

E-coupler assessment TTL

Test report

Title:	E-coupler assessment TTL
Type:	Test report
Document-No.:	2024-001-WP14-TR01
Test Laboratory:	WP 14 - Train Test Lab
Version:	V01
Date:	22.02.2024

Confidentiality

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

Document history		
Revision	Date	Description
V01	22.02.2024	Initial report

Report contributors		
Name	Company	Details of contribution
Julian Beck	DB Systemtechnik GmbH	Main author
Daniel Wolfram	DB Cargo	Main author Main report and annexes 2 to 4
Jan Sporleder	DB Cargo	Main author Main report and annexes 0
Saskia Discher	Institut für Bahntechnik GmbH	Contributing author
Ba-Quy Merz	DB Cargo	Contributing author

Signatures		
Name	Contact	Signature
Julian Beck	DB Systemtechnik GmbH, TT.TVP213 Pionierstraße 10, 32423 Minden E-Mail: julian.j.beck@deutschebahn.com	
Daniel Wolfram	DB Cargo AG, L.CBX Bessie-Coleman-Str. 7, 60549 Frankfurt a. Main E-Mail: daniel.wolfram@deutschebahn.com	

Disclaimer

The information in this document is provided "as is", and no guarantee or warranty is given that the information is fit for any particular purpose. The content of this document reflects only the author's view – the Joint Undertaking is not responsible for any use that may be made of the information it contains. The users use the information at their sole risk and liability.

The content of this test-report does not reflect the official opinion of the Europe's Rail Joint Undertaking (EU-Rail JU). Responsibility for the information and views expressed in the test-report lies entirely with the author(s).

Table of Contents

Abbreviations & Acronyms.....	4
1 Project description and objective	5
1.1 WP14 Train Test Lab.....	5
1.2 Objective for e-coupler tests and report structure	6
1.3 Contact persons.....	7
2 Introduction and description of systems under test	8
2.1 E-couplers – general remarks.....	8
3 Infrastructure.....	9
3.1 Test location	9
3.2 Wagons	10
3.2.1 Shimmns_6025.....	10
3.2.2 Shimmns_9383.....	12
3.2.3 Samms_1781	13
3.2.4 Samms_3779	15
4 Test description and schedule summary	17
5 References.....	18
6 Appendices.....	19

Abbreviations & Acronyms

Abbreviation / Acronym	Description
BoB	Best of both – criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Project description and objective

The TRANS4M-R consortium within Flagship Area 5 (FA5) 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). In addition to mechanical force transmission and pneumatic coupling, the DAC is also intended to enable a power and data line in the train. This requires so-called e-couplers. Within the consortium, two partner companies have developed different solutions that are not interoperable. The consortium must decide in favour of one of the solutions presented by Voith and Knorr Bremse. In order to make a valid decision, it is essential to have as much information as possible about the two systems. A list of criteria was drawn up as the basis for the decision. Both companies have created prototypes of their designs, which will be tested on the basis of the criteria. 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. In addition, tests were carried out on test benches of the industry partners and in demonstrator trains (SBB+ train and DAC4EU train).

1.1 WP14 Train Test Lab

A Train Test Lab is a local site that has special characteristics and thus provides resources for special tests. 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. Tests for the e-coupler assessment are a good example. 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.

To achieve these goals, the Train Test Lab must fulfill a number of requirements. Figure 1 shows an overview of the available infrastructure at the test location Berlin-Spandau.

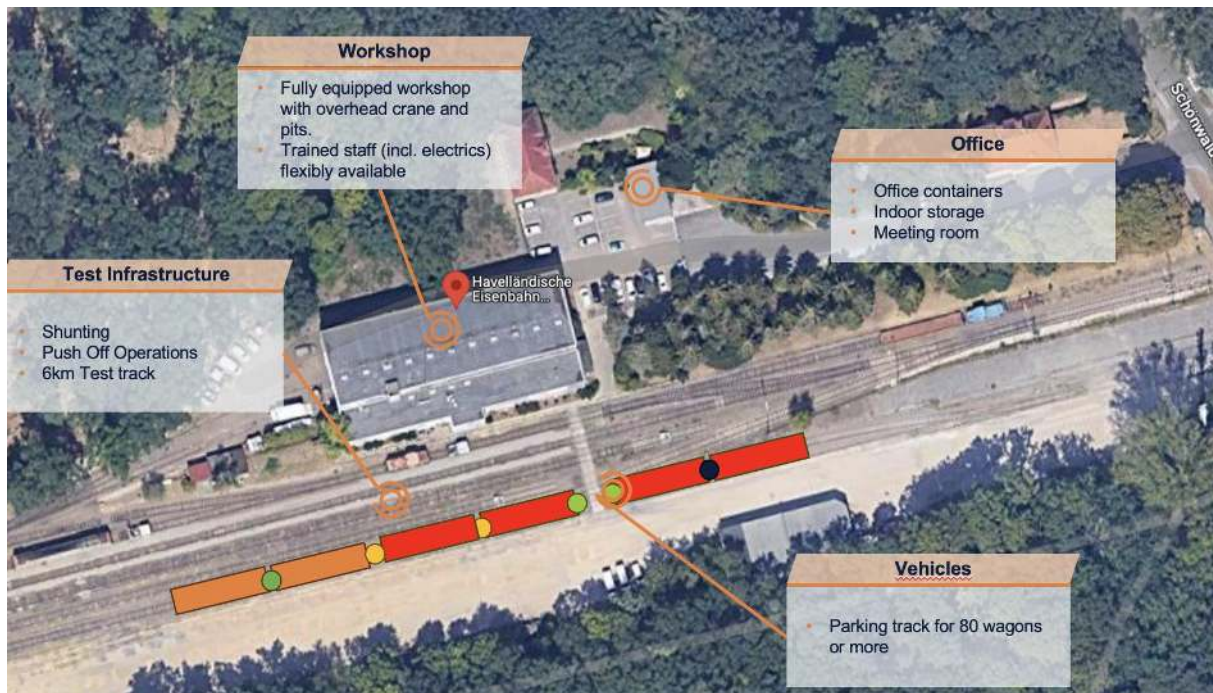


Figure 1: Train Test Lab overview

1.2 Objective for e-coupler tests and report structure

The basis for the tests to be executed is the list of criteria developed by a group of experts within TRANS4M-R [Matrix_B04]. For validation of the criteria, corresponding test cases were derived for the field tests and recorded in the Polarion software tool. This is also where a test instance is assigned for execution. The following test cases were assigned to WP14:

Table 1: Relevant test cases and criterias

Test case name (polarion)	Polarion ID	Criteria names	Criteria List Cell [Matrix_B04]
e-coupler – Impact tests	[IP-TRANS 2399]	Impact test	A2 – 2.4
e-coupler - Installation and maintenance	[IP-TRANS 2388]	Bolting Special tooling Maintainability (incl. ease of exchangeability)	A14 – 14.2 A15 – 15.1 B2 – 2.1
e-coupler - manual access to pins	[IP-TRANS 2380]	Hand access to pins	A11 – 11.1
e-coupler - Movement area and interaction with wagon components	[IP-TRANS 2377]	Installation checks	A1 – 1.2
e-coupler – Influence of dirt	[IP-TRANS 6555]	Bucket full of dirt	A10 – 10.1

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 presents the e-couplers to be analysed in more detail. Chapter 3 describes further infrastructure 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. Each test case is also supplier-specific for reasons of confidentiality.

Note

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

The relevant annexes are listed in chapter 6.

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, whereby the company partners only receive the appendices relevant to them. Further distribution should only take place in accordance with the above-mentioned confidentiality.

Table 2: Contact persons

Role	Name	E-Mail
WP14 lead – responsible for content	Daniel.Wolfram	Daniel.Wolfram@deutschebahn.com
Technical test lead	Julian Beck	Julian.J.Beck@deutschebahn.com
Operational test lead and safety	Harald Nitzsche	Harald.Nitzsche@hvle.de
Voith test engineer	Ulrich Deghela	ulrich.deghela@voith.com
KB test engineer	Norman Kreisel	Norman.Kreisel@knorr-bremse.com
Expert group lead	Ulrich Meuser	ulrich.meuser57@web.de

2 Introduction and description of systems under test

The purpose of this chapter is to introduce the e-coupler and the systems to be tested. A general overview is given first. Two samples of e-couplers of each supplier were available in the train test lab. These are described in detail in annex 0.

2.1 E-couplers – general remarks

Purpose of the e-coupler of the DAC is to transmit power and data from one wagon to another. This is achieved by electrical contacts on the front face of the e-couplers of two mating DACs. When coupling, the contacts of the mating DACs approach each other until they physically meet and thus can conduct electric signals or electric power respectively. Electric power and signals are transferred to the wagon by electric cables attached to the e-coupler on one side and a junction box on the wagon on the other side.

Note: Due to the geometric constraints of DACs approaching each other from opposite sides, the contact pattern of the contact block of the e-couplers must be designed mirrored along the centerline, which makes all contacts redundant.

The coupling of the e-coupler is intentionally accompanied by coupling of the mechanical coupler of the DAC (Scharfenberg-coupler). When two DACs are physically approaching each other, both the mechanical and the e-coupler will couple in a timely manner. However the exact timing of the e-coupler coupling versus the mechanical coupling may be different depending on the concept used.

One major challenge for e-couplers in freight rail wagons is connected to the required robustness. Operations in freight rail context in general are less controlled in terms of exposure of the components to mechanical loads. This does not only apply to the actual operation of the components, but also to environmental impacts caused by normal freight operation (loading, unloading, environmental conditions etc). One remarkable factor in this regard is the mechanical load to coupler components during shunting. High impact speeds with resulting high loads compared to passenger traffic applications must be handled by the components of the DAC and thus also the e-coupler. Technically this leads to increased requirements for the process of connecting the e-coupler contacts (centering, connection speed, support of e-couplers on coupler head, etc). Previous concepts of e-couplers rigidly mounted to the top of the mechanical coupler did not withstand these challenges sufficiently. Both tested concepts provide solutions for this issue which will be described in annex 0.

3 Infrastructure

3.1 Test location

All tests were executed at the HVLE premises in Berlin-Spandau (Schönwalder Allee 51, GER-13587 Berlin).

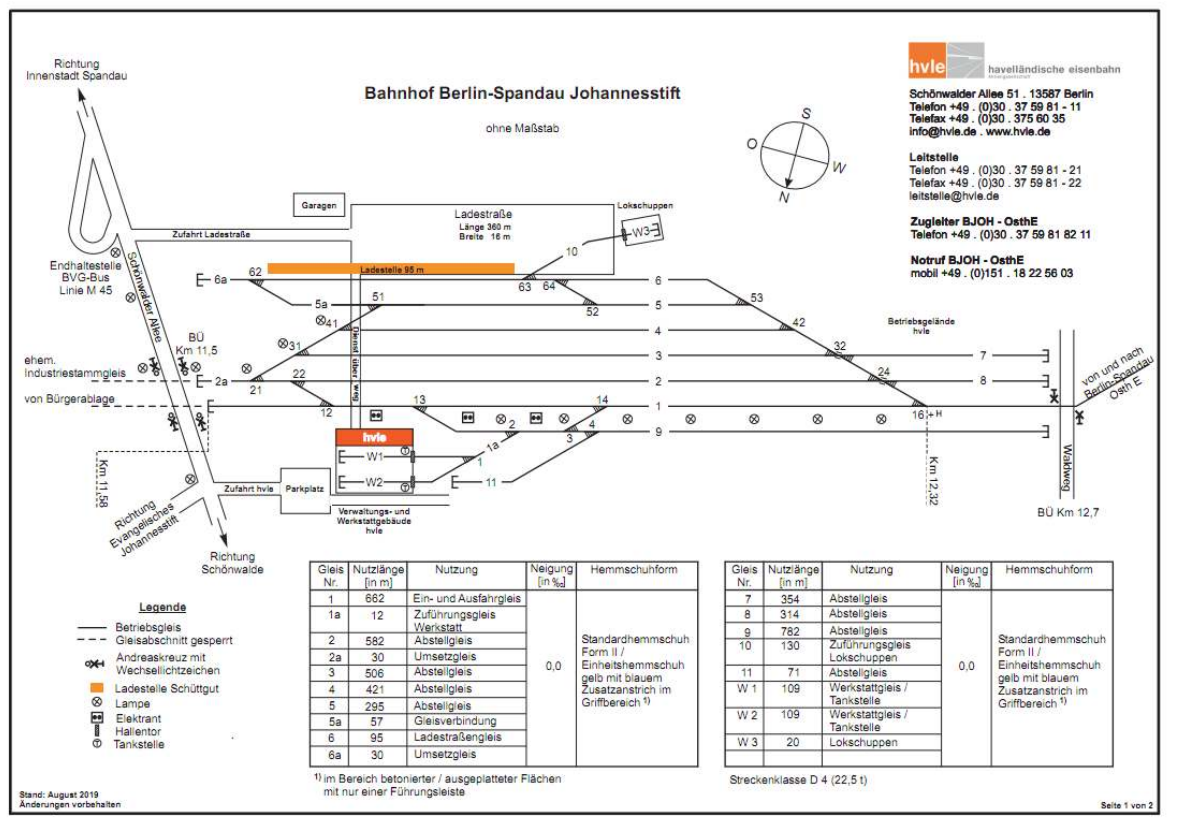


Figure 2: Track layout of the HVLE, location Berlin-Spandau [HVLE_TL].

3.2 Wagons

Four different wagons of two different types were used for the tests.

3.2.1 Shimmns_6025

Model: Shimmns-ttu

Type: 722

Description: Coil transport wagon

Number: 31 80 4675 602-5

Config:

Wagon	Config.	Date	Change
Shimmns_6025	#002	21.11.2023	Initial status before tests: Coupler A: VT_DAC4_004 Coupler B: Screw coupler Load state: empty
Shimmns_6025	#003	04.01.2024	Change of loading: Load state: full
Shimmns_6025	#004	09.01.2024	Damage of wheel bearings
Shimmns_6025	#005	10.01.2024	Change of loading: Load state: empty

Loading:

Load state	Weight	Source / description / remark
empty	23.600 kg	Sources: - Wagon-inscription. Remarks: - Measurement system not included. - Screw coupler exchanged with DAC.
full	86.400 kg	Sources: - Wagon-inscription. - Coil-inscriptions (Coil 1: 31 t and Coil2: 31,8 t) Remarks: - Measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 3: Shimmns_6025.



Figure 4: Loading of the Shimmns_6025 with 2 steel coils.

3.2.2 Shimmns_9383

Model: Shimmns-ttu

Type: 722

Description: Coil transport wagon

Number: 31 80 4675 938-3

Config:

Wagon	Config.	Date	Change
Shimmns_9383	#003	30.11.2023	Initial status before tests: Coupler A: Screw coupler Coupler B: KB_DAC45_005 Load state: empty
Shimmns_9383	#004	22.01.2024	Change of loading: Load state: full

Loading:

Load state	Weight	Source / description / remark
empty	23.600 kg	Sources: - Wagon-inscription. Remarks: - Measurement system not included. - Screw coupler exchanged with DAC.
full	86.400 kg	Sources: - Wagon-inscription (see above) - Coil-inscriptions (Coil 1: 31 t and Coil2: 31,8 t) Remarks: - Measurement system not included. - Screw coupler exchanged with DAC.

Photo documentation:



Figure 5: Shimmns_9383.

3.2.3 Samms_1781

Model: Samms

Type: 489

Description: Flat wagon

Number: 31 80 4852 178-1

Config:

Wagon	Config.	Date	Change
Samms_1781	#002	21.11.2023	Initial status before tests: Coupler A: KB_DAC45_001 (KB coupler, only used for installation tests) Coupler B: VT_DAC4_003 Load state: empty
Samms_1781	#003	04.01.2024	Change of loading: Load state: full
Samms_1781	#004	09.01.2024	Damage of flap on side B due to moving load
Samms_1781	#005	17.01.2024	Change of loading: Load state: empty

Loading:

Load state	Weight	Source / description / remark
empty	29.400 kg	Sources: - Wagon-inscription. Remarks: - Screw coupler exchanged with DAC.
full	86.400 kg	Sources: - Wagon-inscription. - Manufacturer information (20 concrete blocks with a weight of 2,7 t each). - 3 t of sleepers (estimated weight) Remarks: - Screw coupler exchanged with DAC.

Photo documentation:



Figure 6: Samms_1781 (loaded).



Figure 7: Concrete block with a weight of 2,7 t.

3.2.4 Samms_3779

Model: Samms

Type: 489

Description: Flat wagon

Number: 31 80 4852 377-9

Config:

Wagon	Config.	Date	Change
Samms_3779	#003	Prev. to 21.11.2023	Initial status Coupler A: KB_DAC45_006 Coupler B: KB_DAC45_002 (KB coupler, not used for the tests) Load state: empty
Samms_3779	#004	17.01.2024	Change of loading: Load state: full

Loading:

Load state	Weight	Source / description / remark
empty	29.400 kg	Sources: - Wagon-inscription. Remarks: - Screw coupler exchanged with DAC.
full	94.200 kg	Sources: - Wagon-inscription. - Manufacturer information (24 concrete blocks with a weight of 2,7 t each). Remarks: - Screw coupler exchanged with DAC.

Photo documentation:



Figure 8: Samms_3779 (unloaded).



Figure 9: Samms_3779 (loaded).

4 Test description and schedule summary

A detailed description of the systems under test and the test schedules can be found in annex 0.

A detailed description of the executed tests can be found in the annexes listed in chapter 6.

EXTRACT - 24.02.2026
(No Results)

5 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[HVLE_TL]	-	Gleisplan – Bahnhof Berlin-Spandau Johannesstift	HVLE	08.2019	-
[IP-TRANS 2377]	-	Polarion: e-coupler – Installation space and interaction with wagon components Link: https://polarion.rail-research.europa.eu/polarion/#/project/IPTRANS4MR/workitem?id=IPTRANS-2377	Daniel Wolfram	26.01.2024	-
[IP-TRANS 2380]	-	Polarion: e-coupler – manual access to pin Link: https://polarion.rail-research.europa.eu/polarion/#/project/IPTRANS4MR/workitem?id=IPTRANS-2380	Daniel Wolfram	26.01.2024	-
[IP-TRANS 2388]	-	Polarion: e-coupler – Installation and maintenance Link: https://polarion.rail-research.europa.eu/polarion/#/project/IPTRANS4MR/workitem?id=IPTRANS-2388	Daniel Wolfram	05.12.2023	-
[IP-TRANS 2399]	-	Polarion: e-coupler – Impact tests Link: https://polarion.rail-research.europa.eu/polarion/#/project/IPTRANS4MR/workitem?id=IPTRANS-2399	Daniel Wolfram	15.12.2023	-
[IP-TRANS 6555]	-	Polarion: e-coupler – Influence of dirt Link: https://polarion.rail-research.europa.eu/polarion/#/project/IPTRANS4MR/workitem?id=IPTRANS-6555	Daniel Wolfram	27.01.2024	-
[Matrix_B04]	-	E-coupler assessment MATRIX_B04	-	05.12.2023	B04

6 Appendices

Annex		Vn.	Title	Content
Annex 0_	KB	01	System under test and schedule – Knorr-Bremse	Description of the tested objects and the test schedule – Knorr-Bremse
	VT	01	System under test and schedule – Voith	Description of the tested objects and the test schedule – Voith
Annex 1_	KB	01	Impact tests – Knorr-Bremse	e-coupler – Impact tests [IP-TRANS 2399] – Knorr-Bremse - Test concept and results
	VT	01	Impact tests – Voith	e-coupler – Impact tests [IP-TRANS 2399] – Voith - Test concept and results
Annex 2_	KB	01	Installation and maintenance tests – Knorr-Bremse	e-coupler - Installation and maintenance [IP-TRANS 2388] – Knorr-Bremse - Test concept and results
	VT	01	Installation and maintenance tests – Voith	e-coupler - Installation and maintenance [IP-TRANS 2388] – Voith - Test concept and results
Annex 3_	KB	01	Manual access to pins – Knorr-Bremse	e-coupler - manual access to pins [IP-TRANS 2380] – Knorr-Bremse - Test concept and results
	VT	01	Manual access to pins – Voith	e-coupler - manual access to pins [IP-TRANS 2380] – Voith - Test concept and results
Annex 4_	KB	01	Movement area and interaction with wagon components – Knorr-Bremse	e-coupler - Movement area and interaction with wagon components [IP-TRANS 2377] – Knorr-Bremse - Test concept and results
	VT	01	Movement area and interaction with wagon components – Voith	e-coupler - Movement area and interaction with wagon components [IP-TRANS 2377] – Voith - Test concept and results
Annex 5_	KB	01	Influence of dirt - Knorr-Bremse	e-coupler – Influence of dirt [IP-TRANS 6555] – Knorr-Bremse - Test concept and results
	VT	01	Influence of dirt – Voith	e-coupler – Influence of dirt [IP-TRANS 6555] – Voith - Test concept and results

Annex 1_KB

Impact tests

E-coupler: Knorr-Bremse

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 1_KB
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	7
2.1 Description of execution of impact tests	7
2.1.1 Test preparation / Initial setup	7
2.1.2 Push-off operation.....	8
2.1.3 Impact.....	8
2.1.4 Reset to couple-position and uncouple.....	9
2.1 Infrastructure	10
2.1.1 Wagons and couplers.....	10
2.1.2 Test-location	10
2.2 Measurement equipment / Documentation	13
2.2.1 Measurement equipment.....	14
2.3 Criteria for a valid test execution	23
2.4 Evaluation	23
3 Test execution – further measurements	24
3.1 Insulation	24
3.2 Coupler heights.....	25
4 Results	28
4.1 Impact tests	28
4.1.1 Summary.....	28
4.1.2 Electrical disconnections.....	29
4.1.3 Damages on the e-coupler	30
4.1.4 Further abnormalities	40
4.2 Insulation measurement.....	43
4.3 Coupler heights.....	44
5 Conclusion.....	45
6 References.....	46
7 Annex 1.1 – Extract of protocol	47

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

Symbol	Description
	Brake shoe
	Coupler not defined
	DAC - coupled
	DAC - not coupled
	Marker
	Screw coupler - coupled
	Screw coupler - not coupled / push off mode

1 Description of test case

This annex is focusing on the test case “e-coupler – Impact tests” described in Polarion ID “IPTRANS-2399” [IP-TRANS 2399]. Objective of the tests is the evaluation of e-couplers regarding the reliability during coupling and uncoupling operations. Besides the e-coupler, the mechanical coupler shall also be observed.

