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FRA/Volpe Center Task Force Observation of Operations at TVE Transrapid Test Facility, Addendum
April 5 to June 4, 1993

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FRA/Volpe Center Task Force Observation of Operations at TVE Transrapid Test Facility, Addendum–April 5 to June 4, 1993

Background

This report is an addendum to a report (No. DOT-VNTSC-RR393-PM-93-1) prepared in April 1993 describing the operations witnessed and the relevant information obtained by nine members of the FRA/Volpe Center High Speed Guided Ground Transportation Safety Task Force during 9 weeks of observation of maglev developmental certification testing at the TVE Transrapid Test Facility at Emsland, Germany. Those observations were part of an extensive review of the German safety certification process being applied to the Transrapid (TR) system for application in Germany.

Additional certification testing was performed during the spring of 1993. Three members of the Task Force visited the TVE Test Facility to witness operations and testing. This addendum describes the operations witnessed and the relevant information obtained during each of the three visits: April 5 to 7, April 27 to 30, and June 2 to 4.

The Task Force observation team was hosted by and received information from several members of Industrie-Anlagen-Betriebs-Gesellschaft (IABG) and TÜV Rheinland Safety and Environmental Protection GmbH (TÜV). The primary contacts from IABG included the following individuals:

Mr. Raasch, the Director of the TVE Test Facility
Mr. Steinmetz, Deputy Director of the TVE Test Facility for the Operating Control System and Computer Systems

The primary contacts from TÜV included the following individuals:

Mr. Wiedenmann, the Project Manager for Railroad, Control and Software Technology, and the Task Force's liaison with TÜV and principal point of contact
Mr. Vom Hövel, Head of the Department of Railroad, Control and Software Technology
Mr. Blomerius, Project Manager for TÜV at TVE

Items of General Interest Noted by the Observers

This section contains an overview of some of the technology, operations, and terms that appear in the next section--the daily account of the activities during the observation period. Many specific tests and developments involving the items mentioned in this section are described and discussed in greater detail in the daily account.

This report also contains three appendices. Appendix A contains the weekly test schedules, in English, for the observation periods. Appendix B contains the figures referenced in the daily account of activities. Appendix C is part of a new report by TVE on the status of the TR07 vehicle, including noise and major test milestones accomplished as of the end of March 1993.

BLT System

The Betriebsleittechnik (BLT) system is a specific set of hardware and software control items within the TR07 vehicle's Operating Control System (OCS). The BLT consists of three main subsystems:

- Betriebsleittechnik fahrzeugeitige (BLF) - Vehicle-borne control system
- Betriebsleittechnik dezentrale (BLD) - Decentral (wayside) control system
- Betriebsleit zentrale (BLZ) - Central Control and monitoring system

Testing of the BLT system was the major element of the certification testing at the TVE Test Facility.

During the spring of 1993, tests required by TÜV were performed to verify proper operation of the vehicle-borne and decentral elements of the BLT control system, as well as to check all modifications to the software to ensure that the modified elements function properly.

Stator Pack Fixation

Stator pack fastening is still in a state of flux. Personnel of MVP Testing and Planning Company for Maglev Systems employed at TVE are still experimenting with new solutions to improve control over stator pack fatigue.

The new philosophy concerning stator pack dropaway is to make the vehicle "collision tolerant." Collision tolerance would allow the vehicle to continue operating if vehicle magnets contact a dropped stator pack. The redundant nutstein captor screw method is apparently considered to be too maintenance intensive, so more practical solutions are being sought. An approach being investigated at TVE is to mechanically bind two adjacent stator packs so that one pack can provide support for the other. A plate arrangement that grabs a protruding nutstein from two adjacent packs is used for the steel guideway of the southern loop. A capstan screw tightens the plate against the lip of the steel guideway, as shown in Figure 13. A similar arrangement has been tested for use on the concrete guideway on the northern loop. When experimentation with this approach is completed at TVE, the suggestions will be forwarded to Thyssen-Henschel for evaluation and final approval.

Ground-Fault Currents

The FRA is concerned about the possible effects of a ground fault in a stator. Depending on the configuration of the system for fault current protection, a phase-to-ground fault could trigger a generator action from the vehicle kinetic energy, causing current to flow through the failed stator winding even after supply power is removed. This current could cause dynamic braking and decelerate the vehicle at a high rate, possibly injuring passengers. Furthermore, if levitation is lost on one side, a yawing force could cause contact with the guidance rails on the sides of the guideway, and cause a sudden stop. Personnel at TVE mentioned that a system of breakers designed to prevent ground-fault current flow caused by vehicle movement had been developed, but the system did not prove adequate. The consensus of opinion at TVE appears to be that this current would cancel the levitation field and cause the vehicle to set down on one side. The skid action would then cause the vehicle to decelerate, but at a rate that would not be high enough to endanger passengers.

<u>Dissimilar Software</u>

MVP personnel at TVE seemed to be interested in studying dissimilar software as an alternative to "identical software" for each channel of the voting system. This interest was prompted by a common-mode failure that occurred in September 1992, when all three of the vehicle's computers shut down simultaneously causing the vehicle to come down on the skids during a visitor ride. Although the vehicle did come to a safe stop at a random spot on the guideway, the vehicle did not reach a safe stopping point (HHP); thus, "safe hover" was not achieved.

It was mentioned that the Airbus A-320 uses this type of software in its fly-by-wire system where the computer must remain working and has no manual override. The software was developed by the French part of the Airbus Consortium. It is not clear whether TÜV will pursue this alternative.

<u>Reaction Rail</u>

The guideway reaction rails will be refastened at various locations on the concrete guideway. This will prevent full operation of the guideway during the summer and fall. It is believed that the loads experienced by the reaction rails on the sides of the guideway may have weakened the concrete.

<u>TVE- and BLT-Related Terminology</u>

Halle (Versuchshalle) — The main hall building in the TVE Test Center where the TR07 vehicle is normally stationed for storage or static testing (The section of guideway inside the Halle is equipped with standard linear motor long stator windings to allow the vehicle to travel to the main guideway.)

HHP — Hilfes Halte Punkt (Help Halt Point); the safe stopping point for safe hover

HHP is also a programmed feature of the vehicle's BLF system. When the HHP feature is turned on (HHP EIN), the vehicle will try to reach the next HHP in the event of a system failure. When the HHP feature is turned off (HHP AUS), the vehicle will stop immediately at maximum deceleration in the event of a system failure, instead of trying to reach the next HHP.

WSB (wirbelstrombremse)	The vehicle's eddy current brake, which is designed for emergency stopping
SIAB	A feature of the BLD system that safely shuts off propulsion for the vehicle, and sets the vehicle down on its skids SIAB is initiated during a communications failure between the vehicle and the BLD system.

Daily TVE Test Observations

April 5

Mr. Steinmetz briefly described the current testing program and discussed in detail the ride quality problem with the TR07 vehicle. He said that the problem is not related to the basic maglev design, and that it could be solved by modifying the suspension system.

Figure 1 shows the TR07 vehicle with its new BMFT logo, replacing the Transrapid logo. New front magnets with new gap sensors and sloped leading edge have been installed, as shown in Figure 2. The new magnets have improved the vehicle's ability to detect and avoid any loose stators along the guideway. Replacement of all of the remaining magnets is planned for late this year. All of the stators in the guideway have now been examined, and the southern loop is fully operative. However, a better way to attach the "nutstein" to the guideway, using various mechanical devices, is being studied; two options are shown in Figure 3.

The Task Force observer rode the TR07 vehicle twice with other visitors, including the Mayor of Frankenberg-Parchim, several DB-Rhine employees, and Dr. and Mrs. Scott Phelan of the Massachusetts Institute of Technology (MIT). Dr. Phelan worked on maglev concept and design with Dr. Thornton of MIT. (Figures 4 and 5 show the interior of the vehicle.) The vehicle accelerated very fast and reached about 300 km/h at the end of the curve on the northern loop and reached its maximum speed of 400 km/h for a few seconds on the straight Kanalstrasse section of the guideway before slowing down for the southern loop. The ride was rough in the beginning, but became smoother at the top speed. It was very noisy at higher speeds.

Mr. Wiedenmann pointed out the various guideway structures. Two views of the hydraulic high-speed Switch 3, at the southern loop, are shown in Figure 6. The steel span being tested for application in Florida is shown in Figure 7. The three double-span sections being tested near the northern loop are shown in Figure 8. The emergency towing vehicle used to "lubricate" the track before set-down tests is shown in Figure 9.

April 7

The Task Force Observer attended a set-down test of the TR07 vehicle. After circling the entire guideway several times at speeds up to 230 km/h, the vehicle slowed down to 95 km/h in the southern loop at a left-hand turn, and leviation power was shut off. Set down began at about 1.5 km from Switch 3. Loud noises and banging of equipment were followed by dense smoke

smoke in the leading cabin. After a few minutes, the vehicle was re-started and accelerated to 150 km/h for its return trip to the Halle. The observer was told that the systems worked as planned. The set-down test had been delayed for a few days to allow engineers to change some of the fail-safe control software to perform this emergency simulation. More set-down and braking tests were scheduled during the week with TÜV personnel checking the safety features of the vehicle as part of the certification process, as shown in the weekly activity plan (Appendix A).

Tuesday April 27

Mr. Neumann (a test engineer) announced that tests would be conducted during the week to verify that all punch-list items related to the vehicle-borne control system (BLF) had been finished. Some of the tests were intended to verify that all the changes to the software had been made that were needed to remedy the causes of the failures that occurred during previous testing. Expected results from the tests would indicate that the BLF was ready for operation at TVE.

Mr. Neumann discussed the failure of the vehicle to set down during a rollback test in October 1992, and the common-mode failure that occurred in September 1992 causing all three computers to fail at the same time during a visitor's ride. Mr. Neumann seemed to believe that the causes of these failures have now been corrected, and said that some of the week's upcoming tests were intended to verify the corrections. He also mentioned that these tests were intended to confirm situations that would hopefully never occur under normal operation, but were they to occur the outcome would be fail safe.

Some of the new levitation magnets had been installed. (On December 9, 1992, a Task Force Observer was told that four of the new magnets, one at each end corner of each vehicle section, were planned to be installed by mid-February 1993.) During one of this day's tests, an "old" levitation magnet section overheated.

Mr. Raasch, the TVE Facility Director, discussed collision tolerance, dissimilar software, and reaction rail re-fastening. He mentioned that in the last 20 years the German government has spent 1.6 billion marks on the TVE facility and its operations, i.e., 60 percent of the total amount spent on the facility. The new policy after reunification limits the Government contribution to TVE to 35 percent of the total.

