

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Running Ability and Impact Tests on special Infrastructure Test report

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Abbreviations & Acronyms

Abbreviation / Acronym	Description
BP	Brake pipe
CCU	Coupler control unit
CL	Coupling link
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
DC	Dellner Couplers AB
DMS	Strain gauge (ger.: Dehnungsmessstreifen)
e-coupler	Electrical coupler
ERJU	Europe's Rail Joint Undertaking
FT	Faiveley Transport SA / respective: Wabtec Corporation
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
KB	Knorr-Bremse AG
R2C	Ready-to-couple position
S/N	Serial number
T...	Test No. (e.g.: T123 = Test No. 123)
TOR	Top of rail
TTL	Train Test Lab
TTL-ID	Component ID given by the TTL for asset management
VT	Voith GmbH & Co. KGaA
WP	Wabtec position

1 Project description and objective

The TRANS4M-R consortium within Flagship Project 5 (FP5) of the ERJU project aims to develop and validate the Full Digital Freight Train (FDFT). A main component of the FDFT is the digital automatic coupler (DAC). Different suppliers developed DACs that ran through a process of impact tests with identical coupler types.

In order to gain information on the function of the couplers on special / difficult infrastructure, tests on these infrastructures shall be executed with couplers of non-identical type / supplier.

The tests are coordinated by the test management (WP1) within TRANS4M-R and distributed across several test instances. This report covers the tests that were executed by WP14 in TRANS4M-R in the Train Test Lab.

1.1 WP14 Train Test Lab – General overview

The Train Test Lab can be seen as an institution with different sites that have special characteristics and thus provides resources for special tests. The main site is located at the HVLE in Berlin-Spandau. However, since the special infrastructure is not present in Berlin, but available at the TÜV Süd Rail in Görlitz, the tests described in this report were executed there.

The goals pursued in the Train Test Lab can be divided into four areas of action.

On one hand, component testing on vehicle level enables the project participants to test ideas quickly and thus contribute to the development process.

On the other hand, it must be possible to make decisions on component types at defined milestones within the project. The evaluation of the various technical solutions is to be carried out on the basis of defined tests and the results are to be submitted to the decision-makers as a technical test report with a valid factual basis.

The third line of action involves the approval-relevant tests. Currently, there is no complete set of rules for the approval of technical solutions and the required standards still have to be created. Within the Train Test Lab, preliminary tests are to be made possible in order to develop approval tests, but also to check the approvability of the new components, freight wagons and locomotives.

The fourth action area involves the implementation of demonstrations. Experts and workers from the entire sector should be able to understand the new technologies and contribute their know-how and knowledge to the development process. In addition, personnel must be trained in the use of the new technology at an early stage. For this purpose, practical training courses are to be developed and tested in the Train Test Lab.

1.2 Objective for interoperability tests and report structure

The basis for the execution of functional tests on special infrastructure is given in the test scenarios Impact Tests [TS-2025-14] and Running Ability Tests [TS-2025-15].

The overall report consists of a main report and numerous annexes. The main report starts with a description of the project and the environment. The test objectives and report structure are explained in chapter 1. Chapter 2 introduces the DAC and describes the need for impact and running ability tests on special infrastructure. Chapter 3 describes the infrastructure (locations, vehicles, systems under test) used for the different tests. The test schedule summary is shown in chapter 4.

The description of the test concepts required for the realisation of test cases and the results are included as appendices to the main report.

The relevant annexes are listed in chapter 7.

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1.3 Contact persons

The work package (WP14) lead is overall responsible for the planning, execution and documentation of the tests in WP14 as well as for the allocation of required resources to do so.

The technical test lead is responsible for the proper planning and realisation of the tests, as well as the measurement technology.

The operational test lead is responsible for the operational realisation and ensures safety during the execution of the tests.

During the tests, it was essential to always have experts from the respective supplier on site. It was also important to have close contact with the leader of the expert group.

The report is distributed to the persons listed. Further distribution should only take place in accordance with the above-mentioned confidentiality.

Table 1: Contact persons

Role	Name	E-Mail
WP14 lead – responsible for content	Daniel Wolfram	Daniel.Wolfram@deutschebahn.com
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Supplier contact – Knorr-Bremse	Eva Lohmeier	Eva.Lohmeier@knorr-bremse.com
Supplier contact – Voith	Ulrich Deghela	Ulrich.Deghela@voith.com

2 Fundamentals, definitions and technical principles

The following chapters describes the fundamentals of the DACs (chapter 2.1) and the resulting necessity of functional impact tests (chapter 2.2) and running ability tests (chapter 2.3).

The chapters summarize the respective content of the test scenarios [TS-2025-014] and [TS-2025-015]. Further, more detailed information regarding the fundamentals, definitions and technical principles can be found in these documents.

2.1 Basics of DAC in the Scharfenberg design

As the design of DACs was fixed to the Scharfenberg design, all suppliers of DACs within the TRANS4M-R FP5 are developing DACs of that type.

The general design consists of different parts (pneumatical parts in red, electrical parts in blue):

- Coupler head, with:
 - o Manual uncoupling device
 - o Actuator for automated uncoupling
 - With push buttons or remotely operated
 - o Hook plate + coupling link
 - o Guiding horn + cone
 - o Air pipe connection (brake pipe, eventually main reservoir pipe)
 - o Air valve (with connection to brake pipe of wagon)
- E-coupler, with:
 - o Power-line-connection
 - o Data-line-connection
- Coupler shank, with:
 - o Pivot pin for connection between shank and draft gear
- Split collar (or fix connection between shank and head)
- Draft gear, with:
 - o Compression force stop for form closure with wagon
 - o Mounting plate from below
- Vertical support (with centration)

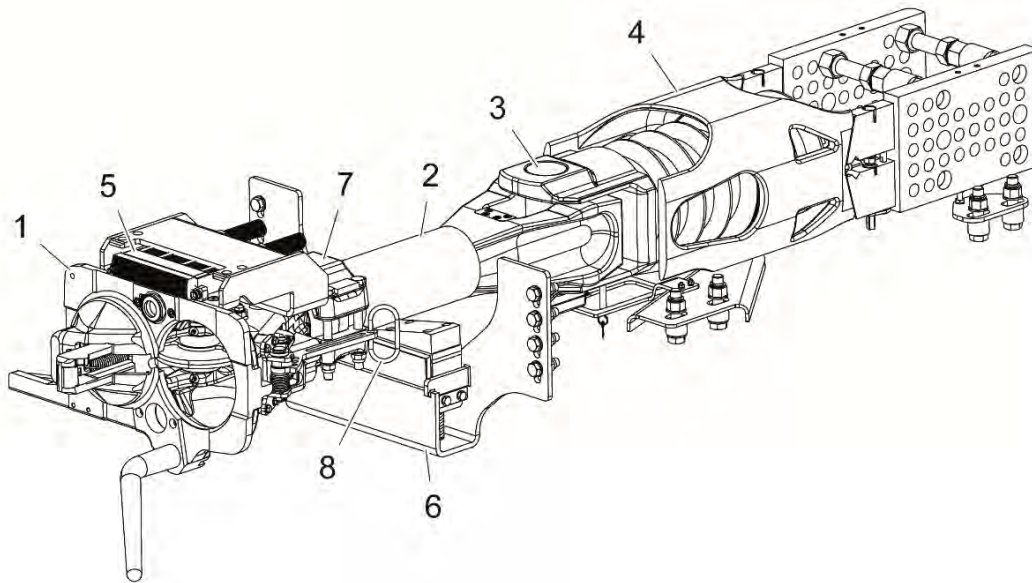


Figure 1: Scheme of the DAC. 1: mechanical coupler / coupler head, 2: coupler shank, 3: pivot pin, 4: draft gear (with compression force stop on the right end and mounting plate below), 5: electrical coupler, 6: vertical support, 7: split collar, 8: manual uncoupling device; Source: [TS-2025-014].

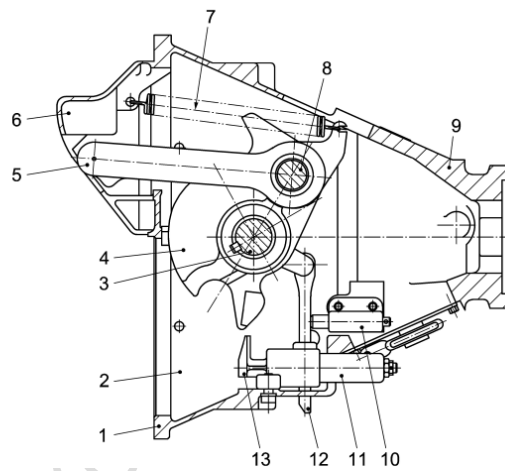


Figure 2: Scheme of the coupler head. 1: coupler face, 2: female cone, 3: main pin, 4: hook plate, 5: coupling link, 6: male cone, 7: tension spring, 8: coupling link pin, 9: coupler head housing, 10: release bar holder, 11: trigger device, 12: release bar, 13: trigger; Source [EN_16019].

To control the electrical parts a CCU (coupler control unit) is used. The power-supply is connected to a junction box. To uncouple the coupler via the actuator, a synchronization signal is used to trigger both actuators and therefore reset both couplers into the ready-to-couple position (R2C).

The suppliers are currently providing DACs which might differ in (focus on mechanical and pneumatical parts):

- Design of front plate
- Behaviour of springs, hook plate and coupler link of the coupler head
- Design of draft gear (e.g. single components or caged)
- Behaviour of draft gear (e.g. spring and attenuation constant, material, etc.)
- Design of mechanical uncoupling mechanism
- Behaviour of air valve (always open or closed when ready-to-couple)
- Behaviour of e-coupler connection (e.g. spring characteristics)

Due to these differences, the interoperability between the DACs of different suppliers should be tested.

2.2 Necessity of functional impact tests – [TS-2025-014]

The functionality of the couplers on special / difficult infrastructure should be proven. [TS-2025-014] defines the worst-case scenario in terms of wagon choice and infrastructure.

Tests regarding the [TS-2025-014] shall be executed. As tests on straight track could be done at the HVLE in Berlin-Spandau, this report and the respective tests at the TÜV Süd Rail in Görlitz focus on the tests on:

- 150 m curve
- 150 m s-curve with 6m intermediate straight
- 75 m curve

Further details regarding the test execution can be found in Annex 1.

2.3 Necessity of running ability tests – [TS-2025-015]

The functional safety of the DACs during train runs should be proven. [TS-2025-015] defines these necessary tests.

All tests defined in the [TS-2025-015] shall be executed on special infrastructure, respective at the TÜV Süd Rail in Görlitz:

- 150 m s-curve with 6 m intermediate straight
- 75 m curve
- Ferry boat ramp (3.5° inclination)

Further details regarding the test execution can be found in Annex 2.

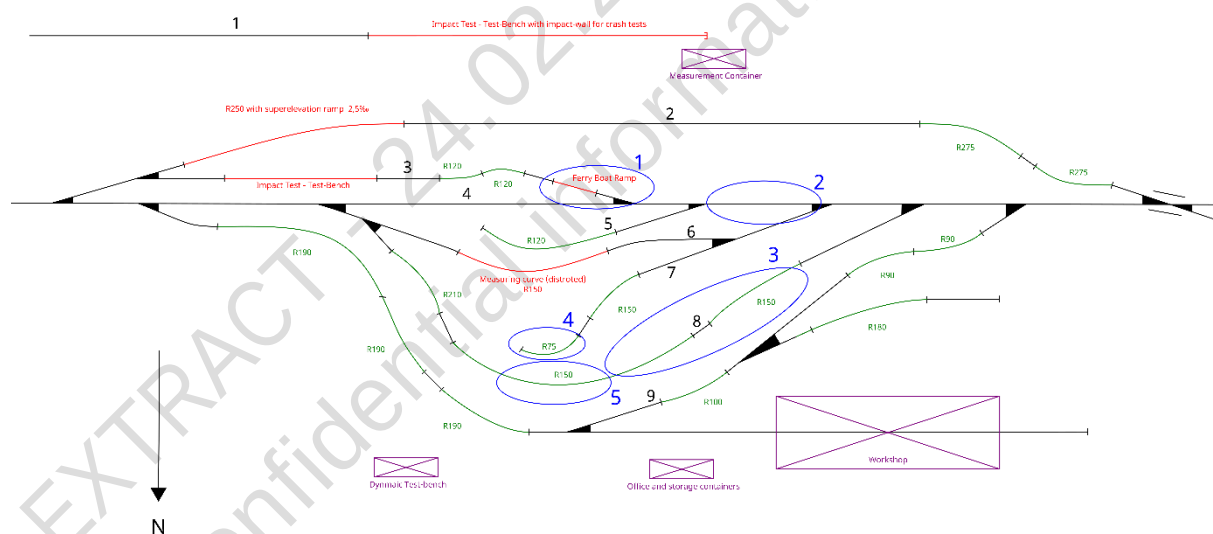
3 Infrastructure

3.1 Test location

All tests were executed at the location of TÜV Süd Rail in Görlitz (Hans-Georg-Dehmelt-Str. 8, GER-02827 Görlitz).



Track Layout - TÜV Süd Rail, Görlitz
(Scheme not to scale)



Number (blue)	Infrastructure	Track No.
1	Ferry boat ramp (3.5° inclination)	3
2	Straight track (speed measurement calibration)	4
3	150 m s-curve with 6 m intermediate straight	8
4	75 m curve	7
5	150 m s-curve	8

Figure 3: Satellite view (top) and track layout of the TÜV Süd Rail, location Görlitz.



Figure 4: Ferry boat ramp. Left: view to the east. Right: Inclination.



Figure 5: 75 m curve - view from the couple position. Left: view to the east, Right: view to the west.



Figure 6: 150 m s-curve. Top: whole view, Left: view to the east from the couple position, Right: view to the west from the couple position.

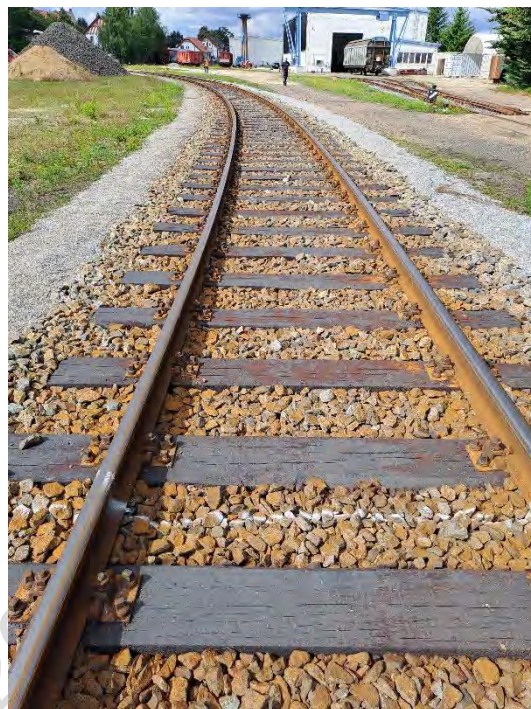


Figure 7: 150 m curve - view from the coupling position. Left: view to the east, Right: view to the west.

3.2 Vehicles

[TS-2025-014] defines the following requirements regarding the used vehicles:

Table 2: Requirements regarding vehicles from [TS-2025-014].

Moving wagon	Standing wagon
4-axle wagon 80 t	2-axle wagon 20 t

[TS-2025-015] defines the following requirements regarding the used vehicles:

- wide distance between bogie pivots / axles
- long overhang

It also shows an exemplary selection of the wagons:

Table 3: Exemplary selection of vehicles shown in [TS-2025-015].

Wagon type	Description	Axles / bogies	Overhang (without buffer) [mm]	Distance between bogie pivots / axles [mm]
Rs 680	Flat wagon	Bogies, 4 wheelsets	2 830	13 000
Zags 119	Pressure gas wagon	Bogies, 4 wheelsets	2 730	12 100
Hbbills 310 / 311	Freight wagon Sliding walls	2 wheelsets	3 005	10 000

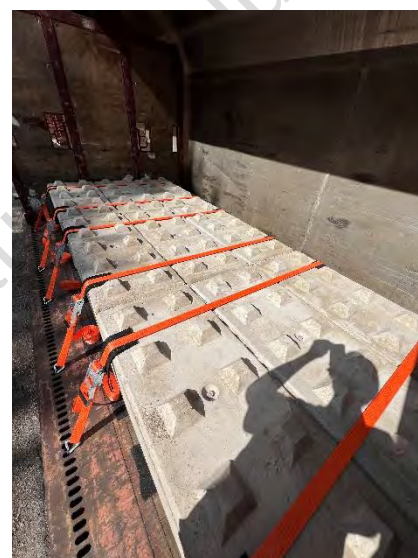
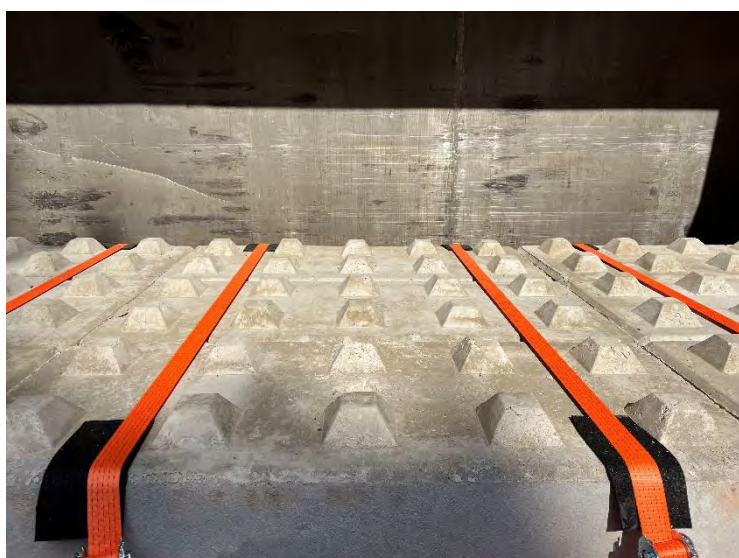
Due to a lack of availability of certain wagon types, the following types were finally chosen as best match for the given requirements:

Table 4: Chosen vehicles.

	2-Axle wagon	4-axle wagon
Type	Hbbillns	Habbills 346
Description	Sliding wall wagon	Sliding wall wagon
Supplier	Mercitalia Rail	DB Cargo
Distance between bogie pivots / axles	9.00 m	18.59 m
Length over buffers	15.50 m	24.10 m
Overhang (without buffer)	2 630 mm	2 150 mm
Weight (tare)	16 500 kg	31 880 kg
Amount of vehicles	4	2

The 4-axle wagons were loaded with concrete blocks (see Figure 8). Per wagon 37 blocks were used (150 x 60 x 60 cm, 1.3 t weight) leading to an additional load of 48.1 t.

The following chapters show the detailed configurations of the used vehicles during the tests.



Scheme:

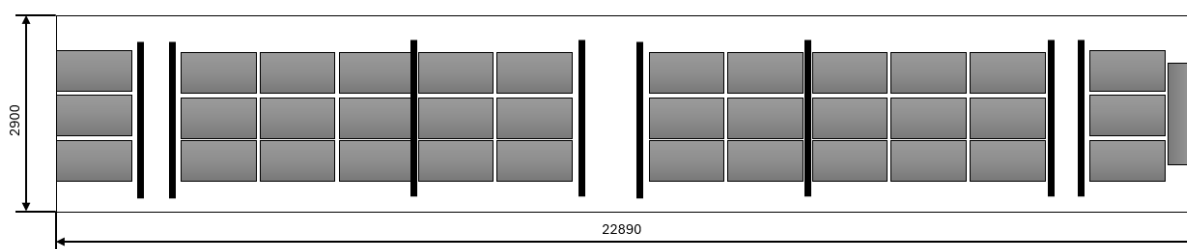


Figure 8: Loading of 4-axle wagons.

3.2.1 Ha_0136

Type regarding Table 4: 4-axle wagon

Number: 31 80 2777 013-6

Config:

Wagon	Config.	Date	Change
Ha_0136	#001	22.07.2025	Initial state (Mechanical installation at TÜV Süd Rail, loading at HVLE previously): Coupler A: Screw Coupler B: KB03 Load state: full Measurement system DBST installed.
Ha_0136	#002	08.08.2025	Exchange of coupler at TÜV Süd Rail: Coupler A: Screw Coupler B: FT03
Ha_0136	#003	13.08.2025	Deinstallation of FT03: Coupler A: Screw Coupler B: Screw

Loading:

Load state	Weight	Source / description / remark
empty	31 880 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.
full	79 980 kg	Sources: - Wagon-inscription. - Manufacturer information (37 concrete blocks with a weight of 1.3 t each) Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 9: Ha_0136.

3.2.2 Ha_0458

Type regarding Table 4: 4-axle wagon

Number: 31 80 2777 045-8

Config:

Wagon	Config.	Date	Change
Ha_0458	#001	22.07.2025	Initial state (Mechanical installation and loading at HVLE previously): Coupler A: Screw Coupler B: DC01 Load state: full Measurement system DBST installed.
Ha_0458	#002	07.08.2025	Exchange of coupler at TÜV Süd Rail: Coupler A: Screw Coupler B: VT03

Loading:

Load state	Weight	Source / description / remark
empty	31 880 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.
full	79 980 kg	Sources: - Wagon-inscription. - Manufacturer information (37 concrete blocks with a weight of 1.3 t each) Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 10: Ha_0458.