In particular impact tests with different speeds, different loading conditions and on different track geometries shall be performed.

Description from [IP-TRANS 2399]:

Polarion ID	IPTRANS-2399		
Title	e-coupler – Impact tests		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Reliability	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

Testing different speeds and loadings, etc.

Detailed Test Specification is available within WP 14.

Summary from [Matrix_B04]:

#	A2
Name	Function
Sub #	2.4
Title	Full coupling function tests on vehicles
P/F or BoB	P/F
Requirement / Test description	TTL to run simplified coupling tests with limited speeds and curves, redundant with Full Quality Gate 1 coupling
Related AUCO	AUCO.17 AUCO.18 AUCO.19 AUCO.52 AUCO.54 AUCO.55 Vehicle.5 Vehicle.6 Vehicle.7 Vehicle.8 Vehicle.10

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

Impact tests to be executed with each coupler (in accordance with [WP14_Task1]):

Case	Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount	Remark
1	empty	empty	2	straight	5	
2	empty	empty	4	straight	5	
3	empty	empty	6	straight	5	
4	empty	empty	8	straight	5	
5	empty	empty	10	straight	5	
6	empty	empty	12	straight	5	
7	empty	full	2	straight	5	
8	empty	full	4	straight	5	
9	empty	full	6	straight	5	
10	empty	full	8	straight	5	
11	empty	full	10	straight	5	
12	empty	full	12	straight	5	
13	full	empty	2	straight	5	Not planned
14	full	empty	4	straight	5	Not planned
15	full	empty	6	straight	5	Not planned
16	full	empty	8	straight	5	Not planned
17	full	empty	10	straight	5	Not planned
18	full	empty	12	straight	5	Not planned
19	full	full	2	straight	3-5	
20	full	full	4	straight	3-5	
21	full	full	6	straight	3-5	
22	full	full	8	straight	3-5	
23	full	full	10	straight	3-5	
24	full	full	12	straight	3-5	
25	empty	empty	2	150 m left	3-5	Not planned
26	empty	empty	4	150 m left	3-5	Not planned
27	empty	empty	6	150 m left	3-5	Not planned
28	empty	empty	2	150 m right	3-5	Planned: 5 times and on 190m curve.
29	empty	empty	4	150 m right	3-5	Planned: 5 times and on 190m curve.
30	empty	empty	6	150 m right	3-5	Planned: 5 times and on 190m curve.
31	full	empty	2	150 m left	3-5	Not planned
32	full	empty	4	150 m left	3-5	Not planned
33	full	empty	6	150 m left	3-5	Not planned
34	full	empty	2	150 m right	3-5	Not planned
35	full	empty	4	150 m right	3-5	Not planned

Case	Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount	Remark
36	full	empty	6	150 m right	3-5	Not planned
37	full	full	2	150 m left	3-5	Not planned
38	full	full	4	150 m left	3-5	Not planned
39	full	full	6	150 m left	3-5	Not planned
40	full	full	2	150 m right	3-5	Planned: 5 times and on 190m curve.
41	full	full	4	150 m right	3-5	Planned: 5 times and on 190m curve.
42	full	full	6	150 m right	3-5	Planned: 5 times and on 190m curve.
43	empty	full	2	150 m left	3-5	Not planned
44	empty	full	4	150 m left	3-5	Not planned
45	empty	full	6	150 m left	3-5	Not planned
46	empty	full	2	150 m right	3-5	Planned: 5 times and on 190m curve.
47	empty	full	4	150 m right	3-5	Planned: 5 times and on 190m curve.
48	empty	full	6	150 m right	3-5	Planned: 5 times and on 190m curve.

To be evaluated:

To evaluate	Criteria	P/F or BoB
Primary – E-coupler:		
Mechanical coupling of e-coupler	The e-coupler is mechanically coupled if the DAC is coupled, the lids are open, and the centring pins engage with each other.	P/F
Establishing power and data connection	Power and data connection is established at least 6s after the mechanical coupling. If a redundant contact fails, this is noted.	P/F
Closing lid after uncoupling	If the DAC is not coupled, the lid must be closed.	P/F
Insulation	The insulation must not be damaged during the tests.	P/F
Damages	The e-coupler must not be damaged during or after the tests.	P/F
Wear and tear	The wear of wear parts, such as contacts and seals, should be noted. Remark: The wear should not lead to failure of the parts, considering the amount of tests.	BoB
Additionally – Mech. coupler:		
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	-
Uncoupling	By mechanically uncoupling on one coupler, both couplers reach the “ready-to-couple”-position.	-

2 Test execution

2.1 Description of execution of impact tests

In general, during the impact tests two DACs are coupled with a defined relative speed by a push-off operation. Therefore, one unbraked standing wagon is positioned on a defined location on the track (straight or curve). A moving wagon is accelerated and pushed-off.

The moving wagon impacts on the standing wagon, the couplers impact on each other.

The steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

In advance to every test, the following was set up:

Standing wagon:

- Brakes deactivated
- Coupler centred
- Coupler in status "ready to couple"

Moving wagon:

- Brakes deactivated
- Coupler centred
- Coupler in status "ready to couple"

The coupler of the standing wagon was placed on a defined, marked location on the track. To brake the wagons after impact, a brake shoe is placed approx. 20 m behind the standing wagon.



Figure 1: Impact tests: Initial setup.

2.1.2 Push-off operation

For the push-off operation, the moving wagon is uncoupled from the loco and accelerated. As the moving wagon is slowing down due to different influences after push-off, the exact speeds during the push-off operation are not defined and decided by the loco driver based on his experience. Only the impact speed is defined.

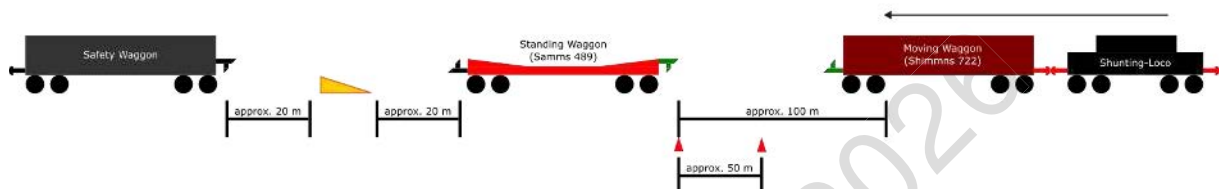


Figure 2: Impact tests: Push-off operation – acceleration phase.

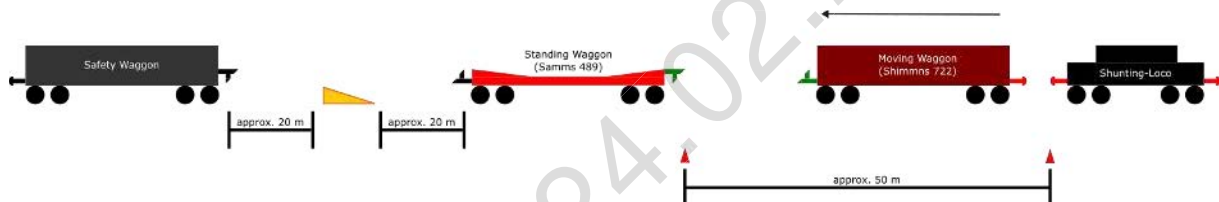


Figure 3: Impact tests: Push-off operation – push-off.

2.1.3 Impact

The moving wagon impacts on the standing wagon. Both wagons move further and are braked by the brake shoe.

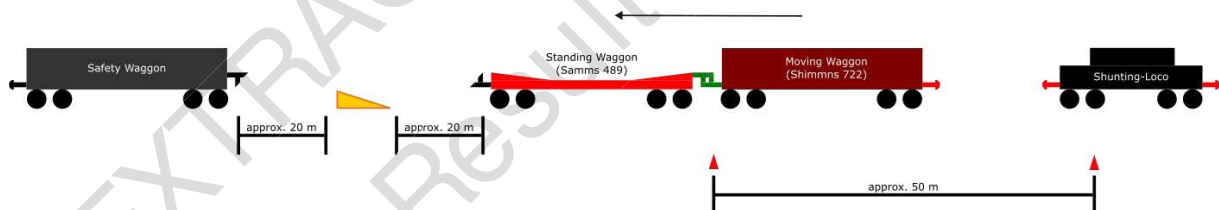


Figure 4: Impact tests: Impact.

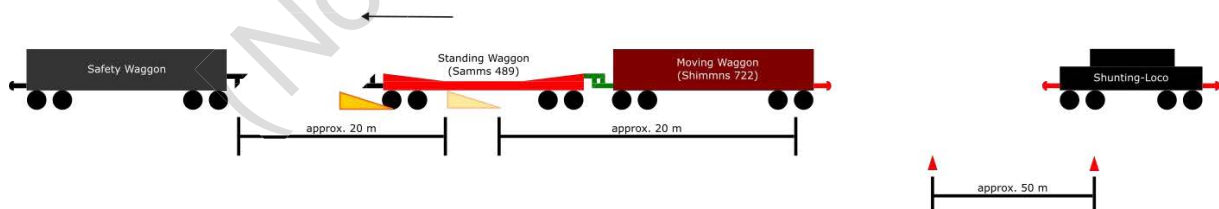


Figure 5: Impact tests: Braking after impact.

2.1.4 Reset to couple-position and uncouple

After braking, the wagons are pulled back to the couple position. The wagons are uncoupled, and the initial setup is re-established. The wagons are uncoupled by means of the mechanical uncoupling device.

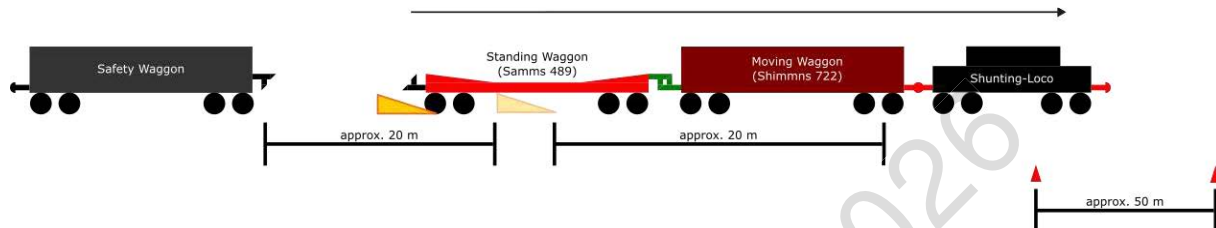


Figure 6: Impact tests: Pull back wagons.

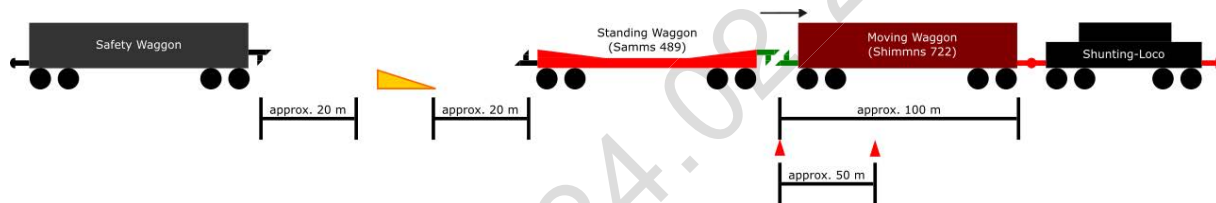


Figure 7: Impact tests: Uncouple and reset to initial setup.

Remark:

The couplers are uncoupled by means of the mechanical uncoupling device. This is expected to not work correctly.

To bring both couplers into the "ready-to-couple" position the following steps were executed:

1. The mechanic uncoupling device is actuated. The couplers will uncouple. The non-actuated coupler is expected to not reach the „ready-to-couple“-position. The actuated coupler is expected to reach the „ready-to-couple“-position.
2. The electric uncoupling device is actuated on the coupler that stayed in "coupled" position. The coupler is expected to reach "ready-to-couple"-position.

2.1 Infrastructure

2.1.1 Wagons and couplers

The couplers were installed on two different wagons:

- Shimmns_9383 → KB_DAC45_005
- Samms_3779 → KB_DAC45_006

The Shimmns_9383 was equipped with a measurement system by DBST (see chapter 2.2.1.1).

Further, more detailed information on the wagons can be found in the main report.

Further, more detailed information on the couplers can be found in annex 0.

2.1.2 Test-location

All tests were executed at the HVLE premises (see also the main report).

Tests on straight track were executed on track 3.

Tests in 190m-curve were executed on switch 12. The tested coupler of the standing wagon was placed in the middle of the switch 12, while the moving wagon was pushed off on track 1 (from the direction of switch 13).

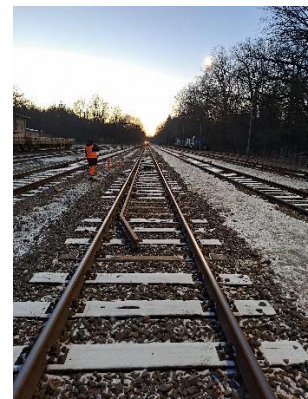


Figure 8: Photos of test-setup for tests on straight track.
Left: test setup for impact tests on straight track, right: the test track (track 3).



Figure 9: Test setup for impact tests in 190m-right-curve (switch 12).



Figure 10: Positioning of standing wagon on the switch 12 (190m-curve).

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
- Moving / Standing wagon and coupler
- Type of actuation of coupler and actuated coupler
- Abnormalities and deviations from procedure

Documentation by video/photo:

- Video documentation of the whole impact test at impact location (see chapter 2.2.1.2.2)
- Photo documentation of the e-coupler on a regular basis (approx. every 5 tests)

Measured by measurement systems:

- Force on the mechanical coupler head
- Impact speed
- Displacement of mechanical coupler head relative to wagon
- Connection of electrical contacts

Every test was recorded by the DBST on-wagon system (see chapter 2.2.1.1) on the moving wagon, the Shimmns_9383.

The impact speed in straight track was measured additionally by a light barrier (see chapter 2.2.1.2.1). The light barrier served as a back-up system. The relevant measurement system for the impact speed was the DBST on-wagon system.

2.2.1 Measurement equipment

The measurement equipment consisted of different parts: a system installed on the Shimmns_9383 wagon by DBST, supported by different additional static systems (e.g. light barrier and cameras) and hand-held systems (e.g. multimeter).

2.2.1.1 On-wagon system (DBST-system)

The on-wagon measurement system was installed on the Shimmns_9383 wagon. It consisted of a Datalogger and two measuring amplifiers. Calibrated measurement chains were used to record the data of the on-board system. This does not apply for GPS-data. The location of installation of the sensors, signal names, identifiers and descriptions are shown in the following table:

Name	New unit	A = analogue D = digital	Description	Source / Installation	Connection	Range
Time			Time	Data-logger		
F_z			Force on coupler	DMS / strain gauges	Top and bottom side of coupler	-2.000 to 2.000 kN
S_x			Displacement (x-axis -> Sideways)	Wire sensor	On rack -> rights side of coupler	0 to 1.000 mm
S_y			Displacement (y-axis -> Up/Down)	Wire sensor	On rack -> above coupler	0 to 1.000 mm
S_z			Displacement (z-axis -> Forward/Backward)	Wire sensor	On rack -> behind coupler	0 to 1.000 mm
S_imp			Impulses (Distance)	Incremental Encoder	Pushed on right wheel	0-70.000.000
U_Pins_Data			Voltage throughput coupler	Voltage sensor	See connection description	0 - 60 V
U_Pins_Power			Voltage throughput coupler	Voltage sensor	See connection description	0 - 60 V
s	m		Distance	- calculated		
v_kmh_sm	km/h		Speed, filtered (over 0.1 s)	- calculated		

2.2.1.1.1 Force on the coupler

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



Figure 11: Strain gauge on the coupler KB_DAC45_006.

2.2.1.1.2 Displacement of the coupler

To measure the displacement of the coupler wire sensors were used in x-, y- and z-axis. 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 12: Wire sensor for forward/backward movement S_z .



Figure 13: Wire sensor for vertical movement S_y .



Figure 14: Wire sensor for horizontal movement S_x .

2.2.1.1.3 Impact-speed

The speed of the moving wagon was measured with an incremental encoder. It measured the rotation of a wheel, pushed to the outer side of the wagon-wheel. 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 15: Incremental encoder with wheel, attached to the wagon wheel.

2.2.1.1.4 Electrical connection

To measure the electrical connection of the coupler, a voltage was applied from the battery pack to the e-coupler of the moving wagon. A short circuit was set in the e-coupler on the standing wagon. The voltage was measured with the measurement system on the moving wagon.

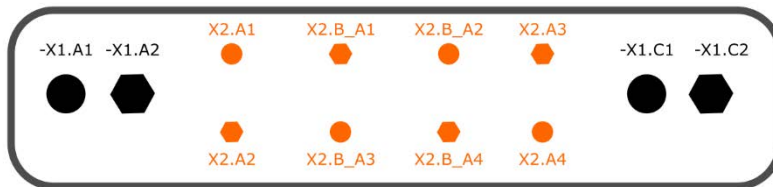


Figure 16: Pin-names of the e-coupler.

For tests KB161 to KB219 one voltage was measured over all power-pins of the e-coupler and all data-pins, except for X2.B_A1 and X2.B_A2, as Knorr Bremse used these pins for data-transfer over the coupler.

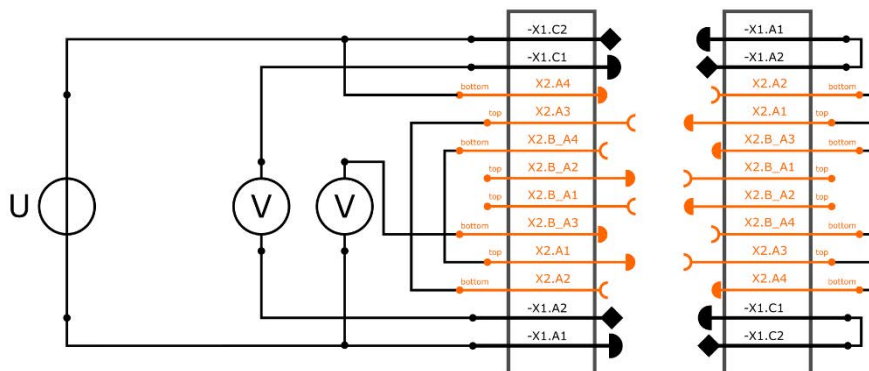


Figure 17: Circuit for voltage measurement until test KB219.

For tests from KB220 onwards, the voltage over the data pins was measured over all pins.

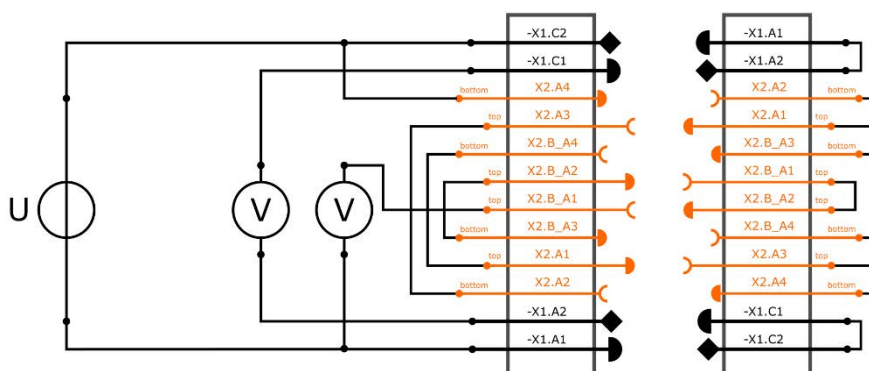


Figure 18: Circuit for voltage measurement from test KB220 onwards.

2.2.1.1.5 Data acquisition

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

- Data logger: QuantumX CX22B-W (HBK)
- Measuring amplifiers: SomatXR MX480B-R (HBK)
- Data acquisition software: CatMan-Easy, Version 5.6.2 (HBK)

The data was measured with a frequency of 1.000 Hz.

For power-supply a battery pack with 48 V was designed and installed by HVLE.



Figure 19: DBST on-wagon measurement system: Data-logger and measuring amplifiers.



Figure 20: DBST on-wagon measurement system: Battery pack with different voltage outputs.

2.2.1.1.6 Data processing

Python-Scripts for editing and graphical presentation of the data were written by the TTL.

2.2.1.2 Static systems

2.2.1.2.1 Light barrier

In addition to the incremental encoder to measure the impact speed, two light barriers were installed. They measured the time it took for the moving wagon to pass through the first and second light barriers. One wheel of the foremost axle was always taken as the reference point. The distance between the light barriers was 1.8 m and thus also corresponded to the distance between the 2 axles in the bogie. This ensured the 1.8 m distance, as the second axle passed through the first light barrier at the same time as the first axle passed through the second light barrier. The speed could be calculated using the measured time and the defined distance. The light barriers were positioned as close as possible to the coupling point, to reduce the loss of speed due to friction. The signals were measured and analysed with an "imc Cronos CS-7008-FD" measurement system. The light barriers were installed as a backup system for the incremental encoder and as a quick way, to analyse the impact speed.