One test was performed on this day:

TEST 2A:

The goal was to verify proper response of the location system (ortung). Testing consisted of protocol recording of all the INKREFA tags and pole counting units in both directions of travel in all switch positions. The test was performed at two speeds: 100 km/h and maximum profile speed. The actual Vmax was recorded for comparison with desired Vmax. The mode of operation (betriebsart) was vehicle (fahrer). The safe stopping point (HHP) feature was turned on (HHP EIN), which means that the vehicle tries to reach the next HHP in the event of a system failure. Three roundtrips of the guideway were completed. No apparent abnormalities were experienced during the test.

There are about 100 INKREFA tag set locations in the guideway, comprising 100 INKREFA sections or BLT abschnitts. A BLT abschnitt may comprise one or more antriebasbschnitt or propulsion long stator sections.

The data collected during this test were compared off line to determine whether any of the stator packs were out of position by more than the accepted tolerance limits. An on-line system to accomplish this has been installed and is operational, but it will not be approved for use until all of the new magnets are installed, probably between July and September. (As noted in Appendix A, one of the activities planned for the first week in May was a test of the on-line system.)

Wednesday April 28

Five static tests were performed in the morning. Some of the original testing procedures prescribed by TÜV had to be modified to accommodate the idiosyncracies of the existing guideway at TVE. The first test (2B), for example, involved prolonged static levitation on the guideway. The original span chosen for the test was steel. Because it was felt that prolonged levitation over a steel span was harmful to the particular steel structure used at TVE (i.e., it could cause too much vibration), the test was moved to a concrete span. The test consisted of levitation at zero speed. Interruption of power would then cause an automatic set down after a waiting period longer than 5 minutes.

TEST 2B:

This was a test of automatic set down due to prolonged levitation at zero speed. This test failed during the acceptance testing in October 1992. The vehicle was stopped on the guideway and waited there for more than 5 minutes until the power shut off, causing the vehicle to be automatically lowered. The test was successful, as the vehicle was set down without the OCS being switched off. The vehicle was then levitated, and it traveled about 500 m in vehicle mode with HHP on.

TEST 2C:

This test also repeated a test that failed during the acceptance testing in October 1992. The objective was to stop at the steepest forward gradient and remove propulsion. The operational mode was vehicle, and HHP was on. As expected, the vehicle set down.

TEST 3A:

This test was the same as 2C, except the vehicle was powered on. As expected, the vehicle set down.

TEST 3B:

The purpose of this test was to check drift. The vehicle was stopped at the steepest gradient. With power applied, the vehicle waited for 5 minutes. The vehicle was monitored during the wait for drift. As expected, no drifting was noticed.

TEST 3C:

The goal was to release forced stop with set down. The operational mode was vehicle, and HHP was on. The vehicle was stopped at a steep forward grade. Propulsion was removed, and as expected, the vehicle set down. This test verified a corrected discrepancy between software coding and specifications.

In the afternoon, travel tests using the entire guideway were performed to verify the efficacy and safe performance of the eddy current brake, wirbelstrombremse (WSB). Five roundtrips of the guideway were completed. The objective was to verify that the BLF speed profile in the BLT II is reduced by continual prolonged cycling of the WSB. The OCS is designed to prevent the vehicle speed from increasing beyond a certain level between applications of the WSB during excessive cycling, to conserve the WSB so that it remains effective for other emergencies. With this feature working properly, the vehicle would continue at a reduced speed after propulsion was restored following a propulsion failure that forced the vehicle to use the WSB. The amount of the speed reduction would depend on previous use of the WSB. (This is shown by the algorithm in Figure 10.)

The paths taken by the TR07 vehicle during the eddy current brake (WSB) testing are shown in Figure 11. The vehicle traveled north from the station, passed through Switch 2 in turnout (reverse) position, and accelerated as it proceeded around the northern loop. During the first roundtrip, the vehicle reached a top speed of 320 km/h, south of Switch 2. At that point, the WSB was applied. North of Switch 3, the WSB was then released, and propulsion braking was restored to continue to slow the vehicle to the speed needed to pass through Switch 3 in turnout (reverse) position and enter the southern loop. This process was repeated during each of the five roundtrips. During the fifth trip, the speed profile was significantly reduced, allowing a maximum speed of only 210 km/h, as shown in Figure 12.

At the final programmed stop, at the battery-charging station on the Kanalstrasse section, the levitation magnet temperature between main poles 5 and 6 (zwischen hauptpolen 5,6) was 137° C. Apparently, these were the old magnets. After the vehicle idled at the charging station for about 20 minutes, the temperature dropped to 105° C. The temperature of another set of magnets (zwischen hauptpolen 9,10) was 90° C when the 137° C reading was noted. It was unknown whether these magnets were new. The ambient temperature was 28° C.

<u>Thursday April 29</u>

A total of ten tests were conducted on this day. These included testing the effect of induced failures on each channel of each of the vehicle's computers. That is, the same channel of each of the three computers was caused to fail at the same time, and correct operation was verified.

A test was performed for each channel (Tests 3D, 3Q, and 3R). Any test (such as 3N) that would have involved a high-speed set down on the skids was performed without an actual set down.

Set down tests had been conducted in early April to verify emergency stop at a designated safety point (HHP EIN) and at an immediate stopping point (HHP AUS). At that time, an emergency stop (HHP EIN) test produced an unintended set down on the skids because an eddy current brake (WSB) monitoring system caused the vehicle to set down sooner than expected. The monitoring system is a safety net required by IABG for the WSB, and is not part of BLT II. This device looks for the WSB when it is called into operation. If it senses the WSB is not on, it calls for set down. During the set-down tests, as BLT II took over the emergency braking function, it turned the WSB on and off in order to maintain a stopping profile rather than keeping the brakes on steadily. This cycling effect then caused the monitoring device to interpret that the brakes had failed, causing a premature set down. Because a high-speed set down damages the skid necessitating repair (and accordingly vehicle down time), the monitoring device was then bypassed to prevent set down. This action also prevented performance of the immediate stop (HHP AUS) test because it would require a high-speed set down on the skids. Additionally, the test personnel felt that since safe stopping was verified during the HHP EIN test an HHP AUS test was not necessary.

It is theoretically possible to obtain higher speeds (up to 500 km/h) with the BLT I at TVE than with BLT II because the BLT I, unlike the BLT II, permits superposition of the WSB to the propulsion brake, producing a higher braking rate. With the higher braking rate, the train can slow down to the speed required to negotiate the loops from higher speeds on the Kanalstrasse section.

TEST 3E:

The goal was to test the towing mode (schleppbetriebes). The vehicle was in the station. It was set down (FZ aussetzen) on the skids, and each of the three channels (A, B, and C) of the safety computer, fahrzeug sicherung (FSI), and the radio-link computer, fahrzeug uebertragung (FUE), was switched off (abschalten). A console was switched on (ein fahrpult einschalten), and the vehicle was switched to tow mode (FZ auf schlepp schalten). The levitation pushbutton was pressed (anhebetaster betatigen), and the vehicle levitated, allowing it to be towed. Thus, the test was successful.

TEST 3F:

The goal was to verify correction of a previous error (possibly due to electromagnetic interference) that had occurred between the vehicle operator's console on the passenger side of the vehicle (i.e., Section 2) and the FSI computer. This test was the same as Test 3E, except all 3 channels (A, B, and C) of the guidance computer, fahrzeug steuerung (FST), were also switched off and only channel C of the FSI and the FUE computers was switched off. The test was successful.

TEST 3G:

The purpose was to test minimum velocity (mindestgeschwindigkeit). The vehicle left the station and traveled toward the northern loop in vehicle mode with HHP on. After the vehicle passed an HHP, the speed was reduced to 0. As expected, the vehicle reached the next HHP.

TEST 3N:

The goal was to verify proper system response when the vehicle travel direction is different from the programmed travel direction. The vehicle is expected to initiate an emergency stop whenever it is unable to read INKREFA tags in the proper sequence; this instruction is pre-programmed into the system for a particular guideway. From the station, the vehicle traveled north toward Switch 2 at a speed less than 50 km/h. Given the initial INKREFA tag recorded at the station, the vehicle was expecting to encounter the appropriate INKREFA tag after the groove count was achieved. Not finding the appropriate tag, the vehicle performed an emergency stop at an HHP. Thus, the test was successful.

TEST 3O:

This was the same test as 3N, except vehicle speed was more than 50 km/h. This test was also successful.

TEST 3T:

The goal was to brake the vehicle before it reached an open switch. The vehicle approached Switch 1 from the north traveling in vehicle mode. The travel speed was Vmax, and HHP was off (HHP AUS), which means that the vehicle stops immediately in the event of a system failure instead of trying to reach the next HHP. The vehicle traveled through Switch 1 to the southern loop through Switch 3 in straight position, continued around the loop and through Switch 3 again (now in the turnout position), and approached Switch 1, which had been moved to the turnout (i.e., open) position. The test was successful, as the OCS sensed that Switch 1 was open and stopped the vehicle before it reached the open switch.

TEST 3D:

The goal was to travel at maximum speed with a failed channel on each computer. The vehicle was set down in the northern loop just beyond Switch 2 headed in the clockwise direction. The operational mode was vehicle, and HHP was off. Channel C of each of the vehicle's three computers was cut off. The vehicle then levitated and traveled through the loop to an HHP in a normal fashion. Thus, the test was successful.

TEST 3Q:

The goal was the same as Test 3D, except channel A of each computer was cut off. The channels were cut off before propulsion was enabled (aufrüsten). The vehicle was then rearmed.

It traveled about 3 km with Vmax and was stopped and set down. It was then levitated again and traveled 1 km in normal fashion. Thus, the test was successful.

TEST 3R:

This was the same test as 3Q, except channel B of each computer was shut off. The result was also the same as in Test 3Q.

TEST 3I:

The goal was to change direction of travel and perform an emergency stop at an HHP. The train traveled south from the northern loop to the station and stopped. The vehicle then reversed direction, traveled toward Switch 2, and accelerated to 300 km/h. When an emergency stop was attempted, the speed profile was violated, and the eddy current brake (WSB) engaged. The vehicle did not set down at 100+ km/h as it would normally under this condition because the automatic set down mechanism was disabled to avoid high-speed set down. The vehicle operator allowed the vehicle to lose sufficient momentum before initiating a manual set down. At this point, the speed was approximately 15 km/h, and an odor produced by skid material loss could be smelled. The failure to stop at an HHP was not attributed to the software; it was attributed to the positioning system. Re-aligning and re-tooling the magnets to allow the vehicle to be collision tolerant may have had an effect on the pole counter and INKREFA system. It was felt that the speed-profile violation may have been due to improper INKREFA feedback.