3.2.3 Hb_3235

Type regarding Table 4: 2-axle wagon

Number: 21 83 2457 323-5

Config:

Wagon	Config.	Date	Change
Hb_3235	#001	22.07.2025	Initial state (Mechanical installation at TÜV Süd Rail): Coupler A: KB01 Coupler B: Screw Load state: empty Measurement system DBST installed.
Hb_3235	#002	31.07.2025	Installation of coupler at TÜV Süd Rail: Coupler A: KB01 Coupler B: VT02

Loading:

Load state	Weight	Source / description / remark
empty	16 400 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 11: Hq_3235.

3.2.4 Hb_3472

Type regarding Table 4: 2-axle wagon

Number: 21 83 2459 347-2

Config:

Wagon	Config.	Date	Change
Hb_3472	#001	22.07.2025	Initial state (Mechanical installation at TÜV Süd Rail): Coupler A: Screw Coupler B: DC03 (New holes for vertical support drilled ¹⁾) Load state: empty Measurement system DBST installed. ¹⁾ The existing holes for the vertical support were not conforming to the standard. Present distance: 840 mm, distance respective standard: 742 mm [UIC_530-1].
Hb_3472	#002	30.07.2025	Installation of coupler at TÜV Süd Rail: Coupler A: VT01 Coupler B: DC03

Loading:

Load state	Weight	Source / description / remark
empty	16 500 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 12: Hb_3472.



Figure 13: New holes for the vertical support on wagon Hb_3472, side B.

3.2.5 Hb_3581

Type regarding Table 4: 2-axle wagon

Number: 21 83 2457 358-1

Config:

Wagon	Config.	Date	Change
Hb_3581	#001	22.07.2025	Initial state (Mechanical installation at HVLE previously): Coupler A: DC02 Coupler B: Screw Load state: empty Measurement system DBST installed.
Hb_3581	#002	29.07.2025	Installation of coupler at TÜV Süd Rail: Coupler A: DC02 Coupler B: FT02

Loading:

Load state	Weight	Source / description / remark
empty	16 500 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 14: Hb_3581.

3.2.6 Hb_3746

Type regarding Table 4: 2-axle wagon

Number: 21 83 2459 374-6

Config:

Wagon	Config.	Date	Change
Hb_3746	#001	22.07.2025	Initial state (Mechanical installation at TÜV Süd Rail): Coupler A: Screw Coupler B: KB02 (New holes for vertical support drilled ¹⁾) Load state: empty Measurement system DBST installed.
Hb_3746	#002	29.07.2025	Installation of coupler at TÜV Süd Rail: Coupler A: FT01 (New holes for vertical support drilled ¹⁾ , loose BP ²⁾) Coupler B: KB02 ¹⁾ The existing holes for the vertical support were not conforming to the standard. Present distance: 840 mm, distance respective standard: 742 mm [UIC_530-1]. ²⁾ The brake pipe of coupler FT01 was not relocated. It was not fixed at the wagon end during the tests.
Hb_3746	#003	13.08.2025	Deinstallation of FT01: Coupler A: Screw Coupler B: KB02

Loading:

Load state	Weight	Source / description / remark
empty	16 500 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems and measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 15: Hq_3746.



Figure 16: New holes for the vertical support on wagon Hb_3746, side A.



Figure 17: New holes for the vertical support on wagon Hb_3746, side B.



Figure 18: The brake pipe on wagon Hb_3746, side A was not relocated and not fixed on the wagon end.

3.3 Systems under test

Four samples of DACs (Dellner, Knorr-Bremse, Voith, Faiveley) were available in the Train Test Lab for the test.

Regarding the function of the air valve, all suppliers delivered couplers with an always-open air valve.

As at the time no fully developed CCUs were available, the electrical parts were controlled via a simulation box. The systems should provide the functions: uncouple and prevent coupling – although the prevent coupling function was not tested during the presented tests. The simulation box and the belonging systems (junction box and push buttons) are positioned the most practical for the tests and planned de-/reinstallations and not as they would be placed on future commercial vehicles.

Furthermore, Voith is the only supplier for e-couplers. Therefore, Voith delivered four e-couplers per supplier for the tests.

The suppliers delivered couplers with different functionalities. Table 5 summarizes these.

Table 5: Summary of the functionalities of the provided assets.

Supplier	Mechanical Coupler	Manual uncoupling	Actuator	Simulation Box	Synchronization signal	Wabtec position ¹⁾
DC	✓	✓	✓	✓	✗	✗
FT	✓	✓	✗	✗	✗	✓
KB	✓	✓	✓	✓	✗ ²⁾	✗
VT	✓	✓	✓	✓	✗	✗

¹⁾ Besides the coupled and ready-to-couple position, Faiveley expanded their couplers by the “Wabtec position” (WP). This position is described in detail in chapter 3.3.2.1.

²⁾ Knorr-Bremse planned to deliver a synchronization signal. The synchronization did not work after the electric installation. Tests were performed without synchronization signal.

The systems under test are described in further detail in the following chapters. First the DAC of the respective supplier is introduced, followed by the configurations for each individual coupler.

3.3.1 Dellner

3.3.1.1 Overview of the coupler

Part	Type
Draft Gear	2013768-DE
Coupler Head	9230/2012892
Vertical support	- no type plate -

The coupler of Dellner is shown in the following figures.

The mechanical coupler consists of:

- Draft gear (one cage)
- Vertical support
- Coupler head (with manual uncoupling)

The electronic system consists of:

- Actuator mounted from the outside of the coupler
- Couple status sensors with couple status flag in a separate box mounted on top of the coupler
- Actuation plate for the e-coupler on separate a bolt, mounted onto the coupler
- Simulation box (containing the junction box)
- Push buttons (optional on both sides) [Buttons: Default/Reset (blue), Uncouple (green), Prevent coupling (yellow), Wake Up (grey)]

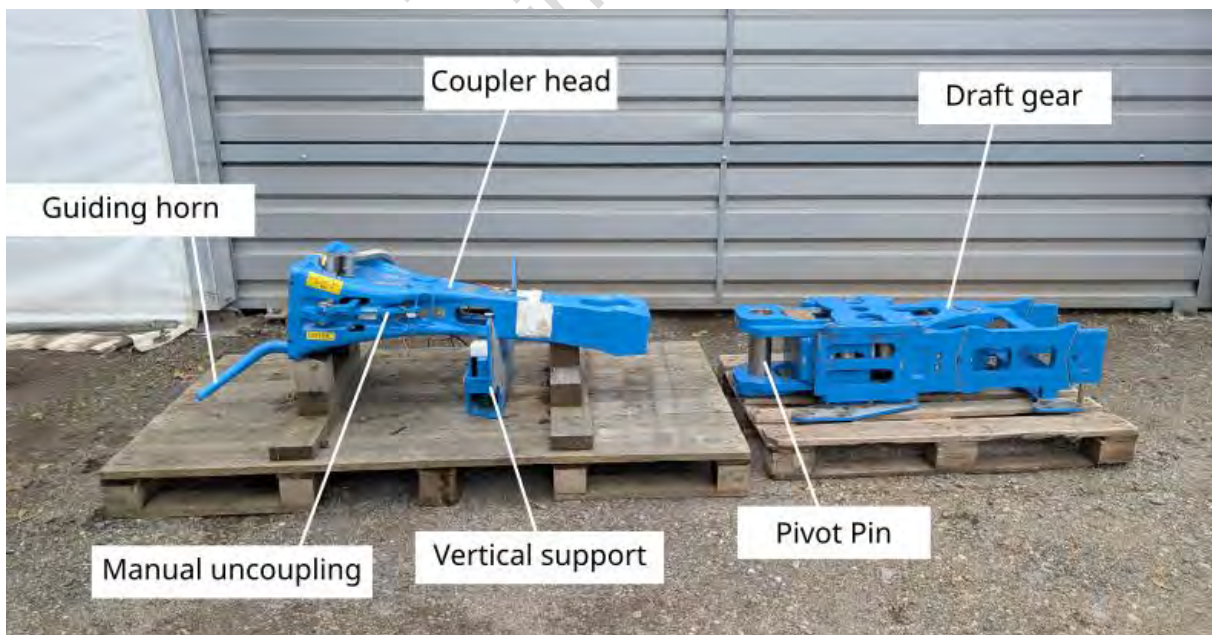


Figure 19: Dellner – Overview of coupler parts – side view.

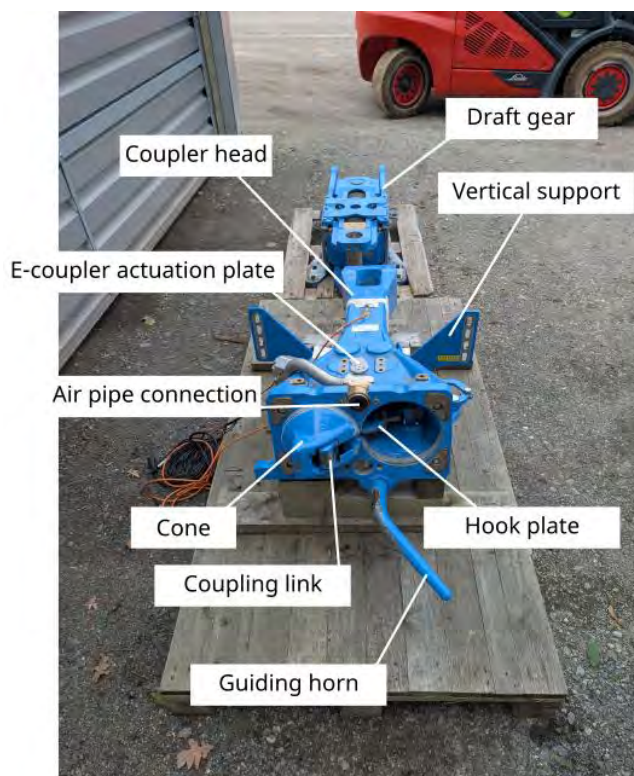


Figure 20: Dellner - Overview of coupler parts - front view.

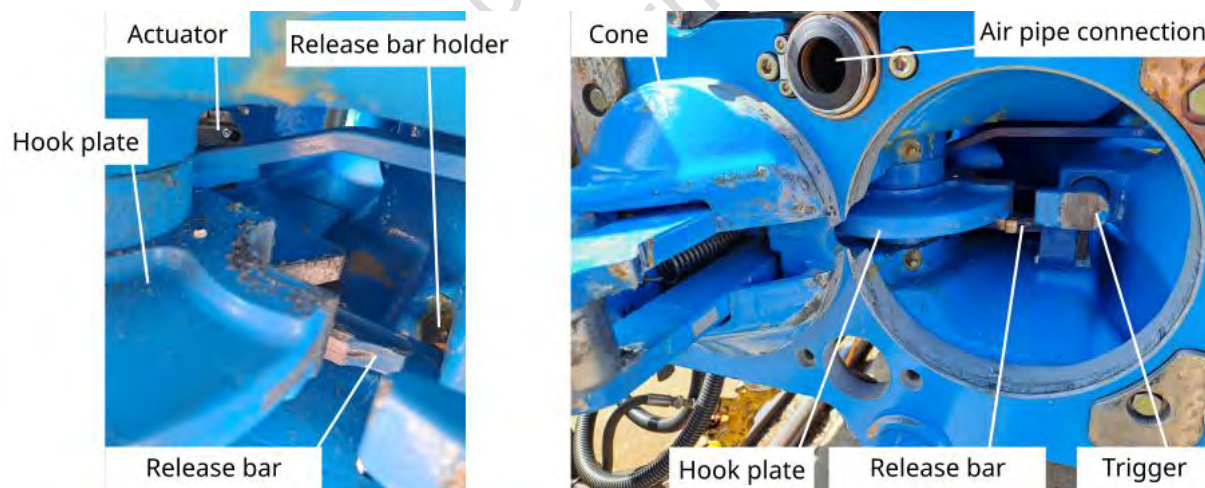


Figure 21: Dellner - Overview of the coupler head.

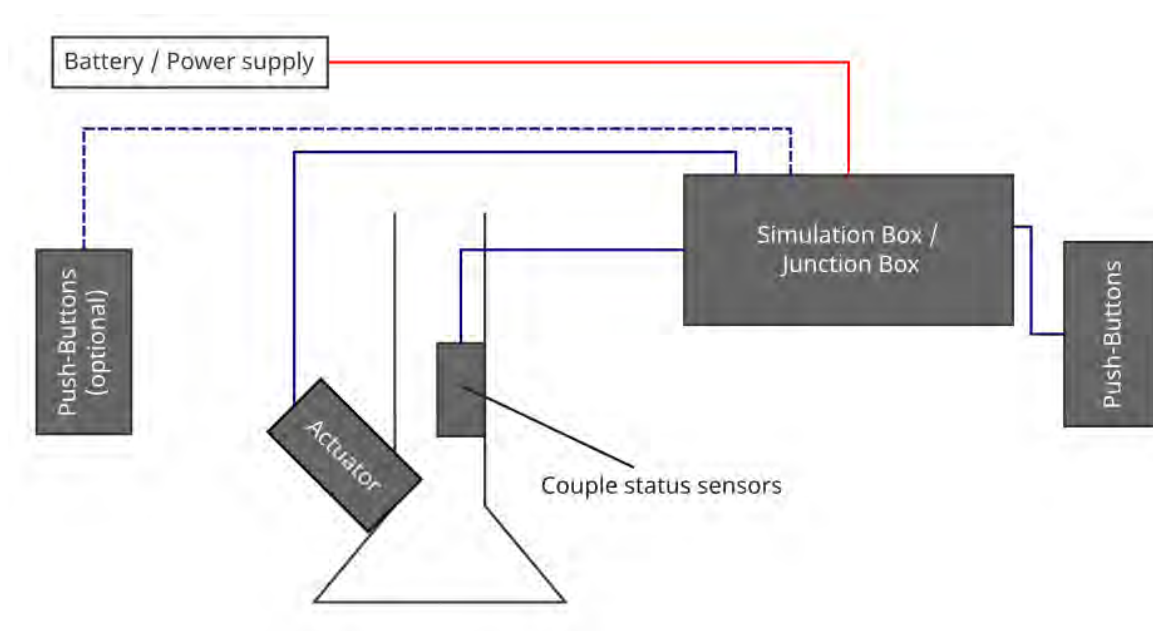


Figure 22: Dellner – Scheme of electronic system.

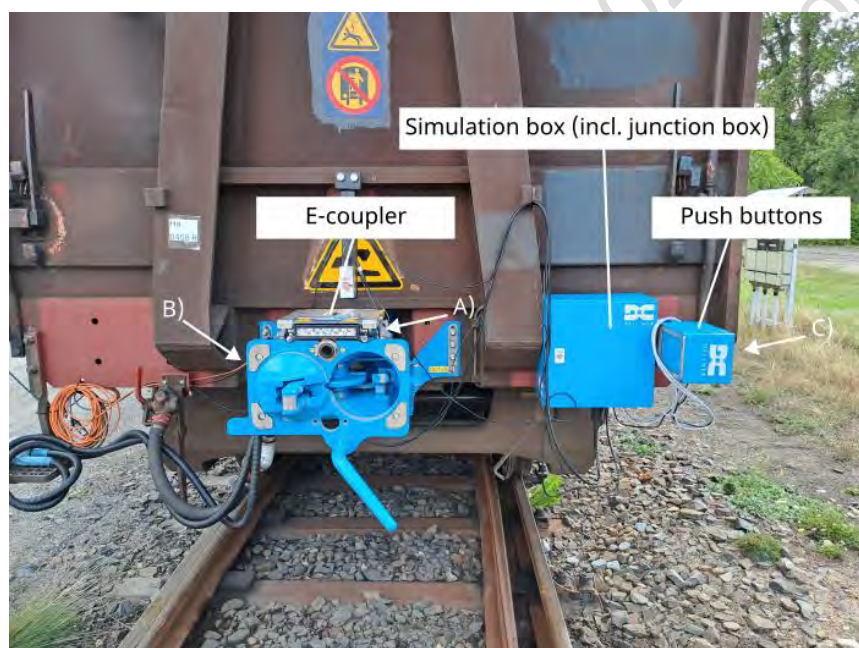


Figure 23: Dellner - Overview of electronic system.

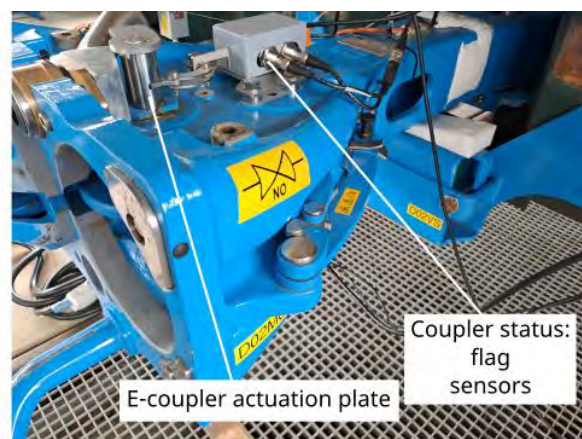
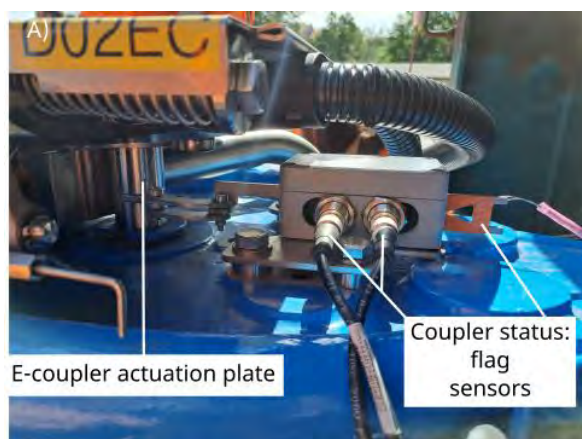


Figure 24: Dellner - Electronic system, View A).

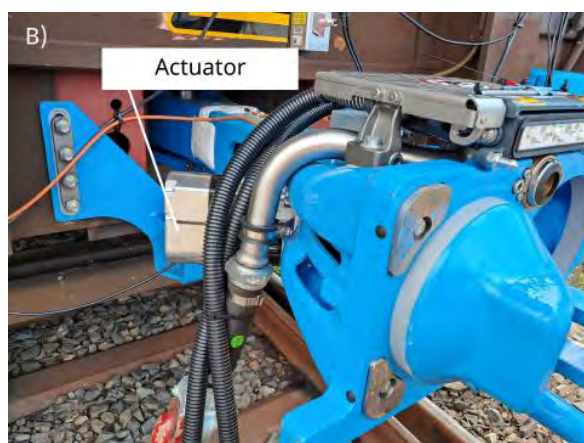


Figure 25: Dellner - Electronic System, View B) and C).

3.3.1.2 DC01

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
22.07.2025	#001	Initial state (Installation at HVLE, Berlin-Spandau previously)	<u>Draft Gear:</u> TTL-ID: D01DG S/N: 008 <u>Coupler Head:</u> TTL-ID: D01MC S/N: 008 Remark: DMS installed. <u>Vertical Support:</u> TTL-ID: D01VS S/N: 008	Ha_0458, side B
24.07.2025	#002	E-coupler installation	<u>E-coupler:</u> TTL-ID: D01EC	Ha_0458, side B
28.07.2025	#003	Different adjustments	<u>Electronics:</u> - Change of coupler status flag - Readjustment of couple-status sensors - Reset of actuator via software <u>E-coupler:</u> De- and remount of e-coupler	Ha_0458, side B
30.07.2025	#004	Deinstallation of coupler status flag	<u>Electronics:</u> Deinstallation of coupler status flag	Ha_0458, side B
30.07.2025	#005	E-coupler demounted	<u>E-coupler:</u> Demounted	Ha_0458, side B
04.08.2025	#006	E-coupler installation	<u>E-coupler:</u> TTL-ID: D01EC	Ha_0458, side B
07.08.2025	#007	Deinstallation		

3.3.1.3 DC02

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
22.07.2025	#001	Initial state (Installation at HVLE, Berlin-Spandau, previously)	<u>Draft Gear:</u> TTL-ID: D02DG S/N: 009 <u>Coupler Head:</u> TTL-ID: D02MC S/N: 009 Remark: DMS installed. <u>Vertical Support:</u> TTL-ID: D02VS S/N: 009	Hb_3581, side A
24.07.2025	#002	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3581, side A
28.07.2025	#003	Actuator changed	<u>Electronics:</u> - Change of actuator - Readjustment of couple status sensors	Hb_3581, side A
29.07.2025	#004	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3581, side A
04.08.2025	#005	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3581, side A
04.08.2025	#006	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3581, side A
06.08.2025	#007	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3581, side A
07.08.2025	#008	Actuator changed	<u>Electronics:</u> Change of actuator	Hb_3581, side A
07.08.2025	#009	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3581, side A
08.08.2025	#010	Actuator deinstalled	<u>Electronics:</u> Actuator deinstalled	Hb_3581, side A
12.08.2025	#011	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3581, side A
13.08.2025	#012	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3581, side A

3.3.1.4 DC03

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
22.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: D03DG S/N: 007 <u>Coupler Head:</u> TTL-ID: D03MC S/N: 007 <u>Vertical Support:</u> TTL-ID: D03VS S/N: 007 Remark: New holes for the connection to the wagon had to be drilled. See chapter 3.2.4.	Hb_3472, side A
24.07.2025	#002	E-coupler installation	<u>E-coupler:</u> TTL_ID: D01EC	Hb_3472, side A
24.07.2025	#003	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3472, side A
31.07.2025	#004	E-coupler installation	<u>E-coupler:</u> TTL_ID: D01EC	Hb_3472, side A
01.08.2025	#005	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3472, side A

3.3.2 Faiveley / Wabtec

3.3.2.1 Overview of the coupler

Part	Type
Draft Gear	730-02045 ("leading noses" not machined / original ¹⁾)
Coupler Head	730-02067
Vertical support	730-02046

¹⁾ After the tests Faiveley decided to machine the leading noses of their draft gears for further tests planned in the project. It is not planned to give them a new batch number. The tests described in this report were executed with the original draft gears with un-machined leading noses.

