Interoperability – Early testing - Voith

Test report

Title:	Interoperability – Early testing - Voith
Type:	Test report
Document-No.:	2024-006-WP14-TR03
Test Laboratory:	WP 14 - Train Test Lab
Version:	V01
Date:	14.06.2024

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Document history		
Revision	*Date*	*Description*
V01	14.06.2024	Initial report

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Abbreviations & Acronyms

Abbreviation / Acronym	Description
BoB	Best of both – criteria
CL	Coupling link
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
DL	Dellner Couplers AB
DMS	Strain gauge (ger.: Dehnungsmessstreifen)
e-coupler	Electrical coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse AG
P/F	Pass / Fail - criteria
TOR	Top of rail
TTL	Train Test Lab
VT	Voith GmbH & Co. KGaA

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1 Project description and objective

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

In order to gain information on the interoperability of the mechanical and pneumatical parts of the DACs, impact tests shall be executed with couplers of non-identical type / supplier.

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

1.1 WP14 Train Test Lab – General overview

The Train Test Lab can be seen as an institution with different sites that have special characteristics and thus provides resources for special tests. The main site is located at the HVLE in Berlin-Spandau. Figure 1 shows an overview of the available infrastructure at the test location Berlin-Spandau.

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

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

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

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

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

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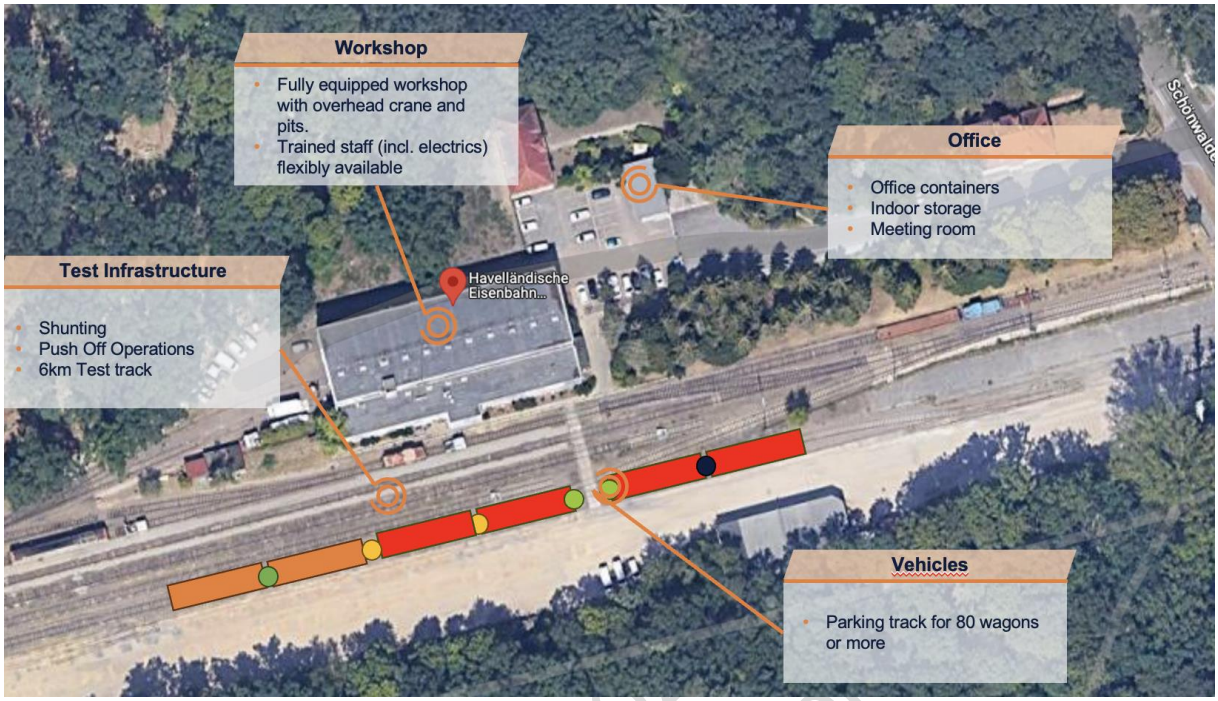

Figure 1: Train Test Lab overview

1.2 Objective for interoperability tests and report structure

The basis for the execution of interoperability tests is given by the deliverable 6.3 [DEL6.3] – Chapter 7.1. In agreement between the WP14 and the responsibles of the deliverable 6.3, the test plan was adjusted with a focus on impact tests.

The overall report consists of a main report and numerous annexes. The main report starts with a description of the project and the environment. The test objectives and report structure are explained in chapter 1. Chapter 2 introduces the DAC and describes the need for interoperability-tests. 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.