Unrelated to that failure was a loss of propulsion that occurred (during a routine run, not during a test) as the vehicle traveled counterclockwise around the southern loop and entered the concrete section of guideway. The immediate cause of the propulsion loss was not known. The vehicle was manually set down at low speed.

Friday April 30

Static tests were performed with the vehicle inside the Halle. Several functions involving levitation and static set down were tested. A total of 35 to 40 reasons for immediate stopping (zwangshaltgrunde) were tested in static mode. The testing appeared to be successful.

The Task Force Observer watched the vehicle operator's console as it monitored a number of items. The display consoles appeared to be plasma display technology, similar to the type of display used in many laptop computers. The consoles had good clarity and wide-angular range of visibility.

A display to the right of the operator's console is partitioned into a 3 by 7 matrix of individual indications. These are 21 subsystems that are being monitored. Since the display is monochrome, the choice of display for each item is limited to dark foreground, bright foreground, and blinking. This could be three states of the subsystem, such as enabled, disabled, or in transition. For example, the battery status can be shown as charged, discharged, or being charged. The level of charge, of course, cannot be indicated. Systems that are monitored by the display include the following:

(1) The two radios (funk)--a digital 40-GHz radio (which is normally used for all communications, including emergencies) and a 160-MHz voice radio (which is used only in emergencies)

(2) Hinge point (gelenkpunkt)

(3) Skids (tragkufen)

(4) Vehicle electrical system (bordnetze)

(5) Battery ventilation (batterie lufter)

(6) Pneumatic system (pneumatik)

(7) Left doors (turen links)

(8) Right doors (turen rechts)

(9) OCS (BLT)

(10) Emergency brakes (zusatzbremsem)

(11) 220 VAC (ladung 220)

(12) 24 VDC (ladung 24V)

(13) Console (fahrpult)

(14) Passenger emergency signal (fahrgastnotsignal)

(15) Car-carried location detection system (INKREFA)

(16) Tooth/groove scanner for fine positioning location (B/V sensor)

(17) Air pressure

A console to the right of the vehicle operator's seat displays various diagnostic messages that are generated to reflect the current conditions, e.g., time of movement, location of faults, status of all computers and their channels (even to the board level), and status of eddy current brakes.

A display facing the operator gives travel direction, time, date, speed, and mode of operation. There are six modes of operation, which are combinations of one or more of the following: manual with vehicle operator in control, manual with Central Control operator in control, and automatic operation.

After the static tests were completed, the vehicle was taken from the Halle for three roundtrips on the guideway to record the stator pack deviations for off-line system verification. Then, the following tests were performed:

TEST 3J:

This was the same test as 3I (performed on Thursday afternoon), except the vehicle was set down and then levitated with the vehicle powered on (aufrüstfahrt).

TEST 3K:

This was the same test as 3I, except it was conducted on the southern loop.

TEST 3L:

This was the same test as 3I, except the vehicle was set down and re-levitated by pressing the emergency stop button and the test was conducted on the southern loop.

TEST 3M:

The goal was to stop the vehicle at an HHP following a stop and change in direction of travel from north to south. After changing direction, the vehicle accelerated to 200 km/h and successfully performed an emergency stop at the next HHP.

TEST 3S:

The goal was to have the BLF cancel a towing operation. The operational mode was vehicle, and HHP was on. The vehicle was set down on the southern loop just past Switch 3 in the turnout direction, tow mode was enabled, and a door was opened. The vehicle lifted up so that it could be towed. The vehicle then set down, tow mode was canceled, the door closed, and the vehicle traveled 1,000 m. All of the functions appeared to operate as expected except the door closing. It was explained that the apparent malfunction was probably in a sensor or door actuator unit, not in the BLF system.

After the day's testing was completed, Mr. Steinmetz mentioned that Thyssen Henschel was working on the ride quality problem, and he appeared confident that it would be improved, probably in a year's time. Ride quality is still a concern, however, and the new magnets are not expected to improve the quality. Other solutions may be needed, such as improvements in the secondary suspension. Even while riding on the relatively straight Kanalstrasse section, which is predominantly concrete, a sideways vibration of approximately 20 Hz was noticeable at 170 km/h. At higher speeds, it was not too noticeable. At lower speeds, the smoothest section for riding appeared to be the 30 concrete-filled steel guideway girders extending south of Switch 1 toward Switch 3 at the entrance to the southern loop.

Problems that were experienced during the week's testing were attributed to interfaces and not directly to software faults. It was felt that some of the changes to the levitation magnets intended to reduce impact with a dropped stator pack may have affected the car-carried location detection system: INKREFA and/or the tooth/groove scanner.

Wednesday, June 2, 1993

This week's tests were the last series of acceptance tests to be conducted by TÜV using the TR07 vehicle for several months. According to Mr. Jubin, a test engineer, tests conducted on Tuesday June 1 included static tests, with the vehicle on the guideway, of the safe propulsion shutoff and vehicle set down (SIAB) feature of the OCS. SIAB is initiated during a communications failure between the vehicle and the decentral (wayside) control system (BLD). Parallel activities during the week included installation of measuring equipment to prove load assumptions on a double-span beam and inspection (measurement) of the stator packs in the northern loop (especially in the steel section).

The acceptance tests began on this day and continued on the next day, Thursday. The purpose of the tests was to examine the performance of the BLD system. They were performed with the vehicle operating, and were monitored by Mr. Jubin. The BLD system consists of wayside stations that communicate with the vehicle and are responsible mainly for controlling the propulsion. Each test was independent (i.e., no history was assumed). The tests were conducted using only the BLT II, although the normal procedure is to use BLT I and BLT II in tandem because the BLT II has not been accepted by TÜV.

TEST 1:

The purpose was to verify proper system response when the TR07 vehicle is switched into tow mode. The vehicle was stopped at the station, the operational mode was set to Central Control (Leitstand), and propulsion and levitation were made available. When the system indicated that propulsion was ready (antrieb frei), Central Control switched the vehicle into tow mode. At that point, as expected, the BLD initiated SIAB, which shut off propulsion and then shut off the tow mode.

TEST 2:

The purpose was to verify proper system operation when the INULL signal from the BLD is removed. The vehicle was in the station. Propulsion and levitation were available, but the vehicle was not levitated (i.e., it was on the skids). Maximum current was set at 0%, and the INULL signal from the BLD was manually interrupted. As expected, the system immediately initiated SIAB. The INULL signal from the BLD was then restored.

TEST 3:

This test was designed to verify proper system operation when the INULL signal from BLD is removed and communication is lost. The vehicle was in the station. Propulsion and levitation were available, but the vehicle was not levitated. Maximum current was set to 0%, the INULL signal from the BLD was manually interrupted, and the communication link between the vehicle and the BLD was interrupted. As expected, the system immediately initiated SIAB. The INULL signal from the BLD was then restored.

TEST 4:

This test was designed to verify system operation when the INULL signal from the BLD is removed and the data bus in the BLD fails. The vehicle was in the station. Propulsion and levitation were available, but the vehicle was not levitated. Maximum current was set to 0%, the INULL signal from the BLD was manually interrupted, and a failure of the data bus in the BLD was simulated. As expected, the system immediately initiated SIAB. The INULL signal from the BLD was then restored.

TEST 5:

The goal was to verify proper system operation when commands are issued in incorrect sequence. The vehicle was in the station. Propulsion and levitation were available, but the vehicle was not levitated. SIAB was also available. The Central Control panel was switched off by turning the key (or removing a fuse). Central Control was switched back on again (re-initialized). With leviation and propulsion still available, a command to drive north for a short distance was then issued from Central Control. No response was expected from the vehicle because no order to levitate was issued. (The vehicle must be levitated before it can drive at all.) The vehicle did not respond. The levitate order was then issued, and the vehicle traveled north for a short distance.

When the vehicle stopped, forward direction was changed to south. Maximum current was set to 40% (DAR-vorgabe is the digital propulsion controller) in agreement with the Central Control operator's propulsion control. The vehicle was ordered to drive back to the station. During the return, propulsion was shut off on the control panel. This action is not supposed to initiate SIAB; only the BLT is programmed to initiate SIAB. The system was monitored to verify that SIAB was not initiated. Propulsion was then restored, and the vehicle continued south to the station. The expected system operation was achieved.

TEST 6:

This was a test of the correct operation of the eddy current brake system (WSB). HHP was off. Some circuit boards were changed on the vehicle to provide a version of the SSW-ABI that would not require vehicle set down. When a signal appears on the control stand indicating that BLT II intends to set the vehicle down, SSW-ABI overrides the signal. Use of the BLT II for emergency braking tests would have required vehicle set down, which is to be avoided when possible. The vehicle was in the station, propulsion and levitation were available, but the vehicle was not levitated. The vehicle traveled north at 150 km/h through Switch 2, in turnout position, and accelerated to 250 km/h. Switch 2 was then set to normal position. The connection between the vehicle's radio-link (FUE) computer and the decentral (wayside) communication computer, dezentral uebertragung (DUE), was interrupted, thereby preventing communication between the vehicle and the wayside. The system reaction was to shut off propulsion. The vehicle remained levitated, and the ride continued until the speed profile was violated. When the speed profile is violated (i.e., becomes slower than expected), the vehicle normally checks propulsion status. Since propulsion was shut off, however, braking could be accomplished only by the WSB. After the WSB was activated, the FUE-DUE connection was restored, and after the radio system checked for continuity of communication, the ride continued. The vehicle then traveled to the station and stopped. The expected system operation was achieved.

TEST 7:

This was a test of the safe hover concept. HHP was on. Vehicle set down was disabled, however. The vehicle traveled north through Switch 2, in turnout position, and accelerated to 320 km/h (maximum). While the vehicle was in the northern loop, the DUE-FUE connection was interrupted, stopping vehicle-wayside communication. The expected system reaction was to shut down propulsion and continue safe hover to the next HHP. When the velocity profile was violated, the eddy current brakes were applied, as in Test 6. The FUE was reconnected with the DUE. The radio system then performed an automatic frequency search to restore communication, permitting the vehicle to return to the station. The expected system operation was achieved.

TEST 8:

This was another test of the safe hover concept. Any operating mode could be selected, and HHP could be on or off (in this case, it was off.) Set down was made impossible by using SSW-ABI. A propulsion area north of the station was shut off. The vehicle proceeded north from the station through Switch 2, in the normal position, with maximum speed set at 250 km/h. The INULL signal was interrupted. When the vehicle passed the 6-degree curve in the northern loop, the Central Control operator turned off the propulsion. The system was expected to trigger the SIAB feature and use the eddy current brakes to stop the vehicle and keep it levitated. (The vehicle operator can set down the vehicle when it reaches a low enough speed.) Expected system operation was achieved.