Figure 21: Installation of light barrier.

Top: Measurement of light-barrier distance. Bottom: installation on track.

2.2.1.2.2 Camera systems

The camera system consists of 5 individual GoPro cameras set up in different positions. For every impact test, the same camera was used in the same position. The first camera was mounted on a tripod and positioned close to the coupling point to get a close-up shot. The second GoPro was also mounted on a tripod but positioned further away to get a long shot of the tests. The third and fourth cameras were mounted on the moving and standing wagon with a view of the e-coupler. They were glued on the front walls of the wagon. The fifth camera was positioned in the track bed to record a view from below.

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

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Primary – E-coupler	
Mechanical coupling of e-coupler	→ Documentation in protocol
Establishing power and data connection	→ Measured with on-wagon system. Evaluation of voltage signals 2s after impact.
Closing lid after uncoupling	→ Documentation of abnormalities in protocol
Insulation	→ Measurement on regular basis, see chapter 3.1.
Damages	→ Documentation of abnormalities in protocol → Photo documentation
Wear and tear	→ Documentation of abnormalities in protocol → Photo documentation
Additionally – Mech. coupler:	
Mechanical coupling	→ Documentation of coupler status after impact in protocol
Compression force	→ Measured with on-wagon system. Max. force during test evaluated.
Uncoupling	→ Documentation of coupler status after uncoupling in protocol

3 Test execution – further measurements

3.1 Insulation

The insulation-resistance was measured from each pin to the housing and from each pin to every other pin. Before the measurement, the wire of every pin was disconnected from attached circuits.

The continuity between the housing and the rail was also measured.

As measurement instrument, a Fluke 1503 [Fluke_1503] with an input-voltage of 500 V was used. The connection was done directly on the pins at the coupler.

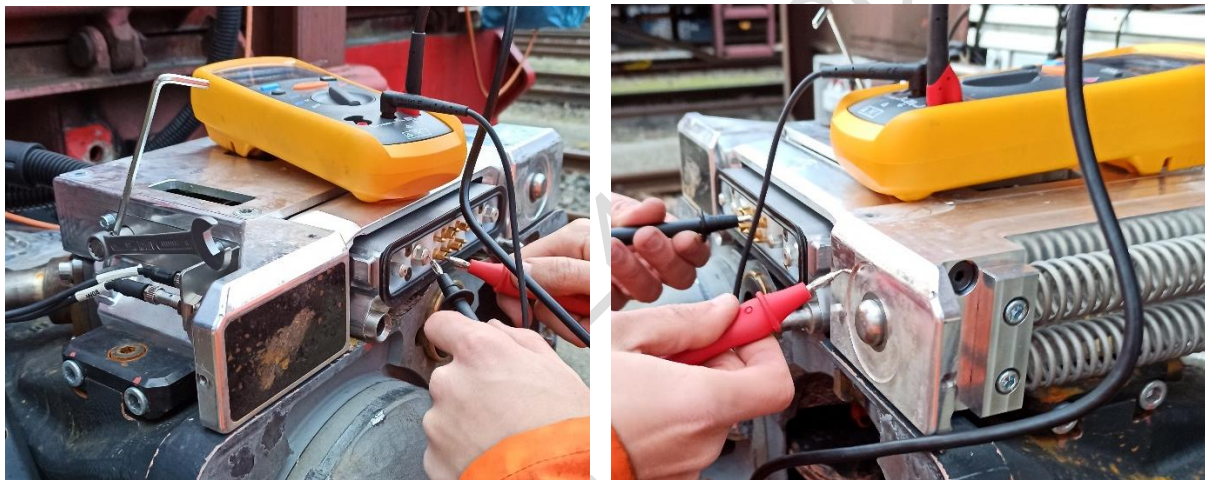


Figure 22: Measurement of insulation-resistance.
Left: measurement pin to pin. Right: measurement pin to housing.

3.2 Coupler heights

For evaluation of the vertical displacement during coupling of loaded and empty wagons, the height of the couplers was measured.

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

- Distance between sleeper and end of coupler bolt (see Figure 23)
- Distance between sleeper and top of rail (see Figure 24)
- Length of coupler bolt (see Figure 25)

The heights were measured with a folding rule and a plumb bob.

The distance between the middle of the coupler bolt (CB) and the top of rail (TOR) is calculated as:

$$Distance_{middle\ of\ CB-TOR} = Distance_{end\ of\ CB-Sleeper} - Distance_{Sleeper-top\ of\ rail} - \frac{1}{2}Length_{CB}$$

The height difference between the loaded and unloaded wagon was also measured directly by stopping the wagons with a small distance to each other and measure the distance between the end of the coupler bolts (see Figure 26).

The measurements took place on the following dates and locations.

Coupler height	Date	Track
Difference between unloaded Shimmns – loaded Samms	18 th January 2024	3
Unloaded Shimmns	17 th January 2024	W1
Loaded Shimmns	25 th January 2024	1
Unloaded Samms	16 th January 2024	W1
Loaded Samms	18 th January 2024	3



Figure 23: Measurement of the distance between sleeper and end of coupler bolt.



Figure 24: Measurement of the distance between sleeper and top of rail.



Figure 25: Measurement of the length of the coupler bolt.



Figure 26: Measurement of the height difference.

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Annex 1_VT

Impact tests

E-coupler: Voith

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 1_VT
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	7
2.1 Description of execution of impact tests	7
2.1.1 Test preparation / Initial setup	7
2.1.2 Push-off operation.....	8
2.1.3 Impact.....	8
2.1.4 Reset to couple-position and uncouple.....	9
2.1 Infrastructure	10
2.1.1 Wagons and couplers.....	10
2.1.2 Test-location	10
2.2 Measurement equipment / Documentation	12
2.2.1 Measurement equipment.....	13
2.3 Criteria for a valid test execution	22
2.4 Evaluation	22
3 Test execution – further measurements	23
3.1 Insulation	23
3.2 Coupler heights.....	24
4 Results	27
4.1 Impact tests	27
4.1.1 Summary.....	27
4.1.2 Electrical disconnections.....	29
4.1.3 Damages on the e-coupler	31
4.1.4 Further abnormalities	34
4.2 Insulation measurement.....	35
4.3 Coupler heights.....	36
5 Conclusion.....	37
6 References.....	38
7 Annex 1.1 – Extract of protocol	39

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

Symbol	Description
	Brake shoe
	Coupler not defined
	DAC - coupled
	DAC – not coupled
	Marker
	Screw coupler - coupled
	Screw coupler – not coupled / push off mode

1 Description of test case

This annex is focusing on the test case “e-coupler – Impact tests” described in Polarion ID “IPTRANS-2399” [IP-TRANS 2399]. Objective of the tests is the evaluation of e-couplers regarding the reliability during coupling and uncoupling operations. Besides the e-coupler, the mechanical coupler shall also be observed.

In particular impact tests with different speeds, different loads and on different track geometries shall be performed.

Description from [IP-TRANS 2399]:

Polarion ID	IPTRANS-2399		
Title	e-coupler – Impact tests		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Reliability	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

Testing different speeds and loadings, etc.

Detailed Test Specification is available within WP 14.

Summary from [Matrix_B04]:

#	A2
Name	Function
Sub #	2.4
Title	Full coupling function tests on vehicles
P/F or BoB	P/F
Requirement / Test description	TTL to run simplified coupling tests with limited speeds and curves, redundant with Full Quality Gate 1 coupling
Related AUCO	AUCO.17 AUCO.18 AUCO.19 AUCO.52 AUCO.54 AUCO.55 Vehicle.5 Vehicle.6 Vehicle.7 Vehicle.8 Vehicle.10

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

Impact tests to be executed with each coupler (in accordance with [WP14_Task1]):

Case	Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount	Remark
1	empty	empty	2	straight	5	
2	empty	empty	4	straight	5	
3	empty	empty	6	straight	5	
4	empty	empty	8	straight	5	
5	empty	empty	10	straight	5	
6	empty	empty	12	straight	5	
7	empty	full	2	straight	5	
8	empty	full	4	straight	5	
9	empty	full	6	straight	5	
10	empty	full	8	straight	5	
11	empty	full	10	straight	5	
12	empty	full	12	straight	5	
13	full	empty	2	straight	5	Not planned
14	full	empty	4	straight	5	Not planned
15	full	empty	6	straight	5	Not planned
16	full	empty	8	straight	5	Not planned
17	full	empty	10	straight	5	Not planned
18	full	empty	12	straight	5	Not planned
19	full	full	2	straight	3-5	
20	full	full	4	straight	3-5	
21	full	full	6	straight	3-5	
22	full	full	8	straight	3-5	
23	full	full	10	straight	3-5	
24	full	full	12	straight	3-5	
25	empty	empty	2	150 m left	3-5	Not planned
26	empty	empty	4	150 m left	3-5	Not planned
27	empty	empty	6	150 m left	3-5	Not planned
28	empty	empty	2	150 m right	3-5	Planned: 5 times and on 190m curve.
29	empty	empty	4	150 m right	3-5	Planned: 5 times and on 190m curve.
30	empty	empty	6	150 m right	3-5	Planned: 5 times and on 190m curve.
31	full	empty	2	150 m left	3-5	Not planned
32	full	empty	4	150 m left	3-5	Not planned
33	full	empty	6	150 m left	3-5	Not planned
34	full	empty	2	150 m right	3-5	Not planned
35	full	empty	4	150 m right	3-5	Not planned

Case	Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount	Remark
36	full	empty	6	150 m right	3-5	Not planned
37	full	full	2	150 m left	3-5	Not planned
38	full	full	4	150 m left	3-5	Not planned
39	full	full	6	150 m left	3-5	Not planned
40	full	full	2	150 m right	3-5	Planned: 5 times and on 190m curve.
41	full	full	4	150 m right	3-5	Planned: 5 times and on 190m curve.
42	full	full	6	150 m right	3-5	Planned: 5 times and on 190m curve.
43	empty	full	2	150 m left	3-5	Not planned
44	empty	full	4	150 m left	3-5	Not planned
45	empty	full	6	150 m left	3-5	Not planned
46	empty	full	2	150 m right	3-5	Planned: 5 times and on 190m curve.
47	empty	full	4	150 m right	3-5	Planned: 5 times and on 190m curve.
48	empty	full	6	150 m right	3-5	Planned: 5 times and on 190m curve.

To be evaluated:

To evaluate	Criteria	P/F or BoB
Primary – E-coupler:		
Mechanical coupling of e-coupler	The e-coupler is mechanically coupled if the DAC is coupled, the lids are open, and the centring pins engage with each other.	P/F
Establishing power and data connection	Power and data connection is established at least 6s after the mechanical coupling. If a redundant contact fails, this is noted.	P/F
Closing lid after uncoupling	If the DAC is not coupled, the lid must be closed.	P/F
Insulation	The insulation must not be damaged during the tests.	P/F
Damages	The e-coupler must not be damaged during or after the tests.	P/F
Wear and tear	The wear of wear parts, such as contacts and seals, should be noted. Remark: The wear should not lead to failure of the parts, considering the amount of tests.	BoB
Additionally – Mech. coupler:		
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	-
Uncoupling	By mechanically uncoupling on one coupler, both couplers reach the “ready-to-couple”-position.	-

2 Test execution

2.1 Description of execution of impact tests

In general, during the impact tests two DACs are coupled with a defined relative speed by a push-off operation. Therefore, one unbraked standing wagon is positioned on a defined location on the track (straight or curve). A moving wagon is accelerated and pushed-off.

The moving wagon impacts on the standing wagon, the couplers impact on each other.

The steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

In advance to every test, the following was set up:

Standing wagon:

- Brakes deactivated
- Coupler centred
- Coupler in status "ready to couple"

Moving wagon:

- Brakes deactivated
- Coupler centred
- Coupler in status "ready to couple"

The coupler of the standing wagon was placed on a defined, marked location on the track. To brake the wagons after impact, a brake shoe is placed approx. 20 m behind the standing wagon.



Figure 1: Impact tests: Initial setup.

2.1.2 Push-off operation

For the push-off operation, the moving wagon is uncoupled from the loco and accelerated. As the moving wagon is slowing down due to different influences after push-off, the exact speeds during the push-off operation are not defined and decided by the loco driver based on his experience. Only the impact speed is defined.

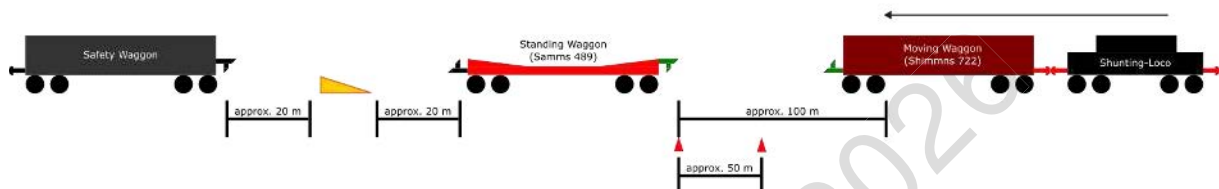


Figure 2: Impact tests: Push-off operation – acceleration phase.

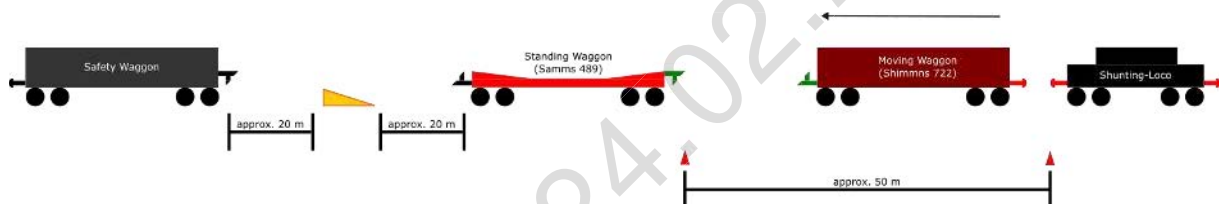


Figure 3: Impact tests: Push-off operation – push-off.

2.1.3 Impact

The moving wagon impacts on the standing wagon. Both wagons move further and are braked by the brake shoe.

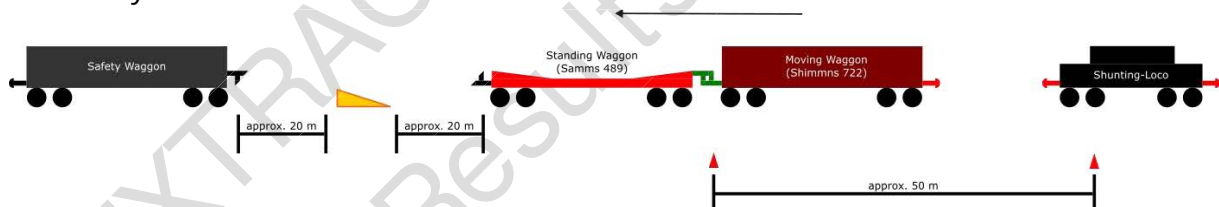


Figure 4: Impact tests: Impact.

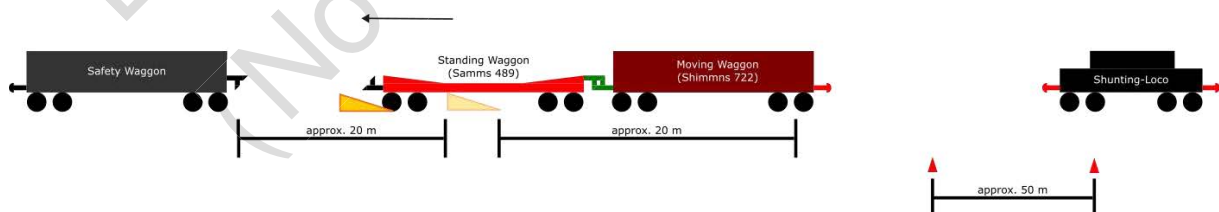


Figure 5: Impact tests: Braking after impact.

2.1.4 Reset to couple-position and uncouple

After braking, the wagons are pulled back to the couple position. The wagons are uncoupled, and the initial setup is re-established. The wagons are uncoupled by means of the mechanical uncoupling device.

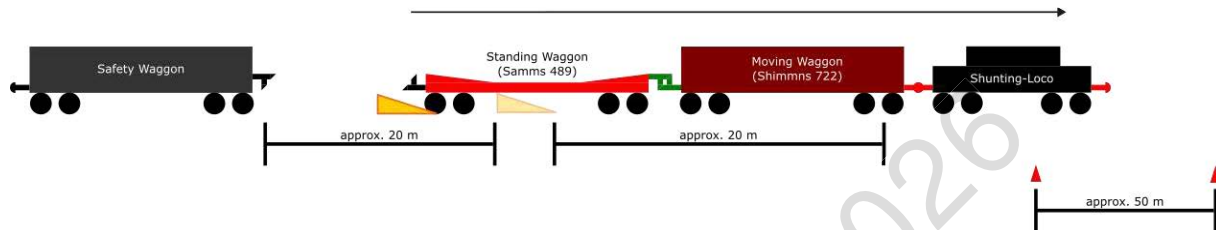


Figure 6: Impact tests: Pull back wagons.

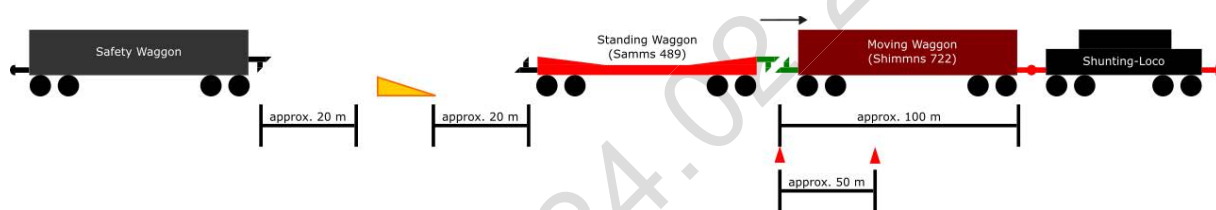


Figure 7: Impact tests: Uncouple and reset to initial setup.

Remark:

The couplers are uncoupled by means of the mechanical uncoupling device. This is expected to not work correctly.

2.1 Infrastructure

2.1.1 Wagons and couplers

The couplers were installed on two different wagons:

- Shimmns_6025 → VT_DAC4_004
- Samms_1781 → VT_DAC4_003

The Shimmns_6025 was equipped with a measurement system by DBST (see chapter 2.2.1.1).

Further, more detailed information on the wagons can be found in the main report.

Further, more detailed information on the couplers can be found in annex 0.

2.1.2 Test-location

All tests were executed at the HVLE premises (see also the main report).

Tests on straight track were executed on track 3.

Tests in 190m-curve were executed on switch 22. The tested coupler of the standing wagon was placed in the middle of the switch 22, while the moving wagon was pushed off on track 2a (from the direction of switch 21).



Figure 8: Photos of test-setup for tests on straight track.
Left: test setup for impact tests on straight track, right: the test track (track 3).



Figure 9: Test setup for impact tests in 190m-right-curve (switch 22).



Figure 10: Positioning of standing wagon on the switch 22 (190m-curve).

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
- Moving / Standing wagon and coupler
- Type of actuation of coupler and actuated coupler
- Abnormalities and deviations from procedure

Documentation by video/photo:

- Video documentation of the whole impact test at impact location (see chapter 2.2.1.2.2)
- Photo documentation of the e-coupler on a regular basis (approx. every 5 tests)

Measured by measurement systems:

- Force on the mechanical coupler head
- Impact speed
- Displacement of mechanical coupler head relative to wagon
- Connection of electrical contacts

Every test was recorded by the DBST on-wagon system (see chapter 2.2.1.1) on the moving wagon, the Shimmns_6025.

The impact speed was measured additionally by a light barrier (see chapter 2.2.1.2.1). The light barrier served as a back-up system. The relevant measurement system for the impact speed was the DBST on-wagon system.

2.2.1 Measurement equipment

The measurement equipment consisted of different parts: a system installed on the Shimmns_6025 wagon by DBST, supported by different additional static systems (e.g. light barrier and cameras) and hand-held systems (e.g. multimeter).

2.2.1.1 On-wagon system (DBST-system)

The on-wagon measurement system was installed on the Shimmns_6025 wagon. It consisted of a Datalogger and two measuring amplifiers. Calibrated measurement chains were used to record the data of the on-board system. This does not apply for GPS-data. The location of installation of the sensors, signal names, identifiers and descriptions are shown in the following table:

Name	New unit	A = analogue D = digital	Description	Source / Installation	Connection	Range
Time		A	Time	Data-logger		
F_z		A	Force on coupler	DMS / strain gauges	Top and bottom inner side of coupler	-2.000 to 2.000 kN
S_x		A	Displacement (x-axis -> Sideways)	Wire sensor	On rack -> rights side of coupler	0 to 1.000 mm
S_y		A	Displacement (y-axis -> Up/Down)	Wire sensor	On rack -> above coupler	0 to 1.000 mm
S_z		A	Displacement (z-axis -> Forward/Backward)	Wire sensor	On rack -> behind coupler	0 to 1.000 mm
S_imp		A	Impulses (Distance)	Incremental Encoder	Pushed on left wheel	0-70.000.000
U_Pins_Data		A	Voltage throughput coupler over data-pins	Voltage sensor	See connection description	0 - 60 V
U_Pins_Power		A	Voltage throughput coupler over power-pins	Voltage sensor	See connection description	0 - 60 V
s	m	A	Distance	- calculated		
v_kmh_sm	km/h	A	Speed, filtered (over 0.1 s)	- calculated		

2.2.1.1.1 Force on the coupler

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



Figure 11: Strain gauge on the coupler VT_DAC4_004.