The coupler of Faiveley / Wabtec is shown in the following figures.

The mechanical coupler consists of:

- Draft gear (one cage)
- Vertical support
- Coupler head (with manual uncoupling)

Faiveley did not provide an electrical system.

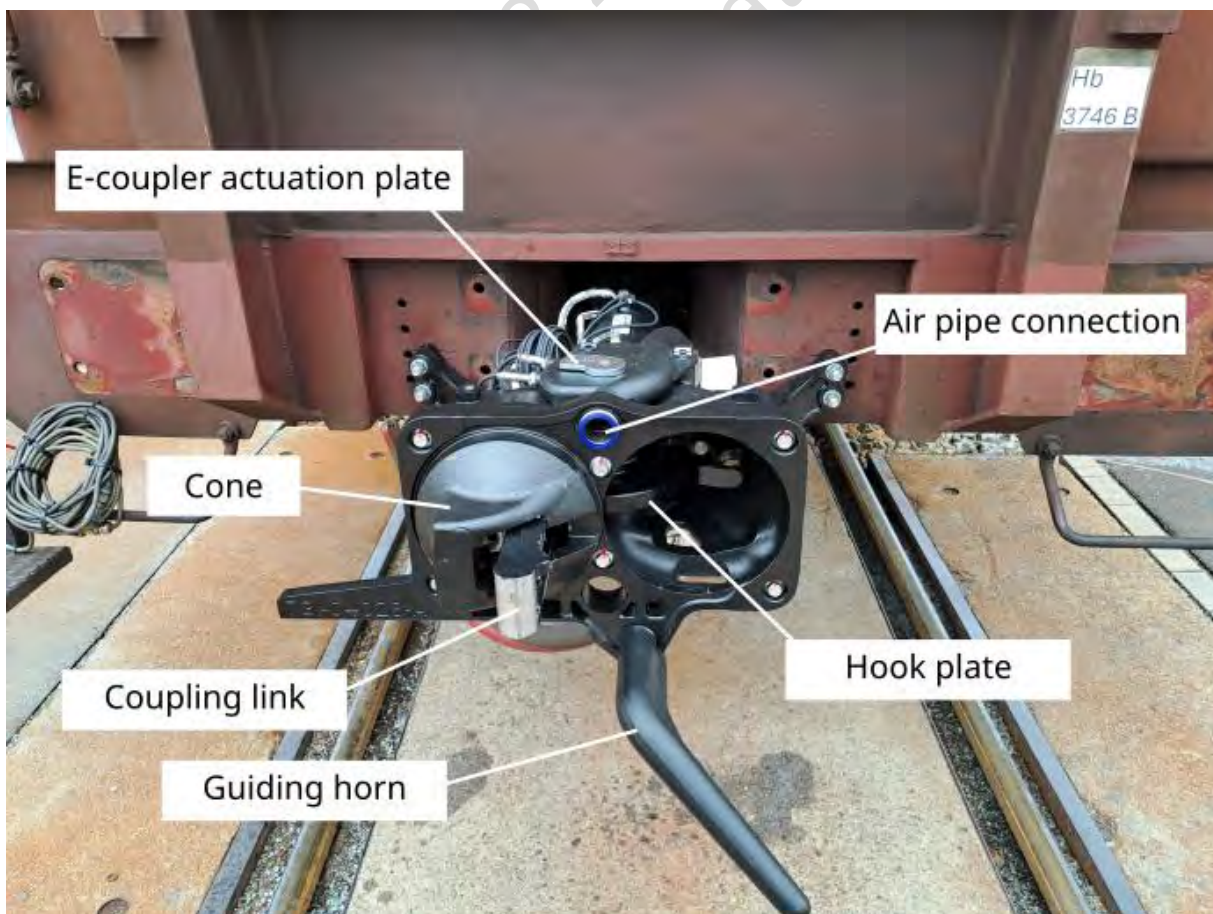


Figure 26: Faiveley - Overview of coupler head - front view.

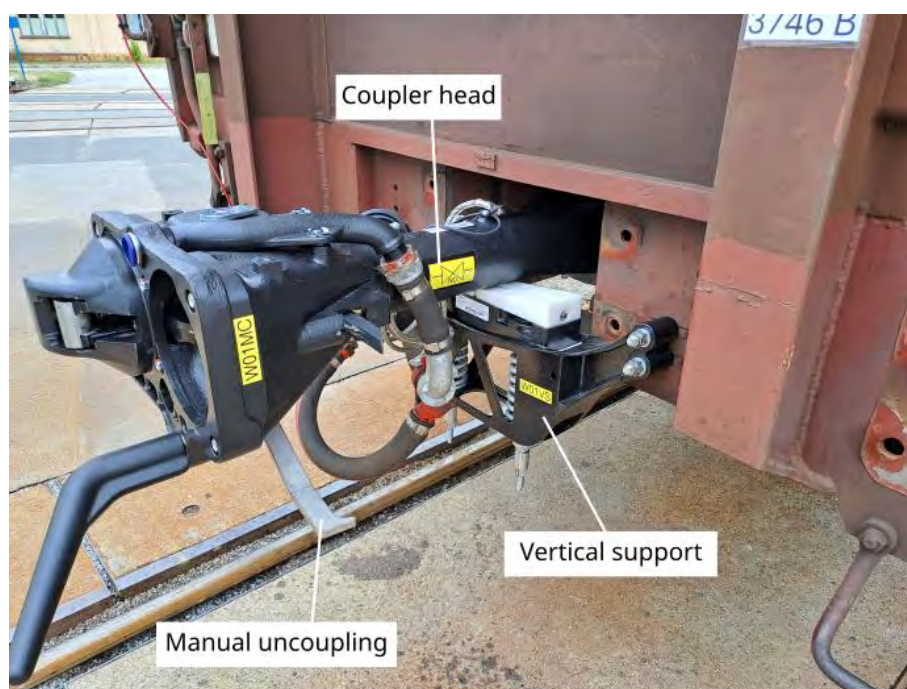


Figure 27: Faiveley - Overview of coupler head - side view.

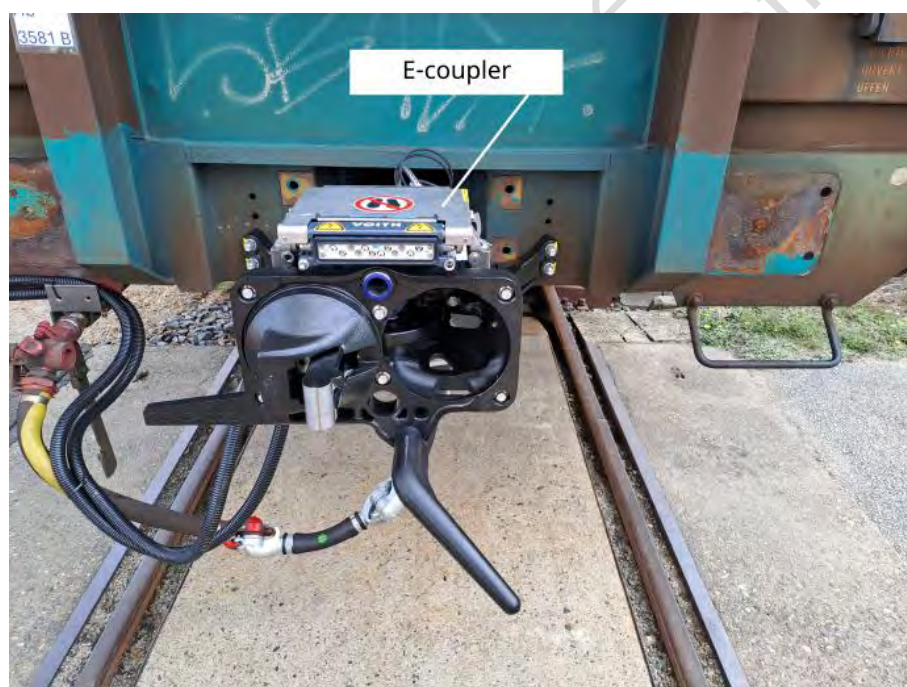


Figure 28: Faiveley - Coupler with installed e-coupler.



Figure 29: Faiveley - Images of draft gear (top - installed).



Figure 30: Faiveley - Vertical support.

A speciality of the Faiveley coupler is the so called “Wabtec Position (WP)”. The goal of the Wabtec position is to provide a third coupler state which will be by default always reached when uncoupling (if the ready-to-couple position is not reached) and with which it is still possible to couple under most circumstances.

The position is enabled by a further notch on the housing for the release bar to catch onto, making it possible to fix the hook plate and coupling link in a position very near the ready-to-couple position.

Further information on the Wabtec position is provided in the following figures.

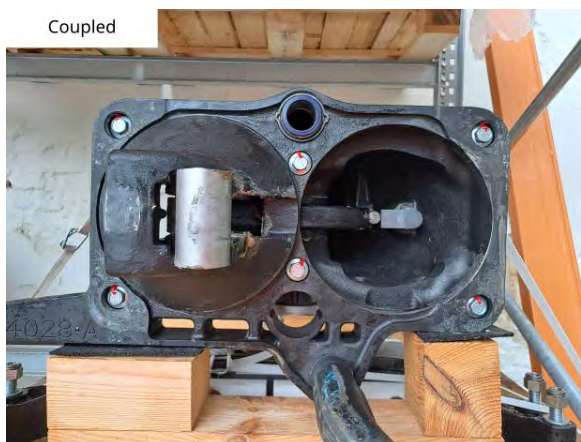


Figure 31: Faiveley - Wabtec position - Coupled status.

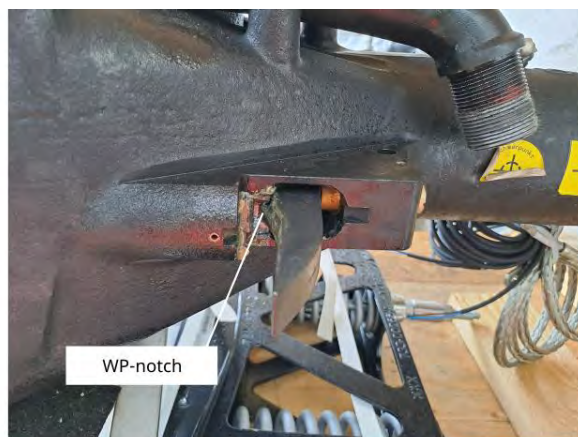


Figure 32: Faiveley - Wabtec position - Wabtec position status.

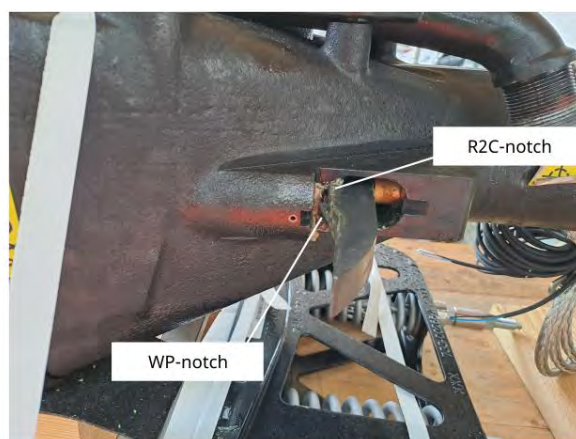
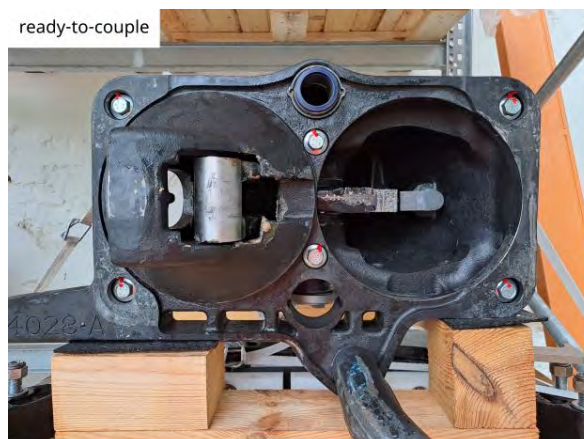


Figure 33: Faiveley - Wabtec position - ready-to-couple status.

3.3.2.2 FT01

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
29.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: W01DG S/N: BS38379 <u>Coupler Head:</u> TTL-ID: W01MC S/N: BS38419 Remark: The brake pipe was not relocated and not fixed on the wagon end. See chapter 3.2.6. <u>Vertical Support:</u> TTL-ID: W01VS S/N: BS33222 Remark: New holes for the connection to the wagon had to be drilled. See chapter 3.2.6. <u>E-coupler:</u> TTL-ID: D02EC	Hb_3746, side B
29.07.2025	#002	Air pipe readjustment	<u>Coupler Head:</u> Broken air pipe screwing. Reattachment of air hose.	Hb_3746, side B
30.07.2025	#003	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3746, side B
31.07.2025	#004	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3746, side B
01.08.2025	#005	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3746, side B
06.08.2025	#006	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3746, side B
06.08.2025	#007	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3746, side B
07.08.2025	#008	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3746, side B
07.08.2025	#009	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3746, side B
12.08.2025	#010	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3746, side B
12.08.2025	#011	Change of draft gear	<u>Old Draft Gear:</u> Leading noses broken away <u>New Draft Gear:</u> TTL-ID: W04DG S/N: BS38377 <u>E-coupler:</u> Demounted	Hb_3746, side B
13.08.2025	#012	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3746, side B
13.08.2025	#013	Damages on draft gear	<u>Draft Gear:</u> Leading noses broken away	Hb_3746, side B
13.08.2025	#014	Deinstallation		

3.3.2.3 FT02

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
29.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: W02DG S/N: BS38380 <u>Coupler Head:</u> TTL-ID: W02MC S/N: BS38418 <u>Vertical Support:</u> TTL-ID: W02VS S/N: BS33219	Hb_3581, side B
30.07.2025	#002	E-coupler installation	<u>E-coupler:</u> TTL-ID: D01EC	Hb_3581, side B
31.07.2025	#003	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3581, side B
31.07.2025	#004	E-coupler installation	<u>E-coupler:</u> TTL-ID: D01EC	Hb_3581, side B
31.07.2025	#005	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3581, side B

3.3.2.4 FT03

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
08.08.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: W03DG S/N: BS38378 <u>Coupler Head:</u> TTL-ID: W03MC S/N: BS38421 <u>Vertical Support:</u> TTL-ID: W03VS S/N: BS33220 <u>E-coupler:</u> TTL-ID: D01EC	Ha_0136, side A
13.08.2025	#002	Damages on draft gear	<u>Draft Gear:</u> Leading noses broken away	Ha_0136, side A
13.08.2025	#003	Deinstallation		

3.3.3 Knorr-Bremse

3.3.3.1 Overview of the coupler

Part	Type
Draft Gear	04061272585004 / KP5311349-3MX
Coupler Head	04061272580221 / KP6948598-1MX
Vertical support	04061272577825 / KP1835697-1MX

The coupler of Knorr-Bremse is shown in the following figures.

The mechanical coupler consists of:

- Draft gear with damper kit (in one cage)
- Vertical support
- Coupler head (with manual uncoupling)

The electronic system consists of:

- Actuator mounted inside the coupler
- (Couple status sensors - not connected to the electric system during the tests)
- Actuation plate for the e-coupler
- Simulation box (containing the junction box)
- Push buttons (both sides needed for a functioning system) [Buttons: uncouple (blue), prevent coupling (white), green button without function]
- (Synchronization signal over the e-coupler - not connected correctly during the tests)

Remarks:

- The synchronization signal was planned but could not be installed correctly by Knorr-Bremse prior to the tests. The tests were executed without a functioning synchronization signal.

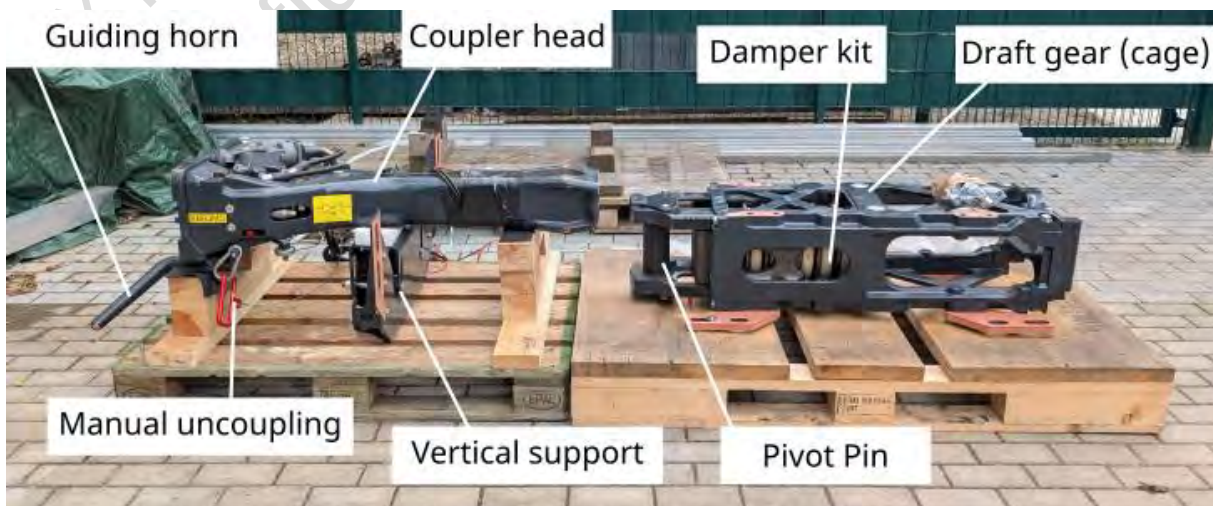


Figure 34: Knorr-Bremse - Overview of coupler parts - side view.

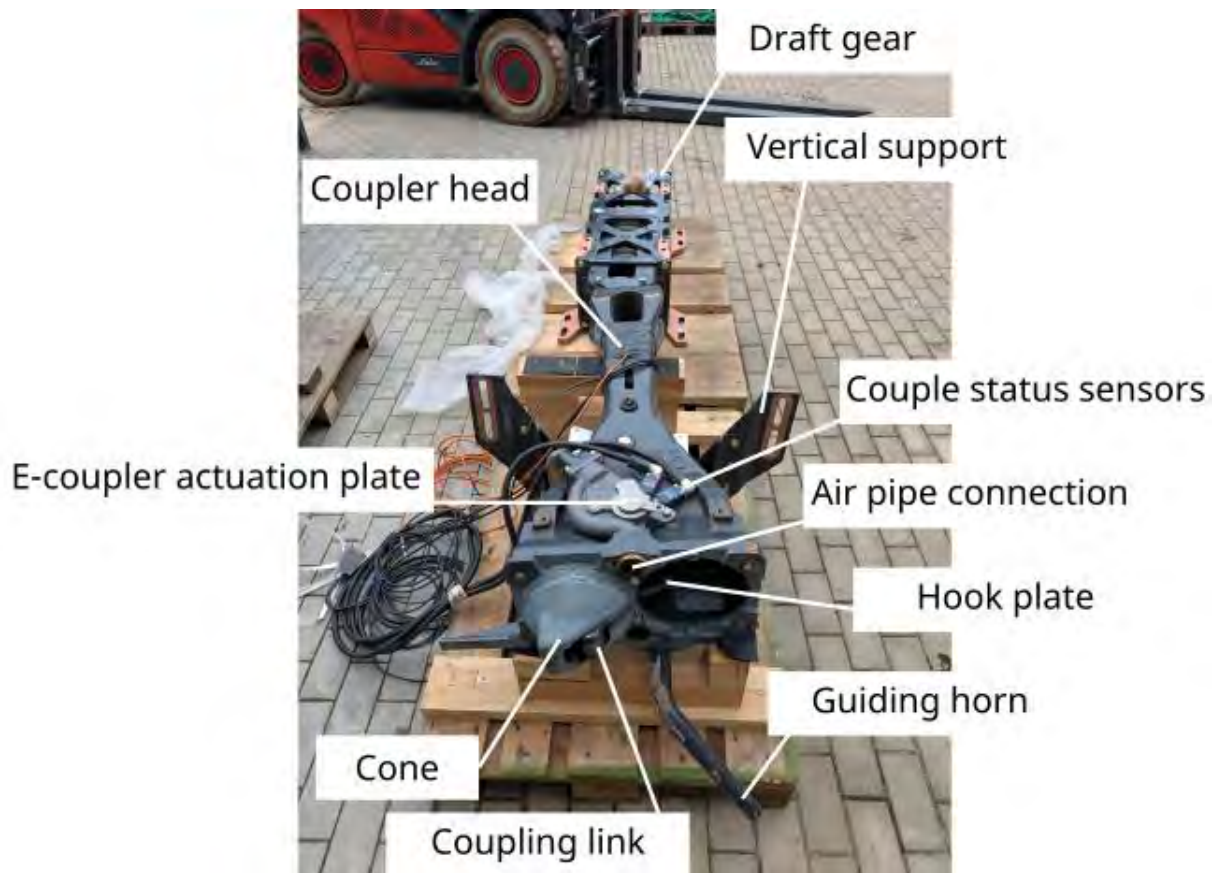


Figure 35: Knorr-Bremse - Overview of coupler parts - front view.