TEST 9:

The purpose was to determine proper system response to loss of the decentral (wayside) control computer, dezentral steuerung (DST). Any operating mode could be selected. HHP was on. Set down was made impossible by using SSW-ABI. The vehicle traveled north from the station through Switch 2, in the normal position, with maximum speed set at 250 km/h. When the vehicle reached the maximum speed, failure of the DST was simulated by interrupting its connection to the data bus. The expected system reaction was to shut off propulsion. When the speed profile was violated, the emergency stop feature was triggered, and the vehicle stopped at the next HHP via the eddy current brakes, as expected.

TEST 10:

The apparent purpose was to verify appropriate reactions when vehicle speed fluctuates around the speed profile. The operating mode was Central Control, and HHP was on. The vehicle traveled south from the station through Switch 3 (in the turnout position) with maximum speed set at 200 km/h. Near the bottom of the southern loop (at a particular pillar location), the Central Control operator issued the command V=0 km/h, reducing the vehicle speed using the propulsion system brakes to less than the minimum speed required to reach an HHP. At that point, the brakes were turned off. Since the guideway descends slightly in this area, the vehicle accelerated slightly down the slope, exceeding the speed profile slightly. When this happened, the propulsion system automatically switched on the brakes again to keep the vehicle speed at the velocity profile. As soon as the proper speed was attained again, the Central Control operator issued the V=200 km/h command and turned off HHP. The vehicle then continued to the station.

Although this test did not fail, it was not executed as planned, as it was difficult to determine the exact location at which to issue the V=0 km/h command so the vehicle would reach the downward slope at the correct speed. Therefore, the test was repeated the next day.

TEST 11:

The purpose was to verify the proper system response when Central Control functions are removed. The vehicle was set down at the station, the direction was known, and zwischenkreis (a special circuit in the semiconductor parts of the propulsion system) was turned on, making propulsion unavailable. The Central Control operator turned the key off. Because this test was performed quickly with little activity, the expected and actual reactions were difficult to determine. The test personnel seemed to be simply looking for an acknowledgement from the system.

TEST 12:

The purpose of this test was also to verify proper system response when Central Control functions are removed. The vehicle was set down at the station, the direction was known, and the Central Control operating mode was switched off by using a key or by removing a fuse. Like Test 11, this test was also performed quickly with little activity, and the expected and actual reactions were difficult to determine. Once again, the test personnel seemed to be simply looking for an acknowledgement from the system.

Following the scheduled testing, an unplanned test was conducted to verify proper system reaction to control inputs when the vehicle was at different points along the guideway and in the vicinity of a switch. While the TR07 vehicle was at the station, the special purpose vehicle (SPV) placed the TR07 vehicle in tow mode and towed it south at about 45 km/h past Switch 3 and then pushed it in reverse back through Switch 3. This procedure was then repeated.

The vehicle was then towed into the Halle and parked for the night. Because BLT II is the only OCS being used for these tests and it has not been accepted by TÜV, the TR07 vehicle is always towed to the Halle to prevent it from running off the end of the guideway if the BLT II fails.

<u>Thursday June 3</u>

The day's activities included continuation of the acceptance tests begun on Wednesday, a visitor ride, and static tests using the switches.

After brief operation on the guideway prior to testing, the vehicle returned to the Halle for replacement of a failed step-up chopper, a failure-tolerant element (i.e., the vehicle can function without it).

These acceptance tests (except Test 12) were performed in Central Control mode, with the SSW-ABI engaged to prevent vehicle set down. Set downs are minimized during testing, as three high-speed set downs from 400 km/h are sufficient to wear out a set of skids. A skid is about 1-meter long and has about six pads, which serve as the sliding contact surface. The side (guidance) rails on the concrete sections of the guideway appeared to be suffering under the high loads imposed by the eddy current brakes.

The eddy current brakes are used only when propulsion is unavailable or when communication with the wayside is lost. The braking effort depends on vehicle speed and on the amount of current in the magnets. At high speed, substantial braking effort is available with low current. As the speed decreases, braking forces also decrease, thereby increasing the current and, in turn, increasing the reaction forces on the guidance rails. This is why the eddy current brakes are not used at vehicle speeds below 100 km/h. Ideas have been proposed for reducing the reaction forces produced by the eddy current brakes so that they could be permitted to function at lower speeds. One approach would be to allow the brake magnets to contact the guidance rails. This would reduce the pulling forces, but would require redesign of the brake. Another option would be to use alternating current instead of direct current.

TEST 1:

The purpose was to verify proper initialization of the vehicle. The test involved "arming and disarming" the system to properly initialize the vehicle. The procedure to enable the vehicle requires manual input (at the Central Control console) to BLT II of the vehicle location and the number of the next INKREFA tag that the vehicle will see. The vehicle was then operated manually to the next INKREFA tag. If the tag is the correct one, the vehicle becomes operational. As expected, the system checked the initialization procedure and initialized the emergency stop capability.

TEST 2:

The purpose was to verify correct system reaction when commands are issued from Central Control in improper sequence. HHP was off, the vehicle was on its skids at the station, and propulsion and levitation were disabled. The Central Control operator issued the appropriate commands to enable propulsion and levitation and then to levitate the vehicle. When the vehicle levitated, the Central Control operator then disabled levitation, but nothing happened because the command to set down the vehicle was not issued. The operator then issued the command to set down the vehicle, followed by a command to disable levitation. These actions were accepted, since they were issued in the proper sequence.

Next, the Central Control operator enabled levitation, but then disabled the vehicle (aussetzen). This mode makes the vehicle unavailable from the perspective of the OCS, and removes the "levitation enabled" indication from the Central Control operator's control panel. The operator tried to enable levitation again, but the system rejected the action. The operator then disabled propulsion and issued commands to the OCS to enable the vehicle (einsetzen).

TEST 3:

This was a test of the emergency stopping function initiated from the vehicle. The vehicle was in Central Control mode, HHP was on, and set down was disabled. The vehicle traveled north from the station through Switch 2, in the turnout position, with maximum speed set at 250 km/h. When the vehicle approached the noise wall on the northern loop, an emergency stop was triggered from the vehicle. As expected, the programmed propulsion brake stopped the vehicle at the next HHP, near the station. The emergency state was then removed manually by turning off HHP, an action that is required before the vehicle can be started again. The vehicle returned to the station. The test was successful, as the proper system response was achieved.

TEST 4:

This was a test of the emergency stopping function as initiated from Central Control. The test was the same, with the same result, as Test 3 except the emergency brake command was initiated from the Central Control console.

TEST 5:

This was another test of the emergency stopping function initiated from the vehicle. The test was the same as Test 3, except HHP was off and maximum speed was set at 320 km/h. When the emergency stop was triggered from the vehicle, as it approached the noise wall in the northern loop, the vehicle operator pressed the red button on the console, and the OCS shut off propulsion and stopped the vehicle via the eddy current brakes. As expected, the vehicle stopped earlier than it did during Tests 3 and 4, when HHP was on. The vehicle operator then released the button, and the vehicle returned to the station.

Triggering a stop by pressing the red button is the only action that the vehicle operator can execute. In the special set up at TVE, the vehicle operator must press and hold the button down. If the vehicle cannot resume operation via the OCS, the vehicle can be operated manually. This provision is available because the BLT II system has not yet been accepted.

TEST 6:

This was another test of the emergency stopping function initiated from Central Control. The test was the same as Test 4, except HHP was off and maximum speed was set at 320 km/h. When the vehicle was near the noise wall in the northern loop, the emergency stop was triggered from Central Control. As in Test 5, the OCS shut off propulsion and stopped the vehicle via the eddy current brakes. The Central Control operator released the emergency brakes (terminating the emergency stop) when vehicle speed was about 200 km/h, and the vehicle continued to the station. In each case, the BLD accepted the emergency brake event after command input from Central Control.

TEST 7:

This was a test of programmed stopping initiated from the vehicle but interrupted by disabling HHP. HHP was on, set down was disabled, and maximum speed was set at 380 km/h. As in

Tests 3, 4, 5, and 6, the vehicle traveled north from the station through Switch 2 in the turnout position. When the vehicle approached the noise wall, the vehicle operator pressed the red button (triggering the emergency braking), held the button until the vehicle slowed to 150 km/h, and then released the button. Triggering the emergency action with HHP on is programmed to initiate "stutter braking" (stotterbremse) with periodic application and release of the brakes (to follow the limiting speed profile) as soon as the speed profile (stored in the decentral control computer) is violated. When the vehicle slowed to 250 km/h, the Central Control operator turned off HHP, removing the target for the braking event. Consequently, the vehicle underwent full emergency braking via the eddy current brakes.

TEST 8:

This was another test of programmed stopping initiated from the vehicle and interrupted by disabling HHP. The test was the same as Test 7, except maximum speed was set at 320 km/h. When the vehicle approached the noise wall in the northern loop, an emergency stop was triggered from the vehicle. The system initiated programmed braking with the next HHP as the target. When programmed braking began, the Central Control operator turned off HHP. As in Test 7, disabling HHP removed the target for braking, and the eddy current brakes attempted to bring the vehicle to a complete stop as soon as possible (no programmed braking).

TEST 9:

This test was a series of trials to determine whether the system responds properly when propulsion segments are unavailable. With HHP off, the vehicle traveled north from the station toward Switch 2 (which was in normal position) to a maximum speed of 320 km/h. As a precondition, propulsion near Switch 3 was turned off. When the vehicle reached a particular point en route to Switch 2, the Central Control operator turned off the propulsion segment for Switch 2. The system reaction was to seal off that propulsion section to vehicle travel. Thus, the vehicle stopped because the guideway was closed to the vehicle beyond Switch 2.

The Central Control operator restored propulsion for Switch 2 so the vehicle could continue the run. The vehicle continued around the northern loop. The Central Control operator then activated the previously disabled propulsion section and disabled a different propulsion section. The vehicle stopped before Switch 2 because the system ignores all changes to propulsion status except when the vehicle is not levitated and vehicle speed is 0. The vehicle was then brought to a stop, and while the vehicle was levitated, the same actions were attempted again. Again, they were refused by the system. Finally, the vehicle was set down, and the commands were repeated. This time, the changes in propulsion status were accepted.

As a variation, while the vehicle was set down, it was also disabled. The closed propulsion section was declared open, and another was declared closed. These actions were accepted. The vehicle was then enabled, the closed section was declared open again, and the other section was declared closed. These actions were also accepted.

Finally, the section containing Switch 2 was declared available, and the vehicle returned to the station.