2.2.1.1.2 Displacement of the coupler

To measure the displacement of the coupler wire sensors were used in x-, y- and z-axis. 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 12: Wire sensor for forward/backward movement.



Figure 13: Wire sensor for vertical movement.



Figure 14: Wire sensor for horizontal movement.

2.2.1.1.3 Impact-speed

The speed of the moving wagon was measured with an incremental encoder. It measured the rotation of a wheel, pushed to the outer side of the wagon-wheel. 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 15: Incremental encoder with wheel, attached to the wagon wheel.

2.2.1.1.4 Electrical connection

To measure the electrical connection of the coupler, a voltage was applied from the battery pack to the e-coupler of the moving wagon. A short circuit was set in the e-coupler on the standing wagon. The voltage was measured with the measurement system on the moving wagon.

No voltage measurement was installed during tests VT003 to VT021.

For tests VT022 to VT073 the voltage over two data-pins of the e-coupler was measured.

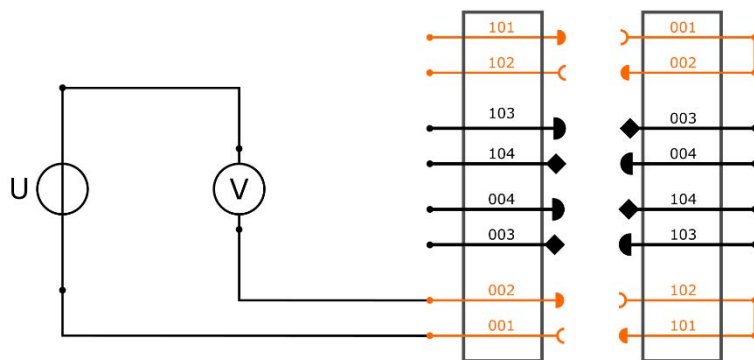


Figure 16: Circuit for voltage measurement over two data pins.

For tests from VT074 onwards, one voltage over all data-pins of the e-coupler and one voltage over the power-pins of the e-coupler were measured.

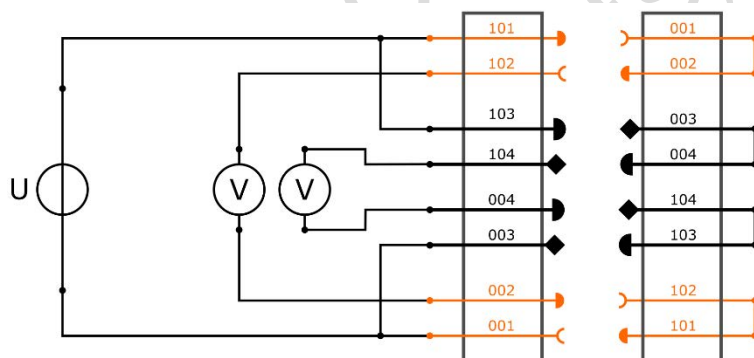


Figure 17: Circuit for voltage measurement over all pins.

2.2.1.1.5 Data acquisition

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

- Data logger: QuantumX CX22B-W (HBK)
- Measuring amplifiers: SomatXR MX480B-R (HBK)
- Data acquisition software: CatMan-Easy, Version 5.6.2 (HBK)

The data was measured with a frequency of 100 Hz and 1.000 Hz. The test program was started with a measurement frequency of 100 Hz (tests VT001 to VT039) and was set to 1.000 Hz from test VT055 onwards.

For power-supply a battery pack with 48 V was designed and installed by HVLE.

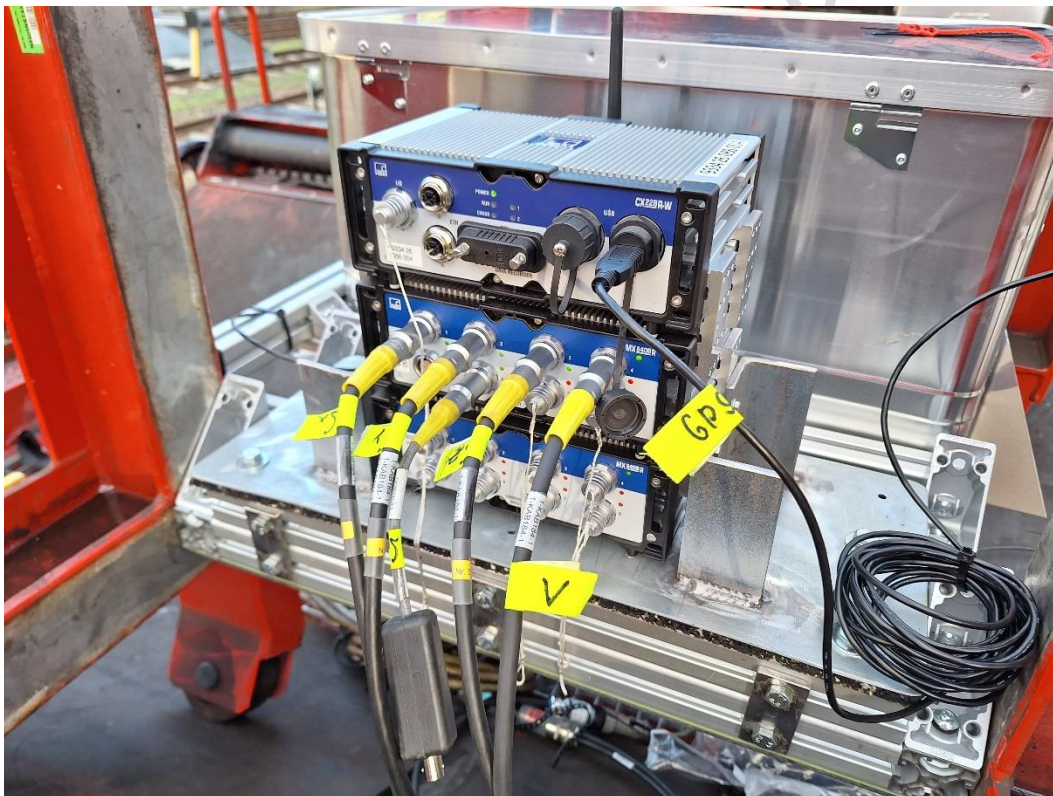


Figure 18: DBST on-wagon measurement system: Data-logger and measuring amplifiers.

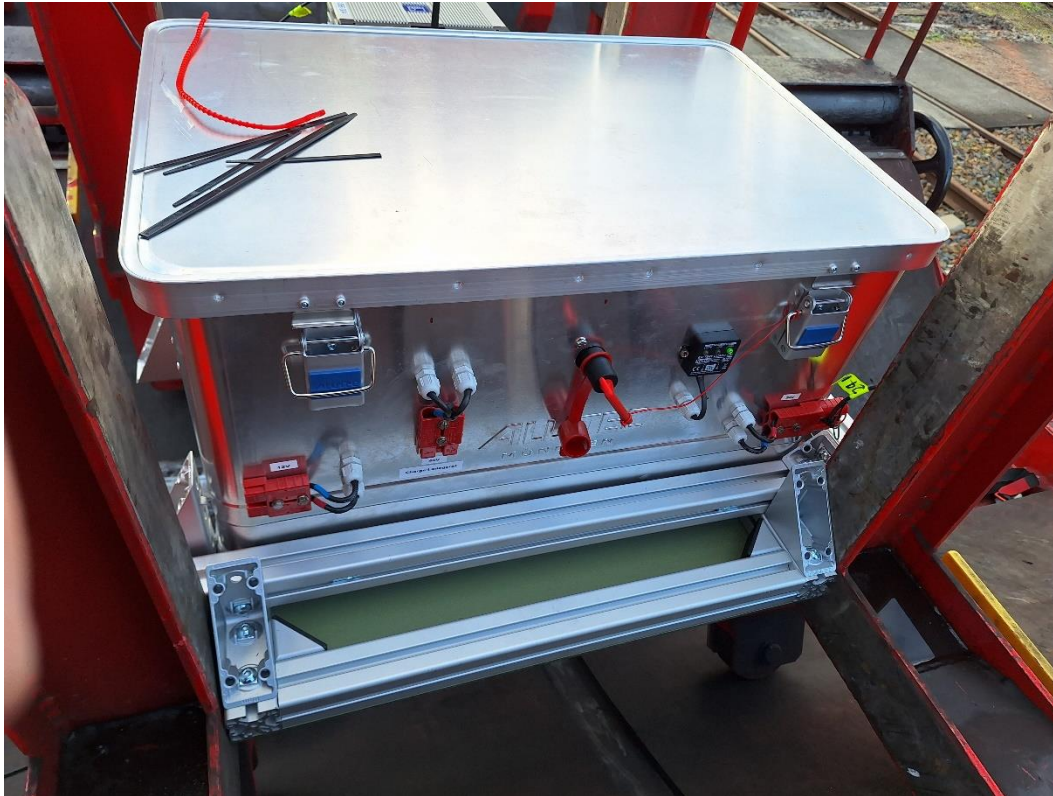


Figure 19: DBST on-wagon measurement system: Battery pack with different voltage outputs.

2.2.1.1.6 Data processing

Python-Scripts for editing and graphical presentation of the data were written by the TTL.

2.2.1.2 Static systems

2.2.1.2.1 Light barrier

In addition to the incremental encoder to measure the impact speed, two light barriers were installed. They measured the time it took for the moving wagon to pass through the first and second light barriers. One wheel of the foremost axle was always taken as the reference point. The distance between the light barriers was 1.8 m and thus also corresponded to the distance between the 2 axles in the bogie. This ensured the 1.8 m distance, as the second axle passed through the first light barrier at the same time as the first axle passed through the second light barrier. The speed could be calculated using the measured time and the defined distance. The light barriers were positioned as close as possible to the coupling point, to reduce the loss of speed due to friction. The signals were measured and analysed with an "imc Cronos CS-7008-FD" measurement system. The light barriers were installed as a backup system for the incremental encoder and as a quick way, to analyse the impact speed.



Figure 20: Installation of light barrier.
Top: Measurement of light-barrier distance. Bottom: installation on track.

2.2.1.2.2 Camera systems

The camera system consists of 5 individual GoPro cameras set up in different positions. For every impact test, the same camera was used in the same position. The first camera was mounted on a tripod and positioned close to the coupling point to get a close-up shot. The second GoPro was also mounted on a tripod but positioned further away to get a long shot of the tests. The third and fourth cameras were mounted on the moving and standing wagon with a view of the e-coupler. They were glued on the front walls of the wagon. The fifth camera was positioned in the track bed to record a view from below.

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

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Primary – E-coupler	
Mechanical coupling of e-coupler	→ Documentation in protocol
Establishing power and data connection	→ Measured with on-wagon system. Evaluation of voltage signals 2s after impact.
Closing lid after uncoupling	→ Documentation of abnormalities in protocol
Insulation	→ Measurement on regular basis, see chapter 3.1.
Damages	→ Documentation of abnormalities in protocol → Photo documentation
Wear and tear	→ Documentation of abnormalities in protocol → Photo documentation
Additionally – Mech. coupler:	
Mechanical coupling	→ Documentation of coupler status after impact in protocol
Compression force	→ Measured with on-wagon system. Max. force during test evaluated.
Uncoupling	→ Documentation of coupler status after uncoupling in protocol

3 Test execution – further measurements

3.1 Insulation

The insulation-resistance was measured from each pin to the housing and from each pin to every other pin. Before the measurement, the wire of every pin was disconnected from attached circuits.

The continuity between the housing and the rail was also measured.

As measurement instrument, a Fluke 1503 [Fluke_1503] with an input-voltage of 500 V was used. The connection was done directly on the pins at the coupler.



Figure 21: Measurement of insulation-resistance.
Left: measurement pin to pin. Right: measurement pin to housing.

3.2 Coupler heights

For evaluation of the vertical displacement during coupling of loaded and empty wagons, the height of the couplers was measured.

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

- Distance between sleeper and end of coupler bolt (see Figure 22)
- Distance between sleeper and top of rail (see Figure 23)
- Length of coupler bolt (see Figure 24)

The heights were measured with a folding rule and a plumb bob.

The distance between the middle of the coupler bolt (CB) and the top of rail (TOR) is calculated as:

$$Distance_{middle\ of\ CB-TOR} = Distance_{end\ of\ CB-Sleeper} - Distance_{Sleeper-top\ of\ rail} - \frac{1}{2}Length_{CB}$$

The height difference between the loaded and unloaded wagon was measured directly by stopping the wagons with a small distance to each other and measure the distance between the end of the coupler bolts (see Figure 25).

The measurements took place on the following dates and locations.

Coupler height	Date	Track
Difference between unloaded Shimmns – loaded Samms	12 th January 2024	Switch 22
Unloaded Shimmns	10 th January 2024	Track 6
Loaded Shimmns	10 th January 2024	Track 6
Unloaded Samms	17 th January 2024	Track 1
Loaded Samms	9 th January 2024	Track 3



Figure 22: Measurement of the distance between sleeper and end of coupler bolt.



Figure 23: Measurement of the distance between sleeper and top of rail.

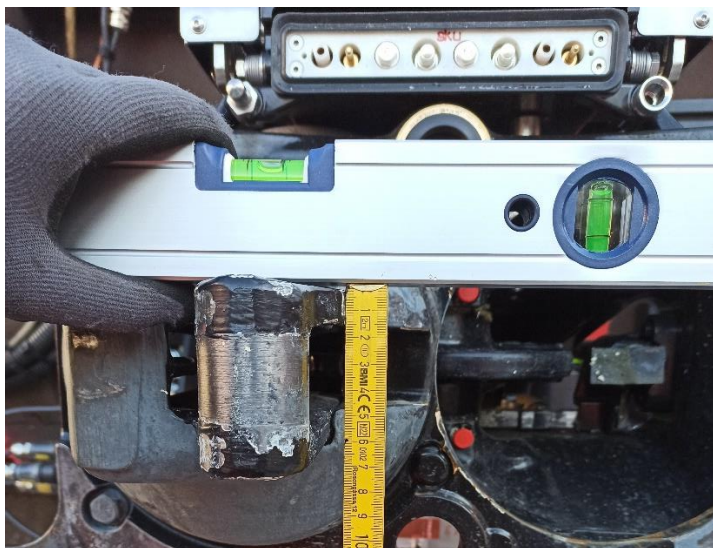


Figure 24: Measurement of the length of the coupler bolt.



Figure 25: Measurement of the height difference.

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Annex 2_KB

Installation and Maintenance tests

E-coupler: Knorr-Bremse

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 2_KB
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	7
2.1 Description of test procedure for installation and maintenance	7
2.1.1 Test preparation / Initial setup	7
2.2 Infrastructure	7
2.2.1 Assets	7
2.2.2 Test location	9
2.3 Measurement equipment / Documentation	9
2.4 Evaluation	10
3 Results	11
3.1 Used tools and material	11
3.2 Initial situation - Coupler head	11
3.3 Installation process	12
3.4 Deinstallation process	13
3.5 Maintenance	13
3.6 Abnormalities	13
4 Conclusion	14
5 References	15

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler - Installation and maintenance” described in Polarion ID “IPTRANS-2388” [IP-TRANS 2388]. Objective of the tests is the evaluation of e-couplers regarding installation and maintainability. It is assumed that the installation and maintenance requirements for the e-coupler are identical to those for the complete coupler system. The corresponding requirements have been adopted and are to be verified.

Description from [IP-TRANS 2388]:

Polarion ID	IPTRANS-2388		
Title	e-coupler - Installation and maintenance		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Ability to install	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

Part of the tests is the evaluation of the e-couplers with regard to installation and maintainability. The following aspects are analysed in particular:

1. Special tooling (BoB)

The use of special tools for maintenance and replacement of the digital automatic coupler or parts of it shall be avoided. Where the use of special tools for maintenance and replacement of the automatic coupler or parts of it is required the customer shall be provided with the detailed information. This document informs about the operational purpose, which measurements have to be made, which values are acceptable (e. g. system technical threshold value) and how the calibration of the special tools has to be made (point of time, procedure).

2. Connecting elements (BoB) and Bolting (P/F)

The main parts of the digital automatic coupler (e.g. coupler head, elastic device, pivot anchor) shall be connected with connecting elements to be solved simply (e.g. screws and nuts).

Attachment points at couplers shall be secured acc. to DIN 25201-4/.

3. Maintenance - intervals, process and time (BoB)

Operate for a period of at least 6 years without requiring maintenance

The contractor shall provide the time required for the maintenance and the different maintenance steps of the automatic coupler (including electrical and data connections).

4. Installation time / Time for e-coupler replacement (BoB)

The contractor shall provide the time required for the replacement of the coupler head including the electrical connections by two persons.

The replacement of a coupler head shall be possible within 60 min by two persons, using standard equipment such as lifting devices.

5. Cable routing (P/F)

Cable routing and mounting shall consider the requirements in EN 50343.

Summary from [Matrix_B04]:

#	A14
Name	-
Sub #	14.2
Title	Bolting
P/F or BoB	P/F
Requirement / Test description	Attachment points at couplers shall be secured acc. to DIN 25201-4/. Note: prEN 17976:2025 "Bolting of railway vehicles and components" is under development
Related AUCO	AUCO.71

#	A15
Name	Installation and maintenance
Sub #	15.1
Title	Special tooling
P/F or BoB	BoB
Requirement / Test description	The use of special tools for maintenance and replacement of the digital automatic coupler or parts of it shall be avoided. Where the use of special tools for maintenance and replacement of the automatic coupler or parts of it is required the customer shall be provided with the detailed information. This document informs about the operational purpose, which measurements have to be made, which values are acceptable (e. g. system technical threshold value) and how the calibration of the special tools has to be made (point of time, procedure).
Related AUCO	AUCO.85 AUCO.43

#	B2
Name	Maintainability (incl. ease of exchangeability)
Sub #	2.1
Title	-
P/F or BoB	BoB
Requirement / Test description	'Dismount E-coupler by qualified staff (2 max.) and measure time Remount E-coupler by qualified staff (2 max.) and measure time
Related AUCO	AUCO.40 adapted to E-coupler AUCO.42

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

To be executed with each coupler:

Case	Description	Amount	Remark
1	Checking required tools	1	
2	Installation e-coupler	5	
3	Deinstallation e-coupler	5	
4	Maintenance e-coupler	1	

To be evaluated:

To evaluate	Criteria	P/F or BoB
Use of special tools	No special tools should be used for installation and maintenance.	P/F
Installation procedure and time	The installation process should be as simple as possible. (Personnel = 1, duration < 5min)	P/F
Connecting elements and Bolting	The main parts of the digital automatic shall be connected with connecting elements to be solved simply (e.g. screws and nuts).	P/F
Possibility of realisation in the field	Evaluation of whether the installation and uninstallation process can also be implemented in the field	P/F
Maintenance - intervals, process	Operate for a period of at least 6 years without requiring maintenance. Time required for the maintenance and the different maintenance steps of the automatic coupler.	P/F

2 Test execution

2.1 Description of test procedure for installation and maintenance

In general, during the installation and maintenance tests an e-coupler is installed on the respective supplier's coupler head and uninstalled again. Furthermore, the tools required for the installation are analysed and other maintenance options are verified.

The steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

Before each test, the manufacturer's installation instructions were made available to the test personnel. A freight wagon was provided in the Train Test Lab workshop. A DAC from the manufacturer was already installed on the freight wagon. The necessary tools were also provided. The tests were carried out by trained personnel from the supplier. The tests were monitored and documented by the WP14 test organisation.

As the detailed installation process is supplier-specific, this is presented in the results (chapter 3).

2.2 Infrastructure

2.2.1 Assets

As a freight wagon, the Samms_1781 - config. #005 was used (for further information see the main report).

The coupler used for the installation tests was the KB_DAC45_001 with the e-coupler KB_EC_005 (see annex 0).

The e-coupler was deinstalled before the tests.

Additional information on the coupler, not given in annex 0:

KB_DAC45_001:

Description: Digital Automatic Coupler

Manufacturer: Knorr Bremse

Type: DAC 4.5

Configurations:

Part	Config.	Date	Change
KB_DAC45_001	#001	30.08.2023	Installation
KB_DAC45_001	#002	23.01.2024	Initial status before tests

Sub-Parts:

Part	Type	Manuf.	Type plate	Config.	Date	Change
KB_DG_001	Draft gear	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation
KB_CP_001	Counter plate	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation
KB_CS_001	Centration support	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation
KB_MC_001	Mechanical coupler	Knorr Bremse	(01)04061272354808 (21)3522300017 (240)KP1629457-MX DACV2Kimberly	#001	Prev. to 29.08.2023	Installation
KB_AV_001	Air valve	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation

2.2.2 Test location

All tests were executed at the loco workshop of the HVLE in Berlin-Spandau. The workshop consists of a large hall with two railway tracks. The work was carried out on track 1 (left-hand side in Figure 1) in an area without a pit.



Figure 1: Loco workshop HVLE – Berlin Spandau

2.3 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Number of staff.
- Used tools.
- Abnormalities and deviations from procedure.