The relevant annexes are listed in chapter 8.

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1.3 Contact persons

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

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

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

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

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

Table 1: Contact persons

Role	Name	E-Mail
WP14 lead – responsible for content	Daniel Wolfram	Daniel.Wolfram@deutschebahn.com
Technical test lead	Julian Beck	Julian.J.Beck@deutschebahn.com
Supplier contact - Voith	Ulrich Deghela	Ulrich.Deghela@voith.com

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2 Introduction – DAC and Interoperability

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

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

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

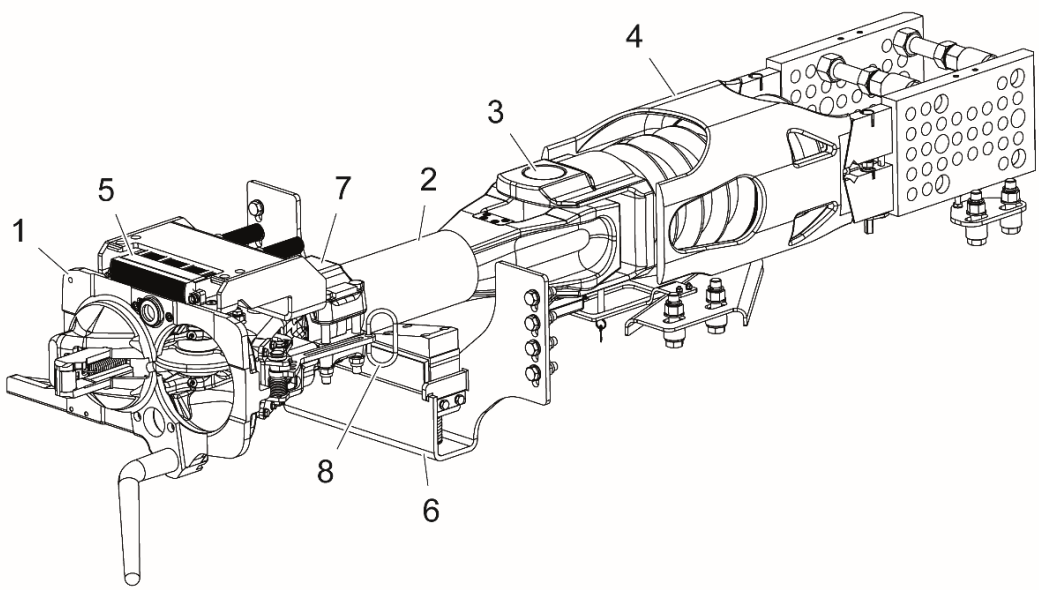

Figure 2: Scheme of the DAC. 1: mechanical coupler / coupler head, 2: coupler shank, 3: pivot pin, 4: draft gear (with compression force stop on the right end), 5: electrical coupler, 6: vertical support, 7: split collar, 8: manual uncoupling device; Source: [DEL6.3], edited.

DACs are classified regarding their level of automation:

Level	1	2	3	4	4.5	5
Mechanical connection	X					
Brake pipe connection		X				
Power line connection			X			
Data line connection				X		
Semi-automated uncoupling					X	
Fully automated remote uncoupling						X

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

- Design of front plate
- Behaviour of springs, hooked plate and coupler link of the coupler head
- Bahaviour of draft gear (e.g. spring and attenuation constant, material, etc.)
- Design of mechanical uncoupling mechanism
- Behaviour of air valve

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

As the electrical connection / e-coupler and actuator are not specified jet, the interoperability is only tested with the mechanical and pneumatical parts of the DAC. Therefore all tested DACs, regarding of their supplier internal automation level, are tested in automation level 2 – “DAC 2”.

Three samples of DAC (Dellner, Knorr-Bremse, Voith) were available in the Train Test Lab for interoperability test. These are described in detail in annex 1.