TEST 10:

The purpose was to verify that the currently active velocity profile cannot be changed unless the vehicle is at zero speed and set down. In Central Control mode with velocity profile "1" selected, the vehicle traveled north from the station at 250 km/h. Then, velocity profile "2" was selected. The system was expected to ignore the command because commands are supposed to be accepted only when the vehicle is on its skids at zero speed. The test was repeated several times. It was successful each time, as the vehicle accepted changes to the pre-programmed velocity profile only when it was set down on its skids.

TEST 11:

This test repeated Wednesday's Test 10, which was not executed as planned, as the V=0 km/h command was not issued at the exact location to permit the vehicle to reach the downward slope at the correct speed. The vehicle was placed on the slope to vary the speed above and below the velocity profile to verify that propulsion and braking would be engaged automatically to adhere to the speed profile. The operating mode was Central Control, HHP was on, and maximum speed was set at 200 km/h. The vehicle traveled south from the station through Switch 3 (in the turnout position). In the sloped section of the southern loop, the minimum speed profile was violated by forcing braking of the vehicle. When the OCS recognized the profile violation, it intervened and attempted to stop the vehicle at the next HHP by braking with the propulsion system. When the vehicle reached the minimum speed, propulsion was turned off. The sloped section of guideway caused the vehicle to accelerate to a speed above the minimum profile, and propulsion was activated again to brake the vehicle back to the proper speed. This is known as a reversible "failure." HHP must be on for the minimum profile strategy to be enabled.

As soon as the propulsion was disabled for the second time, the Central Control operator intervened by issuing a V=200 km/h (actually 184 km/h) command and turning HHP off so that the vehicle could return to the station.

TEST 12:

The purpose of this test was to determine responses to various simulated system failures while the vehicle traveled over the entire guideway in automatic mode. HHP was off, the vehicle was enabled and at the station, and maximum speed was set at 300 km/h for northbound travel and at 170 km/h for southbound travel. Switches 1 and 2 were in the normal position. The following system failures were simulated while the vehicle was traveling:

- Radio (communication) failure
- Emergency stop triggered from the vehicle
- Emergency stop triggered from Central Control

- Disabled propulsion effected by the Central Control operator

- Simulated delay in transmission of switch setting telegram from switch controller box

The vehicle completed one roundtrip of the guideway with no simulated failures. Some changes were then made to the program (speeds, etc.), and the vehicle started a second roundtrip, traveling north from the station at 170 km/h. It then began accelerating. At 230 km/h, it hit a "radio hole" caused by a malfunction of one of the wayside transmitters, which did not toggle frequencies as it was supposed to. The radios work by transmitting to the guideway in two lobes. The vehicle passes through the signal transmitted from each antenna mast twice. The stop due to the radio failure was overridden (since its cause was known), and the vehicle accelerated to 319 km/h. The vehicle operator pushed his button for a moment to check operation, and the vehicle slowed to 284 km/h. The button was then released, and the vehicle accelerated back to 319 km/h. The button was pressed again to reduce vehicle speed to about 180 km/h.

The first test action was to simulate a switch setting failure while the vehicle was on the southern loop. This was accomplished using the switch box, which told the OCS that the switch was in the wrong position. The vehicle responded by slowing to 60 km/h (on its way to a stop). The switch position information was then corrected, and the vehicle accelerated back to 170 km/h.

While the vehicle was in the northern loop, radio interruption was simulated. The vehicle reacted properly. It began to slow, and radio communication was restored.

When the vehicle reached the Kanalstrasse, it increased its velocity to 320 km/h; it then slowed to 180 km/h, as programmed. Several console inputs were tried from Central Control, such as reverse operation. All of these were ignored because they can be accepted only when the vehicle is set down, which is impossible in automatic mode.

The switch controller box is on the Central Control console. Its function is to set switches. This box separates the switch controls from the rest of the OCS. By turning a key, the vehicle operator can interrupt communication of the switch settings to the vehicle. The system should react by stopping the vehicle before the switch, since the system does not know the switch position.

Automatic operation is executed by a program that contains information such as location (in meters) along the guideway (X), velocity in km/h (V), and propulsion (B%). To initiate automatic mode, the vehicle operator must push the joystick to the position that corresponds to a forward speed of 50 km/h. When the vehicle operator pushed the joystick, the system did not acknowledge the action. A line of the program that required the system to "wait for command" was removed from the program, and the test was repeated successfully.

Commands were edited as the program operated using a special syntax interpreter designed specifically for that purpose. The switches were thrown automatically when necessary. Constant voice communication between the vehicle operator and test personnel in the vehicle is required during automatic operation, especially communication of the actual switch settings.

The BLD knows the locations of all the HHPs and the station(s). It communicates the locations of the next two HHPs to the vehicle. The vehicle knows the next INKREFA location that it should see and sends the information to the wayside when it is read. This resets the groove counter. The BLD communicates to the vehicle the number of grooves from this point until the next INKREFA tag. This is how the system inspects for missing INKREFA tags. The system can function with up to two missing INKREFA tags in series. (The system will simulate the two missing tags by using the groove counting procedure). Thus, the vehicle always has the information necessary to stop safely during a communications failure.

Since the radio link between the vehicle and the wayside can be unreliable, transient communication failures are divided into two categories: reversible and irreversible, depending on their duration. Radio packets (telegrams) are always transmitted at pre-defined intervals regardless of whether the operational situation has changed. The control systems on the vehicle and on the guideway know when these telegrams are to be received. Failure to receive a telegram on time or receipt of garbled telegrams indicates an interruption in communication.

Mr. Wiedenmann briefly discussed the possibility of using dissimilar software in the triple safety computer system. Currently, all the computers use the same software, which can cause problems since all the computers will behave in the same way. Mr. Wiedenmann said that it is unlikely that the software for Transrapid would be rewritten to permit dissimilar code to operate in the control computers, as it is a very expensive proposition that would involve retest of the entire system for acceptance. Currently, TÜV does spot checks of Siemens' bench tests of the software. TÜV has performed simulation testing (some of which was witnessed by Task Force observers last year) and "walk-throughs" of the code to verify correct operation. Siemens conducted branch tests of all possible software paths. The BLT I was tested with a computer because it has a special processor (dual channel for each memory location and data flip-flop).

Mr. Wiedenmann also described the "V" procedure. It consists of taking the assembly language from the system's Electrically Erasable Programmable Read Only Memory (EEPROM), recompiling it into a graphical representation, turning it into a high-level representation of the software functions, and comparing it with the software specifications. Since the BLT II code is written in PASCAL, this type of reconstruction is apparently not possible, and software has to be verified through careful examination and testing.

Friday, June 4

The day's only testing consisted of towing the TR07 vehicle to Switch 3 and trying manual inputs to the vehicle control with the switch in various operating positions. The goal was to verify that the OCS would ignore commands issued when switch status was unknown or incorrect. In all cases, the OCS seemed to ignore the commands, which involved use of the switch controller box in Central Control. There is a fiber-optic connection between this box and the BLT. The test was to simulate failure of the box by interrupting its communication with the BLT and trying to reposition the switch from Central Control. Test personnel were in the bungalow at Switch 3 during this test. Because communication was unavailable, the Central Control operator radioed to the bungalow and had Mr. Otto (a test engineer) reposition the switch manually from the bungalow. This series was successful. Another test was to disengage two motors that activate the locking flaps of Switch 3 that fall into slots when the switch is repositioned. Without these flaps in place, the switch setting is not confirmed, causing the control system to put the switch in an unknown position. The proper reaction is to identify the switch as disabled and not usable.

The Task Force observer watched tests of stator pack fastening schemes performed in the Halle by technicians on a small test bed containing a section of magnets and a mockup of a guideway segment. Load cells were used to determine loads on the stator pack and fasteners when the magnets were energized.

The observer noticed and examined Lufthansa's design of a stator pack fastener (see Figure 14); all bolts were loaded in shear. There was concern that this design is too expensive. A special design, which has been installed in a guideway segment, is also being considered. It uses a longer nutstein, which is glued into the stator. This longer nutstein protrudes from the sides of the stator pack sufficiently that two bolts can be installed on each end. This puts the bolts on the outside of the assembly, making them easier to install and inspect. This design may be the proposed final solution for revenue application. Another idea is to make the stators slightly longer and use three nutstein/bolt combinations to reduce bending of the longer stator packs.

The observer also examined and watched installation of the redundant system that is being used in the steel sections on the southern loop. This system consists of two flanges that are bolted together across the joint between two adjacent stator packs. The new longer nutsteins have been installed throughout the southern loop. They protrude through holes in these flanges and are "caught" if the attachment bolt fails (dropping only about 1 mm, which is enough to be detected by the on-line measuring system). This solution has been installed only where the stator packs have been retrofitted with nutsteins that were harder than specified. Three of these harder nutsteins have already failed. The concrete guideway sections have a different system, which consists of a "loop" that wraps around the transverse piece and below the nutstein. These also allow a 1-mm drop if the primary nutstein attachment bolt fails.

The observer also watched a technician remove and replace a heat-damaged magnet (one of the old ones) that was replaced by another old one. Installation and removal of the magnets appears to be a relatively simple operation.

APPENDIX A

Weekly Test Schedules

I A B G INTERNAL MEMO

TM-M-090/93			
IABG* Operating Crew			
	Department TM	Processed by Metzner	Telephone 62-24
	File Number Met/ha	City Lathen	Date 04/01/93

Week's Program for the 14th calendar week (04/05 through 04/08/93) — Remarks

Active operation during the entire week for the joint TÜV and Siemens test program.

Prerequisites for restart of active operation on April 5, 1993

- All scaffolding removed from the guideway (Saturday, 04/05/93) — Thiele
- All vehicles shunted onto the transfer table — Auth
- Connector guideway is free of vehicles
  Switch 1 is left on branch line for this purpose on 04/02/93, at the end of operations

Monday, April 5, 1993

Time	Program	Remarks
0800	Inspection run with special vehicle through the southern loop	Stein Achter
0900	Towed run with TR07 in 1st construction section	Stein Achter
	During the towed run recording of INKREFA readings and evaluation after the run.	Behrens
1000	Propulsion run with TR07 for guideway measuring	
1100	Visitor run	
	Mayor of Frankenberg-Parchim TÜV with U.S. guests	
1130	Visitor run	
	DB-Rheine group and possible U.S. guests	

TMA	Series
Fürst	Name

1400-1500	System check run with BLT II TÜV, Siemens BS	
	Briefing of vehicle operating crew during the first test	
1500-1600	Test runs	
	Use of eddy current brakes for propulsion failure in front of switch 2 on the branch line when approaching from the south	
beginning at 1600	"Lathering" of the guideway with *Sulky* in the eastern branch line of switch 3 (steel guideway) as preparation for the emergency braking test on the next day	Stein Achter

Tuesday April 6, 1993

0900-1030	Test runs per TÜV requirements without set down from high speeds (maximum 10 km/h)	
1030-1100	Preparation/briefing on set down test in the southern loop	
1130-1230	Run into the southern loop at maximum speed. In doing so emergency stop in the eastern branch line of switch 3 (steel guideway) due to the switch reported as not negotiable for the BLT II. After the set down test return run to VZ in towed mode, if necessary.	