Documentation by video/photo:

- Video documentation of installation procedure
- Photo documentation of installation steps and tools

Measured by measurement systems:

- Time via stop watch

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Use of special tools	→ Documentation
Installation procedure and time	→ Measurement of time and video documentation
Connecting elements and Bolting	→ Documentation
Possibility of realisation in the field	→ Documentation
Maintenance - intervals, process	→ Not evaluated

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Annex 2_VT

Installation and Maintenance tests

E-coupler: Voith

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 2_VT
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	7
2.1 Description of test procedure for installation and maintenance	7
2.1.1 Test preparation / Initial setup	7
2.2 Infrastructure	7
2.2.1 Assets	7
2.2.2 Test location	8
2.3 Measurement equipment / Documentation	8
2.4 Evaluation	9
3 Results	10
3.1 Used tools and material	10
3.2 Initial situation - Coupler head	11
3.3 Installation process	12
3.4 Deinstallation process	13
3.5 Maintenance	13
3.6 Abnormalities	13
4 Conclusion	14
5 References	15

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler - Installation and maintenance” described in Polarion ID “IPTRANS-2388” [IP-TRANS 2388]. Objective of the tests is the evaluation of e-couplers regarding installation and maintainability. It is assumed that the installation and maintenance requirements for the e-coupler are identical to those for the complete coupler system. The corresponding requirements have been adopted and are to be verified.

Description from [IP-TRANS 2388]:

Polarion ID	IPTRANS-2388		
Title	e-coupler - Installation and maintenance		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Ability to install	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

Part of the tests is the evaluation of the e-couplers with regard to installation and maintainability. The following aspects are analysed in particular:

1. Special tooling (BoB)

The use of special tools for maintenance and replacement of the digital automatic coupler or parts of it shall be avoided. Where the use of special tools for maintenance and replacement of the automatic coupler or parts of it is required the customer shall be provided with the detailed information. This document informs about the operational purpose, which measurements have to be made, which values are acceptable (e. g. system technical threshold value) and how the calibration of the special tools has to be made (point of time, procedure).

2. Connecting elements (BoB) and Bolting (P/F)

The main parts of the digital automatic coupler (e.g. coupler head, elastic device, pivot anchor) shall be connected with connecting elements to be solved simply (e.g. screws and nuts).

Attachment points at couplers shall be secured acc. to DIN 25201-4/.

3. Maintenance - intervals, process and time (BoB)

Operate for a period of at least 6 years without requiring maintenance

The contractor shall provide the time required for the maintenance and the different maintenance steps of the automatic coupler (including electrical and data connections).

4. Installation time / Time for e-coupler replacement (BoB)

The contractor shall provide the time required for the replacement of the coupler head including the electrical connections by two persons.

The replacement of a coupler head shall be possible within 60 min by two persons, using standard equipment such as lifting devices.

5. Cable routing (P/F)

Cable routing and mounting shall consider the requirements in EN 50343.

Summary from [Matrix_B04]:

#	A14
Name	-
Sub #	14.2
Title	Bolting
P/F or BoB	P/F
Requirement / Test description	Attachment points at couplers shall be secured acc. to DIN 25201-4/. Note: prEN 17976:2025 "Bolting of railway vehicles and components" is under development
Related AUCO	AUCO.71

#	A15
Name	Installation and maintenance
Sub #	15.1
Title	Special tooling
P/F or BoB	BoB
Requirement / Test description	The use of special tools for maintenance and replacement of the digital automatic coupler or parts of it shall be avoided. Where the use of special tools for maintenance and replacement of the automatic coupler or parts of it is required the customer shall be provided with the detailed information. This document informs about the operational purpose, which measurements have to be made, which values are acceptable (e. g. system technical threshold value) and how the calibration of the special tools has to be made (point of time, procedure).
Related AUCO	AUCO.85 AUCO.43

#	B2
Name	Maintainability (incl. ease of exchangeability)
Sub #	2.1
Title	-
P/F or BoB	BoB
Requirement / Test description	'Dismount E-coupler by qualified staff (2 max.) and measure time Remount E-coupler by qualified staff (2 max.) and measure time
Related AUCO	AUCO.40 adapted to E-coupler AUCO.42

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

To be executed with each coupler:

Case	Description	Amount	Remark
1	Checking required tools	1	
2	Installation e-coupler	5	
3	Deinstallation e-coupler	5	
4	Maintenance e-coupler	1	

To be evaluated:

To evaluate	Criteria	P/F or BoB
Use of special tools	No special tools should be used for installation and maintenance.	P/F
Installation procedure and time	The installation process should be as simple as possible. (Personnel = 1, duration < 5min)	P/F
Connecting elements and Bolting	The main parts of the digital automatic shall be connected with connecting elements to be solved simply (e.g. screws and nuts).	P/F
Possibility of realisation in the field	Evaluation of whether the installation and uninstallation process can also be implemented in the field	P/F
Maintenance - intervals, process	Operate for a period of at least 6 years without requiring maintenance. Time required for the maintenance and the different maintenance steps of the automatic coupler.	P/F

2 Test execution

2.1 Description of test procedure for installation and maintenance

In general, during the installation and maintenance tests an e-coupler is installed on the respective supplier's coupler head and uninstalled again. Furthermore, the tools required for the installation are analysed and other maintenance options are verified.

The steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

Before each test, the manufacturer's installation instructions were made available to the test personnel. A freight wagon was provided in the Train Test Lab workshop. A DAC from the manufacturer was already installed on the freight wagon. The necessary tools were also provided. The tests were carried out by trained personnel from the supplier. The tests were monitored and documented by the WP14 test organisation.

As the detailed installation process is supplier-specific, this is presented in the results (chapter 3).

2.2 Infrastructure

2.2.1 Assets

As a freight wagon, the Samms_1781 – config. #005 was used (for further information see the main report).

The coupler used for the installation tests was the VT_DAC4_003 with the e-coupler VT_EC_003 (see annex 0).

The coupler was deinstalled before the tests.

2.2.2 Test location

All tests were executed at the loco workshop of the HVLE in Berlin-Spandau. The workshop consists of a large hall with two railway tracks. The work was carried out on track 1 (left-hand side in Figure 1) in an area without a pit.



Figure 1: Loco workshop HVLE – Berlin Spandau

2.3 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Number of staff.
- Used tools.
- Abnormalities and deviations from procedure.

Documentation by video/photo:

- Video documentation of installation procedure
- Photo documentation of installation steps and tools

Measured by measurement systems:

- Time via stop watch

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Use of special tools	→ Documentation
Installation procedure and time	→ Measurement of time and video documentation
Connecting elements and Bolting	→ Documentation
Possibility of realisation in the field	→ Documentation
Maintenance - intervals, process	→ Not evaluated



Annex 3_KB

Manual access to pins

E-coupler: Knorr-Bremse

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 3_KB
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	6
2.1 Description of test procedure for manual access to pins	6
2.1.1 Test preparation / Initial setup	6
2.2 Infrastructure	7
2.2.1 Assets	7
2.2.2 Test location	7
2.3 Measurement equipment / Documentation	8
2.3.1 Force measuring device	8
2.4 Evaluation	8
3 Results	9
3.1 Push force	9
3.2 Pull force	9
3.3 Push force on plunger	10
3.4 Abnormalities	10
4 Conclusion	11
5 References	12

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler – manual access to pins” described in Polarion ID “IPTRANS-2380” [IP-TRANS 2380]. Objective of the tests is the evaluation of e-couplers regarding worker safety. In particular, the extent to which unintentional opening of the e-coupler lid is possible has to be tested. As some e-coupler pins can be subject to 400V AC electrical voltage, unintentional contact with the pins can lead to injuries. The lid mechanism must therefore be designed in such a way that it cannot be opened by hand. Opening the lid using tools, i.e. intentional opening or vandalism, is not taken into account in this test case.

Description from [IP-TRANS 2380]:

Polarion ID	IPTRANS-2380		
Title	e-coupler – manual access to pins		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Safety	Important for Authorization/TSI	Yes
		Test phase	early test

Test Specification:

Unintentional touching of the contacts inside the E-Coupler must be prevented. For this reason, the protection flap of the e-coupler must be closed when uncoupled and must only be allowed to open with a great effort.

The following steps are to be implemented within this test:

1. check the operation of the front flap closing mechanism
2. pull on the flap up to a force of 250N and check for function and damage
3. check the operation of the front flap closing mechanism

Summary from [Matrix_B04]:

#	A11
Name	Occupational health and safety
Sub #	11.1
Title	Hand access to pins
P/F or BoB	BoB
Requirement / Test description	Simple manual opening of the flap must be prevented. Forces to open the flap above DIN 33411-5. --> Ergonomy of opening the flap --> Measuring the forces required for opening manually Rediscussion by expert group needed about criteria and BoB or P/F
Related AUCO	Wagon_ELEC.053

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

To be executed with each coupler:

Case	Description	Amount	Remark
1	Push force measurement for lid opening	1	
2	Pull force measurement for lid opening	1	
3	Push force on plunger for lid opening	1	

To be evaluated:

To evaluate	Criteria	P/F or BoB
Push force will not open lid	Despite a force of 250N being applied to the lid and plunger, the lid does not open	P/F
Pull force will not open lid	Despite a force of 250N being applied, the lid does not open	P/F
Push force on plunger will not open lid	Despite a force of 250N being applied, the lid does not open	P/F

2 Test execution

2.1 Description of test procedure for manual access to pins

A force of at least 250N is applied at various points on the e-coupler with the intention of opening the lid. A force of more than 250N and a targeted point of action can no longer be considered unintentional. It should also be checked whether and how far the lid opens and whether it is possible to touch the contacts. All possible damage caused by the application of force is documented.

The steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

The lid of the e-coupler opens upwards in a rotating movement. If closed, it is not possible to touch the electrical pins. If open, the pins are accessible.

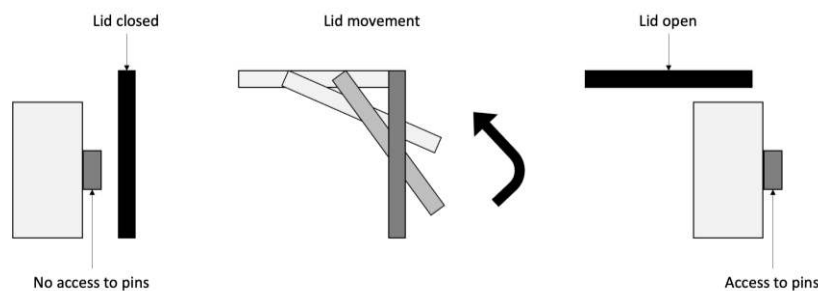


Figure 1: Opening mechanism of e-coupler lid

Manual opening can therefore be made possible via a push or a pull on the lower side of the flap.

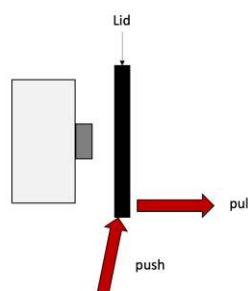


Figure 2: Force directions required to open the lid

A complete coupler system is used for the test (DAC incl. e-coupler), which is installed on a wagon and is not in the coupled position (lid closed). Forces of up to 250N are then applied to the lid as shown in Figure 2 and it is observed whether the lid opens. The exact force induction is shown in the results (chapter 3).

As the KB e-coupler is opened by pressing in the plunger, it must also be ensured that it cannot be pressed in manually by mistake. For this purpose, an additional measurement is carried out in accordance with Figure 3.

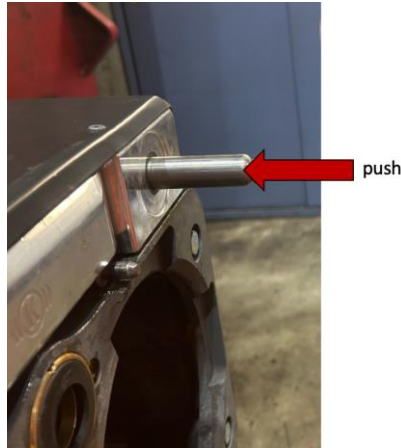


Figure 3: Push force on plunger

2.2 Infrastructure

2.2.1 Assets

As a freight wagon, the Samms_1781 – config. #005 was used (for further information see the main report).

The e-coupler used for the tests was the KB_EC_005 (see annex 0).

2.2.2 Test location

All tests were executed at the loco workshop of the HVLE in Berlin-Spandau. The workshop consists of a large hall with two railway tracks. The work was carried out on track 1 (left-hand side in Figure 4) in an area without a pit.

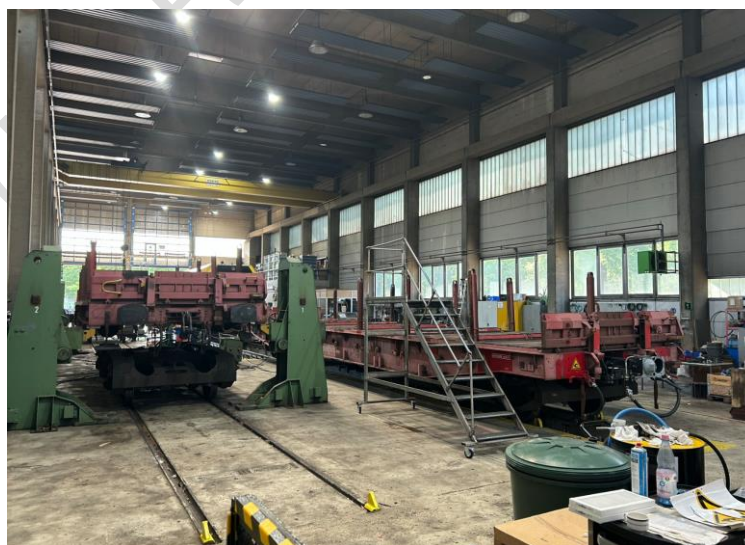


Figure 4: Loco workshop HVLE – Berlin Spandau

2.3 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Abnormalities and deviations from procedure.

Documentation by video/photo:

- Photo documentation of force application

Measured by measurement systems:

- Force

2.3.1 Force measuring device

The FK500 digital force measuring device from Sauter is used for force measurement.



Figure 5: FK500 digital force measuring device from Sauter GmbH

This has various attachments for applying force and has the following specifications:

- $F_{max} = 500N$
- $D = 0.2N$

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Push force will not open lid	→ Measurement of push force until $F > 250 N$ or opening of the lid
Pull force will not open lid	→ Measurement of pull force until $F > 250 N$ or opening of the lid
Push force on plunger will not open lid	→ Measurement of push force on plunger until $F > 250 N$ or opening of the lid

Annex 3_VT

Manual access to pins

E-coupler: Voith

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 3_VT
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	6
2.1 Description of test procedure for manual access to pins	6
2.1.1 Test preparation / Initial setup	6
2.2 Infrastructure	7
2.2.1 Assets	7
2.2.2 Test location	7
2.3 Measurement equipment / Documentation	8
2.3.1 Force measuring device	8
2.4 Evaluation	8
3 Results	9
3.1 Push force	9
3.2 Pull force	10
3.3 Abnormalities	10
4 Conclusion	11
5 References	12

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler – manual access to pins” described in Polarion ID “IPTRANS-2380” [IP-TRANS 2380]. Objective of the tests is the evaluation of e-couplers regarding worker safety. In particular, the extent to which unintentional opening of the e-coupler lid is possible has to be tested. As some e-coupler pins can be subject to 400V AC electrical voltage, unintentional contact with the pins can lead to injuries. The lid mechanism must therefore be designed in such a way that it cannot be opened by hand. Opening the lid using tools, i.e. intentional opening or vandalism, is not taken into account in this test case.

Description from [IP-TRANS 2380]:

Polarion ID	IPTRANS-2380		
Title	e-coupler – manual access to pins		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Safety	Important for Authorization/TSI	Yes
		Test phase	early test

Test Specification:

Unintentional touching of the contacts inside the E-Coupler must be prevented. For this reason, the protection flap of the e-coupler must be closed when uncoupled and must only be allowed to open with a great effort.

The following steps are to be implemented within this test:

1. check the operation of the front flap closing mechanism
2. pull on the flap up to a force of 250N and check for function and damage
3. check the operation of the front flap closing mechanism

Summary from [Matrix_B04]:

#	A11
Name	Occupational health and safety
Sub #	11.1
Title	Hand access to pins
P/F or BoB	BoB
Requirement / Test description	Simple manual opening of the flap must be prevented. Forces to open the flap above DIN 33411-5. --> Ergonomy of opening the flap --> Measuring the forces required for opening manually Rediscussion by expert group needed about criteria and BoB or P/F
Related AUCO	Wagon_ELEC.053

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

To be executed with each coupler:

Case	Description	Amount	Remark
1	Push force measurement for lid opening	1	
2	Pull force measurement for lid opening	1	

To be evaluated:

To evaluate	Criteria	P/F or BoB
Push force will not open lid	Despite a force of 250N being applied to the lid and plunger, the lid does not open	P/F
Pull force will not open lid	Despite a force of 250N being applied, the lid does not open	P/F

2 Test execution

2.1 Description of test procedure for manual access to pins

A force of at least 250N is applied at various points on the e-coupler with the intention of opening the lid. A force of more than 250N and a targeted point of action can no longer be considered unintentional. It should also be checked whether and how far the lid opens and whether it is possible to touch the contacts. All possible damage caused by the application of force is documented.

The steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

The lid of the e-coupler opens upwards in a rotating movement. If closed, it is not possible to touch the electrical pins. If open, the pins are accessible.

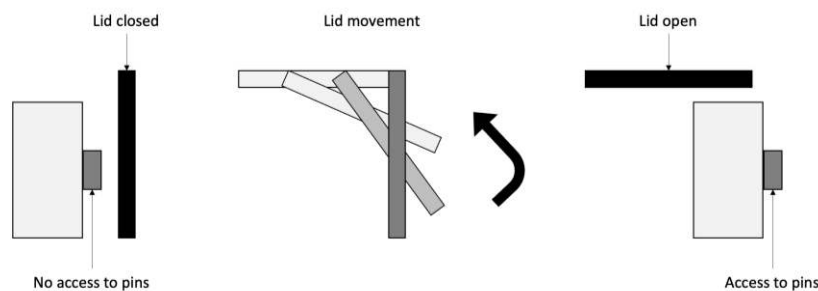


Figure 1: Opening mechanism of e-coupler lid

Manual opening can therefore be made possible via a push or a pull on the lower side of the flap.

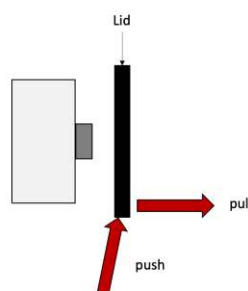


Figure 2: Force directions required to open the lid

A complete coupler system is used for the test (DAC incl. e-coupler), which is installed on a wagon and is not in the coupled position (lid closed). Forces of up to 250N are then applied to the lid as shown in Figure 2 and it is observed whether the lid opens. The exact force induction is shown in the results (chapter 3).

2.2 Infrastructure

2.2.1 Assets

As a freight wagon, the Samms_1781 – config. #005 was used (for further information see the main report).

The e-coupler used for the tests was the VT_EC_003 (see annex 0).

2.2.2 Test location

All tests were executed at the loco workshop of the HVLE in Berlin-Spandau. The workshop consists of a large hall with two railway tracks. The work was carried out on track 1 (left-hand side in Figure 3) in an area without a pit.



Figure 3: Loco workshop HVLE – Berlin Spandau

2.3 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Abnormalities and deviations from procedure.

Documentation by video/photo:

- Photo documentation of force application

Measured by measurement systems:

- Force

2.3.1 Force measuring device

The FK500 digital force measuring device from Sauter is used for force measurement.



Figure 4: FK500 digital force measuring device from Sauter GmbH

This has various attachments for applying force and has the following specifications:

- $F_{max} = 500N$
- $D = 0.2N$

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Push force will not open lid	→ Measurement of push force until $F > 250 N$ or opening of the lid
Pull force will not open lid	→ Measurement of pull force until $F > 250 N$ or opening of the lid

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Annex 4_KB

Movement area and interaction with wagon components

E-coupler: Knorr-Bremse

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 4_KB
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	6
2.1 Description of test procedure for movement area and interaction with wagon components.....	6
2.1.1 Test preparation / Initial setup	6
2.2 Infrastructure	9
2.2.1 Assets.....	9
2.2.2 Test location	11
2.3 Measurement equipment / Documentation.....	11
2.4 Evaluation	11
3 Results	12
3.1 Space in centered position.....	12
3.2 Maximum vertical deflection	13
3.3 No interaction with wagon components	15
3.4 Abnormalities.....	16
4 Conclusion.....	17
5 References.....	18

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler – Movement area and interaction with wagon components” described in Polarion ID “IPTRANS-2377” [IP-TRANS 2377]. Objective of the tests is the evaluation of e-couplers regarding interaction with wagon components. During tests with the first e-coupler prototypes in 2020 and 2021, it was discovered that in freight wagons with front wall flaps, these flaps can collide with the e-coupler. The objective of these tests is to prove that this problem is no longer a factor in the current prototypes.

Description from [IP-TRANS 2377]:

Polarion ID	IPTRANS-2377		
Title	e-coupler – Installation space and interaction with wagon components		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Specific wagon
Component	DAC	Specific Wagon Requirements	wagons with front flaps
Test Objective	Ability to install	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

During operation of the Couplers, it must be ensured that the Coupler components do not collide with parts of the wagon. For this purpose, movement space, that has to be kept clear was defined (see linked requirements). The overall height of older electric couplings was so high that the front flaps of some flat wagons (e.g. Sammns) collided with the electric coupler.