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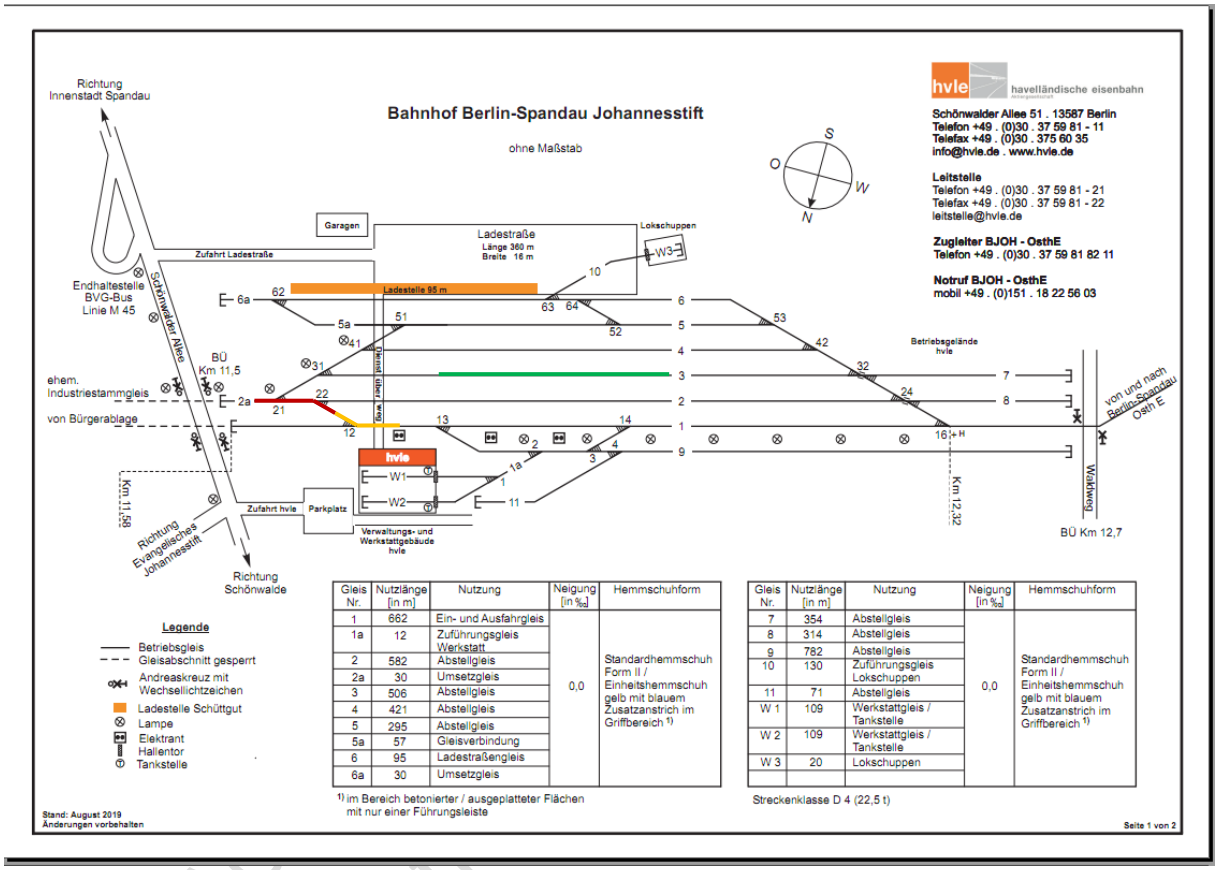
3 Infrastructure

3.1 Test location

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



Gleis Nr.	Nutzlänge [in m]	Nutzung	Neigung [in ‰]	Hemmschuhform
1	662	Ein- und Ausfahrgleis	0,0	Standardhemmschuh Form II / Einheitshemmschuh gelb mit blauem Zusatzanstrich im Griffbereich [1]
1a	12	Zuführungsgleis Werkstatt		
2	582	Abstellgleis		
2a	30	Umsetzgleis		
3	506	Abstellgleis		
4	421	Abstellgleis		
5	295	Abstellgleis		
5a	57	Gleisverbindung		
6	95	Ladestraßengleis		
6a	30	Umsetzgleis		

[1] im Bereich betonierter / ausgeplatteter Flächen mit nur einer Führungsleiste

Gleis Nr.	Nutzlänge [in m]	Nutzung	Neigung [in ‰]	Hemmschuhform
7	354	Abstellgleis	0,0	Standardhemmschuh Form II / Einheitshemmschuh gelb mit blauem Zusatzanstrich im Griffbereich [1]
8	314	Abstellgleis		
9	782	Abstellgleis		
10	130	Zuführungsgleis Lokschuppen		
11	71	Abstellgleis		
W 1	109	Werkstattgleis / Tankstelle		
W 2	109	Werkstattgleis / Tankstelle		
W 3	20	Lokschuppen		

Streckenklasse D 4 (22,5 t)

Colour	Track	Test
Green	Track 3	Impact tests on straight track
Orange	Switch 12 (Push off from direction of switch 13)	Impact tests in 190m-right curve
Red	Switch 22 (Push off from direction of switch 21)	Impact tests in 190m-right curve

Figure 3: Track layout of the HVLE, location Berlin-Spandau [HVLE_TL]. Edit: Test-tracks are coloured.