In the afternoon shop operations for skid checking and, if necessary, skid replacement.

"Lathering""of the guideway with *Sulky* in the set down area for the test on the following day (concrete guideway North). The exact set down area will be promptly announced after details have been coordinated.	Stein Achter
Repair of bending sensors in the guideway girders of the southern loop. The turntable ladder is needed for this activity.	Schaap

Wednesday April 7, 1993

		Remarks
0900 - 1030	Test preparation/briefing and execution of the emergency braking test with a minimum number of eddy current brakes (without set down, test terminated at 150 km/h)	
1030 - 1100	Test preparation/briefing for emergency brake test in the northern loop at secondary stopping point 26	
1100 - 1200	Run through the southern loop at maximum speed in the direction to north and emergency stop initiation in order to approach secondary stopping point. Set down on concrete (if necessary towed run back to VZ)	Willenbar Achter

In the afternoon skid checking and if necessary skid replacement.

Thursday April 8, 1993

		Remarks
0900 - 1100	BLT II system check runs	
1100 - 1200	Test runs per TÜV requirement without set down	
1200 - 1600	System check runs	

During the set down tests on April 6 and 7, 1993, remeasurements in TR07 per «MVP» requirement — Vandersen, Schmorar

Taking oil samples on switch 3 on April 6 or 7, 1993 — Deymer

Prospects for 15th Calendar Week (April 13 - 16, 1993)

In addition to numerous visitor runs, measurements on levitation gap sensors and studies of shutdown behavior of the new bow magnets in static levitation and during propulsion runs by Thyssen — Ellmann

Accompanying measurements to determine propulsion efficiency and running resistance — Behrens, Meyer

/Signature/
Metzner

Week's Program for the 17th Calendar Week (04/26 through 04/30/93)
(Schedules for calendar weeks 18 and 19 are included.)

Monday and Tuesday Mornings April 26 and 27

- TR07 vehicle (power off)

  - Change defective Linear generator coils in 8RR of Section II. (Note that Section II is passenger compartment vehicle of the TR07 train, and Section I is the TR07 vehicle where the monitoring and test instrumentation is located.)

  - Adjust the new levitation magnets in roller. (Some of the new levitation magnets have now been installed. Note that on December 9, 1992 the FRA Task Observer was informed that four of the new magnets, one at each end corner of each vehicle where planned to be installed by mid February 1993. In one of the tests ran later there was overheating of an "old" levitation magnet section as described in this report. Also ride quality is now not expected to ameliorate with the new magnets. Ride quality improvements would have to be realized in the secondary suspension.)

  - Adjust the force equalizer of the hinge point II in the passenger vehicle or Section II.

- Guideway

  - Mounting of measuring stator pack for the assessment of the redundant fastening (assumed to be stator pack) in the steel and concrete double-span beams

  - Application of acceleration receiver for redundant fastening of the concrete double span

  - Visibility control of southern loop guideway and Kanalstrasse (up to the double beam span). Look for damage etc. using the special vehicle.

  - Power off double span and adjacent areas

  - Weekly inspection of Kanalstrasse and the northern loop

Tuesday Afternoon April 27 through Friday April 30)

- TR07 vehicle

  - Guideway rides (Two daily rides for the off-line guideway clearance measuring system data collection are to be accomplished.)

- Repetition of some of acceptance tests of the BLF (Car-carried) subsystem of the BLT control system (To be performed from TÜV-specified tests)

- Calibration of sensor in vehicle for position detection
  (This could be either the pole counter or the INKREFA tag sensor.)

- As done in previous weeks, some of the redundant fastenings of the stator packs, in the steel guideway are actively circuited for monitoring and need to be examined at the end of the daily ride.

Parallel activities

o TR07 vehicle

  - Test of DC/DC converter

o Guideway

  - Repair of sensors for the concrete span length monitoring.

Prospects for calendar week no. 18 activities

Monday May 3 through Thursday May 6:

o TR07 Vehicle rides

  - Test of the on-line system for stator pack deflection detection

  - Double span stator redundant fastening

  - Review of the new nose magnets (new levitation magnets already installed at each corner of vehicles)

  - Voltage measurements of the new levitation magnets

Friday May 7:

No rides

o Power off. Operate the emergency vehicle.

Prospects for Calendar Week 19

No rides

o Inspection of stator fastening against the fault table.
  (off-line system verification of stator-pack alignment)

IABG INTERNAL MEMO			
TM-M-184/93			
IABG Operating Crew	Dept. TM	Processed by Decker	Telephone 62-39
	File Number De/sch	City Lathen	Date 05/28/93

Week's Program for the 22nd Calendar Week (05/31 through 06/04/93)	**APPOINTMENTS Remarks**
Monday, 05/31/93: Pentecost (legal holiday)	
No test operation!	
Tuesday, 06/01/93:	
o TR07 Shop operations	
- Servicing and inspection	vehicle operating
- Suspension and guidance system checks	crew
after 2 p.m.:	
- Acceptance tests conducted by the TÜV Expert [*German Technical Inspection Organization*] (TR07, propulsion and BLT II [*operations control system II*] are powered up - acceptance of SIAB (Sicherheitsabschaltung: safety system shutoff) of the propulsion system)	TÜV, Dr. Krebs SB, Burkert IABG, Otto

TMV	TMA	Department
Steinmetz	Fürst	Name

IABG INTERNAL MEMO	APPOINTMENTS Remarks
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Wednesday, 06/02/93: **after 8:30 a.m.:** o TR07 Propulsion runs for the acceptance tests (Due to the fact that the SIAB is triggered in the BLT II, we will tow the TR07 to the boarding platform and start all tests there). **Thursday, 06/03/93 and Friday 06/04/93:** o TR07 Propulsion runs (with SIAB and additional device) - for the continuation of the TÜV acceptance tests	
Friday, after 1 p.m.: o Stat. acceptance tests of the switches	TÜV, SB , IABG Otto, Brameyer
Parallel Activities: o Completion of test set-up for load assumption verification for the main reinforcement bond in girder 558 (work on girder or column can be performed on Tuesday only).	Müller, Nieters

- Potential renewal of gaskets in actuating cylinder in location 7 of switch 3 (Tuesday)	Pieper
- Determination of installation measurements, location of stators on girder end, etc., in Steel North (Tuesday)	Kuper
- Testing of "load frames" in North Loop	NN
	Thiele, Stein

Preview of 23rd Calendar Week (06/07 through 06/11/93):

o TR07 Propulsion runs

- to furnish load assumption verification in the main reinforcement bond of girder 558
- for array measurements
- for induction measurements on guidance magnets
- for filming *) and
- for demonstration

*) Evening and night shots are still needed for a "special effects film" that will show a Maglev run from Hamburg to Berlin. Filming has tentatively been scheduled for June 7, 1993, (rain date June 14, 1993). As indicated during our morning rounds, we

IABG INTERNAL MEMO	APPOINTMENTS Remarks
would like to ask the following gentlemen to rearrange their work schedules in such a way that they can be present until about 11 p.m. Control Center: Krüssel, Decker Vehicle: Lambers, Körner Ground Crew: Knoop Propulsion: Behrends, Kemker SFZ: Stein Signed: Decker	

