permissible contact voltage in the event of ground fault according to DIN VDE 0115, Part 1, must be evidenced by calculation and measurement. In so doing, the maximum switch-off time of the ground fault detector and the effect of the vehicle on the length of the ground fault must be taken into account. Alternative protective measures, such as potential controlling or isolation, are permissible. Compliance with the limit values for that interference in accordance with DIN VDE 0228, Parts 1, 2, 3 and 4, with communication wires must be checked and documented. The interference voltage must be checked after the system is set up.

3.1.1.2 System Elements With U_N < 1000 V

For reasons of availability, the IT network is preferred over the TN network, since after the first ground contact there is not yet a sink shutoff. The electronic operating equipment must be designed for a ground fault in the feed-in circuits or at the output in such a way that upon the appearance and disappearance of as well as for the duration of the ground fault, it can continue to be operated free of disruption (DIN VDE 0160, Sect. 4.1.4). Grounding via impeders in order to reduce overvoltages and oscillations is permissible. With respect to the insulation monitoring installation and fusing, see Chapter 3, Section 3.1.1.3 of these regulations.

If nominal voltage 660 V is used for the internal consumption of the feeder switch stations and if the IT network is to be used, then it is necessary to examine the question of whether the limits of extension are not exceeded in terms of the overall grounding capacity and whether the condition of DIN VDE 0100, Part 410, Section 6.1.5.3, is met. Ground faults in this system must be indicated by a ground fault monitoring installation.

3.2 Disconnection

Parts of the propulsion unit on which work is to be done must be disconnected. Disconnection is the universal shutoff or isolation of all possible power feed installations and voltage sources for the propulsion unit from all non-grounded conductors.

Attention must be given here to the special feature of the long-stator propulsion, specifically, that a variable voltage source takes effect even in a shut off submotor due to vehicle motion and its synchronous internal voltage.

Thus, work on the long-stator propulsion unit is permissible only when the long stator and feeder bus bars are isolated with interrupt installations that meet the conditions for isolating gaps according to DIN VDE 0670.

Interrupt installations in the feeder circuit must be positioned on the starting side in the direction of the long-stator winding. In order to determine the danger zone, DIN VDE 0108, Part 1, should be consulted. Overvoltage protection must be maintained after disconnection as well. During work behind the interrupt installation--e.g., on the part to the long-stator winding--the entire guideway must be blocked for vehicles in levitating operation (as well as towing operation), and the long-stator segment in question must be grounded. If interrupt installations are not positioned in the feeder circuit for the sake of disconnection in the substation, then output power circuit breakers positioned in the relevant substations or other interrupt installations in accordance with DIN VDE 0670 should be used for universal shutoff and isolation of the relevant feeder bus bars. The SIAB safety off-switch for the propulsion unit (see Section 4.2) is not used for disconnection.

Disconnection can occur:

- In ranges with nominal voltage ≤ 1000 V, by removing fuse cartridges, by shutting off automatic cutouts, load-break switches, fuse breakers or circuit breakers. Contactors alone are generally not suitable for disconnection.

- In ranges with nominal voltages > 1000 V, by installations that meet the conditions for isolating gaps according to DIN VDE 0670. This includes isolating links with at least 1.2 times the value of the minimum gaps according to Tab. DIN VDE 0101, List 2. If carriage-type switchgear is used, they must have a clear separation position.

In systems with nominal voltages > 1000 V, the requirements of installations to guard against reclosing in accordance with DIN VDE 0101, Sect. 4.3.2, must be complied with. Every part of the system that can be disconnected or switched off from the other parts must be able to be grounded and short-circuited. Attention must be given to safe discharge of the cable capacity. At the feeder switch stations, fixed, lockable ground switches must be provided at the long stator on the power feed side. For the feeder bus bars and at the neutral point, at least one grounding option must be provided for a mobile ground.

It must be impossible to apply voltage to disconnected systems via measurement equipment, e.g., parallel secondary windings of voltage converters.

Non-grounded system components in the feeder switch station must be protected against contact, and an isolated long-stator section remains galvanically open as long as it is not grounded, meaning that a vehicle being towed or running without propulsion can also pass this disconnected segment without braking forces due to induced currents.

3.3 Overload and Short-Circuit Protection

For overload and short-circuit protection, the requirements of DIN VDE 0100 apply to networks up to 1000 VAC, and those of VDE 0101 to networks with nominal voltages greater than 1000 VAC. In addition, DIN VDE 0160 is applicable to electronic operating equipment with an effect on heavy power installations. Automatic protection must be provided against the effects of overloads, internal and external faults, and it must restrict the consequences of the faults. All switching equipment must be suitable for the operational frequency range, or it must be ensured that they switch only in the range for which they are designed. Otherwise, diverse elements must be present (e.g., in the substation) that shut off the propulsion phase winding in question.

If no type-tested switch systems are used, tests on behavior in the event of internal faults must be conducted on the basis of DIN VDE 0670, Part 601.

4. System Safety

4.1 Protection Against Loss of Levitation Force During Winding Short Circuit

In the event of a short circuit in the long-stator winding in the local area before the neutral point, the loss of vehicle levitation force on one side is possible under certain conditions.

It must be proven that the one-sided set-down of the vehicle on the guideway caused by the short circuit occurs in such a way that the resulting loads on the vehicle and guideway are tolerated so well that personal injury is not anticipated. As an alternative, it can be proven that the loss of levitation force endangering the guideway or the vehicle is so rare because of incident-prevention measures that this failure remains within the bounds of an acceptable risk.

Thermal overloading of the winding must be excluded.

4.2 Safety Shutoff

During safety-critical fault states of the propulsion unit, a highly reliable shutoff of the propulsion unit (safety shutoff, SIAB) must occur. Since individual switching units cannot be safe, this type of shutoff must be designed with several diverse and/or redundant switching elements. The direction of energy flow, as well as the different switching capacity of the shutoff elements for the operating frequencies and the currents and voltages in question, must be taken into account when choosing. A voltage-wise shutoff is not necessary.

If propulsion-caused, safety-critical fault states are assumed, then shutoff of the propulsion unit must occur by way of a safety shutoff quickly and reliably enough that said fault state does not result in personal injury and/or serious material damage.

If the conditions for emergency braking of the vehicle are in evidence, then a quick operational shutoff of the propulsion unit must be undertaken if the principally different brake should ensure the necessary deceleration.

The operational control system, by way of a safe propulsion-monitoring unit in the substation - e.g., by way of a safe current-zero control - must check to see that the shutoff has actually occurred. If not, then a safety shutoff of the propulsion must take place.

In the current-zero control, interference - e.g., by inverters - may not result in a situation where propulsion shutoff by the SIAB is prevented.

4.3 Operating the Propulsion Unit

With different sites for operating and testing the propulsion unit or its components, reciprocal interlocking must ensure commanding responsibility.

The functions "emergency off" and "propulsion off" must be separated. Besides shutting off the high voltage, the emergency off function must also shut off the internal power consumption of a substation.

5. Subsystems Requirements

5.1 General Design Criteria

For the design of the propulsion unit, the maximum values for motor voltage, motor current, and motor frequency are critical. The voltage rate of rise and short-term voltage peak load in the event of breakdown (conductor against conductor), as well as the maximum instantaneous short-circuit current must be taken into account in designing all propulsion components (cable, see also Section 5.2). The insulation of the operating equipment must be designed for the maximum voltage in the event of a ground fault.

The motor voltage is limited by the electromotive series of the long-stator and feeder cable. If output transformers are used, their transformation ratio must be designed in accordance with the maximum voltage that can occur as commutation peaks during breakdowns in the converter, with due attention to the tolerance ranges of the intermediate circuit voltage. The permissible phase voltage must take into account the tolerance of the intermediate circuit voltage as well as the control reserve.

The resonance behavior of the propulsion network must be taken into account during design.

5.2 Feeder and Long-Stator Cable

The current-based design of the feeder and long-stator cable for intermittent service is permissible. The design to be undertaken in that case for the maximum effective values of the currents should be done in such a way that the maximum permissible temperatures are not exceeded and the vehicle can be braked electrically to a dead stand from the maximum permissible speed in each line segment without an impermissible increase in the temperature of the cable. The max. current conduction time per section and the succession of trains must be determined. Adequate power reserves to compensate for subsystem failures or to provide short-term overload when changing switching sections must also be considered.

In order to determine the electromotive series of the cable, the mode of operation must be considered. Since ground-fault detection with shutoff in the event of a fault is provided, Category A (IEC 502, Amend. 2 of 1987) in conjunction with the max. system voltage U_m is adequate for choosing the nominal voltage U_o of the cable.

The special conditions for use of the cable, with its significantly higher voltage load compared to standard conditions in the event of ground fault and its short-term voltage peaks in commuting the converters, especially during breakdown, must be taken into account during design and testing.

5.2.1 Feeder Cable

The feeder cables must feature shields. They must be laid separately from internal consumption and telecommunications cables. The cable fittings must correspond to DIN VDE 0278 and be suitable for the maximum frequency and the max. possible voltage peaks.

Power rails must be designed for the max. operating frequency, and current displacement should be taken into account.

5.2.2 Long-Stator Cable

The long-stator cable and the cable fittings must be suitable for the planned purpose.

Note: With regard to the TVE, the requirements in specifications [2.1] and [2.2] for the TVE-laid cables, with the supplements to the testing requirements according to [2.3] were complied with.

The requirements specification must also take into account the special conditions of the application system, such as the max. voltage load in keeping with Section 5.1 and the requirement for a ground-fault detection installation. Suitability must be demonstrated by operational experience.

The long-stator cable must be shielded. If this is configured with metallic shielding, then it must be grounded only on one side, in order to avoid short-circuit loops. The insulation of the shielding to the ground must be designed for induced voltage, dependent on vehicle length.

The current-carrying capacity of the shield must be designed for the max. shutoff time in the event of ground faults. It must be taken into account here that the length of the ground fault also depends on the effective duration through the vehicle (synchronous internal voltage).

If the function of mechanical protection and that of the electrical shield are combined in an electrically conductive jacket, then the current-carrying capacity of the shield and its special conductivity are to be set in such a way that a maximum ground-fault resistance is not exceeded - if a possible ground-fault detection installation has a minimum threshold current -

meaning that the ground-fault current does not result in large-scale destruction of the cable within the tripping period of the ground-fault detection unit and below the threshold values for ground-fault detection. The ground and retaining bands must be designed for the maximum ground-fault current for the length of time until shutoff. They can be grounded on both sides and should be connected to the lightning protection ground. The ground lines of these connections must be dimensioned in accordance with DIN VDE 0141. In concrete, at least 2 connections at 50 mm^2 of steel are necessary.

5.2.3 Stator Pack Mounting

The stator pack mounting must be safe life during the planned service life or must feature non-functionally involved redundancy (so-called cold redundancy). In the latter case, failure of the mounting for a pack must be detected through this. The detection time must be determined as a function of the quality of cold redundancy.

Note: A redundant mounting can be ensured, for example, by a mounting whereby upon failure of the mounting level bearing the pack alone, a defined shift within the permissible tolerance range of the stator pack occurs, which is safely detected by a vehicle-side sensing installation.

5.2.4 Mounting of the Cable Winding

The cable winding must be mounted into the stator grooves in such a way that a failure probability comparable to that of the stator pack mounting is achieved.

5.3 Feeder Switch Stations

The feeder switch stations must be in keeping with the Pehla regulations. For the creep distances and clearance, Class C in keeping with DIN VDE 0110 should be selected. The execution must correspond to DIN VDE 0670, Part 6.

If mobile carriage-type switchgears are used, the switches or contactors built in to them may be moved only in the opened position. Switching the switching elements should not be possible during the process.

Because of the inverter, the short-circuit currents in the feeder switch stations are not significantly higher than the standard currents. Electric arcs in the station may not result in damage to the enclosure and must, in the event that they cause a ground fault, result in a shutoff of propulsion through the ground-fault monitoring installations.

Overvoltage protection must be placed before the neutral and feed-in point of the long-stator winding to protect the switch station.

The grounding of the switch stations must be connected to the lightning protection system of the guideway.

5.4 Grounding Systems

5.4.1 System Elements With the Nominal Voltage of the Long-Stator Winding

The ground-fault current is cut off by way of a ground-fault detection installation. The grounding and the shields must be dimensioned for the duration of the max. ground-fault current and for the steady current which is below the detection limit of the ground-fault detection installation in the event of a ground fault.

The shield may not be destroyed for significant lengths.

The ground voltage must be complied with for largest ground-fault current according to DIN VDE 0141/89 and the contact voltage according to DIN VDE 0115, Part 1. Proof must be provided by measuring the ground impedance at least for the range for which the max. ground-fault current was calculated. A preliminary test of impedance may also be necessary for other line segments if large impedances are expected on the basis of soil conditions. The max. operating frequency should be chosen for the measurement frequency. In addition, the requirements concerning minimization of interference by secondary propulsion installations (such as transducer, control, and signaling lines) must be taken into account by configuring the grounding network as a tightly meshed network with a large surface.

5.4.2 System Elements With Medium Voltage, 50 Hz

The grounding systems must be designed for the ground-fault, residual ground-fault and ground current indicated by EVU according to DIN VDE 0141, 1989, Table 4, Column 7. In addition, the requirements pertaining to limiting transient overvoltages must be taken into account.

In order to reduce lightning currents on the feeder cable shields, the grounding system of the substation must be connected to the guideway lightning protection system. In the case of several system components with medium voltage, a ground bus line must be provided.

At the guideway pillars, compliance with the contact voltage of 65 V is not necessary if the ground-fault monitor immediately cuts off the fault whenever that voltage is exceeded.

The lateral guide rails must be grounded at each pillar.

5.4.3 System Elements With Low Voltage, 50 Hz

If the IT network type is chosen for this network, then ground faults must be indicated by way of a ground-fault monitoring installation. The protective conductor should be installed together with the main conductors in one cable. A zero conductor should be excluded in the switch station supply line in particular.
The cross-sections of the protective conductor and of the ground conductor must be dimensioned in keeping with DIN VDE 0100, Part 540, and a connection must be established between the low-voltage protective ground and the high-voltage ground.

In the cases where the TN or TT type of circuit is chosen for low-voltage circuits, DIN VDE 0141, Tab. 7 must be noted for ground systems.

5.5 Ground-Fault Detection Installation

Ground-fault detection installations must be provided that take into account the differences in the design of the switching segments, substation locations, feeder bus bars, the variable feed frequency and circuit configurations (balanced or unbalanced power feed) and the transformer and/or direct operation.

Activated feeder cable and switching segments must be continually monitored for their insulation state.

Faulty components must be shut off with adequate speed, so that the measures to limit the permissible contact voltage are complied with and the current-carrying capacity of the cable shields is not exceeded.

If the ground-fault detection installation is connected to high-voltage transformers, then it must stand up to a voltage test of 2 kV so that transient overvoltages do not result in faults.

The circuit to be used must ensure a clear distinction of the ground-fault from the signal in normal operation at all operational points. If there are operational points where this is not the case, then the transition from these operational points to operational points with clear differentiation must be so fast that the max. shutoff time on which the design of the protective measures is based is not exceeded.

The function of ground-fault detection must be checked at regular intervals.

5.6 Propulsion Control

The propulsion control systems do not assume any responsibility for safety, since fault states caused by them are handled by the operational control system using safety technology. However, they must be configured in such a way that there is a direct hazard to humans neither during normal operation nor in the event of failure.

6. Proofs/Tests

In order to establish the stress values of the propulsion system, an environmental specification must be drawn up in which the environmental conditions that are expected and which must be complied with are listed. For the selection and testing of the components, the operating conditions and the stress values occurring during breakdown must be established. Compliance with the requirements in Sections 2-5 as well as with the requirements from the environmental specification must be proven: for structural components, with type and routine check tests or using proven components, for systems with safety responsibility with a preliminary test of the circuitry records (safety certification) and through acceptance tests on the propulsion unit.

In order to ensure hazard-free, long-term operation, a maintenance and inspection regulation must be formulated that establishes the recurrent tests to be performed in particular.

7. Equally Applicable Standards

Wherever applicable, DIN VDE provisions are valid, especially the relevant parts of the provisions listed below.

DIN VDE 0100	**Provisions on the setup of power installations with nominal voltages of up to 1000 V**
DIN VDE 0101	**Setting up power installations with nominal voltages over 1 kV**
DIN VDE 0105	**Operation of power installations**
Part 1	- General definitions
Part 3	- Additional definitions for railroads
E DIN VDE 0106	**Protection against dangerous body currents**
Part 1 A1	- Classification of electrical operating equipment in terms of protection against dangerous body currents and requirements for protective measures
Part 101	- Basic requirements for safe separation in electrical operating equipment
DIN VDE 0108	**Power installations and safety power supply in structural works for assemblies of people**

E DIN VDE 0109	**Insulation coordination in low-voltage systems**
Part 10	Clearances
DIN VDE 0110	**Insulation coordination for operating equipment in low-voltage systems**
Part 1	- Basic definitions
DIN VDE 0115	**Railroads**
DIN VDE 0141	**Ground systems for power installations with nominal voltages over 1 kV**
DIN VDE 0160	**Equipping power installations with electronic operating equipment**
DIN VDE 0228	**Measures for interference in telecommunications systems by power installations**
Part 1	- General principles
Part 2	- Interference from three-phase systems
Part 3	- Interference from AC railroad systems
Part 4	- Interference from DC railroad systems
DIN VDE 0250	**Insulated power lines**
E DIN VDE 0266	**Cable with improved performance during fire;** **Nominal voltages U_0/U 0.6/1 kV**

DIN VDE 0278	**Heavy-current fittings with nominal voltages U of up to 30 KV**
DIN VDE 0298	**Use of cables and insulated lines for power installations**
Part 2	- Recommended values for current-carrying capacity of cables with nominal voltages U_O/U to 18/30 kV
Part 3	- General provisions for lines
Part 4	- Recommended values for the current-carrying capacity of lines
DIN VDE 0472	**Tests on cables and insulated lines**
DIN VDE 0532	**Transformers and choke coils**
DIN VDE 0558	**Semiconductor rectifiers**
DIN VDE 0660	**Switchgears**
DIN VDE 0670	**AC switchgears for voltages over 1 kV**
DIN VDE 0675	**Guidelines for overvoltage protection installations**
DIN VDE 0800	**Telecommunication technology**
DIN VDE 0816	**External cables for telecommunication and information processing systems**

DIN VDE 0831	Electric railroad signaling systems
DIN VDE 0845	VDE provision on protecting telecommunications systems against overvoltages
DIN VDE 0888	Light-wave conductors for telecommunication and information processing technology
DIN 40050	Enclosures; contact, outside body and water protection for electrical operating equipment
DIN 40046	Environmental tests for electrical technology
IEC 502	Extruded solid dielectric insulated power cables for rated voltages from 2 kV up to 30 kV, Amendment No. 2
Pehla RL	Test guidelines for high-voltage systems
VDI 4005	Effect of environmental conditions on the reliability of technical products

8. Other Literature

[2.1] <u>Specification</u>
Cable, cable connectors of 5/18/1979
Doc. No. TVE T 483004 SS 0002
Publisher: Thyssen Henschel

[2.2] <u>Specification</u>
for the traveling field cable of the "TVE South Loop" project" of 6/15/1984
Doc. No. TH/VNP 1/964/06/84
(responsible for contents: KABELMETAL)-designated "Preliminary! For your information" -

Follow-up document

<u>Specification</u>
Cable of the 3-phase traveling field winding for the TVE South Loop of 7/23/1985
Doc. No. TH/NTSP/2687/12/84
Publisher: Thyssen Henschel

[2.3] <u>Test report</u>
Supplements to the test requirements
Report no. 947/B 79/174 of 11/27/1979
Publisher: TÜV Rheinland

ON-BOARD ENERGY SYSTEMS

Chronology - Chapter 3
"On-Board Energy Systems"

Edition	Revision	Date	Comment
1			missing
2	0		missing
2	1	05/89	
2	2	06/89	No change
2	3	08/89	No change
2	4	09/89	No change
2	5	10/89	Changes
3			missing
4	0	09/90	Changes
4	1	11/90	No change

<u>On-Board Energy Systems</u>

1. Subject

Chapter 3 covers the on-board energy subsystem with requirements for electrical safety, the on-board circuits, and their subsystems:

- energy transmission, no-contact or conventional;
- energy conversion by means of rectifiers, choppers, transformers;
- energy storage units;
- energy distribution, with switching and protective devices as well as cables and lines.