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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	#001	23.04.2024	Initial status before tests: Coupler A: Screw Coupler B: **V1** Load state: empty Measurement system DBST installed. OWITA power and data system installed.
Shimmns_6025	#002	25.04.2024	Change of loading: Load state: full
Shimmns_6025	#003	29.04.2024	Additional train-functions system (automatic brake test) installed by Siemens.
Shimmns_6025	#004	14.05.2024	Exchange of coupler: Coupler A: Screw Coupler B: **D2**

Loading:

Load state	Weight	Source / description / remark
empty	23.600 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems not included. - Screw coupler exchanged with DAC.
full	86.400 kg	Sources: - Wagon-inscription. - Coil-inscriptions (Coil 1: 31 t and Coil 2: 31,8 t) Remarks: - Installed electronic systems not included. - Screw coupler exchanged with DAC.

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Photo documentation:

Figure 4: Shimmns_6025.

Figure 5: Loading of the Shimmns_6025 with steel coils.

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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	#001	23.04.2024	Initial status before tests: Coupler A: Screw coupler Coupler B: **K1** Load state: full_1 Measurement system DBST installed. OWITA power and data system installed. Brake system not functional.
Shimmns_9383	#002	25.04.2024	Change of loading: Load state: empty
Shimmns_9383	#003	25.04.2024	Change of loading: Load state: full_2
Shimmns_9383	#004	14.05.2024	Exchange of coupler: Coupler A: Screw Coupler B: **D3**

Loading:

Load state	Weight	Source / description / remark
empty	23.600 kg	Sources: - Wagon-inscription. Remarks: - Installed electronic systems not included. - Screw coupler exchanged with DAC.
full_1	86.400 kg	Sources: - Wagon-inscription (see above) - Coil-inscriptions (Coil 1: 31,8 t and Coil 2: 31,0 t) Remarks: - Installed electronic systems not included. - Screw coupler exchanged with DAC.
full_2	82.800 kg	Sources: - Wagon-inscription (see above) - Coil-inscriptions (Coil 1: 31,5 t and Coil 2: 27,7 t) Remarks: - Installed electronic systems not included. - Screw coupler exchanged with DAC.

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Photo documentation:

Figure 6: Shimmns_9383.

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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	#001	23.04.2024	Initial status before tests: Coupler A: **D1** Coupler B: **D2** Load state: empty OWITA power and data system installed.
Samms_1781	#002	29.04.2024	Change of loading: Load state: full
Samms_1781	#003	13.05.2024	Change of loading: Load state: empty
Samms_1781	#004	15.05.2024	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. - Installed electronic systems not included.

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Photo documentation:

Figure 7: Samms_1781 (loaded).

Figure 8: 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	#001	23.04.2024	Initial status Coupler A: **K2** Coupler B: **V2** Load state: empty
Samms_3779	#002	13.05.2024	Change of loading: Load state: full
Samms_3779	#003	15.05.2024	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	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. - Installed electronic systems not included.

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Photo documentation:

Figure 9: Samms_3779 (unloaded).

Figure 10: Samms_3779 (loaded).

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4 Test schedule

Date	Location	Action	from Test-Nr.
Prev. to 23.04.2024	HVLE Berlin-Spandau	Installation of couplers and measurement equipment	-
24.04.2024	HVLE Berlin-Spandau	Impact tests KB → DL – full on empty KB → VT – full on empty	 010 – 052 053 – 084
25.04.2024	HVLE Berlin-Spandau	Impact tests KB → VT – full on empty Change of loading of Shimmns_6025: full → empty VT → DL – empty on empty VT → KB – empty on empty Change of loading of Shimmns_9383: full → empty KB → DL – empty on empty Change of loading of Shimmns_9383: empty → full Change of loading of Shimmns_6025: empty → full	 085 – 094 095 – 123 124 – 149 156 – 184
26.04.2024	HVLE Berlin-Spandau	Impact tests VT → DL – full on empty	 185 – 232
29.04.2024	HVLE Berlin-Spandau	Impact tests VT → KB – full on empty Change of loading of Samms_1781: empty → full	 233 – 281
30.04.2024	HVLE Berlin-Spandau	Impact tests KB → DL – full on full	 282 – 330
06.05.2024	HVLE Berlin-Spandau	Impact tests VT → DL – full on full	 331 – 370
13.05.2024	HVLE Berlin-Spandau	Impact tests VT → DL – full on full Change of loading of Samms_1781: full → empty Change of loading of Samms_3779: empty → full	 371 – 380
14.05.2024	HVLE Berlin-Spandau	Impact tests VT → KB – full on full	 381 – 428
15.05.2024	HVLE Berlin-Spandau	Impact tests Change of loading of Samms_3779: full → empty DL → DL – full on empty DL → VT – full on empty	 429 – 471 472 – 485
16.05.2024	HVLE Berlin-Spandau	Impact tests DL → VT – full on empty DL → KB – full on empty	 468 – 517 518 – 530
17.05.2024	HVLE Berlin-Spandau	Impact tests DL → KB – full on empty	 531 – 562

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5 Systems under test

A detailed description of the systems under test can be found in annex 1.