APPENDIX B

Figures

Figure 1. TR07 Vehicle with BMFT Logo

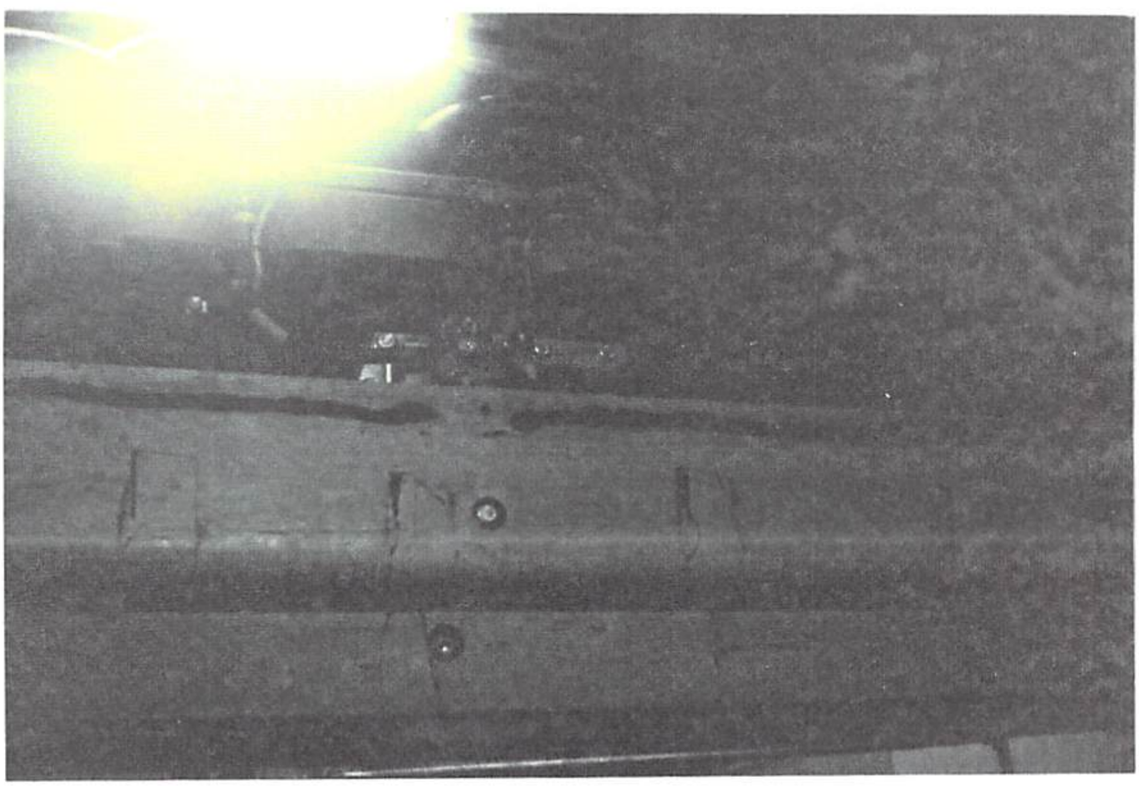

Figure 2. New Gap Sensors at Front Magnet

Figure 3. Options for Nutstein Design

Figure 4. Interior of TR07 Passenger Section

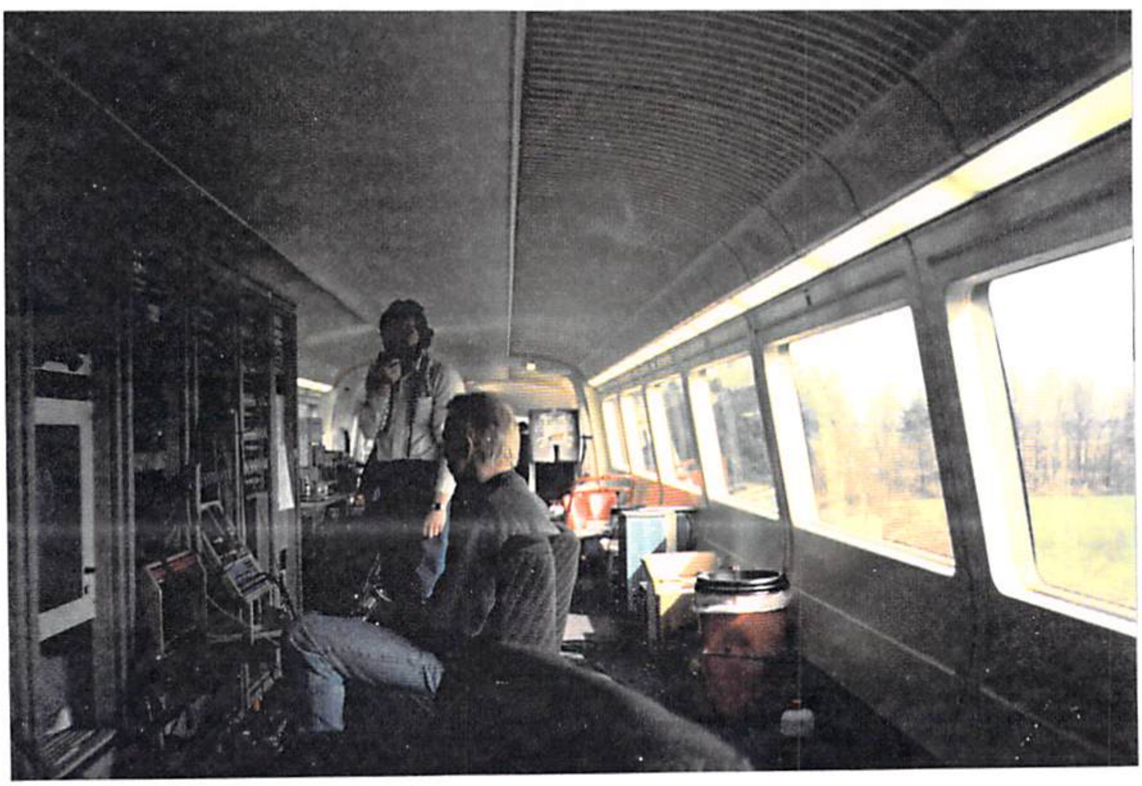

Figure 5. Interior of TR07 Test Unit

Figure 6. Switch 3 (Two Views)