Attention will be given to the requirements made of the on-board circuits for supplying the energy systems in order to ensure the levitation and guidance functions as well as the requirements made of the on-board circuits to ensure the supply of all data processing, open-loop, and closed-loop controls.

2. General Safety Requirements

Besides the requirements of electrical safety--which should be understood as protection against dangerous body currents and protection against fire hazards resulting from the operation of electrical equipment--the on-board energy supply of a high-speed maglev train must especially meet the requirement of functional safety, even in the event of fault.

It must be ensured that the on-board energy systems will always guarantee that a stopping point can be reached safely. To this end, several redundant and mutually independent energy systems (on-board circuits) must be developed.

The minimum number of energy supply networks for the levitation/guidance system needed to ensure safe hovering is 3. In this case, emergency braking must be initiated in the event of failure of one network. The reliability of the respective individual circuits must be so high that the failure of another network must not be assumed during emergency braking.

Note: If operation is to be maintained even after the failure of one circuit network, then at least 4 networks are necessary.

It is then necessary for the levitation and guidance functions that the failure of one component, one subsystem, or one complete on-board circuit does not result in any restriction of operation and that the failure of another on-board power network impairs only part of the levitation function, while harmful effects on the vehicle or guideway do not occur and emergency braking remains possible.

The on-board energy systems are to be developed in such a way that faults in one redundant element will not lead to faults in another redundant element in the same system (independence of redundancy). Faults in one system/subsystem or one component may have an effect on other systems/subsystems/components only to the extent that no more than one redundant element per system is affected.

In the event of individual failures that are critical to safety in combination with a second failure, there must be functional controls in the equipment in question in order to be able to elicit safety responses in time.

Each redundantly fed on-board circuit with sinks that are critical to safety must have a buffer battery. Sinks that are critical to safety, which must be redundant, must be supplied from different, redundant networks.

Note: In exceptional cases, it is possible to do without power feed-in from buffered networks for redundant sinks that are critical to safety, if these sinks are positioned on a changeover network such that in the event of failure of a network, at least one redundant element is not affected by said failure and the failure strategy takes this into account accordingly. Switching state changes in the on-board circuit can be effected during normal operation only by feeding in energy.

3. Electrical Safety

3.1 Protection Against Dangerous Body Currents

All protective measures against dangerous body currents according to DIN VDE 0100, Part 410, November 1983, are permissible. The requirement for "safe hovering" must be given primary consideration in selecting the protective measures in connection with the short-circuit and overcurrent protection to be applied. DIN VDE 0160, January 1986, Sections 4.4 and 5.5, must be observed regarding electronic operating equipment that affects the on-board energy supply.

The

- overcurrent protection installation
- insulation monitoring installation

are of practical significance because the fault-voltage protection system basically cannot be applied and the fault-current protection system can be applied only in AC circuits. Because of the amount of outlay required for design, protective insulation is useful only under certain conditions. For example, protective insulation cannot be used with socket circuits to which equipment with differing types of enclosures are connected. Protective separation can be applied only on a case-by-case basis.

3.1.1 Recommended Safety Measures

The protection plan must take into account the differences in power feed conditions during movement and stationary operation. The TN and the IT networks are possible as network forms during no-contact energy transmission. During stationary power feed, a

TT network form is also possible. Feed-in via current collectors during running operation is not the subject of this body of regulations.

3.1.1.1 DC Networks with Nominal Voltages of > 120 V

Protection against direct and indirect contact must be provided in accordance with the provisions of DIN VDE 0100, Part 410.

3.1.1.1.1 TN Network

Protection is permissible only with overcurrent protection installations according to Section 6.1.7.1, DIN VDE 0100, Part 410, whose DC switching capability has been proven. With operating equipment that is considered power electronics, such as DC-to-DC transformers, choppers, inverters, etc., where there is an electronic current limitation in the event of a short circuit, it must be examined on a case-by-case basis whether the zero voltage conditions are being complied with according to Section 6.1.3.3 of the same regulation. A reduction of the protective conductor gauge according to Table 2, DIN VDE 0100, Part 54, Nov. 83, is not permissible because of the possibly longer-lasting load. The circuit must then be checked to make sure that the protective conductor is always protected by the overcurrent protection units of the outside conductors (see DIN VDE 0160, 6.5.3 a) or the power-electronics equipment is being turned off by suitable devices (e.g., sum current converters, di/dt identification). The protective conductor gauge must be dimensioned in the first case in such a way that in the event of a complete short circuit, the maximum permissible contact voltage cannot result.

If electronic instruments ensure that upon contact with active elements or bodies of faulty operating equipment the voltage at the output terminals will be reduced immediately (< 200 msec) and without turnoff to the permissible values of the contact voltage, then only one protective measure is to be applied against direct contact according to the provisions of DIN VDE 0100, Part 410, Section 4.3.2.1.

Insofar as the vehicle structure cannot or should not serve as the protective conductor, each sink gets a tripolar connection for the active conductors and the protective conductor. The use of a metallic vehicle structure as active return conductor is not permissible.

A central grounding point must be established for the protective conductors at which point one battery pole (preferably the negative pole) as well as the return conductors from the individual network bus bars and the protective conductor rail must be connected with the vehicle body. In connecting the protective conductor to the enclosures and the vehicle ground, attention must be paid to electrolytic corrosion, especially where copper and aluminum are combined. Adjacent sections must be connected with the central grounding point via a separate protective conductor (at least 50 mm^2).

With stationary power feed via an umbilical cord or collector shoes, the compatibility of the protective measures of this means of power supply with the protective measures on the vehicle must be ensured.

According to DIN VDE 510, Part 2, 1986, dipolar battery fuse protection is required for batteries in the intermediate DC circuit with galvanic connection to the feed-in, grounded network. The protective measure applied in the respective three-phase power network is to be retained as protection for the DC circuit--if technically possible--and, if necessary, it must be supplemented by suitable protective measures in such a way that, in the event of fault, no voltage of > 120 V DC or 50 V AC will remain at the body of the operating equipment.

3.1.1.1.2 IT Network

Because of availability, an IT network is preferred over the TN network since as yet there is no sink shutoff after the first body contact. This means that for a ground contact in the feed-in network or at the output, electronic operating equipment should be designed for the appearance or disappearance as well as the duration of ground contact in such a way that they can continue to be described as being free of breakdown (DIN VDE 0160, Section 4.1.4). If operation free of feedback and breakdown cannot be realized in the event of the appearance of a ground contact at the output of individual components, then this ground contact may only result in the shutoff of the components in question.

Operating equipment must be designed for the voltage present during ground contact. It is recommended for this reason that a neutral conductor not be carried.

An active conductor of the system should not be connected directly to the vehicle ground. Grounding via impedors in order to reduce overvoltages and oscillations is permissible.

Contact between the housings and the vehicle ground can be established individually, in groups, or as a whole with a protective conductor. The sections should be connected with each other via a separate protective conductor (at least 50 mm^2). The condition $R_A \bullet I_D \leq U_2$ according to DIN VDE 0100, Part 410, Section 5.1.5.3, is to be tested only with a stationary power supply if no other protective measure is brought to bear for it.

For each galvanically separate network, a separate insulation monitoring device is to be provided, which will indicate the first body contact or ground fault through an optical and acoustic signal. This fault must be eliminated at the end of one day of operation.

In the event of two faults, there must be shutoff via an overcurrent installation according to DIN VDE 0100, Part 430, Section 6.1.3.3, since the IT network becomes a TN network (see also 3.1.1.1.1 of this Chapter).

A dipolar sink fuse must be provided according to DIN VDE 0100, Part 430, Section 4.9.1. A dipolar sink fuse can be omitted only if a double ground contact--which results in bridging of the sink fuse--is safely prevented through a ground-contact- and short-circuit-proof installation of the supply line going to the fuse unit. Overcurrent protection units must in principle be arranged on a conductor with the same polarity (preferably + pole).

In case of bidirectional power feed, it is necessary that dipolar overcurrent protection devices be provided on both sides, unless the current sources are incapable of supplying current that would exceed the current-carrying capacity of the conductors or if they have their own fault detection and can separate. The permissible contact voltage must not be exceeded here. Equipment-internal fuses to protect the operating equipment are not affected by these stipulations. For them, VDE 0160 in particular should be observed.

3.1.1.2 DC Networks With Nominal Voltages ≤ 120 V

Protection against both direct and indirect contact is provided if the conditions according to DIN VDE 0100, Part 410, Section 4.3, "Protection Through Low Functional Voltages" are complied with.

Note 1: Protection using protective low voltage according to DIN VDE 0100, Section 4.1, generally will not be practicable, since according to Section 4.1.5.3, bodies in the protective low voltage circuits may be connected neither with the ground (the vehicle ground), nor with protective conductors or bodies of circuits with a different voltage.

Note 2: For reasons of availability, safe electrical separation according to DIN VDE 0100, Part 410, Sections 4.1 and 4.3 can be required (see also DIN VDE 0160, Section 5.5.1.1.2).

3.1.1.3 AC Networks

Protective measures according to DIN VDE 0100, Part 410, should be applied. When the protective measure fault-current circuit breaker is used, it must be ensured that in the event of faults in DC circuits either the protective measure present there takes effect or there will be no DC influence that would impair the function of the fault-current circuit breakers or a safe electrical separation between the AC circuits and the DC circuits is present.

Insulation monitoring devices in AC networks must be suitable for detecting faults in DC circuits if there is no safe separation of the two types of networks.

3.1.2 Outside Power Feed

The provisions of DIN VDE 0115 must be observed for power feed-in via collector shoes.

3.1.2.1 With Safe Separation to the On-Board Networks

Protective measures in the stationary or mobile circuit network of another vehicle and in the on-board network remain effective for themselves. In the outside network, all protective measures according to DIN VDE 0100, Part 410, are permissible for the TN, TT, and IT networks.

3.1.2.2 Without Safe Separation to the On-Board Networks

The electrical installations on the magnetic levitation vehicle may be connected with a stationary electrical system or with those of another vehicle without safe electrical separation to the outside network if the protective measures used in these systems remain effective for themselves or jointly. Fault-current circuit breakers and insulation monitoring equipment in the AC network may not be influenced by faults appearing in the vehicle if the protective measure in the on-board network also depends on protection in the outside network.

3.1.2.3 Potential Equalization

Vehicles are to be provided with installations that enable potential equalization between vehicle and stationary installations. These installations must work automatically in stopping points and during standstill.

3.2 Disconnection

Parts of the vehicle electrical system on which work is to be done must be disconnected. Disconnecting is the universal shutoff or separation of all possible power supply units and voltage sources for the vehicle, for part of the vehicle, or for operating material from all conductors that are not grounded. Voltage sources are the batteries of the on-board power networks, the outside power feed from the umbilical cord or from collector shoes at the stopping point.

Disconnection is performed as follows:

- On vehicles with nominal voltages of $\leq$ 1000 V, by removing fuse elements, by turning off automatic cutouts, load-break switches, fuse isolating switches or heavy-duty switches as well as by unplugging all plug connections used for external power feed.

  Note: Generally, contactors alone are not suitable for disconnection.

- Vehicles with a nominal voltage of > 1000 V, by means of installations that meet the condition for isolation distances according to DIN VDE 0670.

Capacitors whose automatic discharge is not secured, must be discharged with suitable devices.

The conditions according to DIN VDE 0105 for securing against reconnection must be complied with. In particular, DIN VDE 0105, Part 3, 1988, Sections 9.1.3 and 9.2.2, for auxiliary power supply from a stationary network, must be observed.

3.3 Fire Protection

3.3.1 Overload and Short-Circuit Protection

In determining short-circuit protection plans, special conditions which arise from the need for a safe energy supply must be taken into account.

These conditions are:

- After shutoff of a network affected by a short circuit, there must be no further uncontrolled shutoffs of the fault-free networks.

  Note: Because of a short circuit in a network and the failure of that network, the loss in levitation force of the hovering vehicle causes compensating currents, due to the control process in the unaffected networks that serves to compensate for this loss in levitation force.

- A power feed, especially into the short circuit over a lengthy period of time, via electronic components that are involved in current limitation during a fault must not lead to a danger of fire that would threaten safe hovering. Here one must also take into account short circuits with electric arc generation. In TN networks, a differential current monitoring function must be performed in order to detect high-impedance short circuits, e.g., electric-arc short circuits.

  Note: Dimensioning the lines only with an eye to overloading in the event of this type of fault is inadequate because an electric arc and the attendant danger of fire must also be prevented.

Lines and cables must be protected against the effects of excessive heating due to both routine operational overload and short circuits with overcurrent protection units or equivalent protection devices. The provisions of DIN VDE 0100, Part 430, must be applied to the positioning and selection of protection units and to the protection required of the outer conductors and neutral conductors. For allocation of the protective units to the wire gauge, conditions (1) and (2) of DIN VDE 0100, Part 430, must be complied with. Small overloads of a longer duration may not occur.

The power rating must be selected according to DIN VDE 0298, Part 4, 1988. For lines that do not comply with the standards DIN VDE 0250 and 0282, the power rating must be determined in some other way. The information in DIN VDE 0100, Part 523, 1981, Section 7.3, applies to bus bars. The note under 8.2 should be observed. In special cases, a increase in the load may be tolerated for a short time. However, the permissible operating temperature of the line may not be exceeded.

4. Subsystem Requirements

4.1 Energy Transmission

Energy is transmitted free of contact and/or conventionally using collector shoes and an umbilical cord. No-contact energy transmission must be designed in such a way that a supply of all sinks is ensured after reaching a specified minimum speed and that it is possible to recharge the batteries such that the charge lost from the battery can be compensated for within a given number of defined missions. If the latter is not possible, then the recharge should be performed after the end of a running cycle using an umbilical cord or collector shoes. The temperature dependency of battery capacity should be considered during the charging process. The levitation functions of the sinks connected to an on-board circuit must be preserved after reaching a minimum speed, even without the help of the battery for the network in question.

The failure of one battery must not have any repercussions (overvoltage, instability) on the connected networks, e.g., batteries may not be used as backup capacities in the network.

The failure of individual components of the energy transmission system (linear generators, set-up choppers) may not have any effect on other similar components. The harmonic oscillation load may not exceed the permissible values indicated by the battery manufacturer with regard to the battery's service life.

During no-contact energy transmission, the independence of all on-board circuits must be ensured.

With stationary power feed via an umbilical cord, it must be ensured through pilot contact that double power feed, wrong polarity, and disconnecting when loaded are not possible.

4.2 Energy Storage

Taps on batteries are not permissible. The battery capacity must be adapted to the battery load at a standstill and while running.

The batteries must be functionally without restriction up to a slant of 25°; i.e., no electrolyte may emerge from the cell apertures.

The battery must withstand horizontal and vertical oscillation and shock stresses which are not exceeded in operation and during transport.

The test can be conducted on the basis of DIN VDE 0122. The stress values must be determined in accordance with the environmental specifications for the installation area.

For the power batteries, a charge state monitoring unit and a charge control are necessary to ensure a constant, sufficiently high charge state for a defined running cycle, so that a proper emergency braking/set-down process can always be performed at a given speed and battery temperature. Overcharging the batteries must be prevented by suitable measures. Batteries must be adequately ventilated while moving and at a standstill. DIN VDE 0510, Part 2, Section 7.1, is to be observed with respect to dimensioning the ventilation in terms of precautions against the risk of explosion. Moreover, the ventilation system must be dimensioned more strongly if hydrogen production higher than in Table 3, DIN VDE 0510, is expected. The fan must be kept running for 1 hour after charging. Impermissible heating of the battery or of individual cells must be prevented by a suitable geometric layout of the cells and of the fan arrangement, and by the size of the air current. Compliance with these limits during operation must be proven.

If the fans are configured as extractor fans, then they must comply with the VDMA [Association of German Mechanical Engineering Institutes] Standard 24169, Part 1, Dec. 1983. Operating equipment in which sparks could be generated in the course of routine operation, e.g., circuit breakers, must be installed at least 0.5 m from the cell apertures or in vaporproof housings according to DIN VDE 0165, Sect. 6.3.1.4. An ignitable mixture may be diverted into the interior of the coach neither during normal operation nor in the event of fan failure. The battery ventilation and its monitoring are to be executed redundantly; the redundancy here is necessary only for protection against explosion. If there is excessive heating or excessively unequal heating during a fan failure, redundancy is necessary here as well.