The following steps are to be carried out within this test case:

1. measuring the position of the e-coupler relative to the wagon
2. variation of the coupler angles in the y-axis and z-axis and measurement of the maximum values
3. derive a diagram to visualise the space required for couplers on the wagon in the x,z plane and the y,z plane
4. measure the distances between the electric coupler and the wagon front flaps

Summary from [Matrix_B04]:

#	A1
Name	Dimensions AUCO.15
Sub #	1.2
Title	Installation checks
P/F or BoB	P/F
Requirement / Test description	Installation checks (measurements) on wagons with flaps in static conditions Test with different loads wagon1 vs. wagon 2 and/or define offset and test in lab simulating the wagon flaps? Wagon must comply 200mm min. flap distance and representative
Related AUCO	AUCO.15 Vehicle.22

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

To be executed with each coupler:

Case	Description	Amount	Remark
1	Coupler in middle-middle position	1	
2	Coupler in left-middle position	1	
3	Coupler in right-middle position	1	
4	Coupler in middle-up position	1	
5	Coupler in left-up position	1	
6	Coupler in right-up position	1	
7	Coupler in middle-down position	1	
8	Coupler in left-down position	1	
9	Coupler in right-down position	1	

To be evaluated:

To evaluate	Criteria	P/F or BoB
Space in centred position	6cm space between e-coupler and flap, while in centred position.	P/F
Maximum vertical deflection	No interaction with flaps in maximum height offset of two couplers.	P/F
No interaction with wagon components	During the tests there is no interaction with wagon components (except flaps) allowed.	P/F

2 Test execution

2.1 Description of test procedure for movement area and interaction with wagon components

The coupler is positioned manually to the relevant maximum deflections. The position of the coupling relative to the wagon is determined. In particular, the angle and distance of the e-coupler to wagon flaps should be measured. The space in which the coupler moves should be drawn in a simple diagram similar to Figure 1.

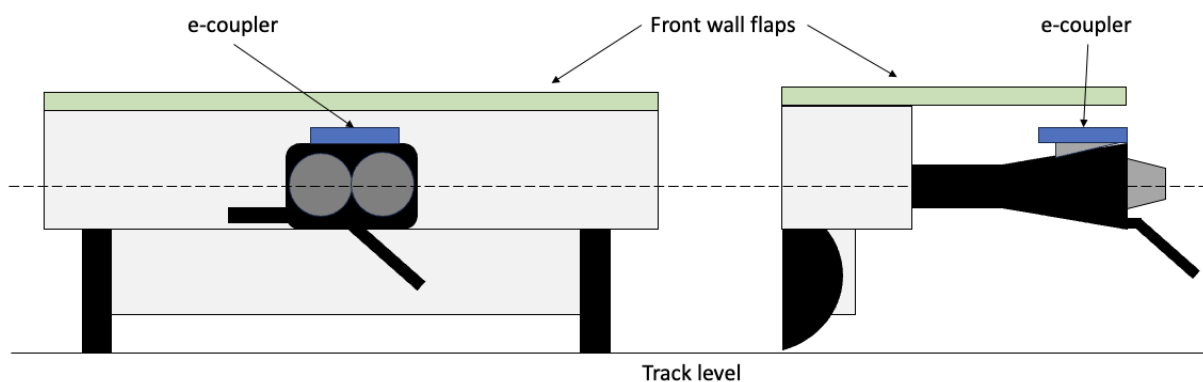


Figure 1: Sketch of e-coupler and wagon front flaps

The next steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

First step is to set the coupler in centered position and to measure the distance of the coupler center line over track and the distance of the upper e-coupler housing to the wagon flaps like shown in Figure 2.

Here is:

- a = height of coupler centre line above track
- b = distance from e-coupler housing to lower front side of flaps
- c = Distance from the front measuring point on the coupler bolt to the pivot point of the coupler in the wagon

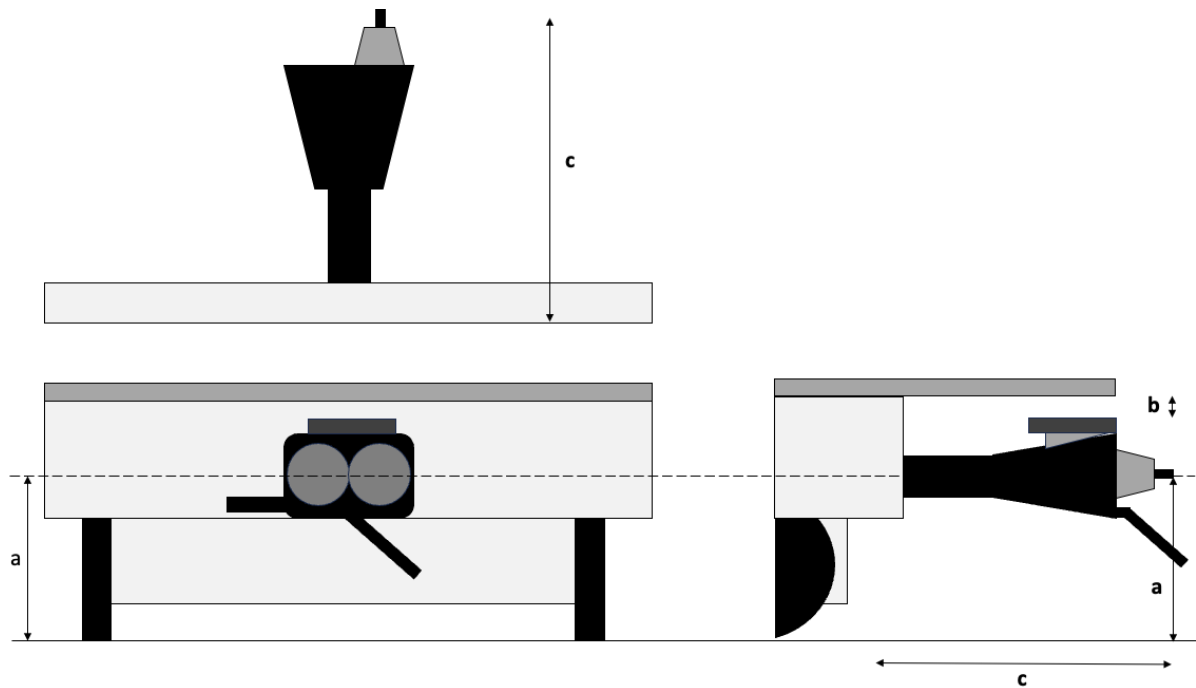


Figure 2: Dimensions and measurements regarding e-coupler, coupler and wagons

In the next step, the coupler is deflected to the left and right. The deflection angle α is also measured analogue to Figure 3.

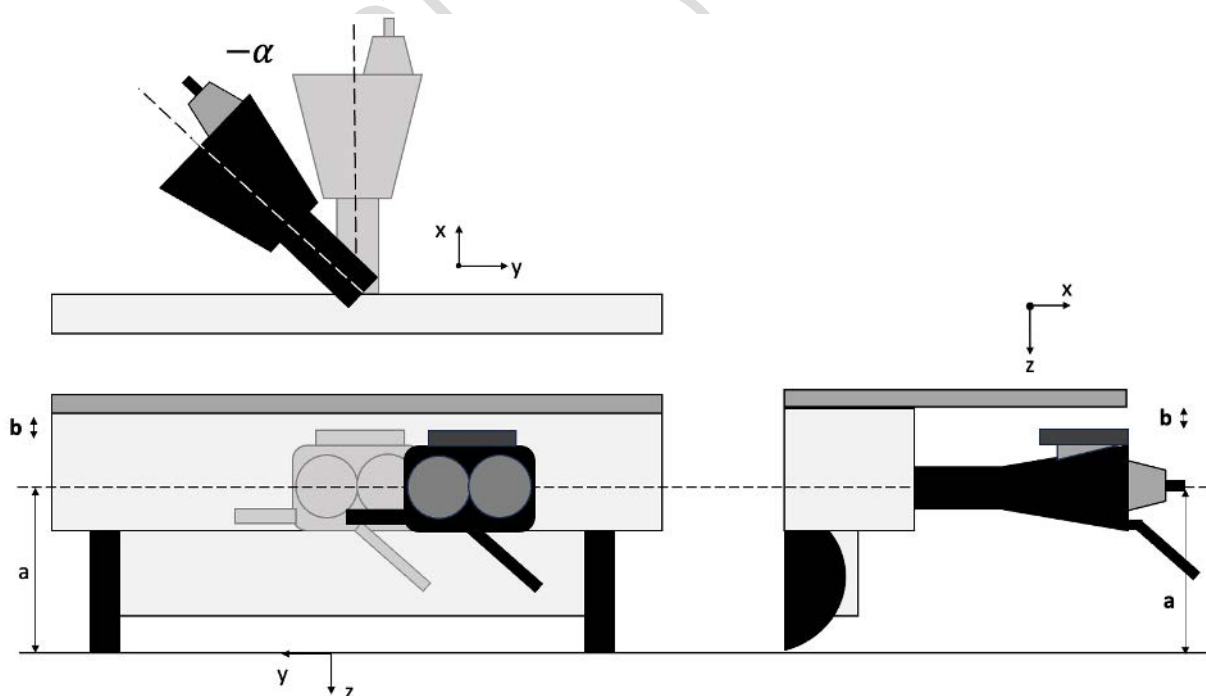


Figure 3: Deflection around z-axis in horizontal x-y-plane

The coupler is then deflected at the very top and bottom by the angle β and the corresponding measured values are determined.

Beta is calculated from c, a and a2:

$$\beta = \arcsin \left(\frac{a - a2}{c} \right)$$

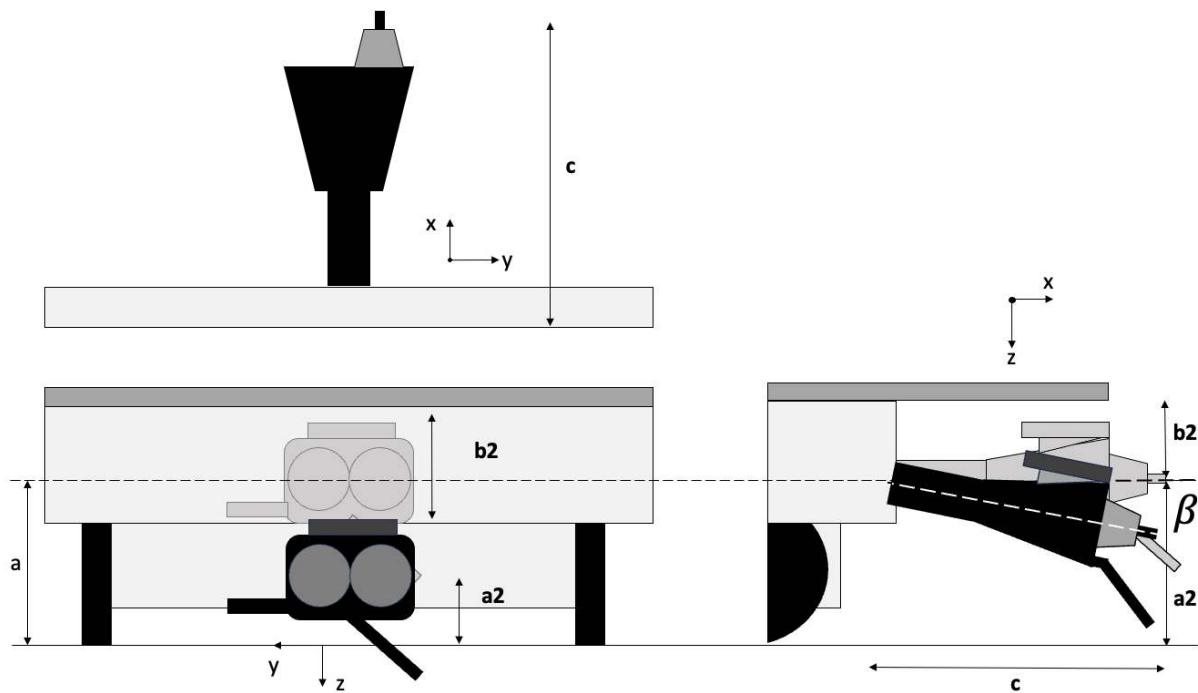


Figure 4: Deflection around y-axis in vertical x-z-plane

The maximum rotation angle +beta is limited by the vertical support. Here it is sufficient to determine the maximum manual deflection. The minimum angle -beta is limited by the contact of the e-coupler with the wagon flaps.

In addition, the respective combinations, e.g. max_alpha and max_beta, i.e. maximum manual deflection to the bottom left and the three other corner points must be determined.

2.2 Infrastructure

2.2.1 Assets

As a freight wagon, the Samms_1781 – config. #005 (Figure 5) was used (for further information see the main report).

The coupler used for the tests was the KB_DAC45_001 with the e-coupler KB_EC_005 (see annex 0).



Figure 5: Samms wagon used for installation tests

The wagon has the described front wall flaps. In the case of very long goods, these may also be folded down during the journey. If the wagons have different payloads, the couplers are offset horizontally. One coupler is therefore aligned downwards, the other is aligned upwards. The aim of the measurements is therefore to determine whether it is possible for the e-coupler and the folded-down front wall flaps of the wagons to touch at the maximum height difference between the wagons.

However, as only one type of wagon with front wall flaps was analysed in these tests, no general statement can be made. In addition, vibrations, impacts and bending of the flaps were not taken into account. This is therefore an initial determination based on one valid wagon type.

Additional information on the coupler, not given in annex 0:

KB_DAC45_001:

Description: Digital Automatic Coupler

Manufacturer: Knorr Bremse

Type: DAC 4.5

Configurations:

Part	Config.	Date	Change
KB_DAC45_001	#001	30.08.2023	Installation
KB_DAC45_001	#002	23.01.2024	Initial status before tests

Sub-Parts:

Part	Type	Manuf.	Type plate	Config.	Date	Change
KB_DG_001	Draft gear	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation
KB_CP_001	Counter plate	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation
KB_CS_001	Centration support	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation
KB_MC_001	Mechanical coupler	Knorr Bremse	(01)04061272354808 (21)3522300017 (240)KP1629457-MX DACV2Kimberly	#001	Prev. to 29.08.2023	Installation
KB_AV_001	Air valve	Knorr Bremse	-	#001	Prev. to 29.08.2023	Installation

2.2.2 Test location

All tests were executed at the loco workshop of the HVLE in Berlin-Spandau. The workshop consists of a large hall with two railway tracks. The work was carried out on track 1 (left-hand side in Figure 6) in an area without a pit.



Figure 6: Loco workshop HVLE - Berlin Spandau

2.3 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Measurements of angles and distances
- Abnormalities and deviations from procedure.

Documentation by video/photo:

- Photo documentation of procedure

Measured by measurement systems:

- none

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Space in centred position	→ Distance b in centred state ($\alpha = \beta = 0$) minimum 6cm.
Maximum vertical deflection	→ Distance a2-a while e-coupler touches flap ($\beta_{\min}$) minimum 12/2cm = 6cm
No interaction with wagon components	→ Documentation

Annex 4_VT

Movement area and interaction with wagon components

E-coupler: Voith

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 4_VT
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	6
2.1 Description of test procedure for movement area and interaction with wagon components.....	6
2.1.1 Test preparation / Initial setup	6
2.2 Infrastructure	9
2.2.1 Assets.....	9
2.2.2 Test location	10
2.3 Measurement equipment / Documentation.....	10
2.4 Evaluation	10
3 Results	11
3.1 Space in centered position.....	11
3.2 Maximum vertical deflection	12
3.3 No interaction with wagon components	14
3.4 Abnormalities.....	15
4 Conclusion.....	16
5 References.....	17

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler – Movement area and interaction with wagon components” described in Polarion ID “IPTRANS-2377” [IP-TRANS 2377]. Objective of the tests is the evaluation of e-couplers regarding interaction with wagon components. During tests with the first e-coupler prototypes in 2020 and 2021, it was discovered that in freight wagons with front wall flaps, these flaps can collide with the e-coupler. The objective of these tests is to prove that this problem is no longer a factor in the current prototypes.

Description from [IP-TRANS 2377]:

Polarion ID	IPTRANS-2377		
Title	e-coupler – Installation space and interaction with wagon components		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Specific wagon
Component	DAC	Specific Wagon Requirements	wagons with front flaps
Test Objective	Ability to install	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

During operation of the Couplers, it must be ensured that the Coupler components do not collide with parts of the wagon. For this purpose, movement space, that has to be kept clear was defined (see linked requirements). The overall height of older electric couplings was so high that the front flaps of some flat wagons (e.g. Sammns) collided with the electric coupler.

The following steps are to be carried out within this test case:

1. measuring the position of the e-coupler relative to the wagon
2. variation of the coupler angles in the y-axis and z-axis and measurement of the maximum values
3. derive a diagram to visualise the space required for couplers on the wagon in the x,z plane and the y,z plane
4. measure the distances between the electric coupler and the wagon front flaps

Summary from [Matrix_B04]:

#	A1
Name	Dimensions AUCO.15
Sub #	1.2
Title	Installation checks
P/F or BoB	P/F
Requirement / Test description	Installation checks (measurements) on wagons with flaps in static conditions Test with different loads wagon1 vs. wagon 2 and/or define offset and test in lab simulating the wagon flaps? Wagon must comply 200mm min. flap distance and representative
Related AUCO	AUCO.15 Vehicle.22

Derived by WP14:

From the listed descriptions, the following individual tests were derived by WP14:

To be executed with each coupler:

Case	Description	Amount	Remark
1	Coupler in middle-middle position	1	
2	Coupler in left-middle position	1	
3	Coupler in right-middle position	1	
4	Coupler in middle-up position	1	
5	Coupler in left-up position	1	
6	Coupler in right-up position	1	
7	Coupler in middle-down position	1	
8	Coupler in left-down position	1	
9	Coupler in right-down position	1	

To be evaluated:

To evaluate	Criteria	P/F or BoB
Space in centred position	6cm space between e-coupler and flap, while in centred position.	P/F
Maximum vertical deflection	No interaction with flaps in maximum height offset of two couplers.	P/F
No interaction with wagon components	During the tests there is no interaction with wagon components (except flaps) allowed.	P/F

2 Test execution

2.1 Description of test procedure for movement area and interaction with wagon components

The coupler is positioned manually to the relevant maximum deflections. The position of the coupling relative to the wagon is determined. In particular, the angle and distance of the e-coupler to wagon flaps should be measured. The space in which the coupler moves should be drawn in a simple diagram similar to Figure 1.

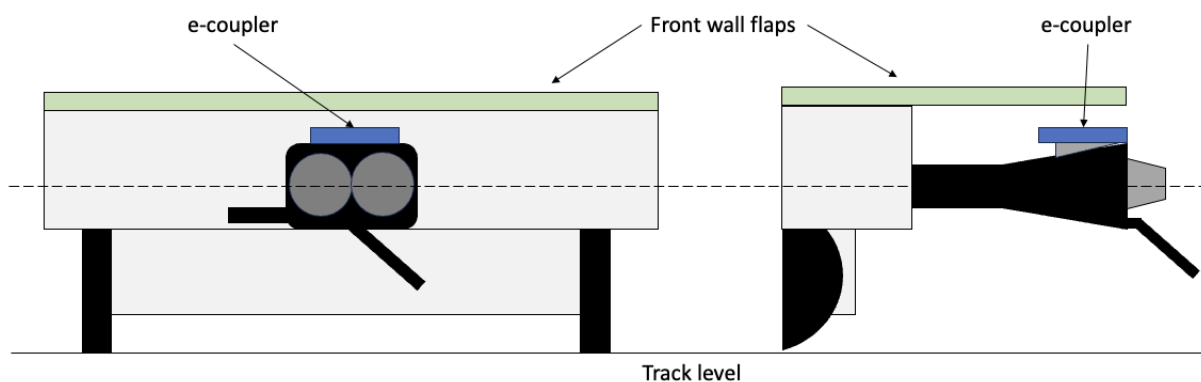


Figure 1: Sketch of e-coupler and wagon front flaps

The next steps are described in more detail in the following chapters.

2.1.1 Test preparation / Initial setup

First step is to set the coupler in centered position and to measure the distance of the coupler center line over track and the distance of the upper e-coupler housing to the wagon flaps like shown in Figure 2.

Here is:

- a = height of coupler centre line above track
- b = distance from e-coupler housing to lower front side of flaps
- c = Distance from the front measuring point on the coupler bolt to the pivot point of the coupler in the wagon

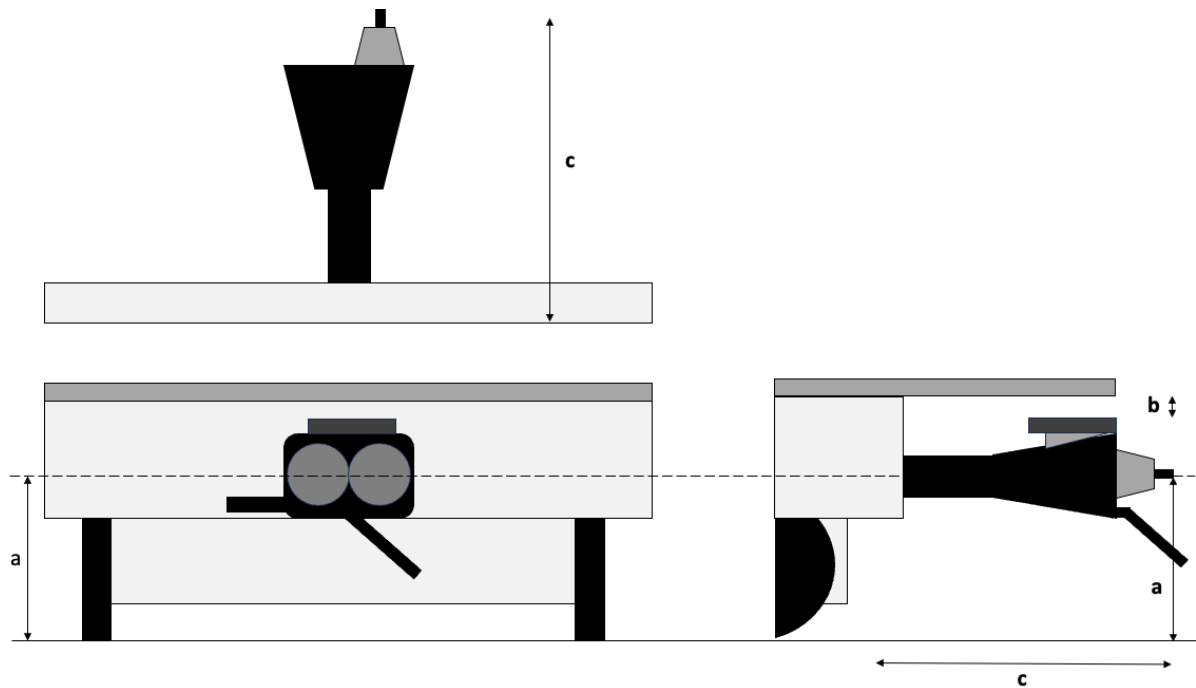


Figure 2: Dimensions and measurements regarding e-coupler, coupler and wagons

In the next step, the coupler is deflected to the left and right. The deflection angle alpha is also measured analogue to Figure 3.