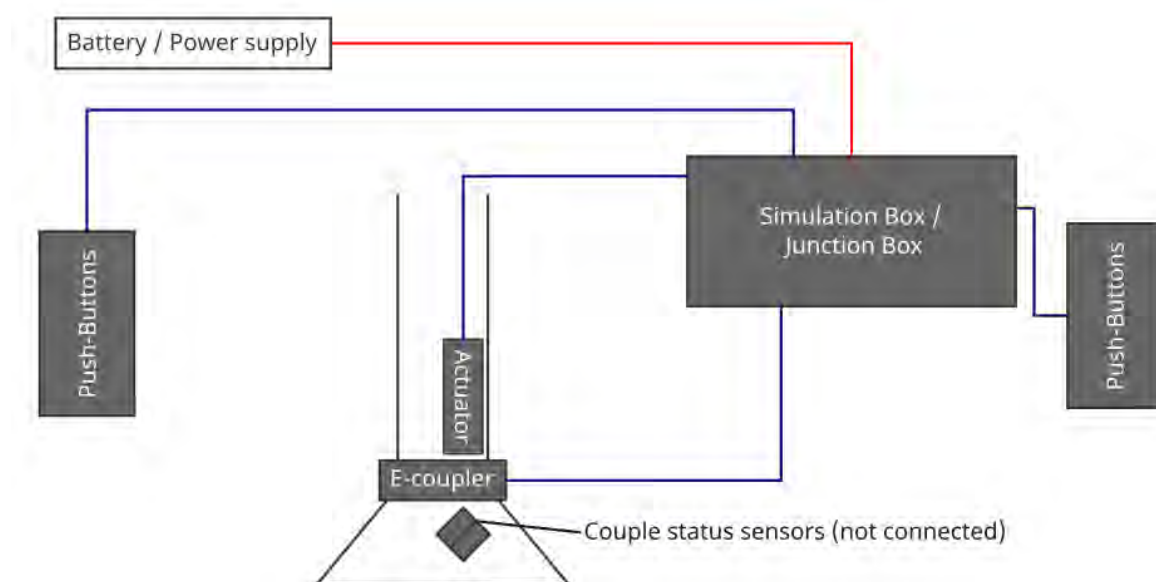


Figure 36: Knorr-Bremse – Scheme of electronic system.

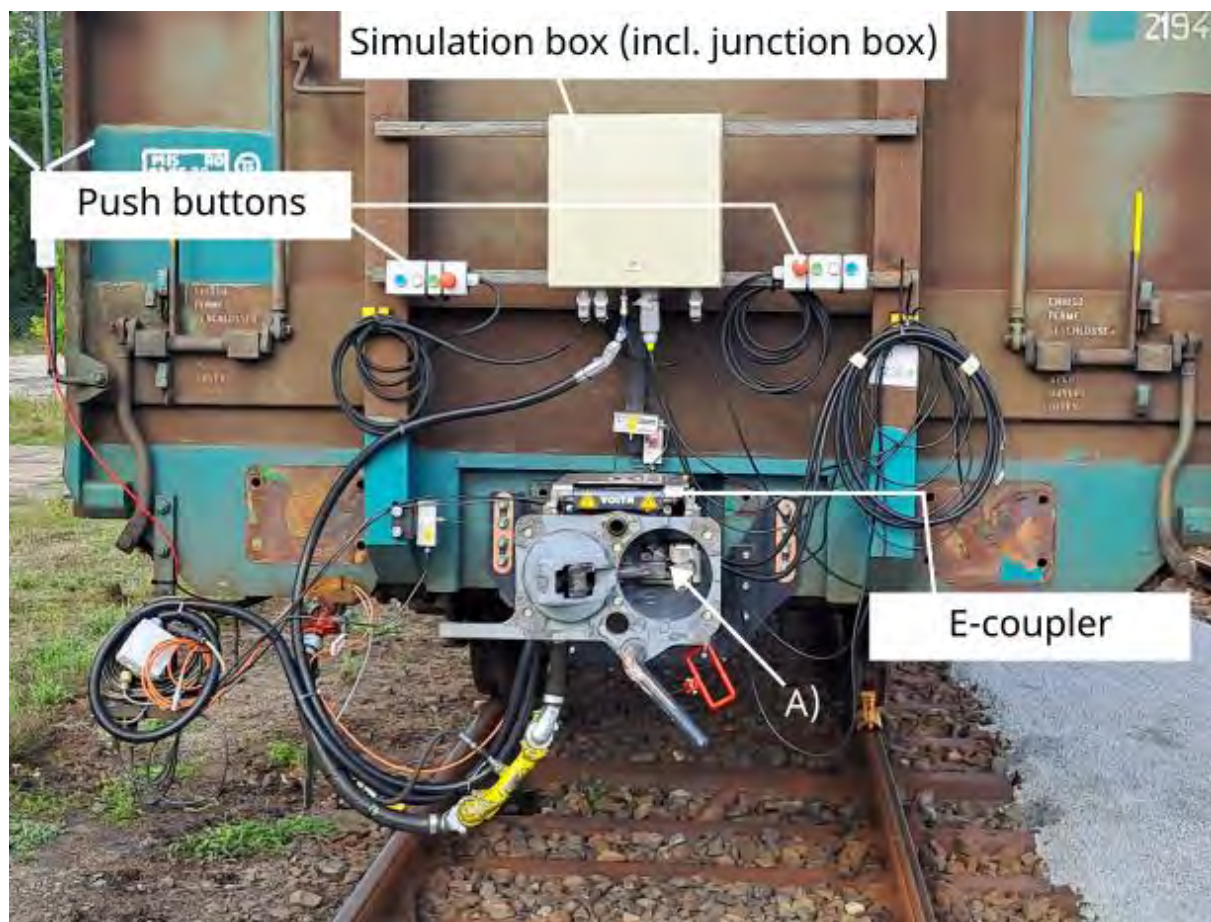


Figure 37: Knorr-Bremse - Overview of electronic system.

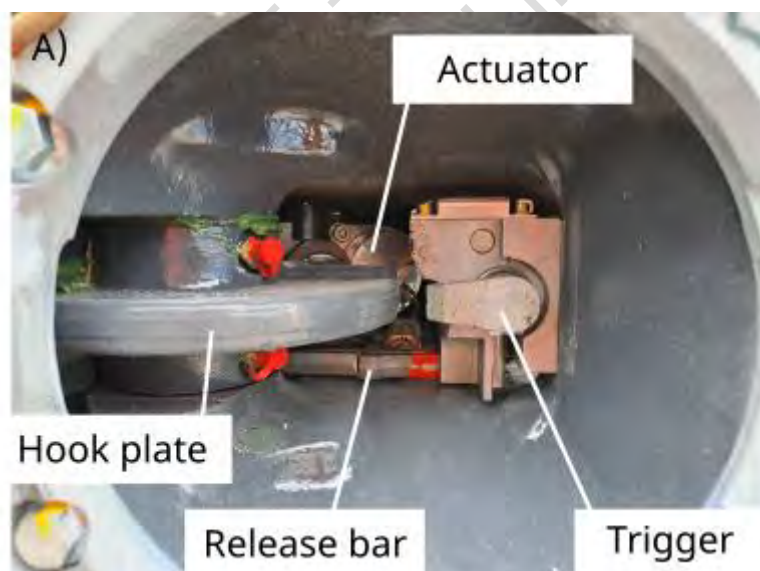


Figure 38: Knorr-Bremse - Overview of the coupler head.

3.3.3.2 KB01

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
22.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: K01DG S/N: <u>Coupler Head:</u> TTL-ID: K01MC S/N: 3525160003 Remark: DMS installed. <u>Vertical Support:</u> TTL-ID: B01VS S/N: 3525160023 <u>E-coupler:</u> TTL-ID: D02EC	Hb_3235, side A
24.07.2025	#002	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3235, side A
31.07.2025	#003	E-coupler installed	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3235, side A
31.07.2025	#004	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3235, side A
04.08.2025	#005	E-coupler installed	<u>E-coupler:</u> TTL-ID: K01EC	Hb_3235, side A
06.08.2025	#006	Adjustment of synchronization signal connection	<u>Electronics:</u> Adjustment of connection of cables for synchronization signal.	Hb_3235, side A

3.3.3.3 KB02

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
22.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: K02DG S/N: <u>Coupler Head:</u> TTL-ID: K02MC S/N: 3525150006 <u>Vertical Support:</u> TTL-ID: K02VS S/N: 3525160014 Remark: New holes for the connection to the wagon had to be drilled. See chapter 3.2.6. <u>E-coupler:</u> TTL-ID: D01EC	Hb_3746, side A
23.07.2025	#002	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3746, side A
31.07.2025	#003	E-coupler installation	<u>E-coupler:</u> TTL-ID: D01EC	Hb_3746, side A
31.07.2025	#004	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3746, side A

3.3.3.4 KB03

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
22.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: K03DG S/N: 3525160007 <u>Coupler Head:</u> TTL-ID: K03MC S/N: 3525160004 Remark: DMS installed. <u>Vertical Support:</u> TTL-ID: K03VS S/N: 3525160020 <u>E-coupler:</u> TTL-ID: K03EC	Ha_0136, side A
05.08.2025		(Installation at TÜV Süd Rail, Görlitz)		
06.08.2025	#002	Adjustment of synchronization signal connection	<u>Electronics:</u> Adjustment of connection of cables for synchronization signal.	Ha_0136, side A
08.08.2025	#003	Deinstallation		

3.3.4 Voith

3.3.4.1 Overview of the coupler

Part	Type
Draft Gear	FN-RP2-01.00.00
Compression force stop	FN-RP-KS-00.01.00
Mounting plate	FN-RP-KS-00.02.00
Coupler Head	230.104399-001
Vertical support	230.054751-001

The coupler of Voith is shown in the following figures.

The mechanical coupler consists of:

- Draft gear and compression force stop with mounting plates
- Vertical support
- Coupler head (with manual uncoupling and couple status indicator [flag])

The electronic system consists of:

- Actuator mounted inside the coupler
- Couple status sensor
- Actuation plate for the e-coupler
- Simulation box
- Junction box
- Push buttons [Buttons: Uncouple (green), Prevent coupling (yellow)]

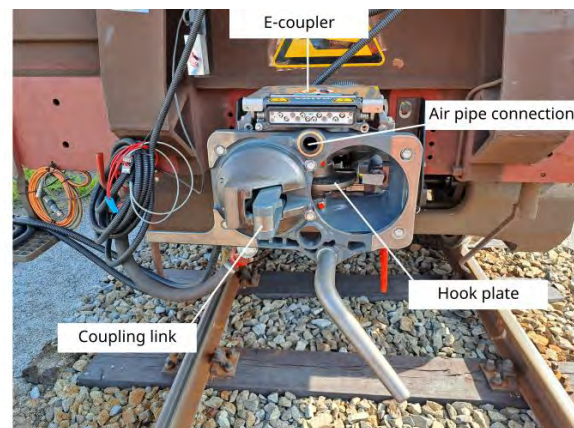
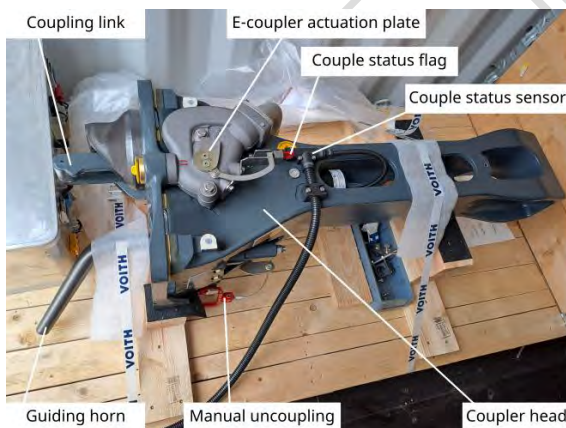


Figure 39: Voith - Overview coupler head.



Figure 40: Voith - Details of coupler head.

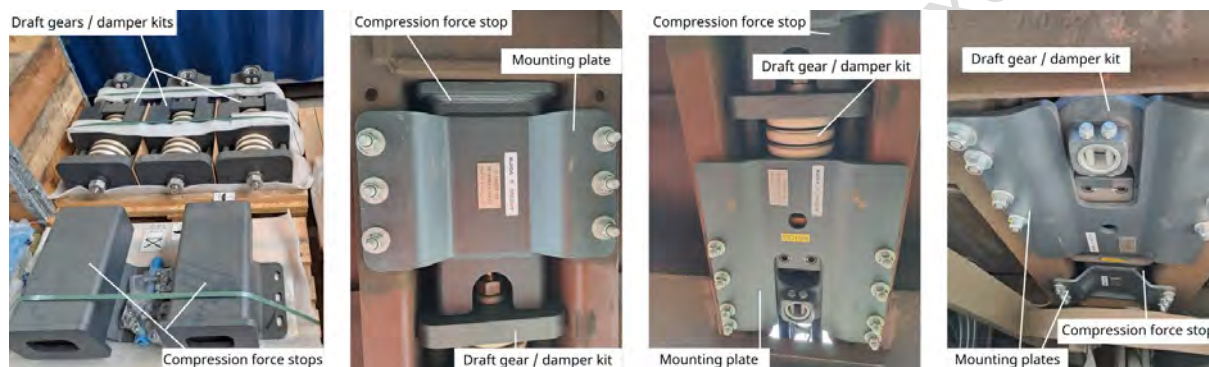


Figure 41: Voith - Overview of draft gear.

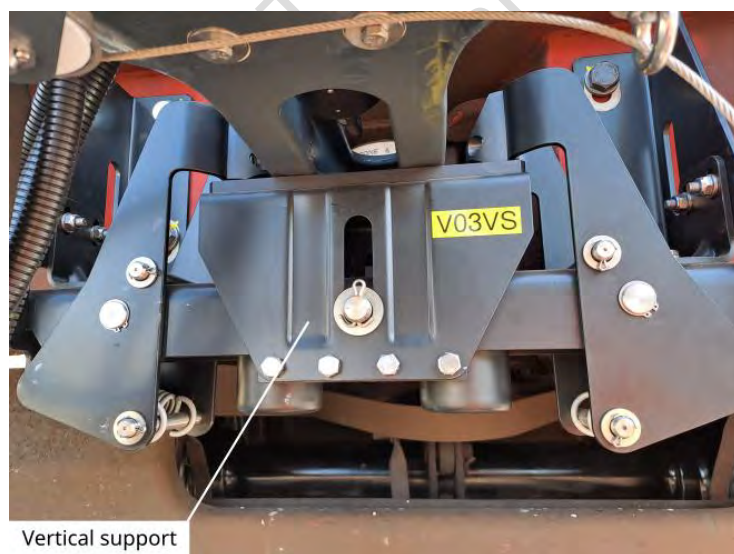


Figure 42: Voith - Vertical support.

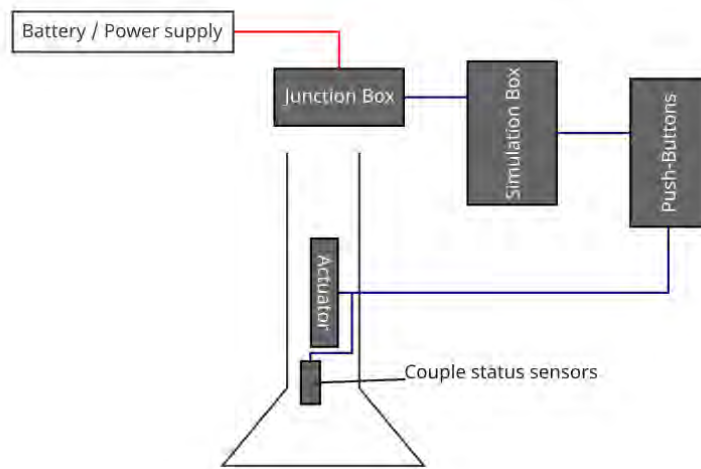


Figure 43: Voith - Scheme of electronic system.



Figure 44: Voith - Overview of electronic system.

3.3.4.2 VT01

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
30.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: V01DG S/N Draft Gear: 24/45386/01 S/N Comp. force stop: 24/45390/12 S/N Mounting plate: 24/45391/11 <u>Coupler Head:</u> TTL-ID: V01MC S/N: 1000028658 <u>Vertical Support:</u> TTL-ID: V01VS S/N: 100000103 <u>E-coupler:</u> TTL-ID: D02EC	Hb_3472, side B
31.07.2025	#002	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3472, side B
04.08.2025	#003	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3472, side B
06.08.2025	#004	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3472, side B
07.08.2025	#005	E-coupler installation	<u>E-coupler:</u> TTL-ID: D02EC	Hb_3472, side B
08.08.2025	#006	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3472, side B

3.3.4.3 VT02

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
31.07.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: V01DG S/N Draft Gear: 24/45386/18 S/N Comp. force stop: 24/45390/11 S/N Mounting plate: 24/45391/16 <u>Coupler Head:</u> TTL-ID: V01MC S/N: 1000028656 <u>Vertical Support:</u> TTL-ID: V01VS S/N: 100000098 <u>E-coupler:</u> TTL-ID: D01EC	Hb_3235, side B
31.07.2025	#002	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3235, side B
04.08.2025	#003	E-coupler installation	<u>E-coupler:</u> TTL-ID: D01EC	Hb_3235, side B
04.08.2025	#004	E-coupler demounted	<u>E-coupler:</u> Demounted	Hb_3235, side B

3.3.4.4 VT03

Configurations:

Date	Config.	Description	Parts / Serial Numbers	Wagon
07.08.2025	#001	Initial state (Installation at TÜV Süd Rail, Görlitz)	<u>Draft Gear:</u> TTL-ID: V03DG S/N Draft Gear: 24/47154/16 S/N Comp. force stop: 24/45390/16 S/N Mounting plate: 24/45391/17 <u>Coupler Head:</u> TTL-ID: V03MC S/N: 1000028657 <u>Vertical Support:</u> TTL-ID: V03VS S/N: 100000106 <u>E-coupler:</u> TTL-ID: D01EC	Ha_0458, side B
08.08.2025	#002	E-coupler demounted	<u>E-coupler:</u> Demounted	Ha_0458, side B

3.3.5 E-couplers

The e-couplers for the executed tests were supplied by Voith. In total 16 e-couplers were delivered (four per supplier). As the e-couplers were delivered with plugs, these had to be modified to be attached to the measurement system (see Annex 1 and 2). One set of e-couplers were modified for the suppliers that did not provide a synchronization signal and therefore did not need to connect their simulation box to the e-coupler (Dellner, Faiveley, Voith): D01EC and D02EC.

As Knorr-Bremse planned to supply a synchronization signal and therefore had to connect their system to the e-coupler, a further set of e-couplers were prepared specifically for Knorr-Bremse: K01EC and K03EC.

In the following chapters the e-couplers are described.

3.3.5.1 Overview of the e-couplers

The delivered e-couplers are of type 230.103701-001 and described in detail in [VT_SK0.7773], chapter 3.4.4. They are mounted on top of the coupler head and are supplied with a moving lid that opens when coupling.

In ready-to-couple position the e-coupler is pulled back by a plate which is connected to the hook plate of the coupler. The lid is closed and protects the e-coupler from dust, water, mechanical damage and prevents inadvertent contact.

When two couplers are coupling, the plate releases the e-coupler, which is then moved in the direction of the coupling point by springs. The lid opens and a centration is done by centration pins.

The e-couplers were delivered with a contact block with mounting-holes for 12 pins, of which 8 pins were attached (4 data-pins and 4 power-pins). The sets of power-pins and data-pins were each connected to a plug of the manufacturer Harting.



Figure 45: E-coupler overview.