Heavy-duty switches or load isolation switches must be provided for disconnecting the batteries. The wiring to these circuit breaker elements must be ground fault- and short circuit-proof. Additional protection for the lines must be provided with a view to the high energy density of the power batteries. Suitable design, increased insulation, and special inspection, especially at the connection points, must see to it that a short circuit in these areas can be ruled out.

The power batteries are to be positioned in covered in such a way that the batteries can be divided into smaller units for maintenance purposes in such a way that a voltage higher than 60 V cannot be picked up in terms of the maximum contactable voltage.

With plug-in batteries, the plug connections must be tested for the anticipated plug cycles. Disconnecting the battery during current flow must be prevented.

4.3 Energy Conversion

The choppers, DC-DC converters, levitation and guidance choppers and brake chopper must meet the requirements according to DIN VDE 0160. In particular, electronic operating equipment must be constructed and the structural elements must be selected in such a way that the equipment are adequately heatproof. The permissible operating temperatures may not be exceeded during fault-free operation. During faulty operation, electric arcs must not remain stationary and fires must not spread. The equipment must be constructed in such a way that a fault in one redundancy will not cause faults in another redundancy of the same system. The effects on other systems must remain limited to the failure of no more than one redundancy in an outside network.

Requirements specific to maglev trains apply to the levitation and guidance choppers and to the brake chopper:

The levitation, guidance, and brake choppers must be constructed in such a way that the magnets can be safely de-energized. The capacity for safe shutoff must be monitored (see further requirements in this regard in the sections on the levitation/guidance system and the braking system in Chapter 1 of these regulations).

Note: An impermissible approach between the magnets and the guideway because of excess currents in the levitation/guidance magnets must be avoided.

4.4 Energy Distribution

Energy is distributed in the vehicle by the switch cabinets or boxes, with their fault-state detection and protection equipment, as well as the cables and lines,

Energy for the individual circuits must be distributed according to the principle of maximum possible spatial separation. In so doing, the battery circuit breakers or isolation switches and the batteries must be positioned in spatial proximity, and the connection between them must be executed in ground fault- and short circuit-proof cabling with additional protection. The vehicle ground may not be used as a return conductor. The sinks must have dipolar fuse protection, unless the bus bars are ground fault- and short circuit-proof as far as the sink fuse. At branching points where bidirectional power feed is possible, corresponding short-circuit protection and overload protection must be provided at both feed-in points. In networks with protective multiple grounding, a differential current monitoring unit must be provided for fault detection in a resistive ground contact. Undervoltage detection can be used to detect short circuits between conductors.

Cables and lines must be halogen-free and flame-resistant. In the event of fire, no toxic gases may be released. Preservation of insulation under a 1-hour flame effect, in the presence of standard oscillation stress in the installation room of the cables and lines, must be ensured for wiring that is relevant to safety.

Teflon-insulated hook-up wires or similar types of cables and lines may also be used in individual components that are housed in a spatially limited and sealed casing.

Cables/lines must be designed for safe life for bending stresses in keeping with the real operational stress. Corresponding proof must be provided by type tests.

Short circuit- and ground fault-proof cables and lines must at least correspond to DIN VDE 0600, Part 500, A5 (currently in draft form), Tab. XII, but at least be single-core. The test voltages should be selected in keeping with DIN VDE 0600, Part 500, Tab. X and Tab. XI.

If protective conductors made of Cu are connected to aluminum components, care must be taken to avoid electrolytic corrosion.

Plug connections on rack units must be tested for the corresponding stresses and plug cycles.

Central switch cabinets must be constructed and tested in accordance with the specified environmental conditions (oscillation and shock tests, heating test, climate test). In particular, the formation of condensation product in the casings must be avoided.

5. Proofs/Tests

An environmental specification listing the anticipated and mandatory environmental conditions must be draw up to establish the stress values for the components and systems. Compliance with the requirements in Sections 2-4 of this Chapter and with the requirements for the environmental test criteria must be proven for components through type and routine check tests, and for systems through a preliminary examination of the wiring records (current diagrams, lists of components) and by acceptance tests on the vehicle at a dead stand, in stationary leviation mode, and during actual train operation.

6. Equally Applicable Standards

Where appropriate, VDE provisions are applicable, especially the relevant parts of the provisions listed below.

DIN VDE 0100	**VDE provision on the setup of power installations with nominal voltages of up to 1000 V**
DIN VDE 0101	**Setting up power installations with nominal voltages over 1 kV**
DIN VDE 0105	**Operation of power installations**

E DIN VDE 0106	**Protection against electric shock**
Part 1 A1	- Classification of electrical and electronic operating equipment
Part 101	- Basic requirements for safe separation in electrical operating equipment.
DIN VDE 0110	**Insulation coordination for operating equipment in low-voltage systems**
DIN VDE 0115	**Railroads**
DIN VDE 0122	**Electrical equipment in electrical road vehicles.**
DIN VDE 0160	**Equipping power installations with electronic operating equipment.**
DIN VDE 0165	**Setup of electrical installations in explosion-prone areas**
DIN VDE 250	**Insulated power lines**
E DIN VDE 266	**Cable with improved performance during fire; nominal voltages U_0/U 0.6/1 kV**
DIN VDE 0282	**Rubber-insulated power lines**

E DIN VDE 0298	**Use of cables and insulated lines for power installations**
E Part 2	- Recommended values for current-carrying capacity of cables with nominal voltages U_0/U to 18/30 kV
Part 3	- General provisions for lines
Part 4	- Recommended values for the current-carrying capacity of lines
DIN VDE 0472	**Tests on cables and insulated lines**
DIN VDE 0510	**VDE provision for accumulators and battery systems**
DIN VDE 0660	**Switchgears**
Part 500	- Low-voltage switchgears - combinations
E Part 500 A5	- - Modification 5
DIN VDE 0670	**AC switchgears for voltages over 1 kV**
DIN 5510	**Preventative fire protection in rail vehicles**
Part 5	- Electrical operating equipment; safety-engineering requirements

DIN 31000/VDE 1000	General guidelines for proper safety in designing technical products
DIN 40050	Enclosures; contact, outside body and water protection for electrical operating equipment
DIN 40046	Environmental tests for electrical technology
VDI 2244	Design of products with proper safety features
VDMA Standard 24169	Guidelines for fans to transport air containing combustible gases, vapors, or smoke

Contents

ON-BOARD CONTROL SYSTEM

Chronology - Chapter 4
"On-Board Control System"

Edition	Revision	Date	Comment
1			missing
2	0		missing
2	1	05/89	
2	2	06/89	Changes
2	3	08/89	Changes
2	4	09/89	No change
2	5	10/89	Changes
3			missing
4	0	09/90	Changes
4	1	11/90	No changes

On-Board Control System

1. Subject

The on-board control system comprises all the functions and installations of the operational control system and of the on-board controls that are located in the vehicle.

Specifically, this includes the following:

- vehicle operational control computer (BLF)
- on-board controls, including door control
- vehicle location
- diagnosis
- operating console
- auxiliary brake control
- passenger emergency signal
- transmission installation on vehicle

It consists of a security installation in the form of a multi-channel, safety computer that monitors and controls processes critical to safety and subsystems, as well as components that supply data on the process status or accept data used to control the vehicle. The term "computer" here and in the following can be replaced by the more general term, "data processing installation."

The transmission installation essentially processes the data transmitted between the vehicle and the stationary installations via a transmission system, e.g., radio. The vehicle location system supplies data for determining location, speed, and travel direction.

2. General Safety Requirements

The on-board control system especially has the special higher-level task of monitoring and controlling the safety-relevant processes of train operation in conjunction with a decentral or central safety installation. To this end, the on-board control system must continually carry out comparisons of demanded and measured values of safety-critical process units, it must accept input from the data transfer computer or the vehicle operating console, or it must send data there.

In this process, safety-relevant data must be safely recorded, transmitted, processed, and output. The functional performance of components with safety-related tasks must be checked periodically during each use of the vehicle if there is no automatic failure detection.

The functional efficiency and correctness of software for controlling safety-relevant functions with computers must be evidenced in keeping with the provisions of Regulation MUe 8004.

If the test of the vehicle safety system indicates an impermissible operating state due to a breakdown, then the on-board control system must initiate a safe emergency braking of the vehicle.

3. Safety Computer

By using a safety computer, the on-board control system performs the task of safe operational control in conjunction with decentral safety installations or the master computer.

In the event of data transmission failure, the vehicle safety computer must effect an immediate emergency braking using the safety braking system.

The interference-proof features of the safety computer system must prevent dangerous breakdown of the vehicle safety system through hardware disruptions. In the event of a fault, the vehicle safety system must effect emergency braking if a further failure means that the safe state is no longer ensured.

The software to be used in the safety computer must also be qualitatively high-grade. In order to meet this requirement, the applicable rules for programming safety-relevant software must be applied. In addition, the validity and correctness of safety-relevant software must be proven through comprehensive checks and tests.

In the event of failure of a non-secured ventilation function of the safety computer, emergency programmed braking must be elicited at the right moment in such a way that there is not an impermissible computer temperature for the required minimum number of undisrupted computer channels while the train is moving.

The energy supply for the safety computer must be safe life.

4. Operating Console

Safety-relevant operational activities must be transmitted to the safety computer via secure, e.g., anti-coincidence data lines or secured telegrams. Safety-relevant operating console information for the safety computer includes the operating console selection, emergency stop, raise vehicle, set down vehicle, doors released left or right, and close doors.

The work environment for the train operator must correspond to the ergonomic requirements for operating consoles according to DIN 33 400 through 33 403, 33 413 and 33 414.

5. Vehicle Location System

The vehicle location system must transmit to the operational control system secure or redundant data for determining the speed, direction of movement, and position of the vehicle. Using cyclical plausibility tests during each run, the trouble-free operation of the vehicle location system and of the transmission installations must be monitored.

At least three sensors must supply identical location data in order to form a reliable coarse location. If another sensor fails, emergency braking must be initiated When there is only two-channel availability of the location data, emergency braking must be initiated as soon as the data are available in only one place due to the failure of a channel. In this case, the reliability of the information installations must be so high that it is possible to dismiss the possibility that the location data will be lost due to another fault in the last channel before reaching the stopping point (see Sect. 5.1, Chapter 1).

Determining a new valid actual speed value must permit the maintenance of a predetermined braking curve.

6. On-Board Controls

On-board controls serve to control and monitor the vehicle functions, e.g., levitation and setting down.

Safety-relevant signals, e.g., levitation and setting down, are transmitted between the on-board controls and the safety computer. The safe transmission of such signals must be guaranteed. Such signals can be transmitted, for example, via anti-coincidence signal lines or secured telegrams.

Depending on the significance of these signals in terms of safety engineering, permanent dynamic or at least periodic monitoring is required.

Typical signals with a special safety level are:

- levitation
- setting down.

Examples with a lower safety level are diagnosis signals.

Safety-relevant signals such as door release left, door release right, doors closed left, and doors closed right are transmitted between the safety computer and the door controls. The signals mentioned must be transmitted in a fail-safe manner. Furthermore, failure detection must be provided for these signals.

The safety computer may give the proceed signal only when all "doors closed" signals are on.

7. Safety Braking System

The safety braking system must be a braking system located on the vehicle which will also work without the involvement of stationary control measures from the control cab. Its propulsion unit-independent component must also consist of several independent braking circuits. The failure of one braking circuit does not require any safety-engineering measure. In the event that the minimum braking deceleration is no longer achieved due to a further failure, the on-board control system must nonetheless elicit emergency braking. If the 2nd braking circuit fails while the train is at a dead stand, then the vehicle may not start moving.

Signal transmission between the safety computer and the safety braking system must be highly reliable. If there is no permanent failure detection for defects in the braking system, then a braking test must be performed after turning on and during every dead stand, together with a plausibility test of the signals.

8. Transmission Installation

The transmission installation receives, processes, and forwards safety-relevant data. The transmission computer must therefore be a fail-safe computer, e.g., it must be a 2 v 3 computer system.

Proof in the form of detailed tests and analyses must be kept on the safety-engineering suitability of the software for the transmission computer.

Note: The state of the art in TR 07 is a wireless transmission installation which is functionally tested in a cyclical manner with a frequency of 0.1 Hz. The data are transmitted in secured telegrams. In order to improve transmission safety, each telegram is additionally transmitted in inverse form and compared to the original telegram. The failure of one of the three computer channels is permitted. If another of the two remaining computer channels fails, then emergency braking is elicited. A transmission channel is assumed to be disrupted if three successive telegram cycles are recognized as faulty.

9. Passenger Emergency Signal

The passenger emergency signal must be transmitted in a fail-safe manner to the safety computer. The safety computer must cyclically monitor the functional effectiveness of the testable lines and signal transmitters through a plausibility test. The on-board control system must, upon activation of an emergency signal, send a report to the conductor, to the diagnosis installations, and to the control center.

10. Proofs/Tests

Compliance with the requirements of operating consoles according to DIN 33 400 through 33 403, 33 414 and 33 414 must be documented. For the other components of the on-board control system, the remarks in Chapter 9, Section 4 of this regulation apply in terms of proofs and/or tests.

11. Equally Applicable Standards

DIN V VDE 0801	**Principles for computers in systems with safety functions**
DIN VDE 0831	**Electric railroad signaling systems**
MÜ 8004	**Principles for technical approval in signaling and communication technology; German Federal Railroad, Federal Railroad Central Office**
DIN 33 400	**Structure of working systems based on ergonomic findings; terms and general guidelines**
DIN 33 401	**Operator controls; terms, suitability, notes on structure**
Insert 1	- Operator controls; remarks on potential applications and notes on suitability for manual operator controls

DIN 33 402	**Human physical dimensions**	
Part 1	-	Terms, measuring methods
Part 2	-	Values
Part 2, Insert 1	-	Values; application of physical dimensions in practice
Part 3	-	Range of movement for various base settings and movements
Part 4	-	Principles for dimensioning corridors, passages and entryways
DIN 33 403	**Climate in the work place and in the working environment**	
Part 1	-	Principles for evaluating the climate
DIN 33 413	**Ergonomic considerations in display equipment**	
Part 1	-	Types, observation tasks, suitability
DIN 33 414	**Ergonomic structure of control centers; seating in work places**	
Part 1	-	Terms, foundations, dimensions

LOAD ASSUMPTIONS

Chronology - Chapter 5
"Load Assumptions"

Edition	Revision	Date	Comment
1 (Chapter 4)	0	09/88	**Title:** Guideway Load Assumptions
1	1	12/88	No change
1	2	12/88	No change
1 (Chapter 5)	3	01/89	No change
2 (Chapter 6)	0	03/89	No change
2	1	05/89	No change
2	2	06/89	No change
2	3	08/89	No change
1 (Chapter 5)	0	09/89	Changes **Title:** Load Assumptions
1	1	10/89	Changes
2, 3			missing
4	0	09/90	Changes
4	1	09/90	Changes
4	2	11/90	Changes

Load Assumptions

1. General Remarks / Definitions

The term "loads" must be understood here in a general sense, as a collective term for all influencing factors (e.g., forces of inertia, those resulting from the wind, temperature, pillar settling, etc.), which generate stresses in the structure, i.e., tensions or deformations.

The loads acting on the guideway and the vehicle can be subdivided as follows.

Interface Loads

In the following, loads acting on the vehicle and the guideway at the interfaces between the vehicle and guideway will be called "interface loads"--the loads acting on the vehicle will be called "vehicle-side interface loads" and the loads acting on the guideway will be called "guideway-side interface loads."

Interfaces exist between:

- lateral guide rail and guide magnets
- lateral guide rail and safety braking system
- stator packs and levitation magnets
- lateral guide rail and guide skids
- slide surface and bearing skids

The interface loads are determined by:

- external factors
  (wind, temperature, pillar settling, etc.)
- mass and rigidity distribution in vehicle and guideway
- geometry of functional surfaces
  slide surface, lateral guide rail, lower edge of stator)
- electrical, electromagnetic, and control-engineering properties of the levitation/guidance system, propulsion unit, and safety braking system
- operating states
  (standard operation, i.e., through run, banking, stationary levitation, opposing traffic, tunnel entrance or exit, etc., as well as emergency braking, set-down, etc.).

This means that it is generally impossible to indicate the interface loads that act on the guideway and the vehicle at the vehicle-guideway interfaces independently of the respective vehicle-guideway pairing.

Instead, the vehicle and the guideway must be regarded as a unit which is joined via magnetic forces or, in case of set-down, via the skids; i.e., the loads acting at the vehicle-guideway interfaces must be determined individually for the respective specific individual case, with due consideration to the actuating variables listed above.

Experience thus far at the TVE facility shows that changes in the controller parameters alone, with otherwise unchanged marginal conditions, can result in considerable changes in the loads acting at the vehicle-guideway interface. Another decisive parameter is the design of the attachments for the individual guideway equipment components.

For the dimensioning of the guideway in practice, see Section 4.

External Guideway Loads

Other loads acting on the guideway will hereafter be referred to as "external guideway loads."

External Vehicle Loads

Other loads acting on the vehicle will hereafter be referred to as "external vehicle loads."

2. External Guideway Loads

For the guideway, which consists of the guideway girders and substructures (including the foundation), and for its components, the following causes of loads must be considered:

2.1 Dead weight of the structural components
2.2 Scheduled initial stress
2.3 Creepage and shrinkage of the concrete

2.4 Girder slackening
2.5 Subsoil movement
2.6 Wind
2.7 Snow, ice
2.8 Thermal effect
2.9 Frictional drag in mobile bearings
2.10 Setting and locking forces in bending switches
2.11 Impact of land vehicles
2.12 Ground pressure loads
2.13 When pillars are founded in rivers and lakes: ice impact and thermal ice pressure, impact by watercraft.
2.14 Earthquakes
2.15 Temporary loads from building equipment, building materials, building elements, etc. under building conditions.

These loads are to be determined based on DS 804, DS 899/59 and DIN 1072, with the following exceptions:

1. The temperature differences in the guideway girder as well as between the guideway girder and the guideway equipment (stator packs, lateral guide rails, slide surface of steel on concrete) are to be established with due regard for [5.1].

2. The bearing reactions resulting from the forced deformation of bending switches should be determined from the relevant bearing shifts.

As regards the environmental loads, (temperature stress, wind stress), it must be noted that the loads determined on the basis of DS 804 and DIN 1072 apply only to Germany or to regions with comparable climates and that they must be adapted accordingly if this transportation system is used in a different region.