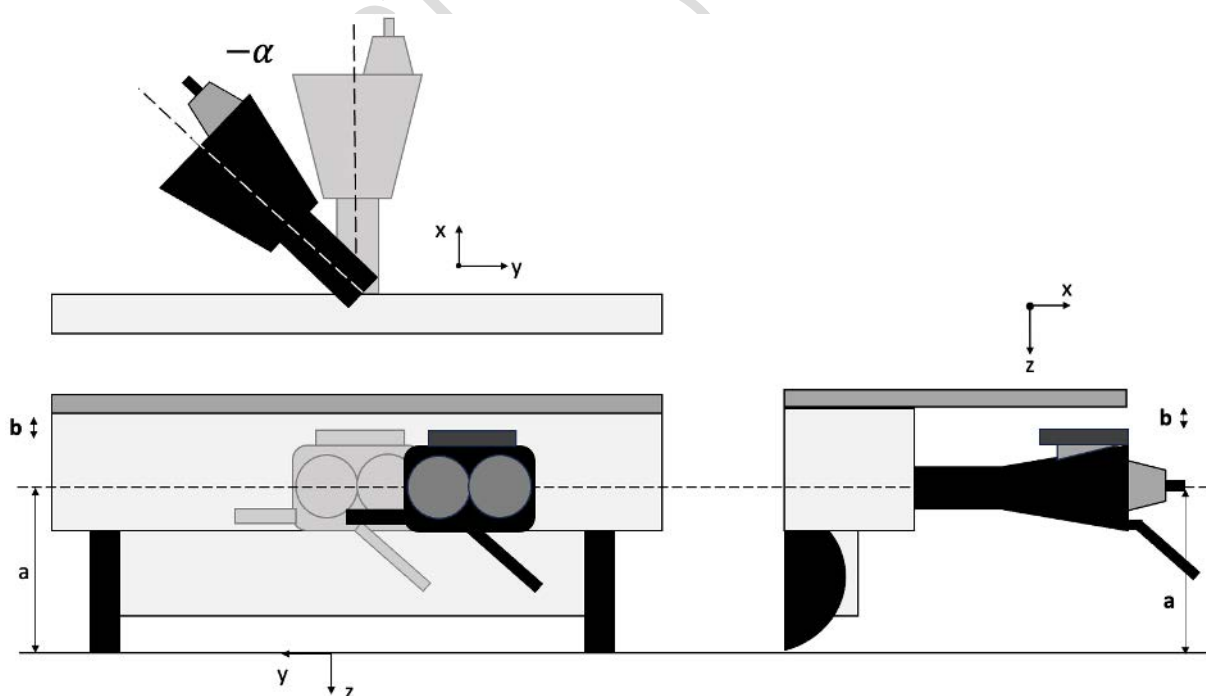


Figure 3: Deflection around z-axis in horizontal x-y-plane

The coupler is then deflected at the very top and bottom by the angle beta and the corresponding measured values are determined.

Beta is calculated from c, a and a2:

$$\beta = \arcsin \left(\frac{a - a2}{c} \right)$$

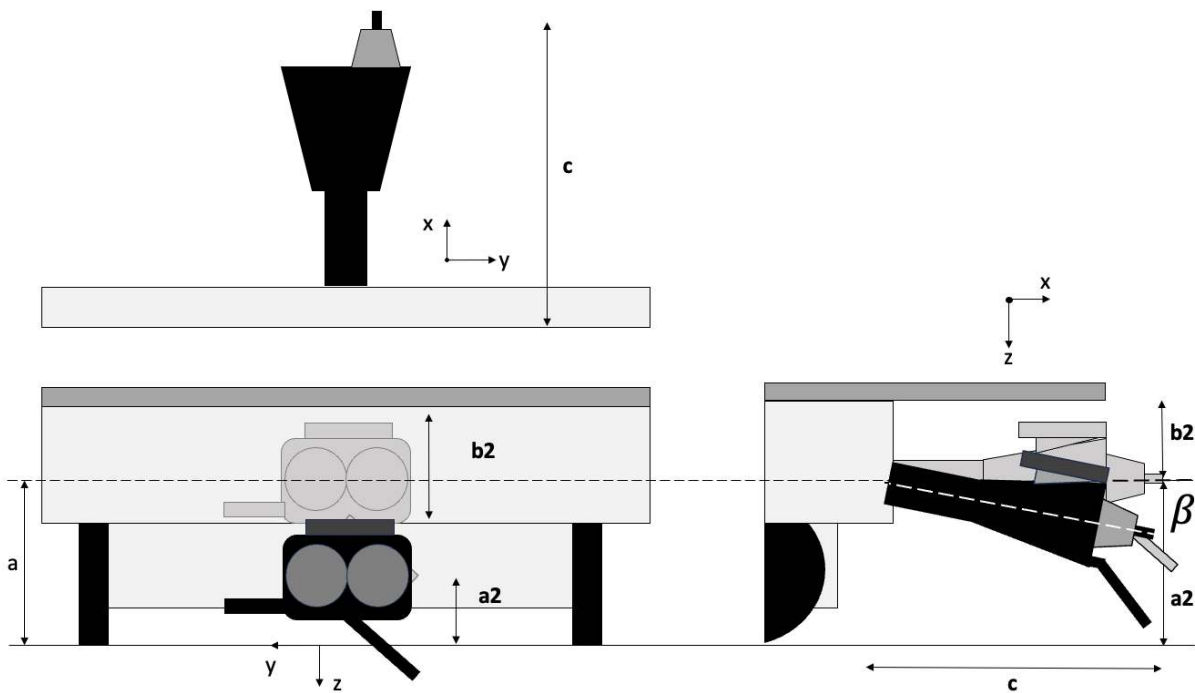


Figure 4: Deflection around y-axis in vertical x-z-plane

The maximum rotation angle +beta is limited by the vertical support. Here it is sufficient to determine the maximum manual deflection. The minimum angle -beta is limited by the contact of the e-coupler with the wagon flaps.

In addition, the respective combinations, e.g. max_alpha and max_beta, i.e. maximum manual deflection to the bottom left and the three other corner points must be determined.

2.2 Infrastructure

2.2.1 Assets

As a freight wagon, the Samms_1781 – config. #005 (Figure 5) was used (for further information see the main report).

The coupler used for the installation tests was the VT_DAC4_003 with the e-coupler VT_EC_003 (see annex 0).



Figure 5: Samms wagon used for installation tests

The wagon has the described front wall flaps. In the case of very long goods, these may also be folded down during the journey. If the wagons have different payloads, the couplers are offset horizontally. One coupler is therefore aligned downwards, the other is aligned upwards. The aim of the measurements is therefore to determine whether it is possible for the e-coupler and the folded-down front wall flaps of the wagons to touch at the maximum height difference between the wagons.

However, as only one type of wagon with front wall flaps was analysed in these tests, no general statement can be made. In addition, vibrations, impacts and bending of the flaps were not considered. This is therefore an initial determination based on one valid wagon type.

2.2.2 Test location

All tests were executed at the loco workshop of the HVLE in Berlin-Spandau. The workshop consists of a large hall with two railway tracks. The work was carried out on track 1 (left-hand side in Figure 6) in an area without a pit.



Figure 6: Loco workshop HVLE - Berlin Spandau

2.3 Measurement equipment / Documentation

The following data was documented or measured:

Documented in the protocol:

- Measurements of angles and distances
- Abnormalities and deviations from procedure.

Documentation by video/photo:

- Photo documentation of procedure

Measured by measurement systems:

- none

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Space in centred position	→ Distance b in centred state ($\alpha = \beta = 0$) minimum 6cm.
Maximum vertical deflection	→ Distance a2-a while e-coupler touches flap ($\beta_{\min}$) minimum 12/2cm = 6cm
No interaction with wagon components	→ Documentation

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Annex 5_KB

Influence of dirt

E-coupler: Knorr-Bremse

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 5_KB
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	7
2.1 Pollutant	7
2.2 Description of test procedure for influence of dirt	9
2.2.1 Preparatory Work	9
2.2.2 Pollution from above	13
2.2.3 Operation of coupler	15
2.2.4 Targeted pollution	16
2.2.5 Operation of coupler	18
2.2.6 Documentation after tests	18
2.3 Test-objects and infrastructure	19
2.4 Measurement equipment / Documentation	19
2.5 Evaluation	20
3 Results	21
3.1 After pollution from above and coupling	21
3.2 After targeted pollution and coupling	21
3.3 Dismounting of e-coupler	23
4 Conclusion	26
5 References	27

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler – Influence of dirt” described in Polarion ID “IPTRANS-6555” [IP-TRANS 6555]. Objective of the tests is the evaluation of e-couplers regarding the influence of dirt. The performance of the e-coupler shall be tested after the application of a pollutant. The test is not required to be comparably executed. The focus is to find weak points of the e-couplers.

Description from [IP-TRANS 6555]:

Polarion ID	IPTRANS-6555		
Title	e-coupler – Influence of dirt		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Reliability	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

Test Specification/Description of Validation Process: Bucket full of dirt tests

Summary from [Matrix_B04]:

#	A10
Name	Environment / Pollution
Sub #	10.1
Title	-
P/F or BoB	BoB
Requirement / Test description	Bucket of sand and stone test
Related AUCO	-

Derived by WP14:

From the listed descriptions, the following individual test-steps were derived by WP14:

Step	Description	Documentation	Remark
1	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts before test
2	Re-assembly of e-couplers	.Photos of re-assembled e-couplers	
3	Couple the mechanical couplers including e-couplers to one another	.Photos of coupled e-couplers	
4	Apply 2 litre of pollutant to the e-couplers	.Photos of e-couplers after application of pollutant .Write down any findings of visual inspection	Apply pollutant on the top of the coupled e-couplers' housings, make sure that the whole surface of the e-coupler housings are covered by pollution mix
5	Accelerate pollutant ingress by mechanical processing of the outside of e-couplers	.Photos of e-couplers after mechanical processing .Write down potential findings during this step	Mechanical processing of each outer side of e-coupler, including interface between e-couplers (sealing of contact block). Mechanical processing to be done with a hand broom or manually by hand
6	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant
7	Apply 0,5 litres of pollutant to one e-coupler from all sides (in de-coupled position / flaps closed)	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Apply pollutant onto the e-coupler (and between e-coupler housing and coupler head) horizontally and vertically from each side of e-coupler
8	Pour pollutant over the e-coupler	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Pour the rest of the pollutant over the coupler from above
9	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant
10	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts after test

To be evaluated:

To evaluate	Criteria	P/F or BoB
Mechanical coupling of e-coupler	The e-coupler is mechanically coupled if the DAC is coupled, the lids are open and the centring pins engage with each other.	BoB
Opening lid after coupling	If the DAC is coupled, the lid must be open.	BoB
Mechanical uncoupling of e-coupler	The e-coupler is mechanically uncoupled and the lids are closed.	BoB
Closing lid after uncoupling	If the DAC is not coupled, the lid must be closed.	BoB
Damages on the e-coupler housing	The outside area of the e-coupler must not be damaged during or after tests.	BoB
Damages on the contact block	The contact block of the e-coupler must not be damaged during or after tests.	BoB
Damages on the pins	The pins of the e-coupler must not be damaged during or after tests.	BoB
Dirt ingress contact block	The contact block must be clear from all pollution.	BoB
Dirt ingress pins	The pins must be clear from all pollution.	BoB
Dirt ingress in the centration pins.	The centration pins must fulfil their function.	BoB
Dirt on the outside of the-coupler housing	The outside of the e-coupler housing must be clear from all pollution.	BoB
Dirt ingress inside the e-coupler housing	The inside of the e-coupler housing must be clear from all pollution after disassembly the e-coupler-	BoB
Functional after cleaning	The e-coupler must be functional after cleaning	BoB

2 Test execution

The explained steps can be grouped into the following phases:

- Preparatory work (including documentation before test)
- Pollution from above on coupled couplers
- Operation of e-couplers
- Targeted pollution on uncoupled coupler
- Operation of e-couplers
- Collect/document results

After documentation of the condition before test, a defined pollution was applied to the e-couplers. The following operation of the e-couplers is meant to (a) show first influence of the pollution and (b) further promote the applied pollutant into the e-couplers (e.g. mechanics, front face contact block, etc). The steps of pollution and operation were done twice. Firstly, the pollutant is applied from above on the coupled e-couplers. Secondly, the pollutant is applied from all sides. The actual testing phase was followed by documentation of visible changes versus the initial state of the e-couplers.

The steps are described in more detail in the following subchapters.

2.1 Pollutant

The pollutant consisted of (Figure 1):

- 2 litres of water
- 2 litres of braking-sand
- 1 litre of dirt (fine sand + small stones)

For the sand, calibrated braking sand according to TL 918 224 was used. The ingredients were mixed in a bucket prior to application to the test objects (Figure 2).



Figure 1: Components of the pollutant.
Left: 2 litres of water and 2 litres of braking sand. Right: 1 litre of dirt.



Figure 2: Mixed pollutant.

2.2 Description of test procedure for influence of dirt

2.2.1 Preparatory Work

Step	Description	Documentation	Remark
1	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts before test
2	Re-assembly of e-couplers	.Photos of re-assembled e-couplers	
3	Couple the mechanical couplers including e-couplers to one another	.Photos of coupled e-couplers	

In advance to starting the actual application of pollution to the e-couplers, the above-mentioned steps were executed in order to prepare the e-couplers and document the initial state of the e-couplers before testing.

The level of disassembly in step 1 depended on the coupler concept and the engineering judgement of which parts may be impacted by the following test. The following guideline tries to describe to which level the e-couplers has been disassembled:

- Dismount e-coupler from coupler head (to access mechanism under e-coupler housing)
- Dismounting of outer housing
- Dismounting of gearcase

Photo documentation was taken at each step, however if no added value was assumed for the reader of this report, not all pictures were included (e.g. photos of e-couplers after coupling if no special relevance).

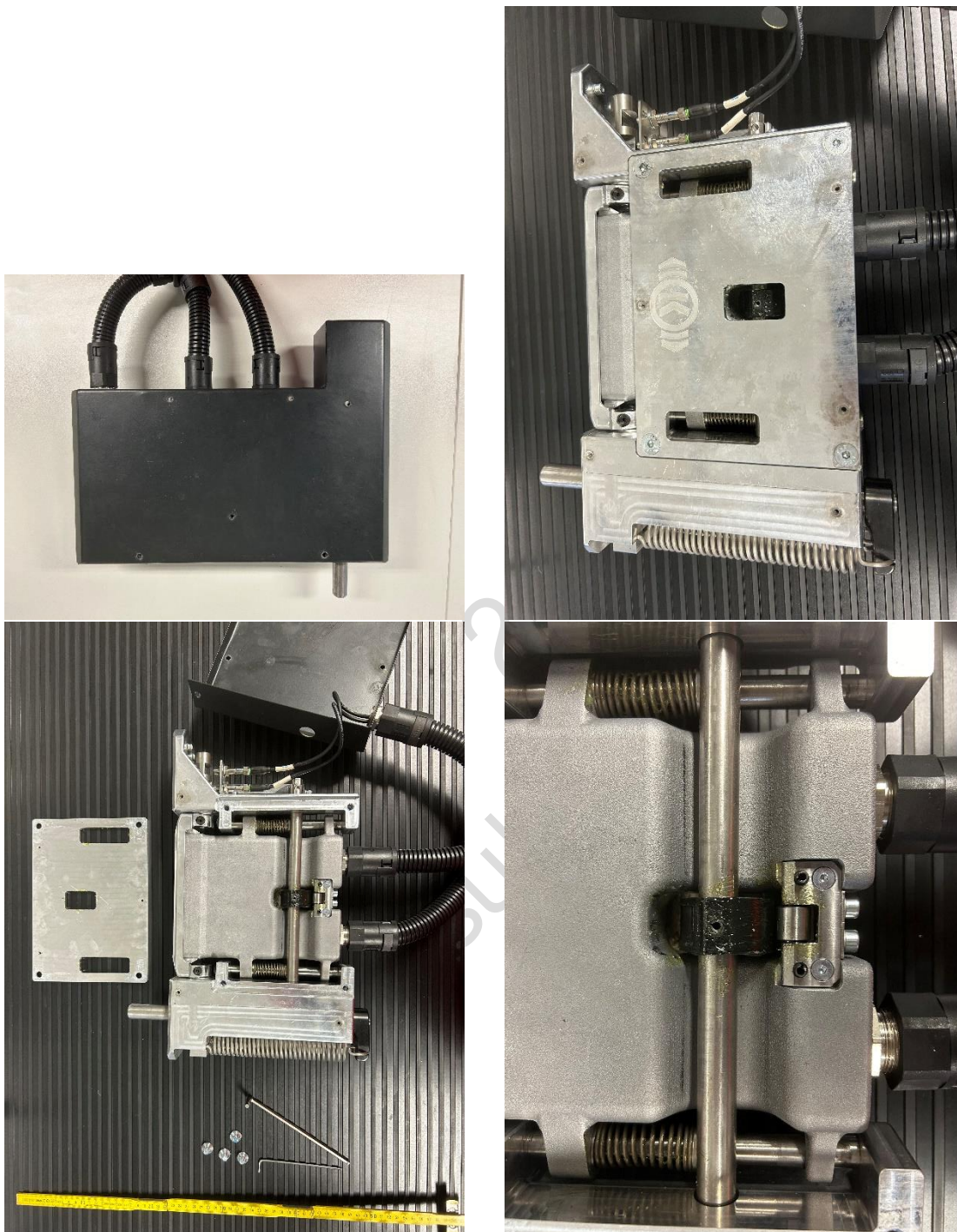


Figure 3: Top views of dismantled e-coupler.

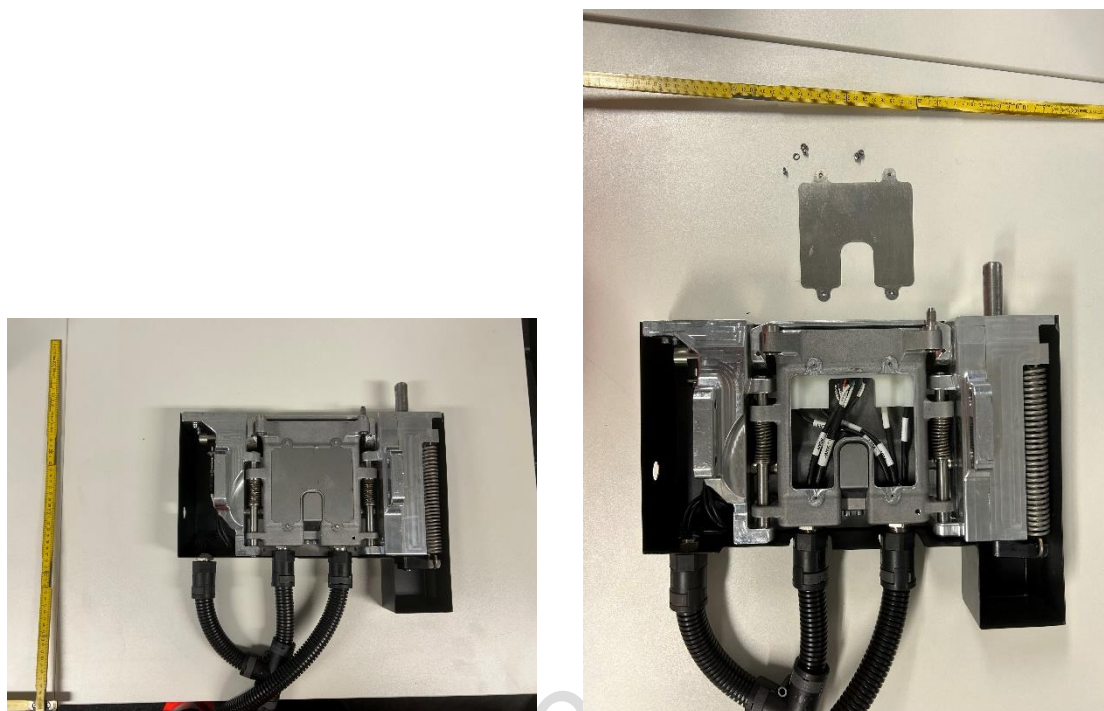


Figure 4: Bottom views of the e-coupler.



Figure 5: Front view of the e-coupler with closed lid.