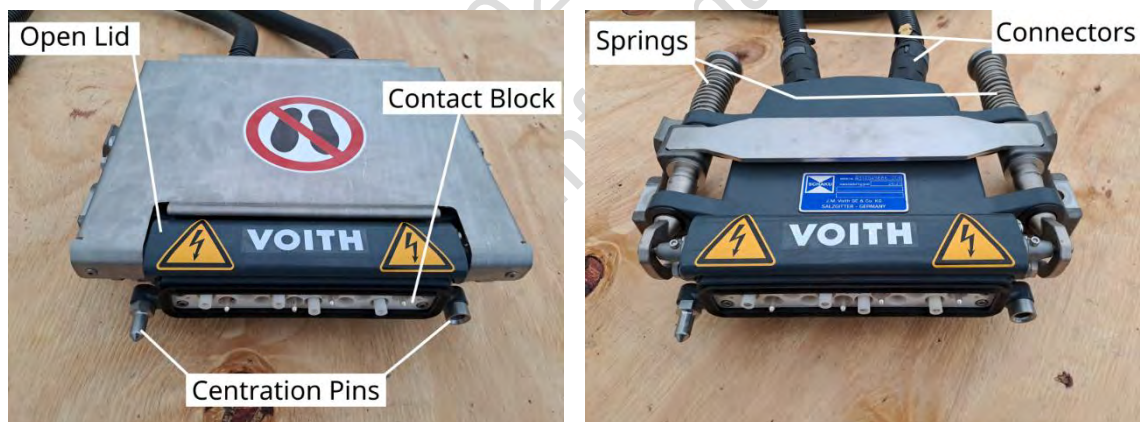


Figure 46: E-coupler top-view. Right side: Cover demounted.

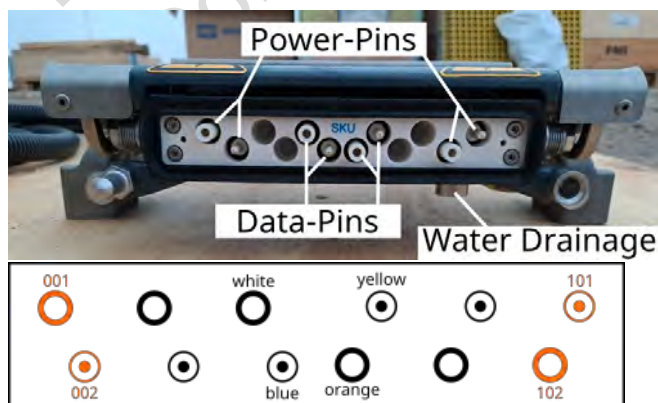


Figure 47: E-coupler front view with pin setup below. Orange: power-pins, black: data-pins.

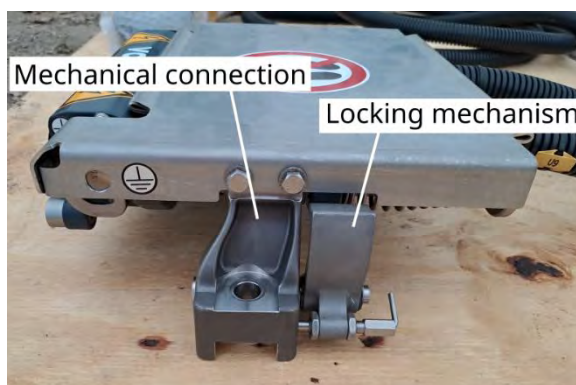
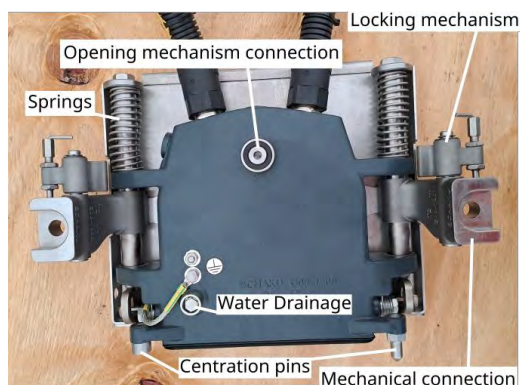


Figure 48: E-coupler bottom and side view.

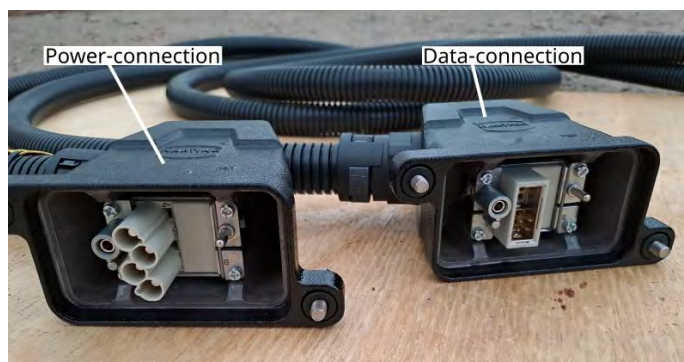


Figure 49: E-coupler Harting connectors.



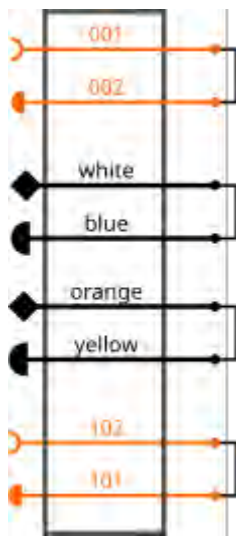
Figure 50: E-coupler connections on the coupler head. Exemplary with Voith coupler head.

3.3.5.2 D01EC

This e-coupler (S/N: 4510049886-005) was modified to enable a throughput measurement with the measurement system (see also Annex 1 and 2). Therefore, the plugs were disconnected, and the cables were connected inside a waterproof box regarding Figure 51, a.).

From the 05.08.2025 (T285) onwards the coupler had to also be coupled with K01EC and K03EC. Therefore, the cables were reconnected regarding Figure 51, b.):

a.)



b.)

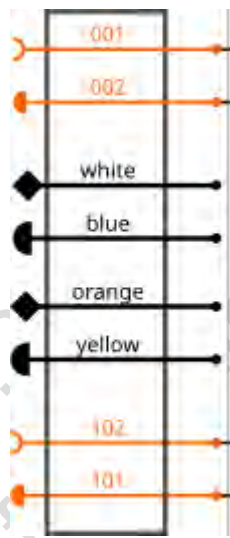


Figure 51: D01EC - Wiring. a.) wiring over all pins. b.) wiring over power-pins to enable measurement with synchronization signal.

Furthermore, the e-coupler housing had to be modified to fit the Dellner couplers. To allow this, the following adjustments were done:

- Demounting of the water drainage and sealing by tape
- Demounting of locking mechanism (left side, front view)

3.3.5.3 D02EC

This e-coupler (S/N: 4510049886-003) was modified to enable a connection to the measurement system (see also Annex 1 and 2). Therefore, the plugs were disconnected, and the cables were connected inside a waterproof box the following way:

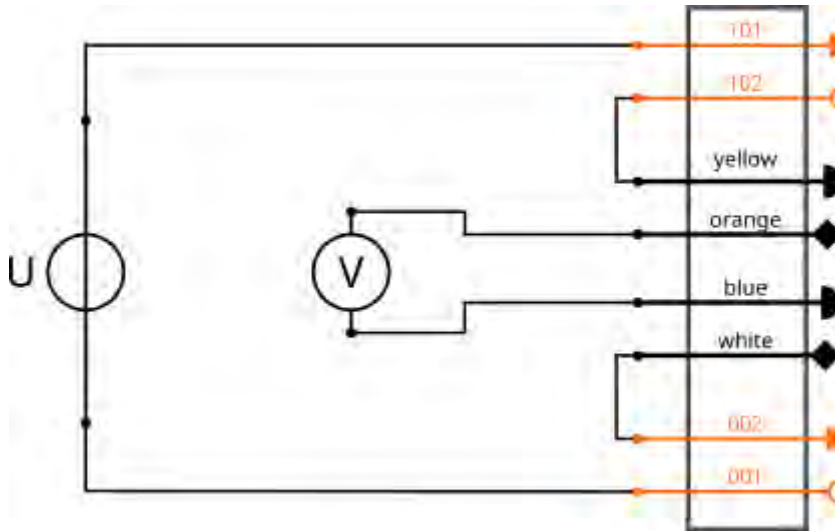


Figure 52: D02EC - wiring over all pins.



Figure 53: D02EC - wiring box.

From the 05.08.2025 (T285) onwards the coupler had to also be coupled with K01EC and K03EC. Therefore, the cables were reconnected the following way:

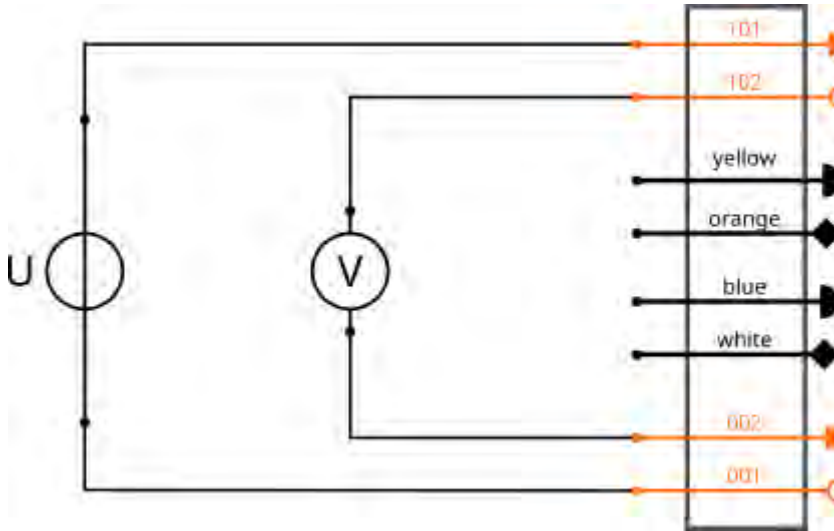


Figure 54: D02EC - wiring over power-pins.

Furthermore, the e-coupler housing had to be modified to fit the Dellner couplers. To allow this, the following adjustments were done:

- Demounting of the water drainage and sealing by tape
- Demounting of locking mechanism (left side, front-view)

3.3.5.4 K01EC

This e-coupler (S/N: 4510049886-006) was modified specifically for Knorr-Bremse couplers, as the synchronization signal was connected to the data-pins. To enable this, the plugs were disconnected.

Two pins of the data-lines were used for the connection of the synchronization signal.

The power-line pins were used to connect the measurement system (see also Annex 1 and 2). They were wired inside a waterproof box.

The wiring was done the following way:

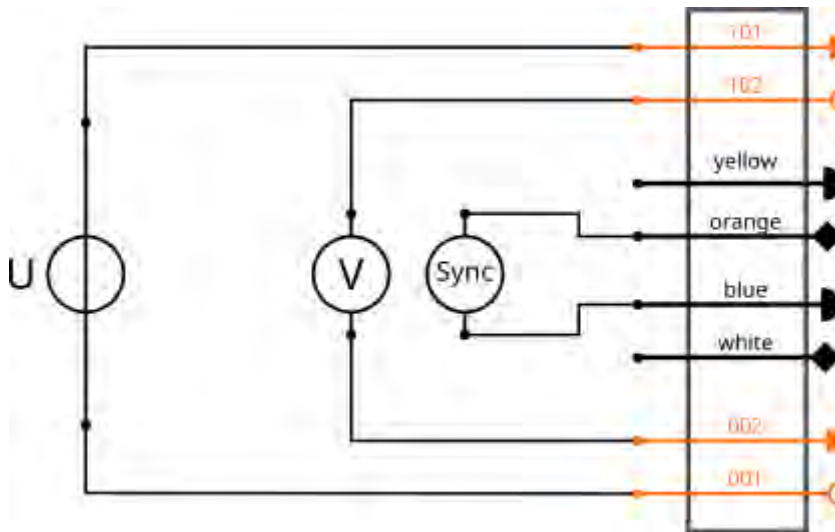


Figure 55: K01EC - wiring.



Figure 56: K01EC - Left: wiring box, Right: KB-plug for synchronization signal.

3.3.5.5 K03EC

This e-coupler (S/N:) was modified specifically for Knorr-Bremse couplers, as the synchronization signal was connected to the data-pins. To enable this, the plugs were disconnected.

Two pins of the data-lines were used for the connection of the synchronization signal.

The power-line pins were used to enable a throughput measurement with the measurement system (see also Annex 1 and 2). They were wired inside a waterproof box.

The wiring was done the following way:

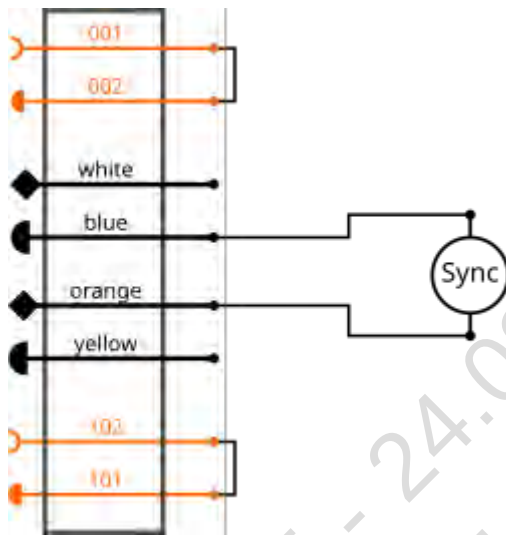


Figure 57: K03EC - wiring.

4 Test schedule

Date	Location	Action	from Test-Nr.
03.06.2025	HVLE, Berlin-Spandau	Delivery couplers Dellner	-
25.06.2025	HVLE, Berlin-Spandau	Delivery couplers Knorr-Bremse	
02.07.2025 to 11.07.2025	HVLE, Berlin-Spandau	Installation and calibration of DMS on DC01, DC02, KB01 and KB03 at the DBST, Minden. Installation of couplers and measurement equipment. Installed couplers: DC01, DC02 Loading of wagons.	-
14.07.2025	HVLE, Berlin-Spandau to TÜV Süd Rail, Görlitz	Transfer of wagons	-
15.07.2025 to 22.07.2025	TÜV Süd Rail, Görlitz	Preparation of wagons and measurement systems. Electro installation Dellner. Installation of coupler: DC03, KB01, KB02, KB03 21.07.2025: Delivery e-couplers. Delivery couplers Faiveley / Wabtec (except coupler head).	-
23.07.2025	TÜV Süd Rail, Görlitz	Running ability tests: KB – KB	013 – 036
24.07.2025	TÜV Süd Rail, Görlitz	Running ability tests: DC – KB DC – DC	037 – 054 057 – ...
25.07.2025	TÜV Süd Rail, Görlitz	Impact tests: DC – DC (except 75 m curve)	... – 107
28.07.2025	TÜV Süd Rail, Görlitz	Delivery coupler heads Faiveley / Wabtec. Installation of FT01 and FT02.	-
29.07.2025	TÜV Süd Rail, Görlitz	Impact tests: DC – DC (75 m curve) DC – FT (except 75 m curve) Delivery couplers Voith. Installation of couplers: VT01, VT02. Electro installation Voith (VT01 and preparation for VT03).	110 – 118 119 – ...
30.07.2025	TÜV Süd Rail, Görlitz	Impact tests: DC – FT (75 m curve) FT – FT Electro installation Voith (VT01 and preparation for VT03).	... – 149 150 – 167
31.07.2025	TÜV Süd Rail, Görlitz	Running ability tests: FT – VT VT – VT KB – VT FT – KB	168 – 187 188 – 205 206 – 223 224 – 242
01.08.2025	TÜV Süd Rail, Görlitz	Running ability tests: DC – FT	243 – 265

Date	Location	Action	from Test-Nr.
		Electro installation Knorr-Bremse.	
04.08.2025	TÜV Süd Rail, Görlitz	Running ability tests: VT - DC Electro installation Knorr-Bremse.	266 - 283
05.08.2025	TÜV Süd Rail, Görlitz	Impact tests: DC - KB DC - VT	285 - 315 316 - 341
06.08.2025	TÜV Süd Rail, Görlitz	Change of coupler on Ha_0458 started (DC01 -> VT03). Impact tests: KB - VT KB - KB KB - FT KB - DC (start)	344 - 372 373 - 401 402 - 427 428 - ...
07.08.2025	TÜV Süd Rail, Görlitz	Change of coupler on Ha_0458 finished (DC01 -> VT03). Impact tests: KB - DC (finish) VT - DC VT - FT VT - VT VT - KB Change of coupler on Ha_0136 started (KB03 -> FT03).	... - 456 457 - 485 486 - 511 512 - 538 539 - 564
08.08.2025	TÜV Süd Rail, Görlitz	Change of coupler on Ha_0136 finished (KB03 -> FT03). Preparation for impact tests with FT.	-
11.08.2025	TÜV Süd Rail, Görlitz	Impact tests: FT - KB FT - VT	565 - 592 593 - 626
12.08.2025	TÜV Süd Rail, Görlitz	Impact tests: FT - FT (started) FT - DC	627 - 642 643 - 675
13.08.2025	TÜV Süd Rail, Görlitz	Impact tests: FT - FT (finished)	676 - 713

5 Execution and results

A detailed description of the executed tests can be found in the annexes listed in chapter 7.

6 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[EN_16019]	DIN EN 16019:2014-06	Railway applications – Automatic coupler – Performance requirements, specific interface geometry and test method	-	06.2014	-
[TS-2025-014]	2025-014-DAC-TS01	Impact Tests – Test Scenario	Saskia Discher	27.02.2025	02
[TS-2025-015]	2025-015-DAC-TS01	Running Ability Tests – Test Scenario	Julian Beck	27.02.2025	02
[UIC_530-1]	UIC 530-1 VE	Constructional conditions for wagons to be observed with a view to fitting the automatic coupler of the Member Railways of the UIC and OSJD respectively	UIC	01.04.1982	2
[VT_SK0.7773]	-	User manual – Semiautomatic Scharfenberg Coupler	Voith Group	17.04.2025	Issue 1

7 Appendices

Annex	Vn.	Title	Content
1	01	Description - Impact Tests	Description of the execution of the impact tests. Deviations regarding [TS-2025-014].
2	01	Description - Running Ability Tests	Description of the execution of the running ability tests. Deviations regarding [TS-2025-015].
3	01	Results – General Results	Supplier independent results: - E-coupler - DAC-design specific - Wagon-specific
3.1	01	Results – Dellner	Results of the impact and running ability tests involving Dellner couplers.
3.2	01	Results – Faiveley / Wabtec	Results of the impact and running ability tests involving Faiveley / Wabtec couplers.
3.3	01	Results – Knorr-Bremse	Results of the impact and running ability tests involving Knorr-Bremse couplers.
3.4	01	Results – Voith	Results of the impact and running ability tests involving Voith couplers.

Annex 1

Description - Impact tests

Test report:	2025-014-WP14-TR01
Annex No.:	Annex 1
Annex - Version:	V01

Confidentiality

The overall report is only made available to the suppliers.
Distribution to third parties without the approval of the respective supplier and the WP14 test management is not permitted!

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Abbreviations & Acronyms

Abbreviation / Acronym	Description
BP	Brake pipe
CCU	Coupler control unit
CL	Coupling link
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
DC	Dellner Couplers AB
DMS	Strain gauge (ger.: Dehnungsmessstreifen)
e-coupler	Electrical coupler
ERJU	Europe's Rail Joint Undertaking
FT	Faiveley Transport SA / respective: Wabtec Corporation
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
KB	Knorr-Bremse AG
R2C	Ready-to-couple position
S/N	Serial number
T...	Test No. (e.g.: T123 = Test No. 123)
TOR	Top of rail
TTL	Train Test Lab
TTL-ID	Component ID given by the TTL for asset management
VT	Voith GmbH & Co. KGaA
WP	Wabtec position

1 Description of test case

This annex is focusing on the description of the impact tests on special infrastructure. Basis for the tests is the test scenario [TS-2025-014]. This annex summarizes the test scenario and describes deviations.

[TS-2025-014] defines the following tests, that shall be executed on special infrastructure:

Table 1: Summary of tests from [TS-2025-014] - Tests on special infrastructure.

Case	Moving wagon	Standing wagon	Infrastructure	Velocity	Amount of tests
Functional impact tests					
1xx11	4-axle 80 t	2-axle 20 t	150 m curve	2 km/h	3
1xx12	4-axle 80 t	2-axle 20 t	150 m curve	4 km/h	3
1xx21	4-axle 80 t	2-axle 20 t	150 m s-curve	2 km/h	3
1xx31	4-axle 80 t	2-axle 20 t	75 m curve	2 km/h	3

The tests are to be executed with the following coupler configurations:

Table 2: Interoperability-configurations to be tested.

		Moving wagon			
		DL	FT	KB	VT
Standing wagon	DL	111xx	121xx	131xx	141xx
	FT	112xx	122xx 122xxWP ¹⁾	132xx	142xx
	KB	113xx	123xx	133xx	143xx
	VT	114xx	124xx	134xx	144xx

¹⁾ As Faiveley / Wabtec have the Wabtec-position, this position was also tested in the configuration FT-FT.