3. External Vehicle Loads

The following external loads act on the vehicle:

3.1 Inherent load of structural components
3.2 Working loads
3.3 Forces of inertia resulting from:
3.3.1 Elevation and set-down of vehicle
3.3.2 Accelerations
3.3.3 Braking using
3.3.3.1 Operational braking system
3.3.3.2 Safety braking system (electrical/mechanical)
3.3.3.3 Partial set-down
3.3.4 Passing over humps and depressions
3.3.5 Banking
3.3.6 Unsteadiness in guideway geometry
3.3.7 Deviations of guideway geometry from plan figures (within tolerance ranges)

The magnitude of these forces of inertia is determined by the required riding comfort and must be coordinated with the respective operator on a case-by-case basis.

At the TVE facility, the values listed in [5.2] were applied.

3.4 <u>Aerodynamic loads due to:</u>

3.4.1 Relative wind

3.4.2 Cross-wind stationary/gusty

3.4.3 Tunnel entry

3.4.4 Tunnel passage

3.4.5 Tunnel exit

3.4.6 Opposing traffic on open line/in tunnel

3.4.7 Windshading

as a function of the train speed.

The wind stresses must be known not only in terms of their resultants and with regard to the point of impact (line of application) of their resultants, but also with regard to their distribution (pressure/base drag) in order to dimension the individual components of the enclosed vehicle structure.

The wind stresses on the one hand depend on the vehicle shape and on the other hand depend on the environmental geometry:

- vehicle headway for opposing traffic
- geometry of tunnel entry and exit areas

- tunnel cross-section
- shape and position of structures near the line.

In general, they must be determined by measurement.

The wind stresses determined for TR07 are listed in [5.3].

3.5 Thermal effects

3.6 Loads from breakdowns caused by the environment, e.g.:

3.6.1 Bird impact (e.g., according to UIC 651, 1 kg Deutsche Bundesbahn standard stone)

3.6.2 Collision with an obstacle (e.g., a local snow embankment)

3.7 Coupling forces

4. Interface Loads

Among interface loads, we must distinguish between the **global** interface loads acting on the guideway or the vehicle and the **local** interface loads impacting on the load entry points of the guideway or vehicle.

Load entry points at the guideway are:
- stator pack mounting
- guide rail mounting

- slide surface mounting

Load entry points at the vehicle are:
- levitation magnet suspension
- guide magnet suspension
- eddy-current brake suspension
- bearing skid
- guide skid

The interface loads must be studied for the following operating states and/or loads.

4.1 Routine operation
4.1.1 Through run
(including passage through depressions and over humps).
4.1.2 Banking
4.1.3 Aerodynamic loads
4.1.3.1 Tunnel entry
4.1.3.2 Tunnel passage (especially multi-track tunnels)
4.1.3.3 Tunnel exit
4.1.3.4 Opposing traffic
4.1.3.4.1 On open track
4.1.3.4.2 In a tunnel
4.1.3.5 Operation during crosswind
4.1.3.5.1 Stationary crosswind
4.1.3.5.2 Gusty crosswind
4.1.3.6 Passing by structures near the track
4.1.4 Passing over permissible guideway irregularities
4.1.5 Passing over permissible tolerance-related deviations from the guideway geometry

Specifically, for the following modes of operation

- Stationary operation (i.e., v = const.)
- Acceleration (propulsion)
- Deceleration (operating brake)

4.2 <u>Braking with safety braking system (emergency braking)</u>

4.2.1 Through run

4.2.2 Banking

4.3 <u>Controlled set-down</u>

4.3.1 Through run

4.3.2 Banking

4.4 <u>Towing (recovery) of a vehicle</u>

4.5 <u>Vehicle- or propulsion-based breakdowns</u>

4.5.1 Shutoff or failure of magnets

4.5.2 Shutoff or failure of suspension and roller stabilizer

4.5.3 Maladjustment and other failures of sensor equipment

4.5.4 Failure in control circuits and in control settings that does not result in shutoff of the magnets involved

4.5.5 Propulsion (acceleration/deceleration) is different on the two sides and other failures in the propulsion (e.g., loss of synchronism)

4.5.6 Uncontrolled set-down on one side (entry into short-circuited stator loop before neutral point

4.6 Appearance of breakdowns due to the environment, e.g.,

4.6.1 Hitting an obstacle (local snow embankment)

4.7 Exclusion of interface loads

The breakdowns listed below

- striking of levitation or guide magnets
- set-down when $v > v_{set-down}$
- uncontrolled set-down on both sides
- violation of the clearance profile

are also possible. If it is proven that they are adequately improbable and/or harmless, then they need not be taken into consideration when dimensioning the support components of the vehicle and guideway.

The interface loads thus far determined experimentally for TR06 and TR07 in conjunction with the TVE guideway are listed in [5.4].

5. Equally Applicable Standards

DS 804 **Regulation for railroad bridges and miscellaneous engineering structures (VEI)**

DS 899/59 **Special provisions for railroad bridges on new railroad lines**

DIN 1072 **Street and road bridges, load assumptions**

UIC 651 Structure of driver's cabs in locomotives, rail cars, rail car trains and control cars

At present, there are no specific standards that apply especially to interface loads in high-speed maglev trains.

6. Other Literature

[5.1] Technical Report
Temperature measurements on the TVE guideway and their evaluation (not yet available).

[5.2] Specification
for the vehicle of the TRANSRAPID Test Facility in Emsland (of 10/12/84)
Doc. No. TVE K 10000/2/SS/2/001
Publisher: Krauss-Maffei

[5.3] Technical Report
Wind tunnel studies TR06 II, loads caused by crosswind (of 3/19/87)
Doc. No. NTK/375/02/87
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

[5.4] Technical Report
Load measurements on the TVE guideway and their evaluation (not yet available)

STABILITY ANALYSES (GUIDEWAY/VEHICLE)

Chronology - Chapter 6
"Stability Analysis (Guideway/Vehicle)"

Edition	Revision	Date	Comment
1, 2, 3			Missing
4	0	09/90	
4	1	11/90	Changes

Stability Analyses (Guideway/Vehicle)

1. General Remarks

Means of transportation, including the corresponding transport routes, should be designed in such a way that they are usable, safe, lasting, economical, and compatible with the environment.

Compliance with the demand for safety and durability must be proven through the stability analysis.

The stability analysis contains proof that amidst all possible combinations of loads or building and operating conditions

- adequate safety of all structural parts against failure is ensured.

  This proof is called a **strength analysis.** It consists of

  * General stress analysis
  * Stability analysis
  * Operational strength analysis

- parts of the guideway are unable to change position as a result of tilting, lifting, or sliding, and that no soil movement can occur in the area of the foundation.

This proof is called a **positional safety analysis.** It consists of proofs of adequate safety against

* lifting
* tilting
* sliding
* soil movement

- no changes (shifts, torsion as the result of warping and/or subsoil movement and bearing shifts) occur in the geometry of the functional surfaces that could result in impermissible operating conditions.

  This proof is called a **deformation analysis.**

2. Classification of Loads

For dimensioning and design, load assumptions are made that are not exceeded by the loads or load combinations that actually occur during the construction phase and the total service life. Depending on the frequency of their occurrence, a distinction is made between **primary loads (P), secondary loads (S), and special loads (Sp).**

2.1 Definition of Primary Loads, Secondary Loads, and Special Loads

The loads are differentiated into primary, secondary, and special loads in order to represent and thus guard against dangerous load limits and/or tension limit situation (onset of breaking load, yielding point, or instability) caused by the behavior of the material and the design.

Thus, **primary loads** should be regarded as all loads whose effect influences stability during normal operation.

All other loads - with the exception of special loads - are **secondary loads.**

Special loads are all low-frequency loads that do not occur during scheduled operation. Furthermore, it should be assumed that two or more special loads will not act on a structural component at the same time.

2.2 Classification of the Loads for the Vehicle

The loads for the vehicle are those listed in Chapter 5, Sections 3 and 4.

Primary loads include all loads that are continually present in operation regularly or along certain line segments.

Load effects due to discontinuities in or deviations by the guideway from the ideal value are primary loads, since they meet the above criterion.

Loads due to crosswind up to an established wind velocity of v_1 are classified as primary loads, those up to v_2 as secondary loads. v_2 is the wind velocity up to which unrestricted running operation is permitted.

Note: The following applies to the TVE:

$$v_1 = 10 \text{ m/s}$$
$$v_2 = 25 \text{ m/s}$$

The following table summarizes the classification of loads.

Table 1: Classification of Loads (External Loads and Interface Loads) for the Vehicle (continued on next page)

Type of load	
Forces of gravity	
- Dead weight of the vehicle, including equipment, supplies, passengers	P
- During beginning of hovering	P
- During hovering	P
- During regular startup, acceleration, and braking	P
- During emergency braking (safety braking system)	Sp
- During banking	P
- Due to discontinuity in the guideway geometry	P
- During regular setdown	P
- While lifting the vehicle with a crane	Sp

Table 1, continued

Type of load		
Aerodynamic forces		
-	On set-down vehicle	P
-	Relative wind	P
-	Crosswind v_s ($v_s \leq v_1$)	P
-	Crosswind v_s ($v_1 < v_s \leq v_2$)	Se
-	During entry in and exit from tunnel	P
-	During tunnel passage	P
-	Opposing traffic	Sp
-	Passing structures near the track	Sp
Other loads		
-	From thermal effects	Se
-	Impact from a bird	Sp
-	Crashing into an obstacle	Sp
-	Coupling forces	P
-	Shutoff and failure of magnets and corresponding springs	Sp
-	Failure of springs	Sp
-	Faults in and failure of sensor equipment and of control circuits	Sp

Note: Where relevant, loads according to Chapter 5, Sect. 4.7 are to be classified as special loads

2.3 Classification of the Loads for the Guideway and the Guideway Equipment

The loads for the guideway are those listed in Chapter 5, Sections 2 and 4. According to this list, a distinction is made between loads on the guideway unaffected by the vehicle and loads from operation of the vehicle.

While it is possible to classify loads unaffected by the vehicle for the entire guideway, a distinction must be with vehicle loads (interface loads) according to whether individual types of loads occur regularly or only occasionally in certain line segments. Thus, for example, in the stopping point area one may operationally expect forces of gravity from initiating hovering and setting out as well as braking and setting down. Similarly, during tunnel entry and exit, as well as inside the tunnel, heightened, continually present wind loads from the relative wind can be expected. Thus, these are primary loads.

Additional strains on the guideway resulting from discontinuities or deviations from the planned values of the guideway geometry always occur at the same spot, for which reasons these loads taken into account in the primary loads.

The classification of the loads is summarized in the following tables.

Table 2: Classification of External Guideway Loads
(continued on next page)

Type of load	Steel guideway Open track	Steel guideway Stopping points	Concrete guideway Open track	Concrete guideway Stopping points
Dead weight of guideway structure	P	P	P	P
Dead weight of guideway equipment	P	P	P	P
Creepage and contraction	-	-	P	P
Prestress forces	-	-	P	P
Girder slackening	P	P	P	P
Probable foundation soil movement	P	P	P	P
Possible foundation soil movement	Se	Se	Se	Se
Lifting of the guideway for change of bearing	Sp	Sp	Sp	Sp
Wind load	Se	Se	Se	Se
Ground pressure loads	P	P	P	P
Assembly equipment (in building phase)	P	P	P	P
Snow load	Se	Se	Se	Se
Thermal effects	Se	Se	Se	Se
Displacement resistance of the bearings	Se	Se	Se	Se

Table 2, continued

Type of load	Steel guideway		Concrete guideway	
	Open track	Stopping points	Open track	Stopping points
Forced deformation (only in switches)	P	P	-	-
Impact loads of vehicles	Sp	Sp	Sp	Sp
Ice impact and thermal ice pressure	Sp	Sp	Sp	Sp
Effects of earthquake	Sp	Sp	Sp	Sp

Table 3: Classification of Guideway-Based Interface Loads (continued on next page)

Type of load	Guideway: Open track	Guideway: Stopping points	Guideway: Guideway equipment
Forces of gravity			
Due to hovering	P	P	P
- Due to initiating hovering	Se	P	P
- Due to setting out, accelerating or braking (operationally)	P	P	P
- Due to emergency braking	Sp	Sp	Sp
- Due to operational setdown	Se	P	P
- Due to set-down vehicle	Se	P	-
- Due to centrifugal forces while banking	P	- 1)	P
- Due to discontinuities in the guideway geometry	P	P	P
- Due to deviations of the the guideway geometry from planned values	P	P	P

1) If possible, stopping points should be provided only along straight track.

Table 3, continued

Type of load	Guideway: Open track	Guideway: Stopping points	Guideway: Guideway equipment
Aerodynamic forces			
- On the set-down vehicle	Se	Se	-
- Crosswind			
v_s ($v_s \le v_1$)	P	P	P
v_s ($v_1 < v_s \le v_2$)	Se	Se	Se
- During tunnel entry or exit	P	-	P
- In tunnel	P	-	P
- Opposing traffic	P	-	P
- When passing structures near the track	P	P	P

3. Compilation of the Load Combinations to Be Studied

3.1 Vehicle

The loads compiled and classified in Table 1 must be combined into load combinations.

The load combinations to be studied are:

Load case P:	Primary loads in the most unfavorable configuration If only one secondary load is present aside from the primary loads, then it should also be treated as a primary load
Load case PSe:	Primary and secondary loads in the most unfavorable configuration
Load case $PSeSp_1$:	Primary, secondary, and special loads during emergency braking
Load case $PSeSp_2$:	Primary, secondary, and special loads during crashing into an obstacle
Load case $PSeSp_3$:	Primary, secondary, and special loads during shutoff or failure of magnets, springs, sensors or control circuits
Load case Sp_4:	Impact of a bird on the front windshield. The primary load "relative wind" should be included locally.

Load case Sp_5:	Lifting of the vehicle with crane. Consideration must be given to the vehicle weight, including supplies and equipment and excluding passengers, crew, and luggage.

3.2 Guideway and Guideway Equipment

The loads (types of loads) compiled and classified in Tables 2 and 3 must be combined into load combinations (load cases).

The following load combinations must be studied:

Load case P:	Primary loads in the most unfavorable configuration If only one secondary load is present aside from the primary loads, then it should also be treated as a primary load
Load case PSe:	Primary and secondary loads in the most unfavorable configuration
Load case $PSeSp_1$:	Primary, secondary and special loads from emergency braking
Load case $PSeSp_2$:	Primary and special loads from ice impact or thermal ice pressure or impact with watercraft
Load case $PSeSp_3$:	Primary, secondary, and special loads from earthquakes
Load case Sp4:	Continual loads and special loads from impact with vehicles

The most unfavorable configuration of loads in load case P, PSe or $PSeSP_i$ is determined by combining the types of loads acting on a structural component of the guideway at the same time. Of the possible load combinations thus determined, the one that is most unfavorable for design is to be selected to determine the stress.

Load case $PSeSp_3$ should be considered only in areas with seismic activity. For the area of the Federal Republic of Germany, see DIN 4149, Part 1, Figure 1, "Map of Earthquake Zones." In this regard, the guideway must be designed in such a way that deformations are kept so small that the vehicle can be brought to a dead stand without injury to persons.

Analogous to DS 804, the following load combinations are recommended as load case $PSeSp_3$:

100% of the continual load
100% of the forces of gravity from normal running operation for one track
50% of the wind loads
125% of the foundation pressure forces
100% of the equivalent load for earthquake effects

The assumed standard value for horizontal acceleration is to be established by the certifying authorities. If necessary, special regulations must be drawn up for constructions abroad.

The most unfavorable load combination cannot be established for the guideway as a whole; rather, these determinations must be made for each structural component separately.

It is expedient for the load combinations to be determined separately for the following structural components:

- Substructures, including foundations and/or primary support structures
- Guideway girders
- Girders of the bending switches, including bearing and locking
- Guideway equipment

For special structures such as transfer tables, maintenance stations, siding facilities, and so on, special determinations must be made. In determining the stress of the guideway, furthermore, it is necessary to examine whether different payloads in the individual sections of the vehicle should be considered.

It must be ensured that the load on the guideway from the maintenance vehicle and from maintenance work does not generate greater stress than is permissible in load case PSe.

4. Necessary Safety Factors, Permissible Failure Probabilities

4.1 General Remarks

The safety factors to be applied in the individual proofs and/or the permissible failure probabilities must be determined as a function of

- the probability that the loads or load combinations applied to the corresponding proof will occur.

- the consequences of the failure of a component

With respect to the consequences of the failure of a component, a distinction is made between the following risk classes:

- **Class I**, catastrophic risk

  The failure of a component can result in a significant endangerment to human life and/or very major material damage (e.g., danger to the vehicle and its occupants).

- **Class II**, serious risk

  The failure of a component can endanger human life and/or result in significant material damage (e.g., danger to third parties outside the vehicle, as participants in traffic crossing the guideway).

- **Class III**, sustainable risk

  The failure of a component results only in an interruption of service and/or small-scale material damage, but not in a threat to persons

- **Class IV**, negligible risk

The failure of a component results in no interruption in service and only insignificant material damage.

Proof of adequate stability can be provided in various ways.

- Proof that a permissible failure probability is not exceeded.

- Proof that the susceptibility to stress of components in the flow of forces is not exceeded by the design values of the effect combinations, which are the effects of an effect combination multiplied by component safety coefficients and combination coefficients.

- Proof of compliance with a (global) safety factor indicated as necessary, or proof that a permissible tension established with a global safety factor is not exceeded.

Of these options, the proof that a permissible failure probability is not exceeded is generally preferred.

The permissible failure probabilities can be determined as follows, for example, based on [6.1].

for structural components of	permissible failure probability, relative to the total service life	
Class I	10^{-a}	in each case for
Class II	10^{-b}	sum of all
Class III	10^{-c}	components of the
Class IV	10^{-d}	respective risk class

The exponents a, b, c, and d have yet to be determined.

Proof using the permissible failure probability would have the advantage of rendering a classification of loads into primary, secondary, and special loads unnecessary, since the probability of occurrence of the individual effects and their maximum values in combination with the occurrence of other effects is included directly in the proof. The problem, however, is that the basic statistical data necessary for this (especially the distribution functions in the tapering areas) are generally unknown.

In the meantime, the concept of proving adequate security using the design values of the effect combinations has developed so far that it is used in the standards currently available in Germany (e.g., DIN 18 800, Part 1, Nov. 1990) for the design of steel structures. With respect to the component safety coefficients for the individual effects and the combination coefficients for the individual effect combinations to be used here, however, reference is made to the pertinent special regulations in the individual application standards.