Figure 7. Beam Section for Orlando Project

Figure 8. Double-Span Test Sections

Figure 9. Emergency Towing Vehicle

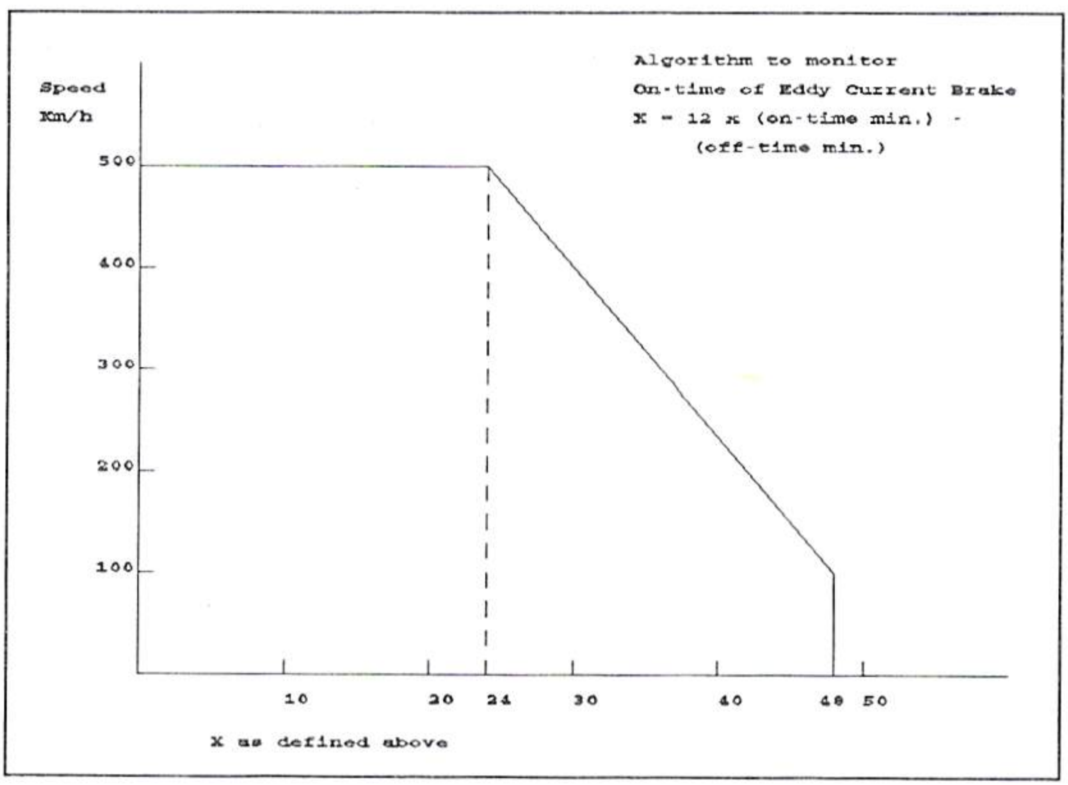

Figure 10. Algorithm for Computing On-Time for Eddy Current Brakes

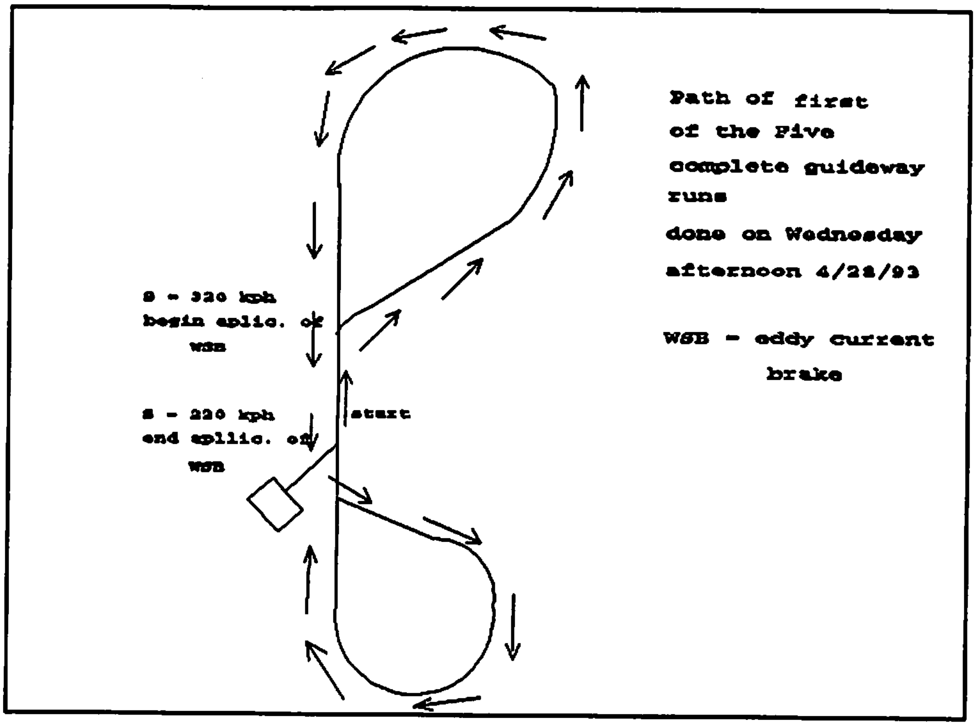

Figure 11. First Complete Loop Around Guideway

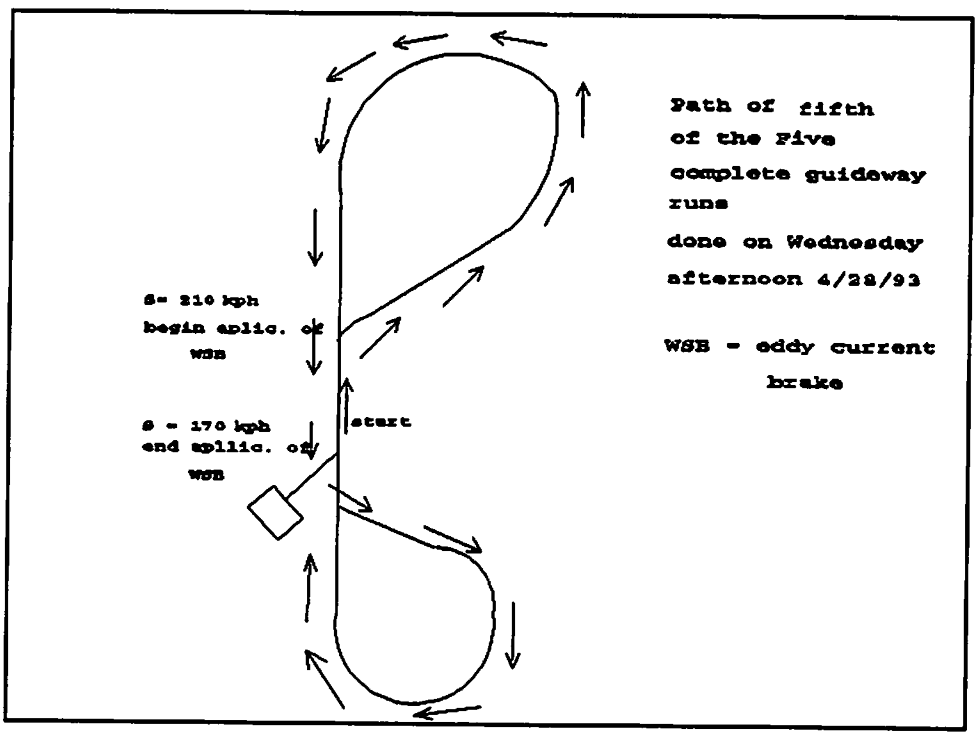

Figure 12. Fifth Complete Loop Around Guideway

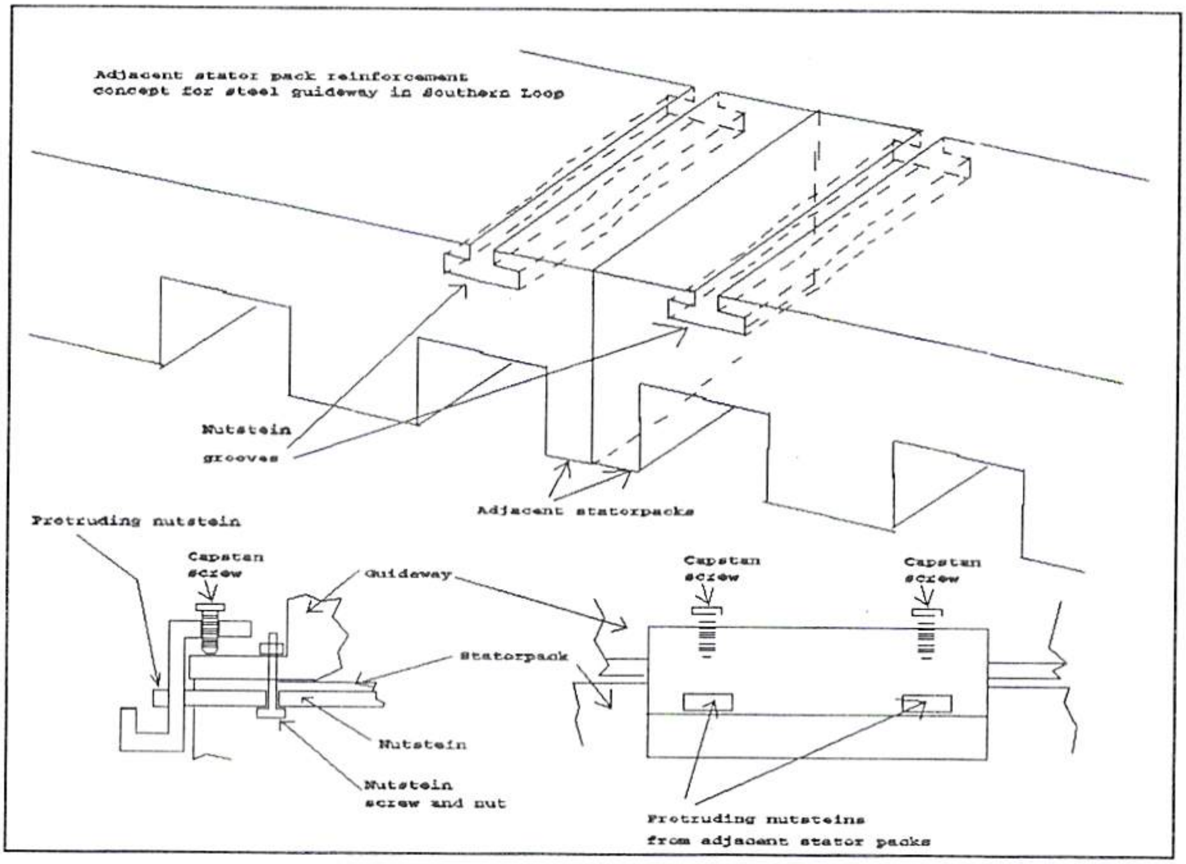

Figure 13. Stator Pack Dropaway Prevention Concept for Steel Guideway on Southern Loop

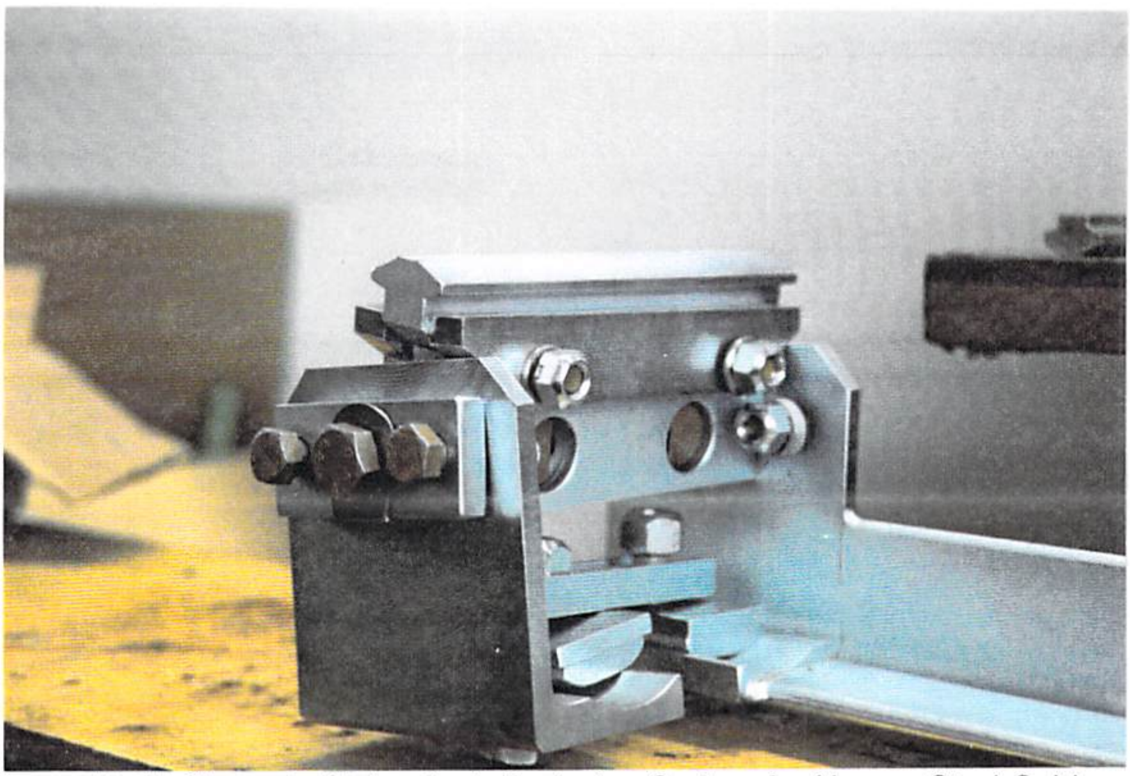

Figure 14. Lufthansa's Stator Pack Fastening System for Use on Steel Guideway

APPENDIX C

The MVP Testing and Planning Company for Maglev Systems Introduces Itself

The MVP Testing and Planning Company for Maglev Systems introduces itself:

The **MVP** was founded in 1981 at the suggestion of the Federal Minister for Research and Technology (BMFT). The objective was to test the TRANSRAPID maglev train from the standpoint of a potential operator and to make preparations for its operation. The members of the MVP consortium are the Deutsche Bundesbahn [German Federal Railway], Deutsche Lufthansa AG and Industrieanlagen-Betriebsgesellschaft mbH (IABG) [Industrial Installations and Operations, Ltd.].

In 1985 MVP took over the **TRANSRAPID Test Facility Emsland (TVE)** which had been financed with BMFT funds and built by the TRANSRAPID Maglev Consortium.

After continued technical and organizational development of the TVE, ensuring and implementing experimental operation in recent years and responsibility in the assessment of technical readiness for application (1991), MVP assumed the central function of program management in the development of the TRANSRAPID Project. This includes especially preparations from the viewpoint of an operator for the introduction of the TRANSRAPID system with respect to approvability and satisfying requirements that relate especially to the first application sections.

By integrating the Berlin-Hamburg line into the 1992 Federal Traffic Route Plan the first TRANSRAPID application in Europe has come within reach.

Based on the almost 10 years of experience through tests at the TVE and the conducting of studies and research on the introduction of the high speed maglev railway in Germany (among others, the study published in 1991 entitled "Application of New High Speed Rail Systems"), MVP is considered a reliable partner in TRANSRAPID matters among decisionmakers in the field of politics, business, government and the general public.

The **TRANSRAPID Test Facility Emsland (TVE)**, with a total length of 31.5 km is the largest test line for maglev vehicles in the world. Here all components and subsystems of the maglev railway are rigorously tested before TRANSRAPID can be approved as a new means of transportation. With one straight section and two terminal loops, the TVE has all the prerequisites for continuous operation under realistic conditions (see also "Milestones" on the next page).

The IABG conducts experimental operations on the TVE on behalf of MVP.

TVE Guideway

Elevated and at-grade guideway.
Pillars in mix-in-situ concrete, guideway beams in concrete and steel construction, single and double span beam.

Total length	31.5 km
Beam lengths	25 and 50 m
Gauge (lateral guide rail)	2.80 m
Maximum transverse slope	12 degrees
Longitudinal gradient	up to 35 per thousand
Curve radii	1690 m (northern loop)
	1000 m (southern loop)
Clearance height under guideway	4.70 m
High speed turnout length	150 m

Environmentally relevant data

Noise level (when passing at a distance of 25 meters)

at 200 km/h	79 dB(A)
at 300 km/h	86.5 dB(A)
at 400 km/h	93.5 dB(A)
Power consumption in running cycle up to 400 km/h	63 Wh/seat km
Clearance width	11.80 m
Area required (per pillar)	approx. 20 m^2

TECHNICAL DATA

Vehicle Data TR 07

Length of one section	25 m
Width	3.7 m
Height	4.06 m
Empty weight of one section	46 tons
Payload	9 tons
Passenger compartment	
Width	3.37 m
Height	2.01 m
Design speed	up to 500 km/h
Last speed record	436 km/h
Application vehicle	2 to 10 sections with 70 - 100 seats per section

TVE-specific Propulsion Data

Electrical linear synchronous motor

Thrust TR07	85 kN
Acceleration power	max. 11 MW
Maximum acceleration	0.8 m/sec^2
Rated motor current	1200 amps
Motor frequency	0 - 215 Hz
Motor section length	approx. 300 - 2100 m
Air gap	approx. 10 mm
(between levitation magnet and stator)	

MILESTONES AT THE TVE

Total mileage over 135,000 kilometers

Longest nonstop run on the TVE: 1050 kilometers

More than 300,000 visitors at the TVE

More than 40,000 visitors "transported" to date

Greatest daily mileage: 2476 kilometers

Speed record: On December 13, 1989, the TRANSRAPID 07 accelerated to 436 km/h.

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