The different test-cases were coded. The report and test protocol refer to the test-cases with help of these codes. The coding system is explained in the following table:

Table 3: Exemplary coding for test-case 12312.

	Test	Coupler wagon 1 (moving)	Coupler wagon 2 (standing)	Infrastructure	Speed
Number	1	2	3	1	2
Definition	1 = Impact test 2 = Running ability test (see annex 2)	1 = DC 2 = FT 3 = KB 4 = VT	1 = DC 2 = FT 3 = KB 4 = VT	1 = 150 m curve 2 = 150 m S-curve 3 = 75 m curve	1 = 2 km/h 2 = 4 km/h

During the tests the following parts had to be evaluated:

Table 4: Evaluation criteria - overview.

To evaluate	Criteria
Impact / Coupling	
Mechanical coupling	The couplers are mechanically coupling during each impact test.
Compression force	The force does not exceed 2.000 kN during the impact phase.
Pneumatic coupling	The brake pipes of both wagons must be coupled during each impact tests. No major leakage of the brake pipe (and main reservoir pipe if present) shall be detected. ¹⁾
Electric coupling	The e-coupler must be coupled during each impact tests.
Critical damages coupler	The coupler must stay functional and not be critically damaged during or after the tests.
Critical damages wagon	The wagon must stay functional and not be critically damaged by the DAC during the tests.
Wear and tear	The wear of parts should be noted. Remark: The wear should not lead to failure of the parts, considering the amount of tests.
Uncoupling	
Uncoupling	By uncoupling on one coupler, both couplers reach the "ready-to-couple"-position.

¹⁾Leakages were not evaluated with the measurement system. Major, audible leakages were documented in the protocol.

2 Test execution – Impact tests

2.1 Test procedure

The test procedure is described in detail in [TS-2025-014], chapter 5.2. The following deviations were made:

Pt. in [TS-2025-014], chapter 5.2	Content	Deviation
1.1	Measured parameters	See chapter 2.2.
1.2.4	Documentation of operator	The operator of the coupler during uncoupling was not documented, as the couplers should be electronically uncoupled. Mainly all operations were done by the same operator.
2	Coupler status prior to impact	As Faiveley delivered couplers with the Wabtec position, this position was also tested. The tests were only executed in the configuration FT→FT. Prior to the impact test both couplers were set to the Wabtec position.
3	A push-off operation is performed	For tests with 2km/h no push-off operation was performed. The loco was connected to the moving wagon while coupling. Therefore, the impacting mass was increased. Data of the loco: Type: V22b – VEB LKM Babelsberg Weight: 24 000 kg Length: 9.64 m Axles: 2 Distance between axles: 2.5 m
6	Uncoupling	- No Deviations – Remarks: - Uncoupling was always executed on the coupler of the standing wagon. - Uncoupling was done with the electronic system (push buttons and actuator). As Faiveley did not provide an electronic system, the Faiveley couplers were uncoupled with the help of the manual uncoupling. - Due to damages to the actuator of a Dellner coupler, DC02 was actuated by means of the manual uncoupling from T478 onwards.
Remark	Direction of coupling	During all impact tests the moving wagon moved from East to West (Test location see Main report, chapter 3.1). Therefore, during all impacts in curves, the couplers were aligned via the guiding horns.

2.2 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Environmental conditions
- Initial status of couplers, wagons and track
- Coupler status after coupling and uncoupling
- Moving / Standing wagon and coupler
- Type of actuation of coupler and actuated coupler
- Abnormalities and deviations from procedure

Documentation by video/photo:

- Photo documentation of the couplers on a regular basis (approx. after every supplier configuration)

Measured by measurement systems:

- Every test was recorded by a measurement system consisting of sensors on the moving and on the standing wagon described in the following chapters.

The measurement equipment consisted of various parts:

- systems installed on the wagons by DBST that were able to communicate via a remote connection (chapter 2.2.1 ff.).
- a system for measurement of the coupler heights (chapter 2.2.2.1).

In contrast to the test scenario, the measurement system was split between the standing and moving wagon.

2.2.1 On-wagon systems

2.2.1.1 Data acquisition and processing

For Data acquisition a system by HBM was used, consisting of:

- Data logger: SomatXR CX22B-R-W (HBK) [HBK_CX22]
- Measuring amplifiers: SomatXR MX480B-R (HBK) [HBK_MX480]
SomatXR MX1601B-R (HBK) [HBK_MX1601]
- Data acquisition software: CatMan-Easy, Version 5.6.2 (HBK) [HBK_CM]

The measurement frequency is shown in chapters 2.2.1.2 and 2.2.1.3.

For power-supply a battery pack with four 12 V batteries (12 V, 24 V and 48 V output possible) was installed. If no actuator was installed and therefore no high-ampere 48 V-output was needed, a smaller battery pack was installed.

The systems were connected via antennas which provided a remote connection.

Python-Scripts for editing and graphical presentation of the data were developed by the TTL and executed on a measurement computer.

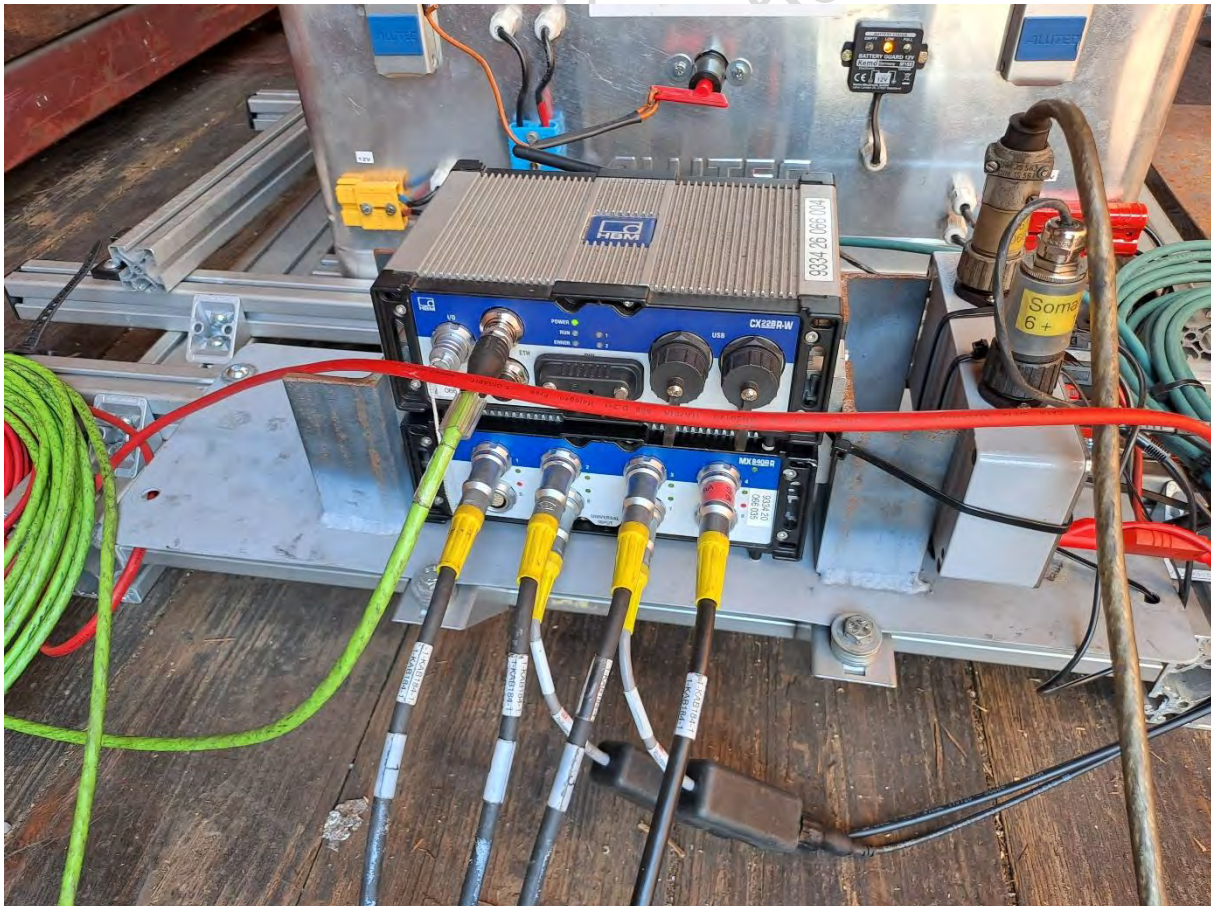


Figure 1: 2-axle wagon measurement system: Data-logger and measuring amplifier.



Figure 2: 4-axle wagon measurement system: Battery packs and measuring amplifier.



Figure 3: DBST on-wagon measurement system: Battery pack with different voltage outputs.



Figure 4: Antenna installed on the wagon to provide remote connection.

2.2.1.2 2-axle wagon system (standing wagon)

The measurement system on the 2-axle wagons consisted of a Datalogger and one or two measuring amplifiers. Calibrated measurement chains were used to record the data of the on-board system. The location of installation of the sensors, signal names, identifiers and descriptions are shown in the following table:

Table 5: Measurement configuration 2-axle wagons.

Name	A = analogue D = digital	Description	Source / Installation	Connection	Range	Sampling Frequency
Time	A	Time	Data-logger			
CoupleInd	A	Couple Indicator (Flag)	Wire Sensor	Clamp -> behind coupler	0 to 1.000 mm	1000
S_y	A	Displacement (y-axis -> Sideways)	Wire Sensor	Clamp -> left side of coupler	0 to 1.000 mm	100
S_z	A	Displacement (z-axis -> Up/Down)	Wire Sensor	Clamp -> above coupler	0 to 1.000 mm	100
pBP	A	Brake Pipe Pressure	Pressure Sensor in Brake Pipe	Stäubli-socket-adapter between coupler and hose	0 to 10 bar	100
U_EC	A	Voltage throughput E-Coupler	Voltage Sensor	Connection description	0 to 60 V	100
U_Act	A	Voltage Actuator	Voltage Sensor	Measured directly after Battery	0 to 60 V	100
I_Act	A	Current Actuator	Current Sensor (Clamp ammeter)	Measured directly after Battery (divided by 4)	0 to 100 A	100
P_Act		Power Actuator	- calculated		0 to 100 A	100
ECoupleInd_bin		E-Coupler Indicator (binary)	- calculated			
CoupleInd_bin		Couple Indicator (binary)	- calculated			
GPS		GPS Location of wagon	GPS Sensor	USB-connection - COM7		

2.2.1.2.1 Couple indicator

The suppliers Dellner and Voith delivered couplers with couple indicators in form of a flag which shows when the coupler is coupled.

The status of the indicator is measured with the help of a wire sensor. A wire sensor with a high mechanical resistance was used to prevent vibrations. The zero position of the wire sensors is the coupled position.

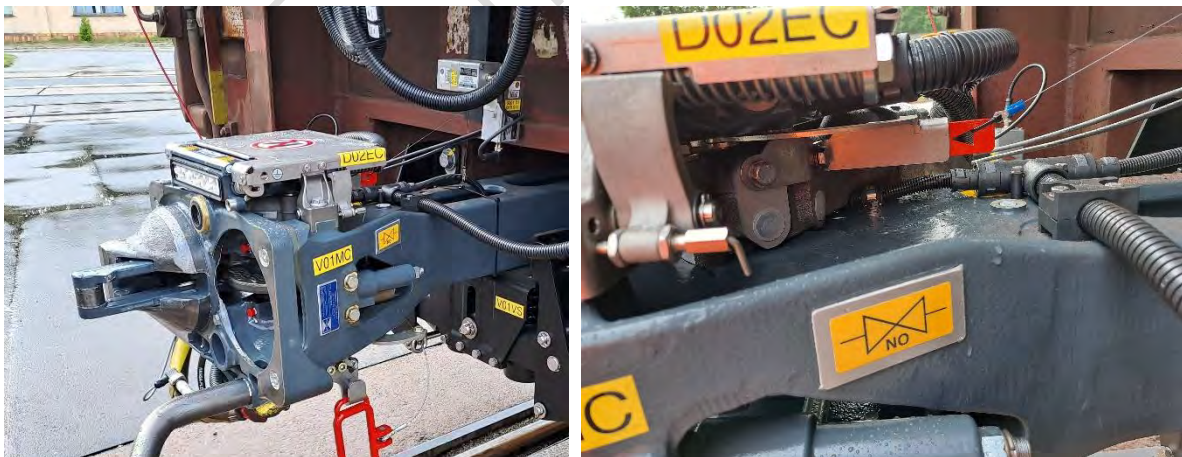


Figure 5: Couple indicator (right, red) measured with wire sensor.

2.2.1.2.2 Displacement of the coupler

To measure the displacement of the coupler wire sensors were used in y- (sideways), and z-axis (up-/down). The x-direction (forward/backward) was not measured on the 2-axle wagon. Wire sensors with a high mechanical resistance were used to prevent vibrations. The sensors were aligned with the axis of movement to prevent high elongation during off-axis movement of the coupler. The zero position of the wire sensors is the straight aligned uncoupled position.



Figure 6: Wire sensors to measure y-displacement (left) and z-displacement (right) of coupler.

2.2.1.2.3 Brake pipe pressure

The brake pipe pressure was measured with the help of an adapter equipped with a pressure sensor. The adapter could be inserted on the brake line couplings between the wagons hose and the couplers hose.



Figure 7: Pressure sensors attached to the adapter (yellow) between the wagons and couplers air hoses.

2.2.1.2.4 E-coupler connection

To measure the electrical connection of the e-coupler, a voltage (24 V) was applied from the battery pack of the standing wagon. The voltage was looped through the e-coupler on the moving wagon and measured with the measurement system on the standing wagon.

While the Knorr-Bremse couplers were not used for the tests, the voltage was measured over all pins (Figure 9). As Knorr-Bremse used the data pins to apply their synchronization signal, from the 05.08.2025 (T285) the voltage was only measured over the power-pins (Figure 10).

See also further information in the main report, chapter 3.3.5.

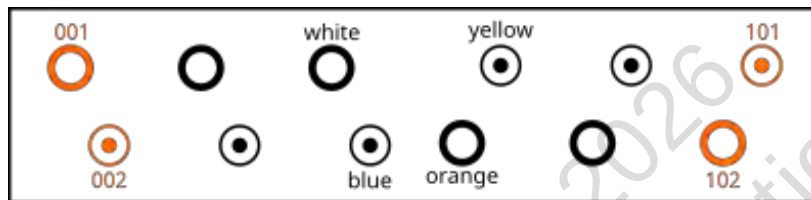


Figure 8: E-coupler - Pin layout, front view. Orange: power-pins, Black: data-pins.

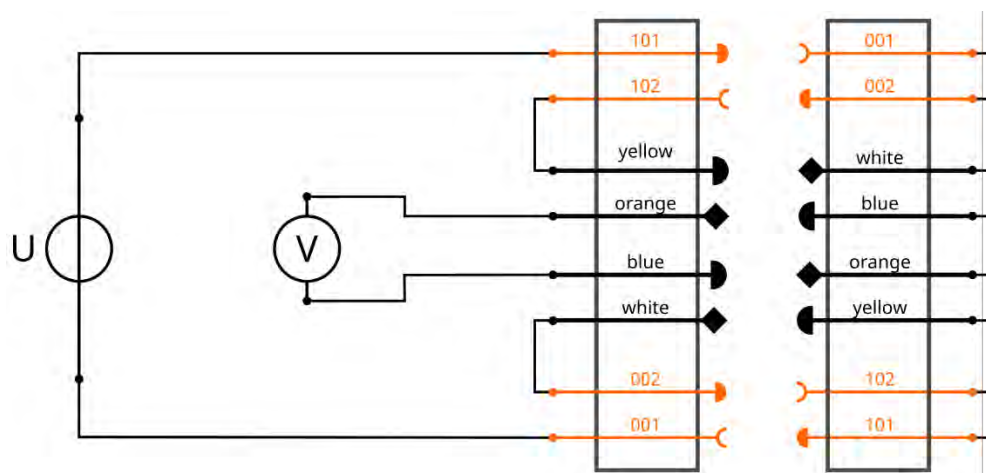


Figure 9: Circuit for measurement of electrical connection until T285.

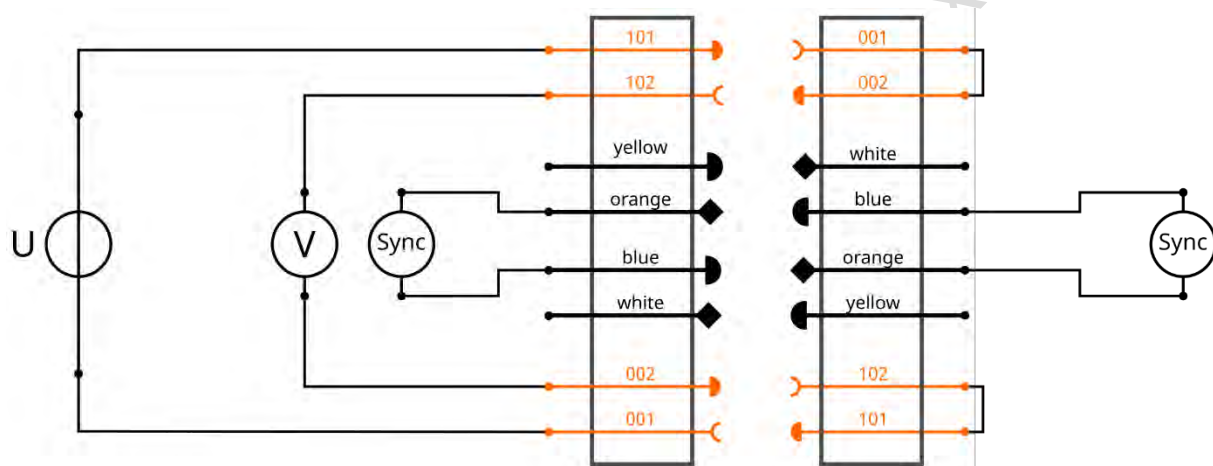


Figure 10: Circuit for measurement of electrical connection from T285 onwards. Synchronization-signal ("Sync") only present on couplers from Knorr-Bremse.

2.2.1.2.5 Power consumption of the actuator

To measure the power consumption of the actuator, the supply-voltage and current were measured. They were measured directly at the battery connection point (48 V), which means, that the passive power consumption of the electronic system was also included in the measured data.

The current was measured with a clamp-on ammeter. To raise the sensitivity, the positive wire was passed through the clamp four times (corrected in the data-processing).

Faiveley did not supply an electrical system, therefore no measurement was done on the Faiveley couplers.

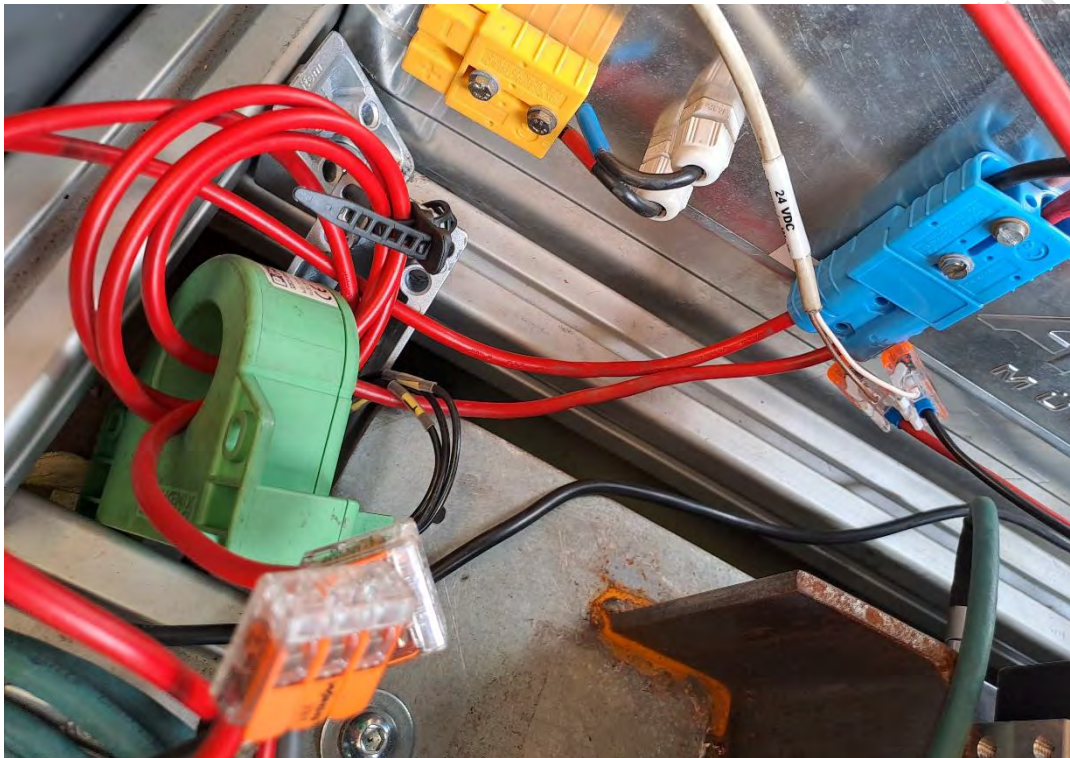


Figure 11: Clamp-on ammeter (green) to measure current of the actuator.