Such regulations are not yet available for areas of application comparable to high-speed maglev trains, i.e., proving adequate stability normally must be done on the basis of the hitherto usual method through global safety factors.

The correlation between the global safety factor (or permissible stress) on the one hand and failure probability on the other hand is generally unknown due to the lack of basic statistical data.

The only thing that can be said is that when applying the hitherto usual safety factors in conjunction with the hitherto usual

- load estimates,
- methods for determining stresses,
- methods for determining susceptibility to stress,
- materials,
- production and assembly methods,
- design forms, and
- design and test methods,

cases of damage occurred with adequate infrequency.

4.2 Vehicle

All elements of the vehicle whose failure threatens the integrity of the passenger compartment must be assigned to risk class I. Classification to other risk classes is possible only if thorough examination of the consequences of the failure justify such a classification. Generally, mathematical proof to this effect is inadequate.

If the failure results in the detachment of elements installed outside the passenger compartment, then this must be assigned to risk class II.

All other failures must be assigned to risk classes III and IV, whereby the decisive criteria are the occurrence of interruptions in service and the expected level of damage.

Insofar as failure probabilities are not used, the design can be considered adequately safe if the safety factors in effect for rail vehicles (passenger transport at speeds > 200 km/h) of the German Federal Railroad are met.

4.3 Guideway

With respect to the components of risk classes I and II, the guideway may be considered to be adequately safely dimensioned if the safety level of DS 804, DIN 1045, DIN 4227, and DIN 18 800, Part 1 is met for the load cases listed in Section 3.

Insofar as it is not possible after the occurrence of a special load case to check the integrity of the guideway beyond any doubt through a structural edifice inspection in the area in question, this special load case must be treated as a PSe load case.

4.4 Guideway Equipment

The components of the guideway equipment lying in the flow of forces and their connection to and/or integration into the guideway (guideway girders, switch girders, etc.) are to be assigned to risk class I (catastrophic risk), insofar as no further studies relating to the consequences of a failure of these components permit a different classification.

These components may be regarded as adequately safely dimensioned if the following conditions are met.

The mountings of the stator packs and their windings on the guideway must be configured through dimensioning, quality assurance during production and assembly, and regular tests/measurements during operation in such a way that safety-threatening failures are not anticipated. All mounting elements must be theoretically and practically qualified in the sense of a type certification. The type and extent of the design certification test must take into account the stresses, ambient conditions, and planned service life.

The condition noted above can be met by "cold redundancy with failure detection" (see Chapter 7, Section 2.2.2.3), for example.

The redundancy requirements must be established with due regard for the failure detection time (which also means due regard for the reliability of the pertinent monitoring installations) as well as any subsequent operating time until the fault is eliminated.

The requirements of the lateral guide rail, the mounting of the lateral guide rail, and transmission of the stresses from the stator packs, lateral guide rails, and slide surfaces to the guideway (guideway girder, switch girder, etc.) may be regarded as adequately met if the safety level of the regulations named in Section 4.3 is met for the load cases listed in Section 3.2 and the design is chosen in such a way a looming structural component failure can be detected in time through regular inspections.

More detailed requirements must be defined for the possibility that this additional condition cannot be met.

Insofar as it is not possible after the occurrence of a special load case to check the integrity of the guideway beyond any doubt through a structural edifice inspection in the area in question, this special load case must be treated as a PSe load case.

5. Permissible Deformations

The basic deformations permitted in the deformation analysis must be established as a function of

- the permissible tolerances of the functional surfaces
- the nominal gaps and the gap needs of the levitation/guidance system

- the properties (lining, cushioning, etc.) of the bearing/guide skids

in such a way that

- during **normal operation** there is no contact between the levitation/guidance magnets and the corresponding functional surfaces.

- during **breakdown,** the resulting deformations of the functional surfaces guarantee at least danger-free emergency braking, and in the event of an earthquake a dead stop by the vehicle without personal injury.

The uncertainties contained in the mathematical deformation analysis must be fully taken into account as early as in the determination of the permissible deformations.

The values specified as permissible for the TVE guideway in conjunction with the TR06 and TR07 are listed in [6.2].

6. Equally Applicable Standards

DIN 1045 Concrete and reinforced concrete, dimensioning and execution

DIN 4149 Structures in German earthquake zones
Part 1 - Load assumptions, dimensioning and execution of standard tall structures

DIN 4227 Prestressed concrete

DIN 18 800 Steel structures
Part 1 - Dimensioning and design

DS 804 Regulation for railroad bridges and miscellaneous engineering structures (VEI)

7. Other Literature

[6.1] RMS Program
(reliability, material conservation, service life)
Technical Guideline L2 (TR-L2)
Specifications and requirements of service life; Publisher: Federal Office for Defense Technology and Procurement, Koblenz

[6.2] Permissible deformations of the TVE guideway
Guideway of the TRANSRAPID high-speed maglev train, Part III, deformation and tolerances
Technical Report No. NVA/0693/03/89,
Publication date: 4/10/1990, TH

DESIGN, PRODUCTION AND, QUALITY ASSURANCE
OF MECHANICAL STRUCTURES

Chronology - Chapter 7
"Design, Production, and Quality Assurance of the Mechanical Structures"

Edition	Revision	Date	Comment
1	0	05/90	
2, 3			missing
4	0	09/90	Changes
4	1	09/90	Changes
4	2	11/90	Changes

Design, Production and, Quality Assurance of the Mechanical Structures

1. General Remarks

The following are the necessary goals of the regulations for design, production (including assembly), and quality assurance:

- Fulfillment of the preconditions of stability documentation with respect to design, materials, and production technology.

- Assurance of the guideway geometry necessary for no-contact running (normal operation) as well as for running with skid contact (partial or full setdown during operation) and/or magnet contact.

- Guarantee that no hazard emanates from the vehicle or guideway through mechanical impacts.

2. Structural Design Requirements

All structural elements relevant to vehicle and guideway stability and all primary connections (especially in the guideway equipment) must be accessible for inspection purposes without destruction to primary structural elements. Installations in the vehicles must be joined with detachable connections.

During design, matings of metallic materials and surface coatings must be evaluated in terms of the formation of voltaic elements.

2.1 Vehicle

2.1.1 General Requirements

Since there are no existing regulations for the design of maglev trains, there are currently no restrictions applicable to the structural design of the vehicle beyond the generally recognized rules of technology, as long as the further requirements noted are met.

2.1.2 Protection of Persons in the Vehicle

The vehicle must be structurally designed in such a way that persons in the vehicle are not endangered, where possible, by objects that have come detached or are loosely mounted.

2.1.3 Exceptions

Exceptions to the regulations mentioned under 2.1.1 are permissible if the suitability of the alternative design has been demonstrated to the approval authority. This proof must apply to all the modes of operation listed in Chapter 5.

2.2 Guideway

2.2.1 General Requirements

In principle, the following technical regulations must be observed and/or applied accordingly in the structural design of the guideway components: DIN 1045; DIN 1075; DIN 4227; DIN 18 800, Part 1; DS 804 and DS 899/59.

2.2.2 Further Requirements

As exceptions to 2.2.1 (or going beyond 2.2.1), the following requirements must be met:

2.2.2.1 Requirements of the Geometry of Functional Surfaces / Maximum Permissible Tolerances

A distinction must be made between types of deviations from the ideal guideway geometry, as follows:
- continuous deviations (e.g., wave-like progressions),
  and
- discontinuous deviations (misalignments at points of junction, e.g., stator pack junction, lateral guide rail junction, slide surface junction)

and between causes for these deviations, as follows:
- deviations due to production
- deviations due to assembly, and
- deviations due to load (e.g., temperature, settling, or operational load)

The ideal guideway geometry is characterized as the projected alignment of the functional surfaces at a particular reference temperature resulting

- from the planned camber of the guideway girders, and
- from deflection due to the permanent loads of the guideway girders.

The maximum permissible deviations from the ideal guideway geometry must be established for the underside of the stator pack, the slide surface, and for the outside of the guide rail, with due regard for

- the critical running speed, and
- the time dependency of controlling the levitation/guidance system and the resulting way-over-time curve of the levitation/guidance magnets
- the properties of the bearing/guide skids
- changes in the shape of the guideway in such a way that
- during normal operation there is no contact between the levitation, guidance, and braking magnets and the pertinent functional surfaces, and
- during a breakdown, the stresses resulting from any contact between the guidance and braking magnets or between the bearing and guide skids and the pertinent functional surfaces do not exceed the permissible values.

For the lateral guide rails in their function as slide rail for the guide skids and for the slide surface, the permissible misalignment must be limited to such an extent that the stress resulting from the sliding action and the resulting wear and tear remain within the bounds of the permissible values.

The required geometry of the functional surfaces and the permissible deviations from this projected geometry are dependent on the vehicle and its interaction with the guideway. Thus, they cannot be established independently of the vehicle and/or of the guideway, but rather must be determined with due regard for the special vehicle/guideway mating.

The applicable values based on current considerations are found in [7.1] - [7.6].

There must be measuring systems available (preferably vehicle-based) that can promptly detect impermissible changes in the guideway geometry and localize them on the guideway.

The guideway girder as a whole, as well as the components of the guideway equipment for levitation and guidance, may not vertically and laterally exceed the permissible tolerances at the points of junction. This requires in particular safe attachment of the stator packs and of the guide rails to the guideway and a suitable bearing of the guideway girders.

2.2.2.2 Protecting Persons Near the Track

Measures to protect persons and property in the guideway area (e.g., to protect crossing traffic and/or in the case of an at-grade guideway) must be provided if necessary.

2.2.2.3 Diverse Mounting

With all guideway components for which it is not possible to exclude faults with adequate certainty through dimensioning, quality assurance during production and assembly, as well as recurrent tests during operation, the design that is chosen must be such that the failure of one component cannot result in a situation that threatens overall operation.

This condition can be met through standby redundancy with fault detection, for example.

"Standby redundancy with fault detection" means:

1. The load must be supportable by way of two paths (branches), whereby of the two branches only one may be operational, i.e., the second branch may be brought to bear only after the first one has failed completely.
2. Upon failure of the first branch and activation of the second branch, an indicator of this event must be activated

which can be reliably (and with optimal ease) detected by tests accompanying operation.

3. The second branch must be configured in such a way that operational safety is guaranteed until the breach is detected and the subsequent remaining operating time is guaranteed until the first branch is repaired (e.g., within the framework of regular inspections or using continuous, vehicle-based control measurements).

2.2.2.4 Locking of the Switch Girders

The switch girders must be locked mechanically in their end positions. It must be ensured that as a result of the unavoidable play in the lock (taking wear into account), no unacceptable misalignments into the function surfaces can emerge at the transition from the switch girder to the fixed guideway.

2.2.2.5 Subsidence

Insofar as subsidence cannot be reliably excluded, the bearing of the guideway girder (including the switch girder) must be configured in such a way that the shifts and/or torsion of the guideway girders caused by this subsidence can be compensated for in an adequately simple manner, if necessary.

3. Production (Including Assembly) and Quality Assurance Requirements

3.1 Vehicle

3.1.1 General Requirements

In principle, the following technical regulations must be observed and/or applied accordingly in the production and quality assurance of the vehicle components:

EN 29000	Quality management and quality standards Guideline for selection and application
EN 29001	Quality assurance systems. Model for interpretation of quality assurance in design/development, production, assembly and customer service.
EN 29002	Quality assurance systems. Model for interpretation of quality assurance in production and assembly.
EN 29003	Quality assurance systems. Model for interpretation of quality assurance in the final inspection.
EN 29004	Quality management and elements of a quality assurance system - guideline.

3.1.1.1 Materials

Materials for the vehicle components may be used if there exist for them technical regulations on material quality in DIN standards, Eurostandards, LN standards, steel-iron material guidelines, the Materials Handbook of German Aviation, VdTÜV material guidelines or the Materials Handbook of Military Technology.

Materials may be used only if material documentation from a recognized testing institution are available that confirm correspondence with the properties named in the technical regulations.

For synthetics and composite materials that contain synthetics, the required aging stability must be proven. This applies in particular to synthetics that are exposed to sunlight.

3.1.1.2 Semifinished Goods

Semifinished goods for primary structures that has not been processed further must comply with ISO tolerance field h 9.

3.1.1.3 Connections

3.1.1.3.1 Non-detachable Connections

Weld Joints

In principle, weld joints must be produced and tested with regard for the following technical regulations: DVS 1603, DVS 1604, DVS 1608, DVS 1609, DVS 1610, DVS 1611, DIN 65118.

Welds on primary components may be done only by welders who have been examined according to DIN 29591 or DS 952.

Bonding

The suitability of bonding agents in terms of the materials to be connected, the hardening times with the corresponding strength verification, and the long-term behavior must be proven. All parameters affecting the strength of the bond must be documented.

3.1.1.3.2 Detachable Connections

Screw Connections

With respect to the shape of the connections, notes in VDI 2230 and DIN 18 800, Part 1 must be observed.

Screw connections must be easily accessible for the purpose of testing for loosening.

Other Connections

Detachable positive and non-positive connections must be configured in such a way that loosening is either safely prevented or can be detected in time before damage occurs.

3.1.1.4 Documentation

The documentation for the production, assembly, and testing procedure must contain at least the following:

- Drawings of the design carried out with the stamp of approval from quality assurance
- Parts lists of the design carried out with the stamp of approval from quality assurance
- Qualification proof for the personnel involved
- Material certificates
- Certification of internal and/or external quality assurance on the performance of work in accordance with regulations.

The documentation must be kept separately from offices in charge of production and assembly.

3.2 Guideway

In principle, the following technical regulations must be observed and/or applied accordingly in the production and quality assurance of the guideway components: DS 804, DIN 1045, DIN 1075, DIN 1084, DIN 4227.

A separate quality assurance program must be formulated and applied for the assembly of the guideway functional components.

4. Equally Applicable Standards

DIN 1045	**Concrete and reinforced concrete, dimensioning and execution**
DIN 1075	**Concrete bridges, dimensioning and execution**
DIN 1079	**Steel road bridges, priniciples for structural design**
DIN 1084	**Quality supervision in concrete and reinforced concrete construction**
DIN 4227	**Prestressed concrete**
DIN 18 800	**Steel Structures**
Part 1	- Dimensioning and design
DIN 29 591	**Aerospace travel; examination of welders; welding metallic components.**
DIN 65 118	**Aerospace travel; welded, metallic components**
Part 1	- Data in construction plans
DS 804	Regulation for railroad bridges and miscellaneous engineering structures (VEI)
DS 899/59	Special provisions for railroad bridges on new railroad lines

DS 952	Welding metallic materials to rail vehicles and technical machinery
DVS 1603	Resistance spot welding of steel in rail vehicle construction
DVS 1604	Resistance spot welding of aluminum in rail vehicle construction
DVS 1608	Fusion welding of aluminum in rail vehicle construction
DVS 1609	Resistance spot welding of high-alloy steel in rail vehicle construction
DVS 1610	General guidelines for planning weld production in rail vehicle construction (with inserts 1 and 2)
DVS 1611	Evaluation of irradiation images in rail vehicle construction
VDI 2330	Systematic calculation of highly stressed screw connections

5. Other Literature

[7.1] Technical Report
"Guideway of the TRANSRAPID High-Speed Maglev Train,
Part I: General Requirements"
Doc. No. NVA/0604/03/89 - Date: 4/10/90
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

[7.2] Technical Report
"Guideway of the TRANSRAPID High-Speed Maglev Train,
Part II: Load Assumptions"
Doc. No. NVA/0320/02/89 - Draft: 8/89
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

[7.3] Technical Report
"Guideway of the TRANSRAPID High-Speed Maglev Train,
Part III: Deformation and Tolerances"
Doc. No. NVA/0693/03/89 - Date: 4/10/90
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

[7.4] Technical Report
"Guideway of the TRANSRAPID High-Speed Maglev Train,
Part IV: Maintenance"
Doc. No. NVA/2870/11/89
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

[7.5] Technical Report
"Guideway of the TRANSRAPID High-Speed Maglev Train,
Part V: Requirements of the Stator Pack"
Doc. No. NBSQ/0363.02/89
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

[7.6] Technical Report
"Guideway of the TRANSRAPID High-Speed Maglev Train,
Part VI: Requirements of the Stator Pack Mounting"
Doc. No. NBSQ/3086/12/89
Publisher: Thyssen Henschel, New Transportation Technologies Product Division

SWITCH

Chronology - Chapter 8
"Switch"

Edition	Revision	Date	Comment
1	0	05/90	
2, 3			missing
4	0	09/90	Changes
4	1	11/90	No changes

Switch

1. Object

This chapter deals with the requirements of the bending switch subsystem. Other conceivable design principles for switches of maglev train systems are not dealt with here. The object of Chapter 8 is fail-safe running over the switch, but not fail-safe train operation on the switch. The latter must be guaranteed through measures within the operational control system, and is jointly dealt with in Chapter 9.

With regard to structure and function, the bending switch system comprises the following 5 subsystems:

- Substructures (pillars) and foundations
- Primary (bending) girders, also called continuous girders, with the guideway components of slide surface, lateral guide rails, stator packs, and long-stator winding
- Shunting mechanism with safety mechanisms for holding in place and against force lifting
- Switch gear
- Switch safety (safety mechanism in the sense of railroad signaling technology)

At the bending switch, the total switch guideway can be bent into a straight or turnout setting through an elastic, box-shaped continuous girder in steel construction. Using an adjustment mechanism, this girder is supported on several reinforced concrete pillars. The adjustment mechanism consists of an electrical or hydraulic gear, whereby the position is ensured at the individual setting points by a positive and/or non-positive closure. There is always a positive closure in the junction to the fixed connecting girders.

2. General Safety Requirements

The switch may be run over only if it is in a fail-safe, i.e., secured state.

Such a fail-safe state is in evidence if

- the switch is safely closed at all setting points in the stop position
- the crossing at the thermal expansion gap at the switch end remains free of horizontal and vertical deviations within the permissible tolerances (alignment tolerances of the functional surfaces must be complied with)
- the closed end position has been safely detected and reported
- the once-locked switch remains operable even amidst breakdowns and breakdown warnings from switch subsystems
- an untimely and undesired shunting cannot be initiated.

In order to meet the safety requirements, a separation of control and protection installations should be carried out to whatever degree possible.

Note: This means shifting responsibility for switch safety based on signaling technology to the components of the operational control system.