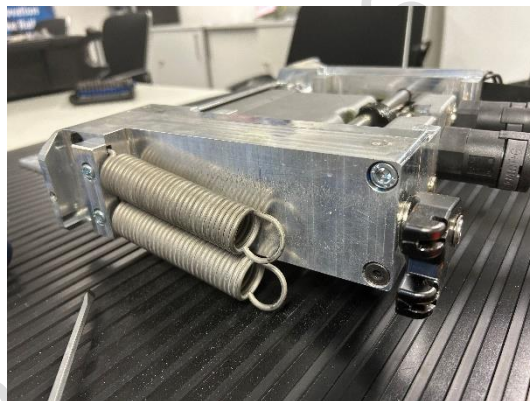


Figure 6: Detailed views of the e-coupler.
Left: Lid-sensors. Right: Springs.



Figure 7: Dismounted gearcase.

2.2.2 Pollution from above

Step	Description	Documentation	Remark
4	Apply 2 litre of pollutant to the e-couplers	.Photos of e-couplers after application of pollutant .Write down any findings of visual inspection	Apply pollutant on the top of the coupled e-couplers' housings, make sure that the whole surface of the e-coupler housings are covered by pollution mix
5	Accelerate pollutant ingress by mechanical processing of the outside of e-couplers	.Photos of e-couplers after mechanical processing .Write down potential findings during this step	Mechanical processing of each outer side of e-coupler, including interface between e-couplers (sealing of contact block). Mechanical processing to be done with a hand broom or manually by hand

Two litre of the pollutant was used for this test. It was applied vertically on the coupled e-couplers (pollutant poured from above onto the e-couplers). It was made sure that the whole area of the e-couplers was covered with pollutant.

In step 5 the pollutant ingress was accelerated by mechanical processing of the pollutant on the outside of the e-couplers. Processing took place by hand to wipe the pollutant over the top, the connection-gap of the e-couplers and over the sealing contact between the e-couplers.



Figure 8: Main input of pollutant to the e-couplers during pollution from above.

Figure 8 shows the main input of pollutant to the e-coupler. It was made sure that the pollutant was especially squeezed into existing slots and gaps (e.g. between the e-coupler housing and the coupler head, sealing surface between e-couplers, gaps between coupler housing and lid etc.).



Figure 9: Input of pollutant to the e-coupler.
Left: Top view. Right: Side view.

2.2.3 Operation of coupler

Step	Description	Documentation	Remark
6	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant

The operation of the coupler was executed by coupling tests. For these tests the couplers were coupled at slow speeds of approximately 2 km/h. Coupling tests were repeated 5 times.

The parameters for the coupling tests were as follows:

Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount	Remark
full	full	Appx. 2	Straight	5	-

Special care was taken regarding the documentation during this test step. As damages, malfunctions or contamination may have occurred or advanced during this phase, a visual inspection of the e-coupler including contact block was performed after each test and documented in photos if deemed appropriate.

In addition to that, a more comprehensive assessment (photos, visual inspection, documentation of additional findings) was done once the 5 couplings were completed.

2.2.4 Targeted pollution

Step	Description	Documentation	Remark
7	Apply 0,5 litres of pollutant to one e-coupler from all sides (in de-coupled position / flaps closed)	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Apply pollutant onto the e-coupler (and between e-coupler housing and coupler head) horizontally from each side of e-coupler
8	Pour pollutant over the e-coupler	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Pour the rest of the pollutant over the coupler from above

Half a litre of pollutant was applied from all sides to the uncoupled e-coupler with closed lid.

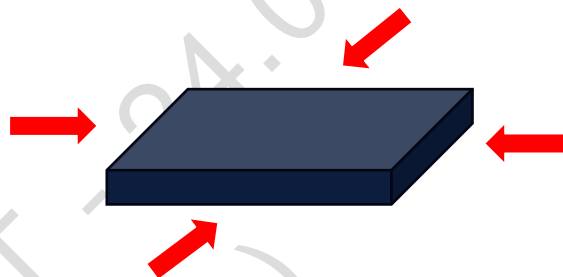


Figure 10: Application directions of pollutant for targeted pollution.

Figure 10 shows the directions in which the pollutant was applied onto the e-coupler. It was made sure that especially the pollutant was applied into existing slots and gaps (e.g. between the e-coupler housing and the coupler head, gaps between coupler housing and lid etc.).



Figure 11: Pollution of e-coupler after step 8.



Figure 12: Pollution from the bottom side of the e-coupler after step 8.



Figure 13: Pollution of the springs after step 8.

2.2.5 Operation of coupler

Step	Description	Documentation	Remark
9	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant

The same operation was executed as stated in chapter 2.2.3.

2.2.6 Documentation after tests

Step	Description	Documentation	Remark
10	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts after test

The actual testing phase was followed by the documentation of the results of the test. Documented were the visual findings such as visible contamination or wear.

Disassembly of e-couplers was executed to the same level as stated in chapter 2.2.

The visual inspection of the disassembled e-couplers focused on changes compared to the initial condition of the parts, especially:

- Cleanliness (ingress of water or sand)
- Wear or damage due to sand ingress to moving components

2.3 Test-objects and infrastructure

The described tests were executed on the 25.01.2024.

The object under test was the KB_DAC45_006 (see annex 0).

The opposing coupler was the KB_DAC45_005 (see annex 0). They were installed on the wagons Shimmns_9383 (KB_DAC45_005) and Samms_3779 (KB_DAC45_006). For wagon descriptions see main report.

All tests were executed at the HVLE premises in Berlin Spandau (see main report for further information).

2.4 Measurement equipment / Documentation

The following data was documented or measured:

Documented by video/photo:

- Video documentation of the steps 2.2.2 to 2.2.5 (pollution and coupling)
- Photo documentation of initial pollution
- Photo documentation of pollution after the tests
- Photo documentation of all steps of the test-procedure

2.5 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Mechanical coupling of e-coupler	→ Documentation of abnormalities
Opening lid after coupling	→ Documentation of abnormalities
Mechanical uncoupling of e-coupler	→ Documentation of abnormalities
Closing lid after uncoupling	→ Documentation of abnormalities
Damages on the e-coupler housing	→ Photo documentation
Damages on the contact block	→ Photo documentation
Damages on the pins	→ Photo documentation
Dirt ingress contact block	→ Photo documentation
Dirt ingress pins	→ Photo documentation
Dirt ingress in the centration pins.	→ Photo documentation
Dirt on the outside of the-coupler housing	→ Photo documentation
Dirt ingress inside the e-coupler housing	→ Photo documentation
Functional after cleaning	→ Documentation of abnormalities

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Annex 5_VT

Influence of Dirt

E-coupler: Voith

Test report:	2024-001-WP14-TR01
Annex No.:	Annex 5_VT
Annex - Version:	V01

Confidentiality

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

Table of Contents

Abbreviations and acronyms	3
1 Description of test case	4
2 Test execution	7
2.1 Pollutant	7
2.2 Description of test procedure for influence of dirt	8
2.2.1 Preparatory Work	8
2.2.2 Pollution from above	10
2.2.3 Operation of coupler	12
2.2.4 Targeted pollution	13
2.2.5 Operation of coupler	14
2.2.6 Documentation after tests	15
2.3 Test-objects and infrastructure	15
2.4 Measurement equipment / Documentation	15
2.5 Evaluation	16
3 Results	17
3.1 After pollution from above and coupling	17
3.2 After targeted pollution and coupling	18
3.3 Dismounting of e-coupler	20
4 Conclusion	22
5 References	23

Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both - criteria
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
E-coupler	Electronic coupler of a digital automatic coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse
P/F	Pass / Fail - criteria
TTL	Train Test Lab
VT	Voith

1 Description of test case

This annex is focusing on the test case “e-coupler – Influence of dirt” described in Polarion ID “IPTRANS-6555” [IP-TRANS 6555]. Objective of the tests is the evaluation of e-couplers regarding the influence of dirt. The performance of the e-coupler shall be tested after the application of a pollutant. The test is not required to be comparably executed. The focus is to find weak points of the e-couplers.

Description from [IP-TRANS 6555]:

Polarion ID	IPTRANS-6555		
Title	e-coupler – Influence of dirt		
Type	Test case	Status	DRAFT
Author	Daniel Wolfram	Validation Method	closed test environment
Project	IP-TRANS4MR	Vehicle Type Required	Any wagon
Component	DAC	Specific Wagon Requirements	-
Test Objective	Reliability	Important for Authorization/TSI	-
		Test phase	early test

Test Specification:

Test Specification/Description of Validation Process: Bucket full of dirt tests

Summary from [Matrix_B04]:

#	A10
Name	Environment / Pollution
Sub #	10.1
Title	-
P/F or BoB	BoB
Requirement / Test description	Bucket of sand and stone test
Related AUCO	-

Derived by WP14:

From the listed descriptions, the following individual test-steps were derived by WP14:

Step	Description	Documentation	Remark
1	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts before test
2	Re-assembly of e-couplers	.Photos of re-assembled e-couplers	
3	Couple the mechanical couplers including e-couplers to one another	.Photos of coupled e-couplers	
4	Apply 2 litre of pollutant to the e-couplers	.Photos of e-couplers after application of pollutant .Write down any findings of visual inspection	Apply pollutant on the top of the coupled e-couplers' housings, make sure that the whole surface of the e-coupler housings are covered by pollution mix
5	Accelerate pollutant ingress by mechanical processing of the outside of e-couplers	.Photos of e-couplers after mechanical processing .Write down potential findings during this step	Mechanical processing of each outer side of e-coupler, including interface between e-couplers (sealing of contact block). Mechanical processing to be done with a hand broom or manually by hand
6	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant
7	Apply 0,5 litres of pollutant to one e-coupler from all sides (in de-coupled position / flaps closed)	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Apply pollutant onto the e-coupler (and between e-coupler housing and coupler head) horizontally and vertically from each side of e-coupler
8	Pour pollutant over the e-coupler	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Pour the rest of the pollutant over the coupler from above
9	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant
10	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts after test

To be evaluated:

To evaluate	Criteria	P/F or BoB
Mechanical coupling of e-coupler	The e-coupler is mechanically coupled if the DAC is coupled, the lids are open and the centring pins engage with each other.	BoB
Opening lid after coupling	If the DAC is coupled, the lid must be open.	BoB
Mechanical uncoupling of e-coupler	The e-coupler is mechanically uncoupled and the lids are closed.	BoB
Closing lid after uncoupling	If the DAC is not coupled, the lid must be closed.	BoB
Damages on the e-coupler housing	The outside area of the e-coupler must not be damaged during or after tests.	BoB
Damages on the contact block	The contact block of the e-coupler must not be damaged during or after tests.	BoB
Damages on the pins	The pins of the e-coupler must not be damaged during or after tests.	BoB
Dirt ingress contact block	The contact block must be clear from all pollution.	BoB
Dirt ingress pins	The pins must be clear from all pollution.	BoB
Dirt ingress in the centration pins.	The centration pins must fulfil their function.	BoB
Dirt on the outside of the-coupler housing	The outside of the e-coupler housing must be clear from all pollution.	BoB
Dirt ingress inside the e-coupler housing	The inside of the e-coupler housing must be clear from all pollution after disassembly the e-coupler-	BoB
Functional after cleaning	The e-coupler must be functional after cleaning	BoB

2 Test execution

The explained steps can be grouped into the following phases:

- Preparatory work (including documentation before test)
- Pollution from above on coupled couplers
- Operation of e-couplers
- Targeted pollution on uncoupled coupler
- Operation of e-couplers
- Collect/document results

After documentation of the condition before test, a defined pollution was applied to the e-couplers. The following operation of the e-couplers is meant to (a) show first influence of the pollution and (b) further promote the applied pollutant into the e-couplers (e.g. mechanics, front face contact block, etc). The steps of pollution and operation were done twice. Firstly, the pollutant is applied from above on the coupled e-couplers. Secondly, the pollutant is applied from all sides. The actual testing phase was followed by documentation of visible changes versus the initial state of the e-couplers.

The steps are described in more detail in the following subchapters.

2.1 Pollutant

The pollutant consisted of (Figure 1):

- 2 litres of water
- 2 litres of braking-sand
- 1 litre of dirt (fine sand + small stones)

For the sand, calibrated braking sand according to TL 918 224 was used. The ingredients were mixed in a bucket prior to application to the test objects (Figure 2).



Figure 1: Components of the pollutant.

Left: 2 litres of water and 2 litres of braking sand. Right: 1 litre of dirt.



Figure 2: Mixed pollutant.

2.2 Description of test procedure for influence of dirt

2.2.1 Preparatory Work

Step	Description	Documentation	Remark
1	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts before test
2	Re-assembly of e-couplers	.Photos of re-assembled e-couplers	
3	Couple the mechanical couplers including e-couplers to one another	.Photos of coupled e-couplers	

In advance to starting the actual application of pollution to the e-couplers, the above-mentioned steps were executed in order to prepare the e-couplers and document the initial state of the e-couplers before testing.

The level of disassembly in step 1 depended on the coupler concept and the engineering judgement of which parts may be impacted by the following test. The following guideline tries to describe to which level the e-couplers has been disassembled:

- Dismount e-coupler from coupler head (to access cam/bearing under e-coupler housing)
- Dismounting of outer housing
- Opening of the lid

Photo documentation was taken at each step, however if no added value was assumed for the reader of this report, not all pictures were included (e.g. photos of e-couplers after coupling if no special relevance).

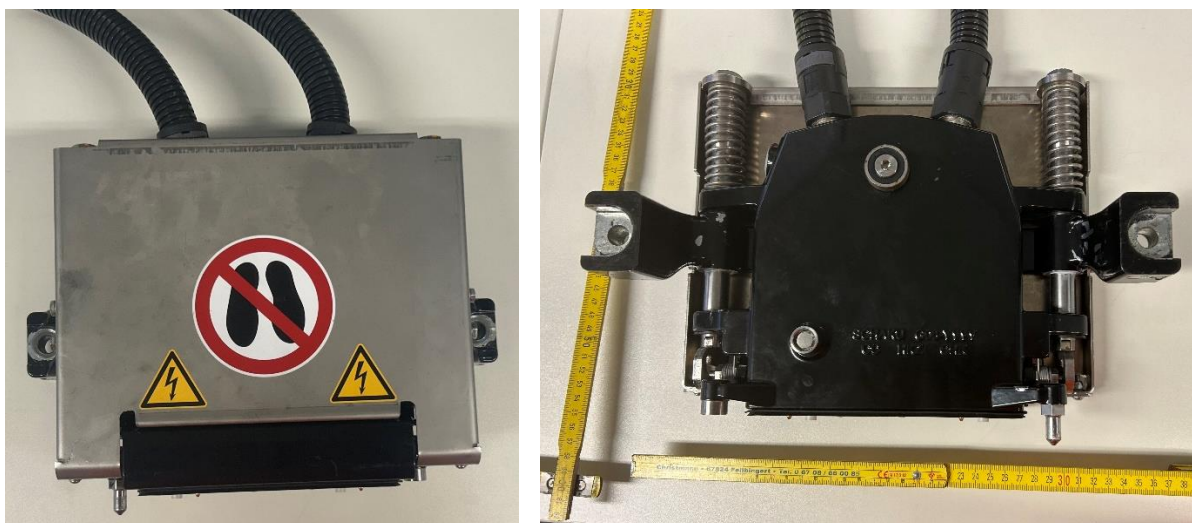


Figure 3: Top and bottom view of dismantled e-coupler.



Figure 4: Front view of the e-coupler with open flap.



Figure 5: Top view on the e-coupler without the outer housing.



Figure 6: Detailed views of the e-coupler.
Left: Screws on the side. Right: Spring.

2.2.2 Pollution from above

Step	Description	Documentation	Remark
4	Apply 2 litre of pollutant to the e-couplers	.Photos of e-couplers after application of pollutant .Write down any findings of visual inspection	Apply pollutant on the top of the coupled e-couplers' housings, make sure that the whole surface of the e-coupler housings are covered by pollution mix
5	Accelerate pollutant ingress by mechanical processing of the outside of e-couplers	.Photos of e-couplers after mechanical processing .Write down potential findings during this step	Mechanical processing of each outer side of e-coupler, including interface between e-couplers (sealing of contact block). Mechanical processing to be done with a hand broom or manually by hand

Two litre of the pollutant was used for this test. It was applied vertically on the coupled e-couplers (pollutant poured from above onto the e-couplers). It was made sure that the whole area of the e-couplers was covered with pollutant.

In step 5 the pollutant ingress was accelerated by mechanical processing of the pollutant on the outside of the e-couplers. Processing took place by hand to wipe the pollutant over the top, the connection-gap of the e-couplers and over the sealing contact between the e-couplers.



Figure 7: Main input of pollutant to the e-couplers during pollution from above.

Figure 7 shows the main input of pollutant to the e-coupler. It was made sure that the pollutant was especially squeezed into existing slots and gaps (e.g. between the e-coupler housing and the coupler head, sealing surface between e-couplers, gaps between coupler housing and lid etc.).



Figure 8: Input of pollutant to the e-coupler.
Left: Top view. Right: Side view.

2.2.3 Operation of coupler

Step	Description	Documentation	Remark
6	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant

The operation of the coupler was executed by coupling tests. For these tests the couplers were coupled at slow speeds of approximately 2 km/h. Coupling tests were repeated 5 times.

The parameters for the coupling tests were as follows:

Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount	Remark
empty	empty	Appx. 2	Straight	5	-

Special care was taken regarding the documentation during this test step. As damages, malfunctions or contamination may have occurred or advanced during this phase, a visual inspection of the e-coupler including contact block was performed after each test and documented in photos if deemed appropriate.

In addition to that, a more comprehensive assessment (photos, visual inspection, documentation of additional findings) was done once the 5 couplings were completed.

2.2.4 Targeted pollution

Step	Description	Documentation	Remark
7	Apply 0,5 litres of pollutant to one e-coupler from all sides (in de-coupled position / flaps closed)	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Apply pollutant onto the e-coupler (and between e-coupler housing and coupler head) horizontally from each side of e-coupler
8	Pour pollutant over the e-coupler	.Photos of e-couplers after application of accelerated pollution .Write down any findings of visual inspection	Pour the rest of the pollutant over the coupler from above

Half a litre of pollutant was applied from all sides to the uncoupled e-coupler with closed lid.

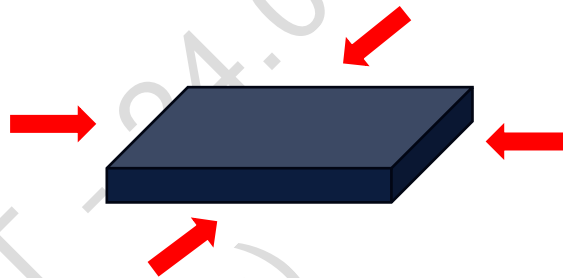


Figure 9: Application directions of pollutant for targeted pollution.

Figure 9 shows the directions in which the pollutant was applied onto the e-coupler. It was made sure that especially the pollutant was applied into existing slots and gaps (e.g. between the e-coupler housing and the coupler head, gaps between coupler housing and lid etc.).



Figure 10: Pollution of e-coupler after step 8.
Left: Front view. Right: Side view.



Figure 11: Pollution from the bottom side of the e-coupler after step 8.



Figure 12: Pollution of the springs after step 8.

2.2.5 Operation of coupler

Step	Description	Documentation	Remark
9	Couple and de-couple 5 times	.Photos of e-couplers after coupling .Photos of contact blocks after coupling .Write down any potential findings during this step	Straight track, 2 kph, no deflection, load condition irrelevant

The same operation was executed as stated in chapter 2.2.3.

2.2.6 Documentation after tests

Step	Description	Documentation	Remark
10	Disassembly of the tested e-coupler	.Photos of disassembled e-couplers .Write down any findings of visual inspection	Focus is to document cleanliness of functional parts after test

The actual testing phase was followed by the documentation of the results of the test. Documented were the visual findings such as visible contamination or wear.

Disassembly of e-couplers was executed to the same level as stated in chapter 2.2.1.

The visual inspection of the disassembled e-couplers focused on changes compared to the initial condition of the parts, especially:

- Cleanliness (ingress of water or sand)
- Wear or damage due to sand ingress to moving components

2.3 Test-objects and infrastructure

The described tests were executed on the 25.01.2024.

The object under test was the VT_DAC4_003 (see annex 0).

The opposing coupler was the VT_DAC4_004 (see annex 0). They were installed on the wagons Shimmns_6025 (VT_DAC4_004) and Samms_1781 (VT_DAC4_003). For wagon descriptions see main report.

All tests were executed at the HVLE premises in Berlin Spandau (see main report for further information).

2.4 Measurement equipment / Documentation

The following data was documented or measured:

Documented by video/photo:

- Video documentation of the steps 2.2.2 to 2.2.5 (pollution and coupling)
- Photo documentation of initial pollution
- Photo documentation of pollution after the tests
- Photo documentation of all steps of the test-procedure

2.5 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Mechanical coupling of e-coupler	→ Documentation of abnormalities
Opening lid after coupling	→ Documentation of abnormalities
Mechanical uncoupling of e-coupler	→ Documentation of abnormalities
Closing lid after uncoupling	→ Documentation of abnormalities
Damages on the e-coupler housing	→ Photo documentation
Damages on the contact block	→ Photo documentation
Damages on the pins	→ Photo documentation
Dirt ingress contact block	→ Photo documentation
Dirt ingress pins	→ Photo documentation
Dirt ingress in the centration pins.	→ Photo documentation
Dirt on the outside of the-coupler housing	→ Photo documentation
Dirt ingress inside the e-coupler housing	→ Photo documentation
Functional after cleaning	→ Documentation of abnormalities