2.2.1.3 4-axle wagon system (moving wagon)

Further measurement equipment was installed on the 4-axle wagons: each wagon was equipped with a measuring amplifier. Calibrated measurement chains were used to record the data of the on-board system. The location of installation of the sensors, signal names, identifiers and descriptions are shown in the following table:

Table 6: Measurement configuration 4-axle wagons.

Name	A = analogue D = digital	Description	Source / Installation	Connection	Range	Sampling Frequency
F_z	A	Force on coupler	Calculated from Raw-Data	Left and right outer side of coupler	-2.000 to 2.000 kN	1000
Imp	A	Impulses (Distance)	Incremental Encoder	Pushed on right wheel	0-70.000.000	1000
S_x	A	Travel of Coupler (x-axis -> Forward/Backward)	Wire sensor	Clamp -> above coupler	0 to 1.000 mm	1000
s	A	Distance	- calculated			
v_kmh_filt	A	Speed, filtered (over 0.1 s)	- calculated			

2.2.1.3.1 Force on the coupler

The tensile force and compression force were measured with a full bridge strain gauge (DMS). The strain gauge was installed and calibrated by the DBST in Minden.

Due to a delayed delivery of couplers from the suppliers Voith and Faiveley, their couplers could not be equipped with strain gauges.



Figure 12: Strain gauge on a Dellner coupler.

2.2.1.3.2 Impact speed

The speed of the moving wagon was measured with an incremental encoder. The incremental encoder was equipped with a wheel, which was pushed onto the wagons wheel and therefore measured its rotation. The impulses of the encoder were transformed into a distance and then differentiated by the time. A mean-filter of 0.1 s was applied for the speed.

To calculate the distance from the given impulses, a calibration was done over a distance of 50 m.



Figure 13: Incremental encoder pushed onto the wagons wheel.

2.2.2 Further systems

2.2.2.1 Measurement of coupler heights

For evaluation of the vertical displacement during coupling, the heights of the couplers were measured.

The measurement of the height of the coupler consisted of two measured distances:

- Distance between top of rail and the bottom of the coupling link
- Height of coupling link

The distance between the top of rail and the bottom of the coupling link was measured with a laser-distance-sensor (Milwaukee LDM 30 [Milwaukee_LDM30]) fixed inside a rack of aluminium-profiles (see Figure 14 and Figure 15).

The heights of the coupling links were measured with a calliper gauge (see Figure 16).

The coupler height – the distance between the middle of the coupling link (CL) and the top of rail (TOR) - is calculated as:

$$\text{Coupler height} = \text{Distance}_{\text{TOR to bottom of CL}} + \frac{1}{2} \text{Height}_{\text{CL}}$$



Figure 14: Left: Laser distance sensor for coupler height measurement [Milwaukee_LDM30]. Right: Laser point on the coupler link.

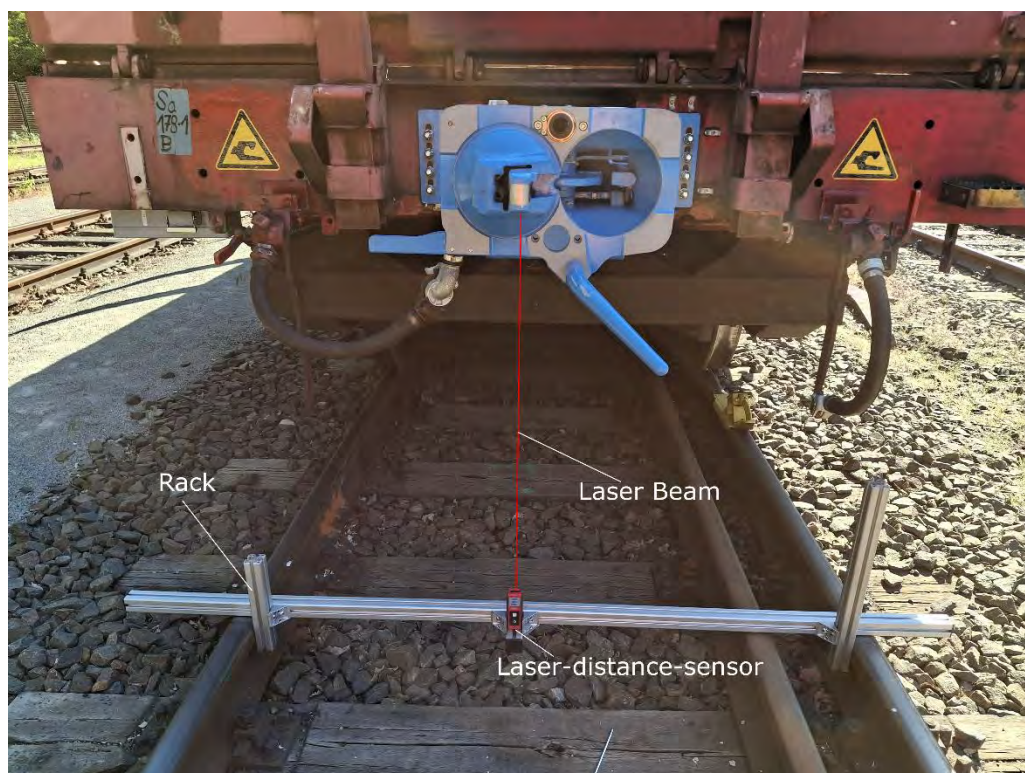


Figure 15: Aluminium rack with laser sensor for height measurement of the couplers.



Figure 16: Measurement of the height of the coupler link with a calliper gauge.

2.3 Criteria for a valid test execution

The test execution was defined as valid in case of:

- Deviation of impact speed < 1 km/h from defined impact speed
- No relevant abnormalities and deviations from test procedure

2.4 Evaluation

To evaluate	Way of evaluation
Impact / Coupling:	
Mechanical coupling	→ Documentation of coupler status after impact in protocol.
Compression force	Measurement of force on the coupler with on-wagon system: → Max. compression force during test evaluated.
Pneumatic coupling	Measurement of brake pipe pressure with on-wagon system: → Connection: Pressure rise after opening air cock of impacting wagon evaluated (Automatic evaluation: rise of min. 2 bar) → Leakage: leakages were not evaluated with the measurement system. Major, audible leakages were documented in the protocol.
Electric coupling	Measurement of voltage throughput with on-wagon system: → Evaluated 5 s after impact: Rise of the voltage signal to min. 10 V.
Critical damages coupler	→ Documentation of abnormalities in protocol → Photo documentation
Critical damages wagon	→ Documentation of abnormalities in protocol
Wear and tear	→ Documentation of abnormalities in protocol → Photo documentation
Uncoupling:	
Uncoupling	→ Documentation of actuated coupler and coupler status after uncoupling in protocol → Measurement of force on the coupler with on wagon-system. Force when uncoupling evaluated.

The graphical representation of the measured data of an exemplary coupling test is shown in Figure 17. Graphical representation of an uncoupling test is shown in Figure 18.

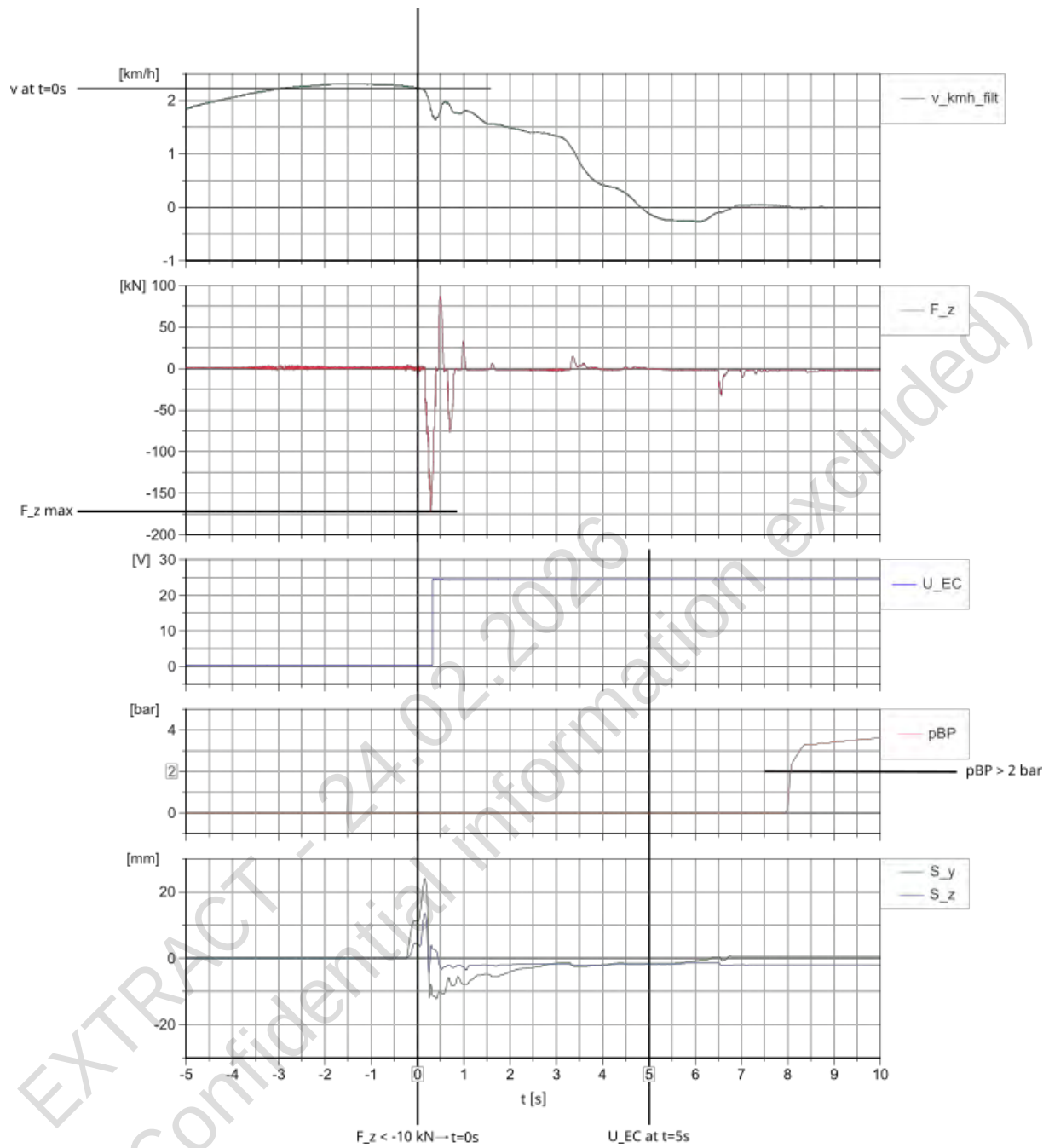


Figure 17: Graphical presentation of an exemplary coupling test.

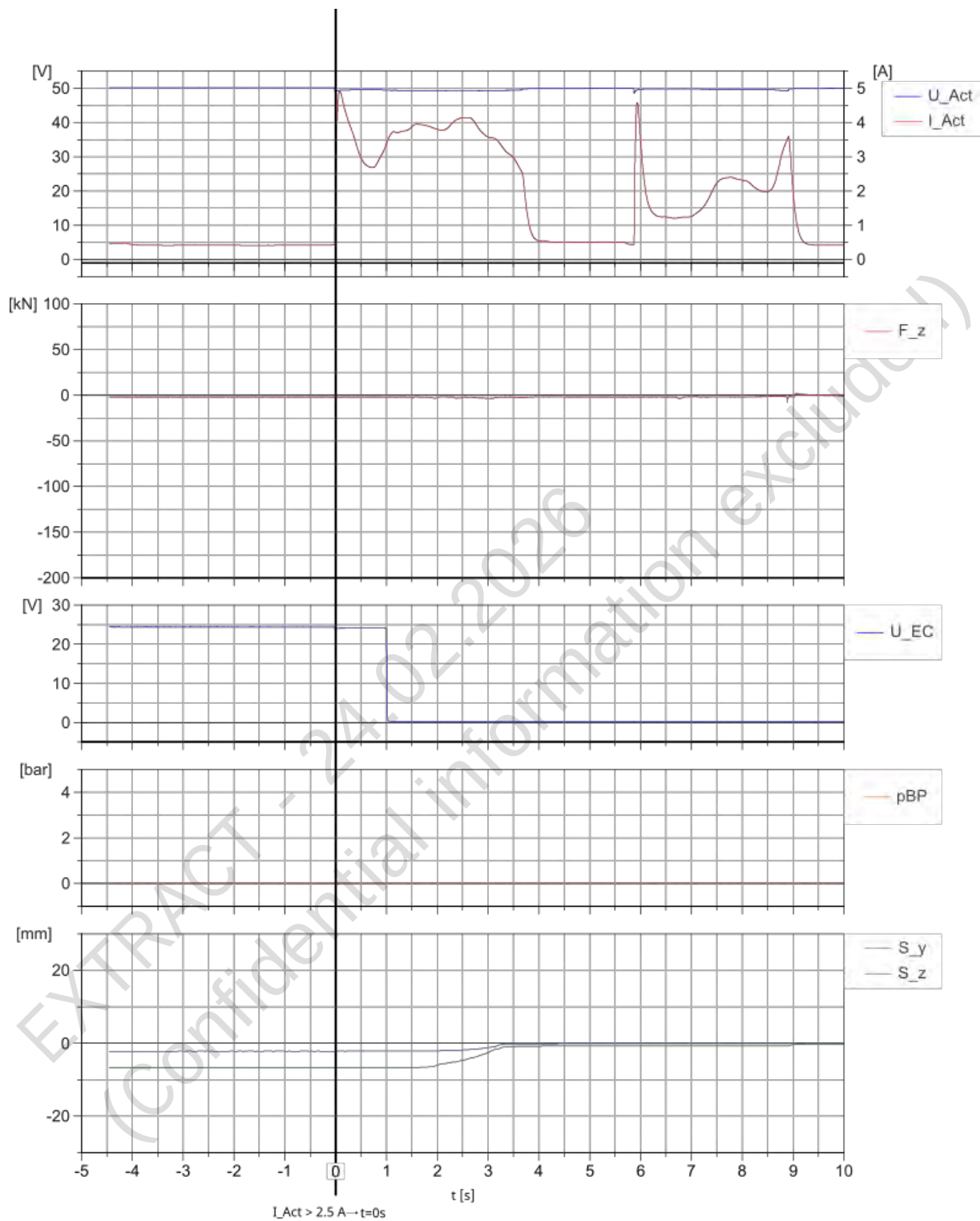


Figure 18: Graphical presentation of an exemplary uncoupling test.

3 Results

3.1 Impact tests

For reasons of confidentiality, the results are presented per supplier in the annexes 3.1 to 3.4.

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3.2 Coupler heights

The results of the coupler heights are summarized in the following table:

Coupler	Date	Wagon	Load state	Height CL	Height TOR - CL Mean of 3	Coupler height
				[mm]	[mm]	[mm]
DC01				70,4		
	25.07.2025	Ha_0458, side B	Full		977	1012
	29.07.2025	Ha_0458, side B	Full		975	1010
DC02				70,4		
	24.07.2025	Hb_3518, side A	Empty		959	994
	25.07.2025	Hb_3518, side A	Empty		957	992
	12.08.2025	Hb_3518, side A	Empty		954	990
DC03				70,4		
	24.07.2025	Hb_3472, side A	Empty		983	1018
FT01				70,8		
	30.07.2025	Hb_3746, side B	Empty		998	1033
	30.07.2025	Hb_3746, side B	Empty		1000	1035
	12.08.2025	Hb_3746, side B	Empty		1005	1040
	13.08.2025	Hb_3746, side B	Empty		997	1032
FT02				70,8		
	30.07.2025	Hb_3581, side B	Empty		994	1029
FT03				70,8		
	11.08.2025	Ha_0136, side A	Full		965	1000
	11.08.2025	Ha_0136, side A	Full		966	1001
	12.08.2025	Ha_0136, side A	Full		953	989
	13.08.2025	Ha_0136, side A	Full		951	986
KB01				71,4		
	23.07.2025	Hb_3235, side A	Empty		979	1015
	24.07.2025	Hb_3235, side A	Empty		977	1012
	07.08.2025	Hb_3235, side A	Empty		972	1008
	11.08.2025	Hb_3235, side A	Empty		977	1013
KB02				71,4		
	23.07.2025	Hb_3746, side A	Empty		977	1013
KB03				71,4		
	06.08.2025	Ha_0136, side A	Full		958	994
VT01				70,4		
	31.07.2025	Hb_3472, side B	Empty		995	1030
	06.08.2025	Hb_3472, side B	Empty		983	1018
	11.08.2025	Hb_3472, side B	Empty		991	1026
VT02				70,4		
	31.07.2025	Hb_3235, side B	Empty		999	1035
VT03				70,4		
	07.08.2025	Ha_0458, side B	Full		983	1018

4 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[HBK_CM]	B04486	Catman Universal data acquisition and analysis software Data Sheet	HBK	14.07.2023	06
[HBK_CX22]	B04717	Somat ^{XR} CX22B-R-W Data recorder Data Sheet	HBK	23.05.2023	04
[HBK_MX840]	B04309	Somat ^{XR} MX840B-R Rugged universal amplifier Data Sheet	HBK	27.07.2022	04
[HBK_MX1601]	B04019	Somat ^{XR} MX1601B-R Ultra-rugged Standard Amplifier Data Sheet	HBK	07.05.2024	05
[Milwaukee_ LDM30]	-	Milwaukee – LDM 30 Original Instructions	Milwaukee	-	-
[TS-2025-014]	2025-014- DAC-TS01	Impact Tests – Test Scenario	Saskia Discher	27.02.2025	02

5 Appendices

Annex	Vn.	Title	Content

Annex 2

Description – Running ability tests

Test report:	2025-014-WP14-TR01
Annex No.:	Annex 2
Annex - Version:	V01

Confidentiality

The overall report is only made available to the suppliers.
Distribution to third parties without the approval of the respective supplier and the WP14 test management is not permitted!

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Abbreviations & Acronyms

Abbreviation / Acronym	Description
BP	Brake pipe
CCU	Coupler control unit
CL	Coupling link
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
DC	Dellner Couplers AB
DMS	Strain gauge (ger.: Dehnungsmessstreifen)
e-coupler	Electrical coupler
ERJU	Europe's Rail Joint Undertaking
FT	Faiveley Transport SA / respective: Wabtec Corporation
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
KB	Knorr-Bremse AG
R2C	Ready-to-couple position
S/N	Serial number
T...	Test No. (e.g.: T123 = Test No. 123)
TOR	Top of rail
TTL	Train Test Lab
TTL-ID	Component ID given by the TTL for asset management
VT	Voith GmbH & Co. KGaA
WP	Wabtec position

1 Description of test case

This annex is focusing on the description of the running ability tests on special infrastructure. Basis for the tests is the test scenario [TS-2025-015]. This annex summarizes the test scenario and describes deviations.

[TS-2025-015] defines the following tests, that shall be executed on special infrastructure:

Table 1: Summary of tests from [TS-2025-015]

Case	Infrastructure	Pushed / Pulled	Velocity	Amount
2xx21	150 m S-curve with 6 m intermediate straight	Pushed	5 km/h ¹⁾	3
2xx22		Pulled		
2xx31	75 m curve	Pushed		
2xx32		Pulled		
2xx41	Ferry boat ramp (3.5° inclination)	Pushed		
2xx42		Pulled		

1) The given speed is a guideline. Due to the resistance deviations when entering the track geometries the speed varies from test to test and within a test. On the ferry boat ramp 3 km/h instead of 5 km/h were reached.

The tests were to be executed with every combination of couplers. Regarding interoperability only one combination must be executed. The following combinations were done:

Table 2: Interoperability-configurations tested.

		Wagon 2 (Leading the pull)			
		DL	FT	KB	VT
Wagon 1 (Leading the push)	DL	211xx	221xx	231xx	
	FT		222xx	232xx	242xx
	KB			233xx	243xx
	VT	214xx		134xx	244xx

The different test-cases were coded. The report and test protocol refer to the test-cases with help of these codes. The coding system is explained in the following table:

Table 3: Exemplary coding for test-case 23132.

	Test	Coupler wagon 2 (leading pull)	Coupler wagon 1 (leading push)	Infrastructure	Pushed / Pulled
Number	2	2	3	3	2
Definition	1 = Impact test (see annex 1) 2 = Running ability test	1 = DC 2 = FT 3 = KB 4 = VT	1 = DC 2 = FT 3 = KB 4 = VT	2 = 150 m S-curve 3 = 75 m curve 4 = Ferry boat ramp	1 = Pushed 2 = Pulled

During the tests the following parts had to be evaluated:

Table 4: Evaluation criteria - overview.