However, according to the state of the art, protective installations should be provided that safeguard the bending girder and elements associated with it during excess electrical, mechanical, or pressure stress, and if necessary interrupt the shunting process.

Setting orders may not be effected uncommanded (fault consideration according to DIN VDE 0831).

3. End Position Safety Mechanism, Limit Switch

Installations to close off the switch at the end position (position safety mechanism) must be provided in such a way that in the event of any assumed failures in the area of the setting points (e.g., at the switch setting or stopping mechanism), no dangerous change of position will occur.

This position safety mechanism must be independent of the setting installation. An untimely switch unlock must be prevented. If the position safety mechanism is not independent of the setting installation, then an equivalent safety level for the latter must be in evidence.

The closure must determine the bending curve. In its design, the stresses caused by the maglev vehicle during regular operation as well as breakdowns must be taken into account.

If positive, mechanical closures are not applied, but rather non-positive closures, e.g., using the hydraulic system of the setting installation, are used, then the non-positive closure must be converted to a positive closure in the event of a fault--e.g., leaks.

Note: If the hydraulic fluid in the cylinder is occluded by stop valves, then a short-term positive closure is in evidence.

A failure of the safety element must be excluded. The failure exclusion must be justifiable on the basis of overdimensionings and quality assurance. No forces may be effected counter to the projected effective direction even during a breakdown.

If no positive, mechanical closures are used, then a second, independent securing system must be present at least at the movable switch end - the thermal expansion gap - which safely keeps the permissible alignment tolerances of the lateral guide rails from being exceeded.

Additional equipment must be provided in the thermal expansion gap, which bridge the temperature expansion gap of the sliding functional surface at the crossing of the switch end.

Note: In the TVE, these are flap bridges. Untimely movement of this equipment must be excluded.

In order to monitor the closure of the switch in the end position at the bearings and installations of the thermal expansion gap (flap bridge, bar flap), limit switches must be used for each end position in accordance with DIN VDE 0660, Part 206 or Part 209. If the switches do not satisfy the noted requirement, then they should be used in conjunction with a safety circuit, for which a fault consideration in keeping with DIN VDE 0831, Sect. 6.2 ff, 7.3 ff is necessary.

4. Synchronism of Switch Setting Gears

The switch setting gears must be reliable. In the event of a fault (failure of synchronism), no structural damage must occur. If the latter is a possibility, then synchronism must be monitored.

5. Operational Control Installations for Train Safety

Switches must feature installations that provide fail-safe reporting on safe usability. These installations may allow a run over the switch only if the end position has been safely reached and safely reported, and thus a change in position is excluded.

The shunting times of the switch must be monitored by this installation. If the new position is not reached within a predetermined time, then the shunting must be interrupted by the higher-order safety system, whereby no release for run may be issued. Untimely shunting must be prevented. While the switch and the corresponding lead-in section of the guideway are being traveled on, the position may not be changed.

Querying the switch position and the setting elements at the respective setting and closure points must be done in such a way that reported disruptions allow one to assess that the new targeted end positions are probably unattainable with future readjustments. The switch must remain fixed for a period to be specified during disruptions in the established operational direction. Changing position must be prevented in the event of a disruption.

In the event of failure of the installations for guideway safety and other operational disruptions, servicing the switch on site must be possible as a part of a special operational mode.

6. Proofs/Tests

Only type-tested components may be used and/or tested components whose suitability and operational acceptability for the case in question or for applications with a comparable safety level have been proven.

In the event of deviations from the above requirement in the design, application, or configuration of components, then the question of which of the following proofs and tests are necessary must be evaluated individually:

- Proofs for operational stability and for the loads for the primary structures and connecting elements must be kept in accordance with DS 804 or DS 899/59 (see Chapter 6).

- The materials used must be documented by producer's certificates.

- Quality assurance by internal and external surveillance must prove the existence of the necessary safety level for safety elements without redundancy.

The testing steps must correspond to the principles for products to which safety requirements apply. Applicable technical regulations include TRGL, TRD, AD.

The testing steps are:

1. Review of design documentation and calculations
2. Acceptance of the preliminary material
3. Examination of manufacturer qualification
4. Testing accompanying production
5. Testing during initial commissioning
6. Recurrent testing

The tests must ensure complete proof of the safety relevant properties of components and interfaces.

7. Equally Applicable Standards

EBO **Railroad Construction and Operation Ordinance**

ESBO **Railroad Construction and Operation Ordinance for Narrow-Gauge Railroads**

ESO **Railroad Signaling Ordinance**

MBO **Maglev Construction and Operation Ordinance, currently in draft form, dated Dec. 12, 1988**

Signaling Ordinance for Streetcars

DS 804 **Regulation for railroad bridges and miscellaneous engineering structures (VEI)**

DS 899/59 **Special provisions for railroad bridges on new railroad lines**

DIN VDE 0100	**Provisions on the setup of power installations with nominal voltages of up to 1000 V**
DIN VDE 0660	**Switchgears**
Part 206	- Auxiliary current switchs; supplemental provisions on force-opening position switches for safety functions
Part 209	- Low voltage switchgears; supplemental provisions for no-contact position switches for safety functions
DIN VDE 0831	**Electric railroad signaling systems**
DIN 24 343	**Fluid technology, hydraulics; servicing and inspection list for hydraulic systems**
DIN 24 346	**Fluid technology, hydraulics; hydraulic systems; principles of execution**
TRB	**Technical regulations for pressurized containers**
TRGL	**Technical regulations for high-pressure gas conduits**
ZH1/153	**Code of Practice for Selection and Installation of Force-Opening Position Switches With Safety Function**

AD Codes of Practice

OPERATIONAL CONTROL SYSTEM

Chronology - Chapter 9
"Operational Control System"

Edition	Revision	Date	Comment
1 (Chapter 8)			missing
2 (Chapter 8)	0		missing
2	1	05/89	
2	2	06/89	Changes
2	3	08/89	Changes
2	4	09/89	Changes
2 (Chapter 9)	5	10/89	Changes
3			missing
4	0	09/90	Changes
4	1	10/90	Changes
4	2	11/90	Changes

Operational Control System

1. Subject, Definition of Terms

This technical regulation contains guidelines for the construction, equipment, function, and operation of technical installations as well as for methods applicable to safety-relevant functions of the operational control system

Safety-relevant functions of the operational control system within the meaning of this body of regulations are guideway and vehicle protection.

1.1 Guideway, Guideway Element, Operational Readiness

From the viewpoint of the operational control system, the guideway comprises the totality of all operational-control guideway elements needed for a run (henceforth referred to as "guideway elements").

A guideway element is the smallest unit of the guideway network that can be distinguished in terms of safety engineering.

Operational readiness of a guideway is the permission to run on the guideway under predetermined conditions.

1.2 Guideway Protection

The goal of guideway protection is:

a) to make a guideway--that consists of one or more guideway elements and that can be travelled without danger--available to a vehicle, if

- the guideway elements are free of obstacles that can be recorded in terms of safety engineering and

- precautions have been taken such that no conceivable obstacles will get onto the guideway

and

b) to make available to the institutions participating in the intended run information on:

- the permissible maximum speed on the respective guideway elements,

- the position and, if necessary, properties of guideway elements and

- the terminal point of the protected guideway.

1.3 Vehicle

Vehicle within the meaning of this body of regulations is the general term covering units that can run independently and are technically protected.

1.4 Vehicle Protection

The goal of vehicle protection is to set vehicle speed on the basis of predetermined data in such a way that:

- permissible maximum speeds will not be exceeded,
- speeds will be no less than permissible minimum speeds,
- the vehicle will not run beyond the terminal point of the protected guideway, and
- those aspects of the rescue plan (see Chapter 12) that apply to speed will not be breached.

Furthermore, it is the task of vehicle protection to prevent operational states that are impermissible in terms of safety engineering and/or to respond to safety-related breakdown reports from the vehicle by adjusting the speed (including stopping).

1.5 Operational Modes

The installations for guideway and vehicle protection work in the following operational modes

- routine operation or
- special operation.

The standard mode is routine operation. The responsibility for safety is borne by technical installations.

In the event of

- breakdowns,
- construction or maintenance work, or
- operationally necessary tests,

it is possible to operate the installations of the guideway and vehicle protection system in the special operations mode. In that case, it is permissible to specify operational submodes.

2. General Safety Requirements

2.1 Properties of Technical Installations

2.1.1 Operating Points

Operational points in the sense of the following explanations are all installations that record and process the information necessary for safe operational guidance and, depending on the task of the operational point, induce corresponding reactions. Besides technical installations, these are also service points occupied by persons. Depending on the structure of the track network and of the automatic train control system, central operational points and control points occupied by personnel are necessary. The number, location, and task of these points depends on the plan in question, and thus can vary greatly. Thus, the minimum requirement consists of the installations described below.

2.1.1.1 Operational Control Center

There must be at least one operational control center for a coherent track network.

Operational control centers must feature technical installations that

- permit an overview of operational areas of competence,
- coordinate and process information from other operational points to the operationally necessary extent, and convey this information to the competent points,
- can generate operationally necessary directions, setting requirements, or other actions
- allow access to the course of operation that is permissible according to safety engineering by competent personnel.

During operation, operational control centers must be continually occupied to the necessary extent by professionally trained, suitable, and competent personnel (operational staff).

2.1.1.2 Other Operational Points

Besides the operational control center(s), depending on the structure and concept, there must be other institutions that record and process operationally necessary information, especially that relating to safety engineering, and that generate suitable actions in accordance with their competence. These operational points are generally organized on a decentralized basis. They can be either stationary or vehicle-based.

Since their functions depend very much on the concrete, individual case, the only requirement that can formulated with general validity is as follows:

The operational points as a whole must record the following information, and depending on structure exchange it among each other and process it to the necessary extent:

Guideway

The status of all guideway elements, for each element separately

- for fixed and mobile guideway elements, insofar as protection segments of a finite length are present
  - occupancy reports
  - breakdown reports
- in addition, for movable guideway elements (e.g., switches)
  - the position,
  - the status of the lock,

Note: It is possible to effect automatic train control systems on the basis of infinitesimally small segments or without protection segments. In this case, relevant information should be recorded by way of the vehicles.

Vehicle

The status of all vehicles; for each vehicle separately

- the current location,
- the speed
- internal information relevant to safety engineering, especially
  - operational readiness in general
  - running status (stopping, ready to start out, running, hovering or set down)
  - breakdown reports

2.1.2 Safety-Oriented Failure Behavior

Technical installations that record, transmit, or process safety-relevant information of the operational control system must be fail-safe in the sense of DIN VDE 0831. Installations that are not safety-relevant but are necessary for trouble-free operation should be highly reliable.

Failures or breakdowns in installations of the operational control system must not have dangerous repercussions. This general requirement is met by components in conventional technology (signaling engineering) if they correspond to the provisions of DIN VDE 0831.

In order to meet the requirements of DIN VDE 0831 in terms of failure analyses, the following is necessary for the information-processing components (data processing systems) in use, in accordance with MÜ 8004 and/or DIN V VDE 0801:

- test programs must be run regularly (self-tests, outside tests), and
- monitoring installations must directly check their proper function.

The result of this is the following requirement:

Technical installations in which a failure analysis according to DIN VDE 0831 is not possible must feature two mutually independent functional units ("2 of 2 systems") for all safety-relevant processes, so that failures or breakdowns in a functional unit are reported without delay and safety-oriented action can be initiated.

If a safety-oriented action is not possible ("no safe state"), at least two mutually independent functional units must initiate a safety-oriented function ("2 of 3 system," error-tolerant") even after a failure or during a breakdown.

2.1.3 Correct Functioning

Correct functioning should be understood as avoiding or handling systematic flaws in complex information-processing installations.

Systematic errors are predominantly design or production flaws, so that software bugs are always systematic errors. In principle, the requirements of DIN VDE 0831 should also be applied to high-speed maglev trains.

With respect to software, the requirements of DIN V VDE 0801 are applicable. Provisions on the use of complex hardware components, such as microprocessors, can be derived from the regulations found in DIN VDE 0831.

2.1.3.1 Hardware

Systematic flaws in technical installations of the operational control system may not have dangerous repercussions. Components for which it cannot be demonstrated, due to their complexity, that they are free of systematic flaws must be operationally proven in terms of their design, and their production quality must be demonstrated on the basis of recognized methods. In any event, the use of components that have not been adequately operationally proven is only permissible in structures with diverse-redundant channels. In these structures, the diversity of the channels must be proven. The necessary channel comparator must be fail-safe in accordance with DIN VDE 0831.

Note: Components can be assumed to be operationally proven if they have been used over a lengthy period, in large numbers, and in different applications, whereby no systematic flaws have been discovered.

2.1.3.2 Software

Requirements can be found in DIN V VDE 0801 pertaining to the design and production of software:

Software components for technical installations of the operational control system should be operationally proven. If said proof is not possible, then it must be demonstrated, through suitable analytical <u>and</u> testing methods, that these components are so free of flaws that no dangerous situation can arise because of them.

In order to avoid programming errors, safety-relevant software components must be formulated according to the rules of structured programming. For all components, their function as well as their interfaces to other components must be fully and clearly documented. These components should be written in programming languages that support structured programming. Operationally proven or validated tools must be used to formulate safety-relevant software components.

Where tools are used that are not operationally proven or validated to convert the program content from one code form into another (e.g., source code generators, compiler, PROM programming systems), it must be demonstrated through analytical or test methods that the conversion process is correct.

For multistage conversion processes, it is enough to document the conversion from the first to the last stage.

Example:

With a non-operationally proven compiler and non-operationally proven PROM programming device, it is enough to demonstrate that the object code contained in the PROM corresponds to the source code. The interim stage (e.g., a linkage editor) need not be checked.

The program and fixed data for safety-relevant functions should be stored only in memory that cannot be written over (e.g., PROMs).

Where possible, safety-relevant and non-safety-relevant software components should be physically and logically separated.

2.2 Operational Procedures of Guideway Protection

2.2.1 General Principles

Runs with passengers are conducted in routine operation. The precondition is that all safety-relevant technical installations function properly and all necessary guideway elements be made operationally ready.

2.2.2 Operational Readiness of Guideway Elements

A guideway element may be made operationally ready for a run only if

- there is no vehicle on it

<u>and</u>

- (provided the guideway element is movable) it has been ensured that it cannot alter its set position

<u>and</u>

- it has been ensured that no

  - other vehicles (flanking, opposing),

  - other technical installations, e.g., mobile access facilities for passengers

  can get into the clearance profile of the respective guideway element

<u>and</u>

- it has not been made operationally ready for another run

<u>and</u>

- it is not blocked for some other reason.

The technical installations for guideway protection must have information available for each operationally ready guideway element in terms of:

- location of the guideway element,
- the locally permissible maximum speed (with due consideration to track design and wind influences)
- suitability of the guideway element as auxiliary stopping point.

2.3 Operational Procedures of Vehicle Protection

2.3.1 General Principles

A vehicle may only run so fast that the headway distance is complied with.

2.3.2 Speed Range

Technical installations for vehicle protection generate a location-dependent speed range for the guideway elements made operationally ready by guideway protection.

This is made up of the following:

- the data about the guideway supplied by guideway protection and
- vehicle-internal data:
    - permissible maximum speed of vehicle,
    - data on the status of the installations for levitation, guidance, and on-board braking installations

Technical installations for vehicle protection must act on the speed in such a way that exceeding the maximum speed is prevented and that during regular operation mode a stop is effected at the next

stopping point that can be reached if the actual speed becomes lower than the minimum speed.

2.3.3 Train Schedule

It must be ensured that dispatch concerns, especially the train schedule, cannot influence the performance of the technical installations for vehicle protection.

3. Measures During Breakdown and Failures, Special Operation

3.1 General Principles

In the event of failure of installations for guideway or vehicle protection and in the event of other operational breakdowns, the portion of the track network affected by this must be excluded from operation and technically protected. In these segments, a special vehicle may then be run at a maximum of 50 km/h (special operation).

No runs with passengers may be started during special operation. In the event of breakdown, vehicles occupied by passengers may be guided to the next stopping point during special operation.

Special operation is permissible only in the cases mentioned under 1.5. A special permit from the competent authority is necessary for any other case.

3.2 Requirements of Technical Installations During Special Operation

3.2.1 Vehicles for Special Operation

Vehicles for uses in special operation must, in keeping with their destination, be capable of being controlled

- on sight and/or
- from the vehicle itself.

3.2.2 Movable Guideway Elements

Movable guideway elements (switches) must be capable of being operated on site within the framework of special operations. (see also Chapter 8).

4. Proofs/Tests

Proofs and tests for technical installations of the operational control system are based on the requirements of DIN VDE 0831 and DIN V VDE 0801. For complex components, it is expedient, wherever possible, to keep proofs and conduct tests for hardware and software separately, except in the case of functional checks and integration tests.

When checking memory-programmable, and thus in this sense information-processing components of automatic train control systems, the following requirements apply:

4.1 Hardware

Hardware must be tested and approved according to type (type approval).

Recurrent tests are required during operation, the type and extent of which are established within the framework of the type approval.

Cyclical self-tests or outside tests that are continually incorporated into the normal course of operation are not considered tests in the sense of the said recurrent tests.

Regular and extraordinary functional tests in accordance with DIN VDE 0831 can be conducted using data processing programs; it must be demonstrated that these programs perform the respective test completely and reliably.

The results of tests conducted with data processing programs should be recorded directly by these programs.

4.2 Software

The special nature of software implies that proofs and tests generally cannot be performed in the "classical" manner (checking documentation, functional testing, etc.); instead, or at least supplemental to this, the use of data processing systems is required.

Within the framework of the safety proof for software, it is necessary according to the current state of the art:

- to inspect the requirement specification for clarity, completeness, unambiguity, and validity. In order to facilitate the inspection, the specification should be drawn up using formal methods.

- to inspect the draft versions of the system or program for correctness compared to the specification. In order to facilitate inspection, the draft versions should be computer-supported and formalized (CASE).

  It may be necessary to perform this review in several steps.

- to inspect the object code for correct implementation on the target storage medium.

  Depending on which development and production tools are used, the inspection shall extend from an understanding of the production method to verification of the development steps.

  The goal of the review is to prove the correctness and the identity; this also includes proving that <u>only</u> the specified functions have been implemented.

- to inspect the test cases for completeness and expedience.

  The entirety of the test cases must meet the requirements of the C1 coverage, i.e., coverage of all branches.

  Note: It is expedient to generate and test the test cases with computer support.

The results of the proofs and tests can be recorded in machine-readable form.

5. Equally Applicable Standards

DIN VDE 0831	**Electric railroad signaling systems**
MUe 8004	**Principles for technical approval in signaling and communication technology; German Federal Railroad, Federal Railroad Central Office**
DIN V VDE 0801	**Principles for computers in systems with safety functions**
UIC 738 E, 2nd edition	**Processing and transmitting safety information**

LIGHTNING PROTECTION, EMC, ESD

Chronology - Chapter 10
"Lightning Protection/EMC/ESD"

Edition	**Revision**	**Date**	**Comment**
1 (Chapter 9)			missing
2	0		missing
2	1	05/89	
2	2	06/89	Changes
2	3	08/89	Changes
2 (Chapter 10)	4	09/89	Changes
2	6	10/89	Changes
3	6	08/90	Changes
4	0	09/90	Changes
4	1	11/90	Changes

Lightning Protection, EMC, ESD

1. Overview - General Requirements

Hazards can result through the effects of lightning (near and distant strikes), outside electromagnetic effects, guideway- and vehicle-based electromagnetic incompatibility of the high-speed maglev systems (electromagnetic compatibility, EMC), and electrostatic discharges (ESD).

Some of the characteristics of lightning strikes are:

- large values for peak current, current rate of rise, energy content, charge
- rare occurrence
- short effective time (less than 1 s)

Some of the characteristics of electromagnetic effects are:

- small energy or power content
- generally continual or long-term effect
- narrowband or wideband frequency spectrum
- reciprocal influences between systems

Some of the characteristics of ESD effects are:

- small to medium charges, high voltages
- charging mechanism is very high-resistive

- wideband frequency spectrum

High-speed maglev trains must be built and operated in such a way that:

- persons are not endangered by direct lightning and ESD effects
- safety-relevant systems are not impermissibly affected by lightning, ESD and electromagnetic effects
- there are no impermissible electromagnetic emissions
- damage within the range of the economically significant is avoided.

Requirements are given in Sect. 2 through 4 of this Chapter.

2. Lightning Protection

2.1 Lightning Parameters

The lightning parameters that must serve as the basis for dimensioning lightning protection measures are taken to be from Part 4 of VG Standard 96 901.

In terms of effects on safety-relevant electronics, the threat values characterized in the standard as "high" should be applied.

Note: Where reference is made below to technical norms in which protective measures are indicated without lightning parameters, considerations in this regard need not be applied.

2.2 Direct Hazard to Persons

2.2.1 Vehicles

Vehicles must meet the requirements of DIN VDE 0185, Part 1, with the following additional stipulations:

1 Protection areas:
Protection areas as in Sect. 2.1.5 and accordingly as in Sect. 5.1 of DIN VDE 0185, Part 1 are to be determined using the lightning ball method according to Professor Wiesinger.
Radius of the lightning ball: 10 m.

2 Grounding:
Section 5.3 of DIN VDE 0185, Part 1 is not applicable.

Even when set down, the vehicle itself cannot be used as part of the external lightning protection according to DIN VDE 0185, Part 1, Sect. 5.

Note: 1. Even with set-down vehicles, it is not possible to count on an adequate lightning current-conductive connection between vehicles and the guideway.

2. Compliance with the aforementioned requirements offers adequate fire protection if it can be assumed that vehicles are neither susceptible to fire in the sense of Sect. 2.1, nor susceptible to explosion in the sense of Sect. 2.3, nor susceptible to explosive materials in the sense of Sect. 2.4 of DIN VDE 0185, Part 2.

3. There is no need to take into account lightning current crossovers between the vehicle and guideway <u>as a result of approximations</u>, due to the two- or three-dimensional lightning current shunts in girders and pillars (where applicable); see DIN VDE 0185, Part 1, Sect. 6.2.1.4 by analogy. However special proofs are necessary with respect to bridgings in the area of the girder joints and pillar bearings; see also Sect. 2.2.2.1.

2.2.2 Operating Systems

Operating systems must meet the requirements of DIN VDE 0185 with the following additional stipulations:

1. Elevated guideway sections must be treated like bridges in the sense of Sect. 4.9 of DIN VDE 0185, Part 2.

Girder joints and pillar bearings (where applicable) must be bridged on both sides.

2. At the connection points (switching stations) for the stator windings, overvoltage arrestors must be installed with adequate lightning current carrying capacity for direct strikes.

   The amplitude of partial currents should generally be set at 5% of the amplitude of the threat value in Sect. 2.1.

   Sections of the guideway where persons may regularly board or deboard vehicles must be protected through permanent lightning protection systems in keeping with DIN VDE 0185.

Notes:

1. Because of the magnetic levitation/guidance principle, lightning current transfers from the vehicle to the stator winding must be expected; see also Note 3 in Sect. 2.2.1 and Note 1 in Sect. 2.3.

2. Stations, stopping places

   Because even the Places of Assembly Ordinance, for example, establishes no special requirements for the design of the lightning protection system, the aforementioned stipulations are considered adequate.

2.3 Hazard to Safety-Relevant Systems

Failures and breakdowns of safety-relevant systems should be prevented wherever possible. When it is impossible, measures should be taken through which <u>impermissible</u> breakdowns and failures are prevented.

The measures must be comprehensible and verifiable, and a lightning protection plan must be formulated.

Notes:

1. Depending on the design of the vehicles and guideway, one must take into account that lightning striking a levitating vehicle will pass into the long-stator winding, e.g., via the levitation magnets.

2. Several lightning current crossover points per lightning strike on both the vehicle and the guideway must be expected.

3. Impermissible breakdowns and failures could include:

   3.1 Impermissible redundancy loss through simultaneous breakdown and/or damage of several systems assumed to be statistically independent in the vehicle and in the operational control system.

4. Suitable measures could include:

   4.1 Potential equalization connections generously dimensioned in terms of quality and quantity
   4.2 Shields
   4.3 Overvoltage limiters

5. Verifiability

   The preconditions are at least the following:

   5.1 Representation of the safety plan without taking lightning protection into account
   5.2 Representation of lightning protection measures
   5.3 Protocols on calculations and/or experimental proofs, if necessary

2.4 Hazard to Material Property

Damage of significant dimensions should be prevented where possible. Where this is impossible or possible only at an unfeasibly high expense, measures should be undertaken to limit the damage.

Notes: 1. Damage of significant dimensions could include:

1.1 Exposure of reinforcing steel in concrete girders and pillars, especially in inaccessible guideway sections

1.2 Punctures in the long-stator cable

1.3 Destruction of switching stations and substation components

2. Measures to limit damage could include:

2.1 Reduction of overvoltages through the type of cabling design, through shielding, etc.

2.2 Overvoltage limitation

2.3 Suitable repair plans, e.g., for damage to the long-stator cable, the vehicle surface, or the vehicle magnets

3. Probability of lightning strikes

The question of whether and to what extent measures to prevent damage are practical can probably be answered only as a function of the probability of lightning strikes, and possibly subdivided according to its parameters (see Sect. 2.1).

2.5 Proofs/Tests/Equally Applicable Standards

VG Standard 96900 from Sect. 2 on is applicable, including the standards and supplements noted there excluding those for the NEMP.

DIN VDE 0185 with the aforementioned supplements is applicable.

VG 96900	**Protection against nuclear electromagnetic pulse (NEMP) and lighting strike; survey**
VG 96901	**Protection against nuclear electromagnetic pulse (NEMP) and lighting strike**
Part 4	- General principles; hazard data
DIN VDE 0183	**Lightning protection installation**
Part 1	- General information on setup
Part 2	- Set up of special installations
Part 100 (draft)	- Specifications for lightning protection of buildings - General principles

3. EMC

3.1 Emissions

High-speed maglev trains must be built and operated in such a way that no impermissible electromagnetic effects are emitted into the environment or the interior of vehicles and buildings.

Notes:

1. Direct hazard to persons:
   According to what is presently known, there is no reason to fear a direct hazard to persons if the emissions satisfy the technical norms.

2. Heart pacemakers:
   No special requirements.

3. It remains to be established which area surrounding installations still pertains to the system, and which pertain to the environment (interface).

3.2 Hazard to Safety-Relevant Systems

Failures and breakdowns of safety-relevant systems from electromagnetic influences that have yet to be established from the environment and from components inside the system must be prevented where possible. When this is not possible, measures must be undertaken to prevent <u>impermissible</u> breakdowns and failures. The measures must be comprehensible and verifiable, and an EMC plan must be formulated.

The plan must include information on at least the following aspects:

1. Effects from the environment that can be expected under proper operating conditions (stipulation).

These stipulations--depending on location, presence of sources of interference, etc.--can be generally applicable or dependent on location, for example.

2. Modularly structured representation of the interaction between the safety-relevant systems, with identification of disruption sources and drains.

3. Conditions under which the safety proofs are applicable <u>without</u> electromagnetic effects.

4. Specified interference distances for safety-relevant and non-safety-relevant systems or subsystems.

5. EMC measures (e.g., shielding plan, overvoltage limitation)

6. Effectiveness of EMC measures in all proper operational states, and vehicle and system configurations.

3.3 Proofs/Tests/Equally Applicable Standards:

At least the following standards should be applied, where applicable:

1. Radio interference:

   DIN VDE 0873 **Measures protecting against radio interference from installations of electric power supply systems and electric train systems**

Part 1	-	Radio interference from installations ≥ 10 kV nominal voltage
Part 2	-	Radio interference from installations < 10 kV nominal voltage and from electric train systems

DIN VDE 0875 Radio interference from electric operating equipment and installations

Part 1	-	Limits and measuring processes for radio interference from electric household appliances, hand-held electric tools and similar electrical equipment
Part 2	-	Limits and measuring processes for radio interference from fluorescent lamps and fluorescent light bulbs
Part 3	-	Radio interference from special electric operating equipment and from electrical installations

Note: The evaluation of click interference and measures to reduce it should be given special consideration with regard to internal interference; see DIN VDE 0875.

2. Immunity to interference:

E DIN VDE 0839 Electromagnetic compatibility

Part 10	-	Assessment of immunity to line-fed and radiated interference

DIN VDE 0843		**Electromagnetic compatibility of measuring and open/closed loop control installations in industrial process technology**
Part 1	-	General introduction
Part 2	-	Immunity to the discharge of static electricity; requirements and measuring methods
Part 3	-	Immunity to electromagnetic fields; requirements and measuring methods
Part 4 (draft)	-	Immunity to rapid, transient interference (burst)
DIN VDE 0847		**Measuring method for assessing electromagnetic compatibility**
Part 2 (draft)	-	Immunity to line-fed interference
Part 4 (draft)	-	Immunity to radiated interference
DIN VDE 40 839		**Electromagnetic compatibility (EMC) in motor vehicles**
Part 1	-	Line-fed interference in power supply lines in 12 V on-board circuits

Notes on radiated interference values:

1. In contrast to DIN VDE 0843, Part 3, noise signals in the frequency range from 0.3 to 3 kHz are to be modulated upon in addition to modulation with sinusoidal signals.

2. The field strength in the test should be established through U_S / 2, i.e., the measuring equipment is calibrated without modulation; only afterwards is modulation turned on, whereby the carrier signal amplitude is not changed.

3. Magnetic fields

DIN VDE 0848	**Hazards from electromagnetic fields**	
Part 1	-	Measurement and calculation methods
Part 2	-	Protection of persons in the frequency range from 10 kHz to 3000 GHz
Part 3	-	Explosion protection
Part 4	-	Safety in electromagnetic fields; limits for field strengths for protecting persons in the frequency range from 0 Hz to 30 kHz

4. Methods

VG 95372	**Electromagnetic compatibility; survey** (including the respective standards and inserts noted, excluding those for detonating and igniting agents.

4. ESD

Because of no-contact operation and the high operating speed, electrostatic charges and subsequent discharges must be expected.

Notes:

1. Energy of an electrostatic charge/discharge:

   1.1 It is recommended that the maximum possible ESD energy level that can act on a person first be determined by calculation or experimental proofs.

   1.2 The max. permissible ESD energy level has yet to be established. According to DIN VDE 0100, Part 410, Edition 11/83: 350 mJ.

2. ESD aspects--e.g., the flash-over field strength--should be taken into account in dimensioning the clearance profile.

3. Hazards can be avoided with technical installations that shunt any charges present on vehicles prior to arrival at a stopping place, or with operational measures that prevent boarding or exiting vehicles

before set-down (and thus grounding and discharging).

It is recommended that only electrostatically conductive materials be used for large-surface synthetic parts on the vehicle if charges are to be shunted.

4.1 Hazard to Safety-Relevant Systems

Failures and breakdowns in safety-relevant systems should be prevented wherever possible. When it is impossible, measures should be taken through which impermissible breakdowns and failures are prevented.

Notes:

1. External ESD hazards are not feared if suitable lightning protection measures in accordance with Sect. 2 are applied.

2. Electrostatic charges inside the systems accessible to persons--e.g., vehicle, control cab--can be adequately diminished through the use of suitable materials, for example.

   For this, see also ZH 1/200 and DIN 54 345.

3. Coordination with regard to the behavior of interference sources and sinks is necessary.

4.3 Proofs/Tests/Equally Applicable Standards

DIN VDE 0100	**Provisions on the setup of power installations with nominal voltages of up to 1000 V**	
Part 410	-	Protective measures; protection against dangerous body currents
DIN 54 345	**Testing of textiles**	
Part 1	-	Assessment of electrostatic behavior; determination of electrical resistance variables
Part 2	-	Assessment of electrostatic behavior; testing of textile floor coverings in the walk test
Part 3	-	Electrostatic behavior; industrial determination of the charge in textile floor coverings
Part 4	-	Electrostatic behavior; determination of the potential for electrostatic charge in textile surface formations
Part 5	-	Electrostatic behavior; determination of electrical resistance in strips made of textile surface formations
ZH1/200	**Guidelines for avoiding ignition hazards due to electrostatic charges**	

FIRE PROTECTION

Chronology - Chapter 11
"Fire Protection"

Edition	Revision	Date	Comment
1 (Chapter 10)			missing
2	0		missing
2	1	05/89	
2	2	06/89	No change
2	3	08/89	Changes
2 (Chapter 11)	4	09/89	No change
2	5	10/89	Changes
3			missing
4	0	09/90	No change
4	1	11/90	Changes

<u>Fire Protection</u>

1. Preface

This technical regulation contains safety-engineering specifications concerning fire protection through demonstrably suitable materials and constructive and accompanying measures.

Managing fire hazards presupposes due attention to the flammability and thermal conduction of materials, to their composition in terms of the creation of corrosive or toxic decomposition products, and to the release of energy in the event of fire, in conjunction with system-related, necessary measures.

2. Applicability and Purpose

This technical regulation applies to fire-protection requirements of supporting structures, fittings and linings, and installations for reporting and fighting fires on vehicles in the sense of the requirements in Sect. 3.4 of MBO.

The fire-protection requirements are intended to protect the passengers, the crew, and the rescue personnel in the event of fire on vehicles in fire protection class 4 according to DIN 5510, Part 1, and should be applied with due regard for the rescue strategy of the respective high-speed maglev train system.

3. Terms

The terms used in this technical regulation are largely taken from DIN 4102, DIN 5510, DIN 50 060.

4. Requirements

4.1 General Requirements

The materials and components used in vehicles must be selected and arranged--with regard to the development, propagation, and transmission of fire--in such a way that dangers for passengers, crew, and rescue personnel are avoided or at least adequately delayed. In particular, the fire behavior of the materials and composite materials must also be noted in terms of fire alarm installations and firefighting measures.

Compliance with the requirements must be proven by qualification reports according to Sect. 5.1 and by monitoring reports according to Sect. 5.2.

4.2 Supporting Structures

With respect to the materials used and their design and arrangement, supporting structures must be chosen such that in the event of fire a breakdown of stability due to burn damage or heating and a transmission of fire is prevented or at least adequately delayed.

Compliance with these requirements must be proven by qualification tests according to Sect. 5.3 and the monitoring tests stipulated in the qualification report according to Sect. 5.1.

4.3 Fire Walls

By using suitable materials, a corresponding design and arrangement of the components, as well as in terms of the positioning and control equipment, fire walls must ensure that partitioning after an adequate escape period is possible and that fire transmission due to a breakdown of stability, heat conduction, or heat radiation can be excluded for a period of time at least as long as that needed to evacuate the passengers and crew.

Where components made of heat-conducting materials are connected or coupled in the area of a fire wall, heat transmission to connecting parts must be avoided by built-in components made of heat-insulating materials.

Compliance with these requirements must be proven on the basis of the results of qualification tests according to Sect. 5.3 in conjunction with functional tests of the control installation, and according to Sect. 5.7 and the monitoring tests stipulated in the qualification report according to Sect. 5.1.

4.4 Fitting and Lining Elements

For components of fittings and linings that do not belong to the supporting vehicle structure, non-combustible materials in keeping with Building Material Class A in DIN 4102, Part 1, should be used, or combustible materials must be used that meet the requirements of DS 899/35, Sect. VI.

When using non-combustible materials, attention must be given to heat conduction that is dangerous in the event of fire, and, if necessary, fire transmission must be prevented by built-in components made of heat-insulating materials.

In the event of fire, combustible materials may neither drain off or fall while burning, nor emit dense or sooty smoke, nor form significant amounts of corrosive or toxic decomposition products, nor release dangerous amounts of heat.

Compliance with these requirements must be proven on the basis of the results of qualification tests according to Sect. 5.5, 5.6 and 5.8 and the monitoring tests stipulated in the qualification report according to Sect. 5.1.

For components made of different materials, the aforementioned requirements apply accordingly to composite materials.

With respect to design structure, the requirements according to DIN 5510, Part 4, are applicable.

Compliance with these requirements must be proven on the basis of the results of qualification tests according to Sect. 5.4 and 5.7 and the monitoring tests stipulated in the qualification report according to Sect. 5.1.

4.5 Batteries and Cabling

Batteries and cables should be positioned outside the passenger areas. When positioned in passenger compartments, the requirements of Section 4.4 must at a minimum be met accordingly

The requirements of Sect. 4.4 apply to the materials of battery cases and containers, to the insulation of cables, and to the materials of cable conduits and bushings that are positioned in passenger areas and control cabs.

Battery cases and containers must be stable in fire-protection terms at least for the period of time necessary to evacuate the passengers and crew.