To evaluate	Criteria
General	
Operation without restrictions	The DAC must not adversely affect the operation of the wagons on the test-infrastructure.
Critical damages coupler	The coupler must stay functional and not be critically damaged during the test.
Critical damages wagon	The wagon must stay functional and not be critically damaged by the DAC during the test.
Mechanical coupler:	
Connection	The mechanical coupler must not uncouple unintentionally during any phase of the test.
Pneumatical coupling:	
Leakage	No leakages of the brake pipe are allowed during the test.
E-Coupler:	
Connection	No connection loss of the e-couplers is allowed during the test.

2 Test execution – Running ability tests

2.1 Test procedure

The test procedure is described in detail in [TS-2025-015], chapter 5.2. The following deviations were made:

Pt. in [TS-2025-014], chapter 5.2	Content	Deviation
1.1	Measured parameters	See chapter 2.2.
3.1	Air pipes decoupled	The air hoses between loco and wagon were not decoupled. The loco did not refill the air pipe.
2 / 5 / 9	Pushing and pulling through the infrastructure	Before the tests it was tested whether the loco can pull the two wagons upwards on the ferry boat ramp. As this was possible and expected to be the worse case, the wagons were pulled upwards on the ferry boat ramp. All tests started with pulling, followed by the pushing. Increase of height of ferry boat ramp: from West to East. Data of the loco: Type: V22b – VEB LKM Babelsberg Weight: 24 000 kg Length: 9.64 m Axles: 2 Distance between axles: 2.5 m Velocity: Due to the resistance deviations when entering the track geometries, the speed varies from test to test and within a test. On the ferry boat ramp 3 km/h instead of 5 km/h were reached.
Remark	Direction of running	During all pulled tests the wagons moved from West to East. During all pushed tests, the wagons moved from East to West (Test location see Main report, chapter 3.1).

2.2 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Environmental conditions
- Initial status of couplers, wagons and track
- Coupler status during the tests
- Wagons and couplers
- Abnormalities and deviations from procedure

Documentation by video/photo:

- Photo documentation of the couplers on a regular basis (approx. after every supplier configuration)

Measured by measurement systems:

- Every test was recorded by a measurement system consisting of sensors on wagon 2, described in the following chapters.

The measurement equipment consisted of various parts:

- system installed on wagon 2 by DBST (chapter 2.2.1.1 ff.).
- a system for measurement of the coupler heights (chapter 2.2.2.1).

2.2.1 On-wagon measurement system (wagon 2)

The measurement system on the 2-axle wagons consisted of a Datalogger and one or two measuring amplifiers. Calibrated measurement chains were used to record the data of the on-board system. The location of installation of the sensors, signal names, identifiers and descriptions are shown in the following table:

Table 5: Measurement configuration 2-axle wagons.

Name	A = analogue D = digital	Description	Source / Installation	Connection	Range	Sampling Frequency
Time	A	Time	Data-logger			
CoupleInd	A	Couple Indicator (Flag)	Wire Sensor	Clamp -> behind coupler	0 to 1.000 mm	1000
S_y	A	Displacement (y-axis -> Sideways)	Wire Sensor	Clamp -> left side of coupler	0 to 1.000 mm	100
S_z	A	Displacement (z-axis -> Up/Down)	Wire Sensor	Clamp -> above coupler	0 to 1.000 mm	100
pBP	A	Brake Pipe Pressure	Pressure Sensor in Brake Pipe	Stäubli-socket-adapter between coupler and hose	0 to 10 bar	100
U_EC	A	Voltage throughput E-Coupler	Voltage Sensor	Connection description	0 to 60 V	100
U_Act	A	Voltage Actuator	Voltage Sensor	Measured directly after Battery	0 to 60 V	100
I_Act	A	Current Actuator	Current Sensor (Clamp ammeter)	Measured directly after Battery (divided by 4)	0 to 100 A	100
P_Act		Power Actuator	- calculated		0 to 100 A	100
ECoupleInd_bin		E-Coupler Indicator (binary)	- calculated			
CoupleInd_bin		Couple Indicator (binary)	- calculated			
GPS		GPS Location of wagon	GPS Sensor	USB-connection - COM7		

2.2.1.1 Data acquisition and processing

For Data acquisition a system by HBK was used, consisting of:

- Data logger: SomatXR CX22B-R-W (HBK) [HBK_CX22]
- Measuring amplifiers: SomatXR MX480B-R (HBK) [HBK_MX480]
SomatXR MX1601B-R (HBK) [HBK_MX1601]
- Data acquisition software: CatMan-Easy, Version 5.6.2 (HBK) [HBK_CM]

The measurement frequency is shown in chapters 2.2.1.

For power-supply a battery pack with four 12 V batteries (12 V, 24 V and 48 V output possible) was installed.

Python-Scripts for editing and graphical presentation of the data were developed by the TTL and executed on a measurement computer.





Figure 2: DBST on-wagon measurement system: Battery pack with different voltage outputs.

2.2.1.2 Displacement of the coupler

To measure the displacement of the coupler wire sensors were used in y- (sideways), and z-axis (up-/down). The x-direction (forward/backward) was not measured. Wire sensors with a high mechanical resistance were used to prevent vibrations. The sensors were aligned with the axis of movement to prevent high elongation during off-axis movement of the coupler. The zero position of the wire sensors is the straight aligned uncoupled position.



Figure 3: Wire sensors to measure y-displacement (left) and z-displacement (right) of coupler.

2.2.1.3 Brake pipe pressure

The brake pipe pressure was measured with the help of an adapter equipped with a pressure sensor. The adapter could be inserted on the brake line couplings between the wagons hose and the couplers hose.



Figure 4: Pressure sensors attached to the adapter (yellow) between the wagons and couplers air hoses.

2.2.1.4 E-coupler connection

To measure the electrical connection of the e-coupler, a voltage (24 V) was applied from the battery pack of the standing wagon. The voltage was looped through the e-coupler on the moving wagon and measured with the measurement system on the standing wagon. The voltage was measured over all pins (Figure 6).

See also further information in the main report, chapter 3.3.5.

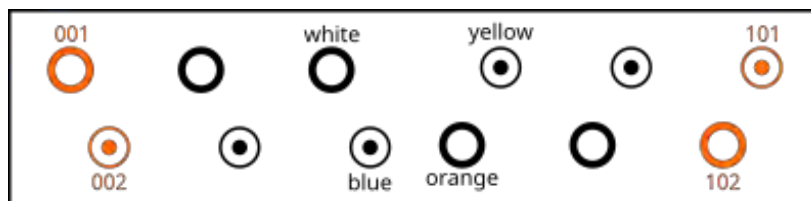


Figure 5: E-coupler - Pin layout, front view. Orange: power-pins, Black: data-pins.

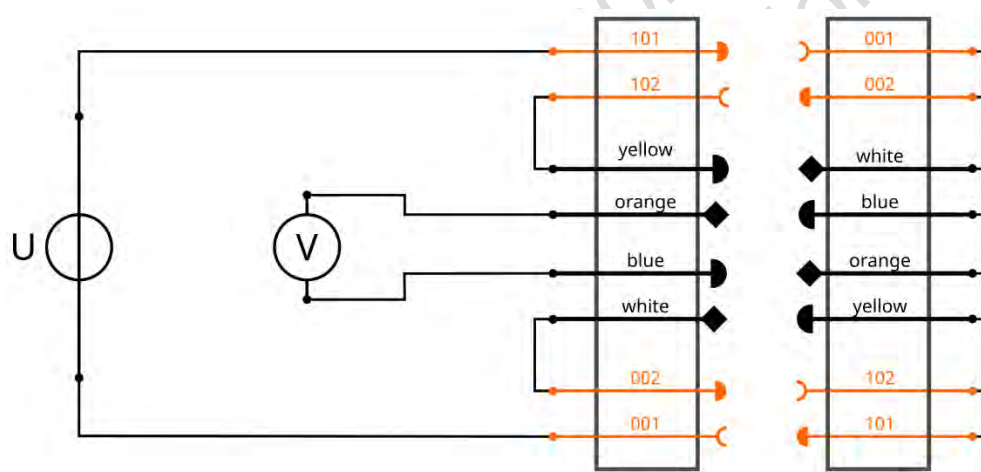


Figure 6: Circuit for measurement of electrical connection.

2.2.1.5 Force on the coupler

The tensile force and compression force were measured with a full bridge strain gauge (DMS). The strain gauge was installed and calibrated by the DBST in Minden.

Due to a delayed delivery of couplers from the suppliers Voith and Faiveley, their couplers could not be equipped with strain gauges.

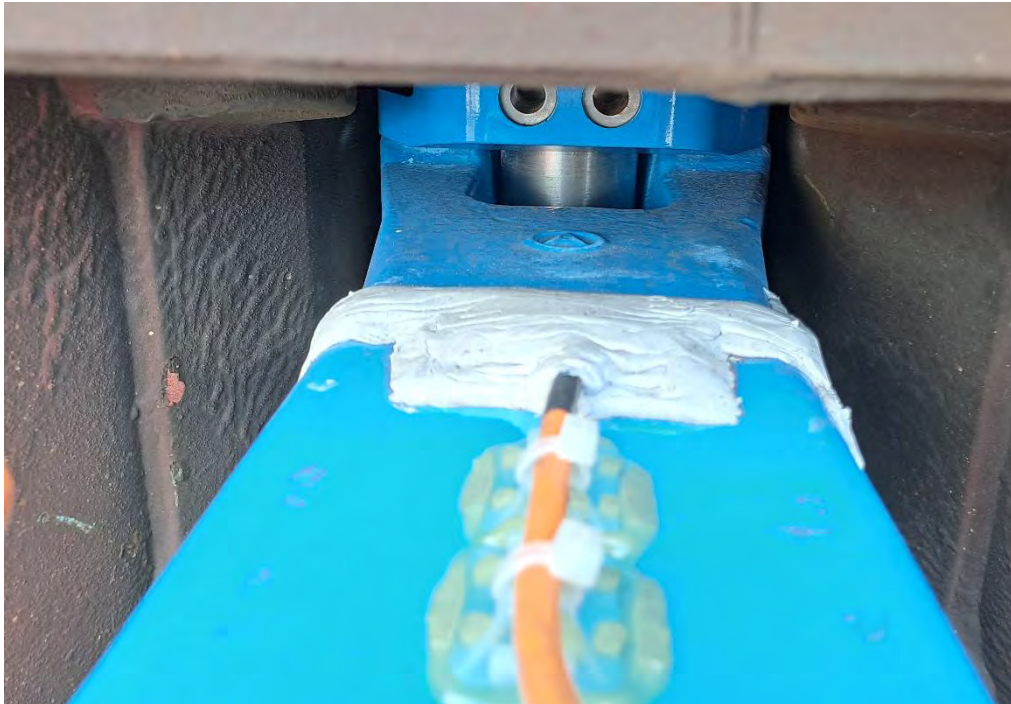


Figure 7: Strain gauge on a Dellner coupler.

2.2.1.6 Running speed

The speed of the wagons was measured with an incremental encoder. The incremental encoder was equipped with a wheel, which was pushed onto the wagons wheel and therefore measured its rotation. The impulses of the encoder were transformed into a distance and then differentiated by the time. A mean-filter of 0.1 s was applied for the speed.

To calculate the distance from the given impulses, a calibration was done over a distance of 50 m.



Figure 8: Incremental encoder pushed onto the wagons wheel.

2.2.1.7 GPS-location

GPS Sensors were installed on some wagons. As not all dataloggers were able to measure the GPS-location, it was not recorded for all tests. Still, the displacement of the coupler is a good indicator of the current location.



Figure 9: GPS sensor attached to wagon side [NL-8012U].

2.2.2 Further systems

2.2.2.1 Measurement of coupler heights

For evaluation of the vertical displacement during coupling, the heights of the couplers were measured.

The measurement of the height of the coupler consisted of two measured distances:

- Distance between top of rail and the bottom of the coupling link
- Height of coupling link

The distance between the top of rail and the bottom of the coupling link was measured with a laser-distance-sensor (Milwaukee LDM 30 [Milwaukee_LDM30]) fixed inside a rack of aluminium-profiles (see Figure 10 and Figure 11).

The heights of the coupling links were measured with a calliper gauge (see Figure 12).

The coupler height – the distance between the middle of the coupling link (CL) and the top of rail (TOR) - is calculated as:

$$\text{Coupler height} = \text{Distance}_{\text{TOR to bottom of CL}} + \frac{1}{2} \text{Height}_{\text{CL}}$$



Figure 10: Left: Laser distance sensor for coupler height measurement [Milwaukee_LDM30]. Right: Laser point on the coupler link.

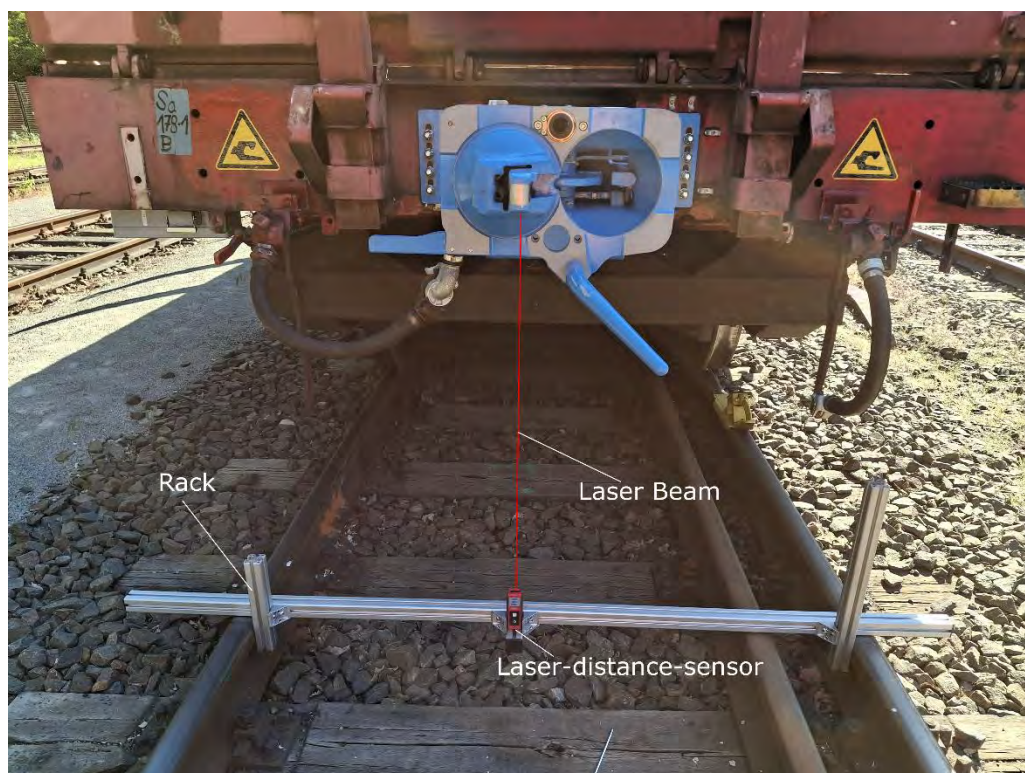


Figure 11: Aluminium rack with laser sensor for height measurement of the couplers.



Figure 12: Measurement of the height of the coupler link with a calliper gauge.

2.3 Criteria for a valid test execution

The test execution was defined as valid in case of:

- No relevant abnormalities and deviations from test procedure
- A deviation of the running speed from the nominal speed is not taken into account (as during the impact tests). Due to the resistance deviations when entering the track geometries the speed varies.

2.4 Evaluation

To evaluate	Way of evaluation
General	
Operation without restrictions	→ Documentation of abnormalities in operation of the wagon due to the DAC in the test protocol
Critical damages coupler	→ Documentation of abnormalities in the test protocol → Regular photo documentation
Critical damages wagon	→ Documentation of abnormalities in the test protocol → Regular photo documentation
Mechanical coupler:	
Connection	→ Documentation of abnormalities in the test protocol
Pneumatical coupling:	
Leakage	Measurement of brake pipe pressure with on-wagon system: → Leakage detection: Pressure drop from beginning to end of tests < 0.05 bar / minute
E-Coupler:	
Connection	Measurement of e-coupler connection with on-wagon system: → No voltage drop below 20 V during test.

The graphical representation of the measured data of exemplary tests are shown in in Figure 13 (ferry boat ramp – pulled) and Figure 14 (150 m S-curve – pulled).



Figure 13: Graphical presentation of an exemplary test on the ferry boat ramp (pulled).

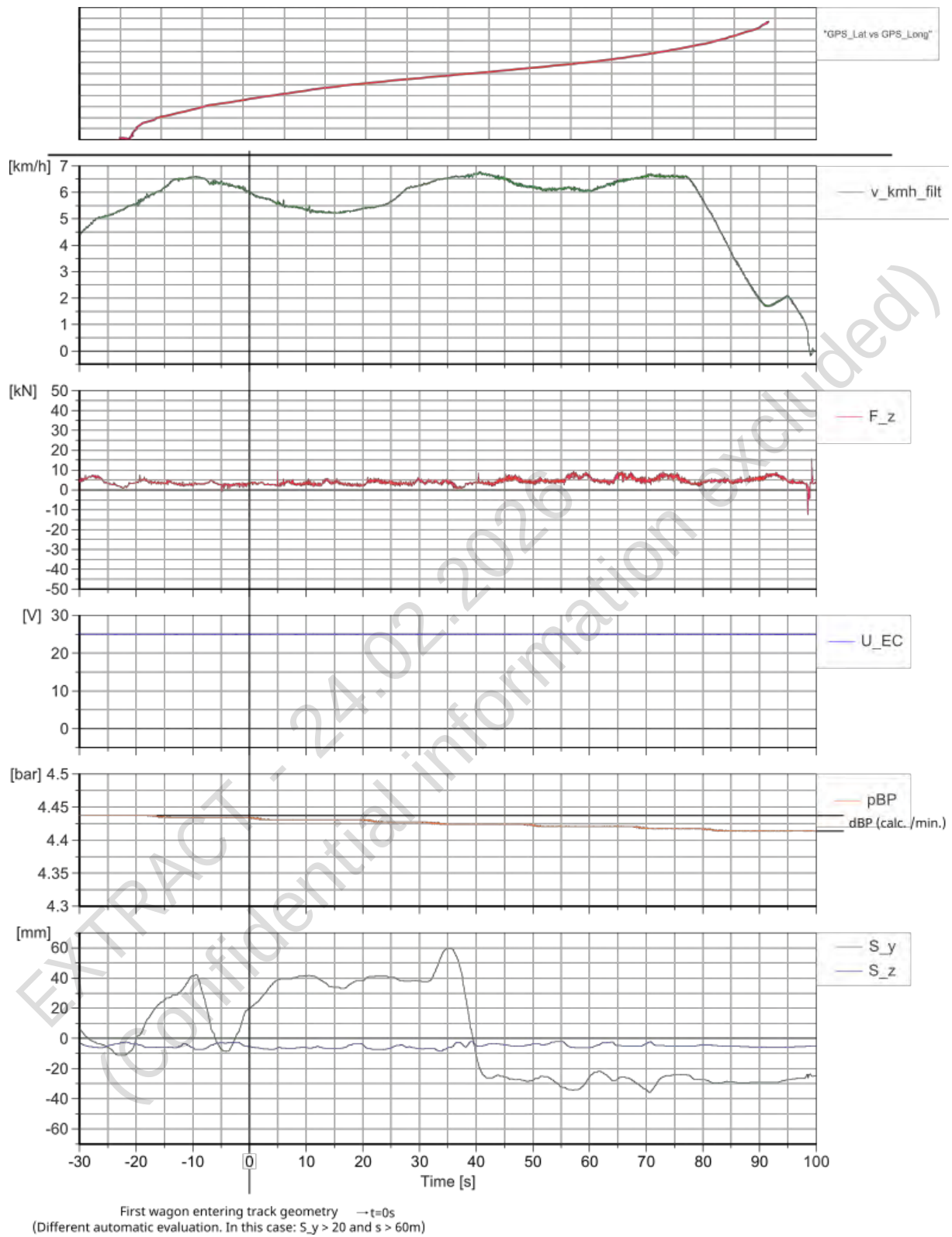


Figure 14: Graphical presentation of an exemplary test in the 150 m s-curve (pulled).

3 Results

3.1 Running ability tests

For reasons of confidentiality, the results are presented per supplier in the annexes 3.1 to 3.4.

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(Confidential information excluded)

4 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[HBK_CM]	B04486	Catman Universal data acquisition and analysis software Data Sheet	HBK	14.07.2023	06
[HBK_CX22]	B04717	Somat ^{XR} CX22B-R-W Data recorder Data Sheet	HBK	23.05.2023	04
[HBK_MX840]	B04309	Somat ^{XR} MX840B-R Rugged universal amplifier Data Sheet	HBK	27.07.2022	04
[HBK_MX1601]	B04019	Somat ^{XR} MX1601B-R Ultra-rugged Standard Amplifier Data Sheet	HBK	07.05.2024	05
[NL-8012U]	-	Datenblatt, Navilock NL-8012U USB 2.0 Multi GNSS Empfänger u-blox 8 4,5	Navilock	07.07.2016	-
[TS-2025-015]	2025-015- DAC-TS01	Running Ability Tests – Test Scenario	Julian Beck	27.02.2025	02

5 Appendices

Annex	Vn.	Title	Content