Compliance with these requirements must be proven on the basis of the results of qualification tests according to Sect. 5.3 and the monitoring tests stipulated in the qualification report according to Sect. 5.1.

4.6 Electrical Operating Equipment

For the electrical operating equipment positioned in passenger areas and control cabs, especially lighting, heating, and air-conditioning systems, the requirements according to DIN 5510, Part 5, are applicable, including the additional provisions in Sect. 3.4 of this standard.

Compliance with the requirements must be proven on the basis of the results of the tests according to DIN 5510, Part 5, Section 4.

4.7 Fire Alarm Systems

The vehicles must be equipped with automatic fire alarms in keeping with the requirements of DIN 5510, Part 6, Sect. 4. The fire behavior of the materials and/or composite materials must be noted.

Compliance with the requirements must be proven by the results of the tests in DIN 5510, Part 6, Sect. 6.

4.8 Firefighting Installations

The vehicles must be equipped with an adequate number of portable fire extinguishers that meet the requirements of DIN 5510, Part 6, Sect. 5. At least 2 fire extinguishers must be provided in each passenger area and control cab, one of which must be mounted in the immediate vicinity of fire walls.

Where automatically activating firefighting installations are installed, the minimum requirements according to DIN 5510, Part 6, Table 1, are applicable.

Compliance with the requirements must be proven by the results of the tests in DIN 5510, Part 6, Sect. 6.

4.9 Prohibition and Danger Notices

Non-smoking zones in the front and rear areas and in the luggage and toilet areas must be marked. The prohibition is to be indicated by permanent, clearly legible, and easily recognizable signs.

5. Proofs/Tests

5.1 Qualification Tests

Prior to initial delivery, compliance with the requirements in Sect. 4 must be proven by the results of qualification tests and confirmed by qualification reports by an expert. Expert qualification reports include stipulations for the monitoring tests according to Sect. 5.2.

Qualification proofs must be kept in the form of verifiable records on the burning behavior of the materials and components or in the form of fire tests with specimens or models of the material or components.

5.2 Monitoring Tests

During production, compliance with the requirements of Sect. 4 must be proven by the results of monitoring tests based on DIN 18 200, with due attention to the stipulations in qualification reports according to Sect. 5.1, and confirmed by monitoring reports by an expert.

5.3 Fire Transmission

The qualification test is conducted through the fire test based on DIN 4102, Part 2, Part 4, or Part 5, performed on components specimens, if necessary in conjunction with connecting components.

5.4 Fire Propagation

The qualification test is conducted through the fire test based on UIC 564-2, Appendix 4, Method A or Method B, on specimens or models of components.

5.5 Burning Behavior

The qualification test is conducted with respect to combustibility, smoke development, and capacity for forming drops, based on DS 899/35, on material specimens.

5.6 Decomposition Products

The qualification test is conducted with respect to corrosive or toxic decomposition products based on ATS 1000.001, Sect. 7.3, on material specimens.

5.7 Heat Transfer

The qualification test is conducted through the burn-through test based on FAR § 25.853, Appendix F, Part III, on material samples.

5.8 Heat Release

The qualification test is conducted through the radiation test based on FAR § 25.853, Appendix F, Part IV, on material samples.

5.9 Execution Tests

Prior to the release or delivery of vehicles to the operator, the correspondence of the execution with the records and stipulationsbased on the qualification report must be checked in terms of the materials used, the design and arrangement, the production and assembly methods, and equipping with fire-protection installations, and certified by a person responsible for monitoring.

6. Equally Applicable Standards

DIN 4102	**Burning behavior of building materials and components:**
Part 2	Components - terms, requirements, and tests
Part 4	Composition and application of classified building materials, components, and special components
Part 5	Fire-protection seals, seals in shaft walls and against fire, resistive glazings, terms, requirements, and tests
DIN 5510	**Preventative fire protection in rail vehicles:**
Part 1	Fire protection grades, fire protection measures and proofs
Part 4	Vehicle design; safety-engineering requirements
Part 5	Electrical operating equipment; safety-engineering requirements

Part 6	Accompanying measures, function of the emergency brake installation, information systems, fire alarm systems, firefighting installations; safety-engineering requirements
DIN 18 200	Monitoring (quality monitoring) of building materials, components, and designs; General principles
DIN 50 060	Test of burning behavior of materials and products Terms
MBO	Maglev Construction and Operating Regulation (draft, 12/88)
DS 899/35	Code of practice for testing the burning behavior of solids
UIC 564-2	Regulations on fire protection and firefighting for vehicles used in international transportation
ATS 1000.001	Airbus Industry - fire-, smoke-, toxicity-test specification
FAR-Part 25	Federal aviation regulations: Air worthiness standards

Explanations:

Preconditions for the technical regulation on fire-protection requirements in -:

- State of the art in fire tests
- Meaningfulness of fire test results
- Significance of the proof requirement to development

RESCUE PLAN

Chronology - Chapter 12
"Rescue Plan"

Edition	Revision	Date	Comment
4	0	09/90	
4	1	11/90	Changes

Rescue Plan

1. **Preliminary Remarks**

This technical regulation contains decisions pertaining to the rescue of persons from vehicles of a high-speed maglev train in an emergency.

An emergency is a situation that can cause a threat to personal safety.

Emergencies are characterized by the fact that evacuation measures must be initiated.

Similarly, an evacuation of the vehicle for reasons of comfort cannot be ruled out entirely. That type of case can occur if, during a breakdown (disruption of regular service, by which an emergency can be caused) an unreasonable waiting time is exceeded without the presence of a danger to personal safety. This case is not the subject of the present technical regulation.

A fire in a vehicle is regarded as a real emergency. The emergency occurs only after the fire cannot be brought under control with on-board resources.

In practical application of the high-speed maglev train, a large part of the guideway is elevated. Because of elevation, the vehicles cannot be deboarded at any spot along the route without additional installations.

The stations are fundamentally well-suited for deboarding the vehicles (operational boarding and deboarding). The existence of a infrastructure for rescue measures can be assumed. For this reason, the vehicle may in principle stop only at stations. Since this requirement cannot be fully complied with, possibilities for evacuating the vehicle between stations must also be provided.

The concept of safe hovering makes it possible to provide for stopping places other than the stopping places before danger points, which the vehicle can reach in the event of a breakdown or emergency in order to achieve easy rescue of the passengers there (stopping place plan). Even in the stopping place plan, an emergency evacuation is necessary between stopping points only after an additional emergency occurs after the stop between stopping points. The requirements applicable to this case are given in Section 6.

If the alignment allows emergency evacuations without stopping places provided for that purpose, then the latter are not necessary. In this case, the guideway segment in question can be regarded in its entirety as a "stopping place." Programmed braking at a particular point is then also unnecessary. However, the quality of the evacuation must be the same as at stopping places (see Sections 3.3 and 6).

2. General Requirements

In order to ensure reliable train operation and to meet the basic requirement--reaching stations--the vehicle/guideway system must be configured as if the stopping place plan were always applicable as the rescue plan. The result of this is the following general requirements.

Dangers for persons must be avoided or the effects of them must at least be adequately delayed until the vehicle can be safely deboarded.

The resulting system requirements and requirements of the individual systems are established in detail in the corresponding folios of this body of regulations.

- Requirements of the overall high-speed maglev train system

  The vehicles must "hover safely."

  "Safe hovering" is the preservation of the levitation function even amidst the maximum conceivable breakdown and/or emergency situations for limited and short-term further operation (see Regulations, Chapter 1).

- Requirements of vehicles

  The vehicle design, including the electrical installations and their mounting, must meet the fire protection requirements for vehicles in fire protection grade 4 according to DIN 5510, Part 1 (fire risk critically defined by use on routes without a safety area) (see Regulations, Chapter 11).

- Requirements of the propulsion

  An adequate thrust reserve must be ensured, so that even in the event of a breakdown (only 50% residual driving power available due to loss of redundancy) the vehicle can still move in the predetermined speed range.

  If the escape velocity is not achieved upon departing from a station, then an emergency stop through emergency braking must be ensured in the deboarding area of the same station. This requirement does not apply to stopping places.

  In the event of a breakdown in the propulsion system, highly reliable propulsion shutdown must be ensured, in order to allow braking with the vehicle's safety brake system (see also Regulations, Chapter 2).

- Requirements of vehicle safety

  The speed of the vehicles should be adjusted and monitored as a function of location in such a way that it is always in a permissible speed range.

  The permissible speed range is limited on the lower end by a minimum speed,

- that is necessary to cover the entire energy needs by way of the linear generators

- where, when not achieved, emergency braking is effected at the next station or stopping place

and is limited on the upper end by a maximum speed,

- that represents the upper limit of the braking characteristic curve

- that represents the alignment-dependent permissible speed outside the braking range (see also Regulations, Chapter 9).

3. Requirements of Vehicles

3.1 Escape Routes

Passengers must be able to get to adjacent sections through the connecting passages of the vehicles.

The connecting passages should be configured as fire walls. The requirements are specified in Regulations, Chapter 11.

For a vehicle consisting of several sections, each section constitutes a fire segment. It must be ensured that a fire will remain limited to a fire segment for at least 30 minutes.

In the event of fire, the escape route from the burning section is into the adjacent section(s). It must be ensured that this is performed along the shortest route from each position in the section in question and that escape routes are not too narrow. (see Chapter 11).

Danger-free deboarding through the exit doors must be ensured at stations and stopping places.

3.2 Signs, Warnings

There must be emergency lighting of the escape routes in the vehicles.

Signs (at least partially illuminated) for escape routes and exit doors must be installed that are discernible from every seat.

Signs must be mounted on firefighting equipment, rescue equipment, and first-aid kits.

The passenger emergency signal activating units must feature a sign indicating the consequences of misuse.

All signs or warnings must be permanent, clearly legible, and easily discernible.

3.3 Equipment

In the sense of the rescue plan, equipment for

- communication
- firefighting
- evacuation
- first aid

must be provided in the vehicles.

Communication equipment

Vehicles must be equipped with two independent communication installations, with which voice contact can be initiated with an operational control center and vice versa.

Firefighting equipment

In sections with driver's cabs, at least two portable fire extinguishers must be provided per driver's cab and passenger compartment, one of which in the immediate vicinity of fire walls.

In sections without driver's cabs, at least two portable fire extinguishers must be provided, one of which in the immediate vicinity of fire walls (see also Regulations, Chapter 11).

Evacuation

- **Stopping place plan**

  Evacuation during an emergency is performed at stopping points. Deboarding equipment must be provided for rescue during a stop between stopping points (see Section 6), so that the vehicles can be evacuated even in elevated track segments.

Note: As a minimum measure, one safety rope unit per exit must be provided. Safety rope evacuation is limited to guideway heights of 20 m (gradient above ground).

Alternatively, rescue slides can also be provided for self-rescue if the operator of the high-speed maglev train system in question so requires. Ejecting the slides must be possible in terms of the guideway height and the surrounding terrain.

Deboarding the vehicle onto the elevated guideway is impermissible.

- **Other rescue plans**

Should emergency evacuation at any place along a line segment be possible (entire line segment as stopping place), then measures/equipment must be provided that enable evacuation of the same quality as at stopping places (see Sections 4 and 6). This can be rescue slides, for example, if ejection is possible in terms of the guideway elevation and the surrounding terrain. Deboarding the vehicle onto the elevated guideway is impermissible.

First-aid equipment

At least one small first-aid kit must be provided per section.

The procedure in the event of a disruption in vital functions (critical!) must be specified in the operating instructions, service directions, rescue plan for the high-speed maglev train system in question (request for rescue services per communication device between conductors and operational control site directly to the next station in the same direction, if necessary the next stopping place as well).

The vehicle equipment must be regularly inspected with regard to its function and storage stability (first-aid equipment).

3.4 Passenger Emergency Signal

Vehicles must be equipped with actuating devices with which passengers can inform the on-board conductors optically and/or acoustically of a breakdown or emergency situation.

It is assumed that the conductors will contact the passengers in the section in question per the communication device and provide information on further action.

Depending on the situation, an emergency stop can be triggered by the conductors.

Activating devices must be clearly discernible and easily accessible to passengers.

4. Requirements of Stopping Places

4.1 Basics

Stopping places are installations for evacuating persons from vehicles and for intervention by rescue services. The following are the minimum requirements. Specifications are made for a special high-speed maglev train system in coordination with the supervisory authorities and the rescue services.

4.2 Interval, Position

Stopping places should be set up

- before danger points (e.g., open guideway end at a bending switch)
- between stations if the available kinetic energy of the vehicles is inadequate to reach the next station in the direction of travel in the case of a breakdown or emergency.

In order to determine the intervals between stopping places on the one hand and between stations and stopping places on the other hand, the free hovering range must be determined for each point along the route, i.e., the range that can be covered from the point in question in the event of a loss in the forward force of the propulsion.

The following factors define the free hovering range:

- lower limit running profile to ensure adequate kinetic energy and battery charge state
- upper limit running profile to maintain the characteristic braking curve and/or the alignment-based maximum speed
- running resistance of the hovering vehicle
- track inclination (ascending and descending gradients)
- head and tail wind; aerodynamic conditions during tunnel passage
- permissible loss of redundancy in the safety braking system
- permissible number of set-down skids

Note: Vehicles moving uphill can, after a certain mirror point, reach a stopping place (station) behind it by using potential energy if the preconditions of operational train control so permit.

4.3 Execution and Equipment

Stopping places must feature

- danger-free deboarding options for persons in the event of evacuation

- communication equipment (voice link with operational control center)

- access points for rescue services.

Depending on local conditions, a stationary energy supply is recommended.

The deboarding area of the stopping places must be at least long enough that a vehicle can be deboarded by way of all external doors on one side. In determining this area, the inaccuracy of the programmed stop during braking at the stopping place with the vehicle-side safety braking system must be considered.

Requirements of deboarding options:

Depending on the height of the gradient, the following deboarding options are possible:

- < 1.5 m (at-grade guideway)
  Evacuation of the vehicle by way of deboarding aids (e.g., ladders transported on board)

- 1.5 m to approx. 9 m (elevated guideway)
  Parallel footbridge with at least one set of stairs at each end; alternatively: rescue slides, whereby the terrain must be correspondingly free. The number must be defined on a case-by-case basis.

- approx. 9 m to 20 m (high elevated guideway)
  Parallel footbridge with at least one set of stairs at each end

- > 20 m (special structures, such as bridges)
  Deboarding of the vehicle onto correspondingly widened bridge supports (see at-grade guideway)

- Tunnel
  Parallel footbridge and escape path from the tunnel

Stopping places and in particular the parallel footbridges must be protected against unauthorized access.

Alternatively, outside means of rescue can be used, depending on the existing infrastructure.

4.4 Evacuation Speed

In the event of fire, the persons move from the section affected by the fire into the adjacent sections and seal the fire walls. Because of the requirement that a fire remain limited to one fire segment for at least 30 minutes, there is an adequately long time interval for evacuating the sections, since a threat to personal safety in the other sections is not assumed.

A hold area for rapid evacuation of the vehicles is not necessary.

4.5 Monitoring of Stopping Places

The installations for communication as well as for protection against unauthorized access must be inspected regularly.

5. Requirements of the Acceleration Areas

A continuous deboarding opportunity for the purpose of evacuation must be ensured in the areas of operational acceleration adjoining a station stop.

The length of these deboarding areas comprises the lengths of the acceleration and deceleration areas that are necessary in order to achieve escape velocity or, in the event that a particular spot is not reached, in order to brake from this speed using emergency braking.

During braking with the vehicle-side safety braking system, the inaccuracy of the spot at which the vehicle will come to a standstill must be considered.

The requirements according to Chapter 4.3 apply to deboarding options. Alternatively, outside means of rescue can be applied, which are to be kept in or in the vicinity of stations. In this case, a permanent parallel road is to be built along the deboarding area.

6. Requirements of Stopping Between Stopping Points

Planned stopping between stopping points is not provided for in a high-speed maglev train system.

Stopping place plan

The following situations result in an unplanned stop between stopping points under the stopping place plan:

- Emergency braking with stopping outside the deboarding area of a station
- Emergency braking after restart from a stopping place (no deboarding area in the acceleration stretch)

With an at-grade guideway, in tunnel sections, and on bridges, the vehicles are deboarded in accordance with Chapter 4.3.

In other cases, the vehicles are deboarded using on-board self-rescue equipment. Because of the requirement that a fire remain limited to a fire segment for at least 30 minutes after the fire walls are sealed, there is a adequate period of time available for evacuation.

The space necessary to use the means of rescue must be available in the vehicles.

Trained personnel must be available to operate the means of rescue. In addition, brief and succinct operating instructions must be available.

Means of rescue may be used only if their function is ensured and their use does not constitute any additional risk.

Other rescue plans

If the entire guideway or individual line segments are to be used as a stopping place, then evacuation options must be provided for the entire segment in question, in accordance with Section 4.3. In particular, a line telephone linked to the operational control center at intervals of approx. 500 m and, depending on local conditions, a third rail for the guideway to which the vehicle can be connected after coming to a halt are required.

7. Requirements of Rescue Planning

Rescue planning should be part of track projections. The organizations for firefighting and rescue services, the proximity of hospitals, and the police should be incorporated. Access roads for operational vehicles, and if necessary landing sites for helicopters, should be constructed.

Alarm systems and operational plans should be prepared.

For a rescue operation between stopping points, planning of measures and execution must involve firefighting services.

8. Requirements of Conductors

The on-board conductors must be able to look after passenger safety in the case of an emergency.

In particular, they must

- be trained in first aid

- be demonstrably and repeatedly trained in the use of means of rescue.

9. Records/Tests

As part of the safety record or safety description, the rescue plan must be presented as a unified plan for a high-speed maglev train system, and must be submitted to the competent supervisory authorities or to a expert commissioned by the authorities for inspection.

For practical documentation purposes, rescue exercises at special points must be conducted, especially with the stopping place plan for rescue operations between stopping points.

10. Equally Applicable Standards

DIN 5510	**Preventative fire protection in rail vehicles**
Part 1	- Fire protection grades, fire protection measures and proofs

Part 4	-	Vehicle design; safety-engineering requirements
Part 5	-	Electrical operating equipment; safety-engineering requirements
Part 6	-	Accompanying measures, function of the emergency brake installations, information systems, fire alarm systems, firefighting installations; safety-engineering requirements

FAR-Part 25 **Federal aviation regulations: Airworthiness standards**

MBO **Maglev Construction and Operating Regulation (draft 12/88)**