6 Execution and results

A detailed description of the executed tests can be found in the annexes listed in chapter 8.

7 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[DEL6.3]	-	Deliverable D 6.3 Reduced Validation/Test procedure of Wagon	Johan Ahman	26.04.2024	4
[HVLE_TL]	-	Gleisplan – Bahnhof Berlin-Spandau Johannesstift	HVLE	08.2019	-

8 Appendices

Annex	Vn.	Title	Content
Annex 1	01	Systems under test	Description of the tested objects
Annex 2	01	Interoperability - Impact tests	Interoperability – Impact tests Test concept and results

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Annex 1

Systems under test

Test report:	2024-006-WP14-TR03
Annex No.:	Annex 1
Annex - Version:	V01

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Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both – criteria
CL	Coupling link
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
DL	Dellner Couplers AB
DMS	Strain gauge (ger.: Dehnungsmessstreifen)
e-coupler	Electrical coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse AG
P/F	Pass / Fail - criteria
TOR	Top of rail
TTL	Train Test Lab
VT	Voith GmbH & Co. KGaA

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1 Systems under test

Systems under test are DACs of three different suppliers: Dellner, Knorr-Bremse and Voith. The tests are focused on the mechanical parts of the couplers. Out of scope are the e-coupler and the actuator.

Each of the mentioned companies supplies a complete system, consisting of:

- Coupler head, with:
  - Manual uncoupling device
  - Hooked plate + coupling link
  - Guiding horn + cone
  - Air pipe connection (brake pipe)
  - Air valve (with connection to brake pipe of wagon)
- Coupler shank, with:
  - Pivot pin for connection between shank and draft gear
- Draft gear, with:
  - Compression force stop for form closure with wagon
  - Compression force indication pin (only for Dellner and Knorr-Bremse couplers)
- Vertical support (with centration)
- Split collar (only for Dellner couplers)

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1.1 Dellner

1.1.1 Overview of the coupler

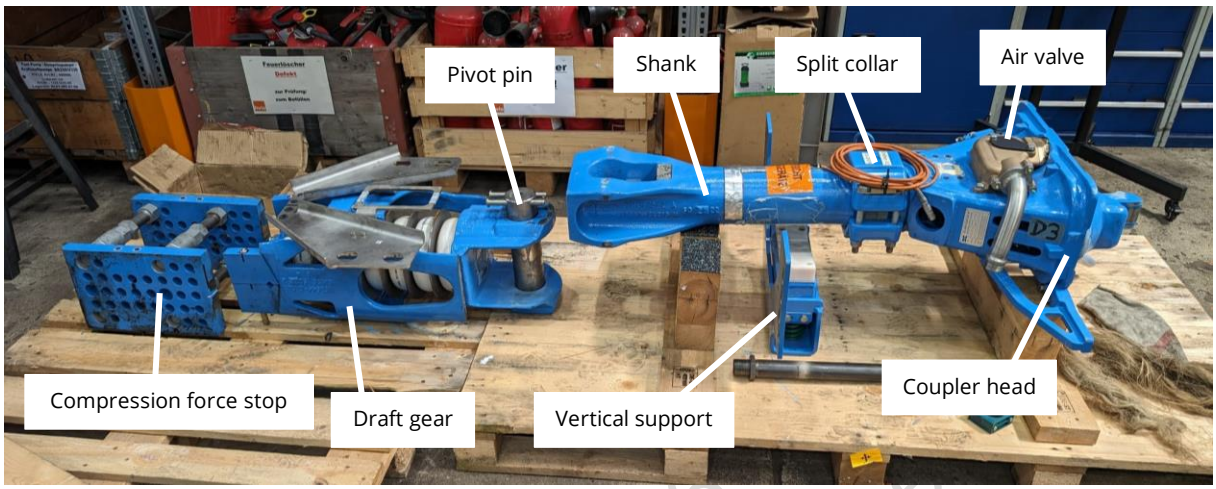

Figure 1: Overview of the parts of a Dellner DAC.

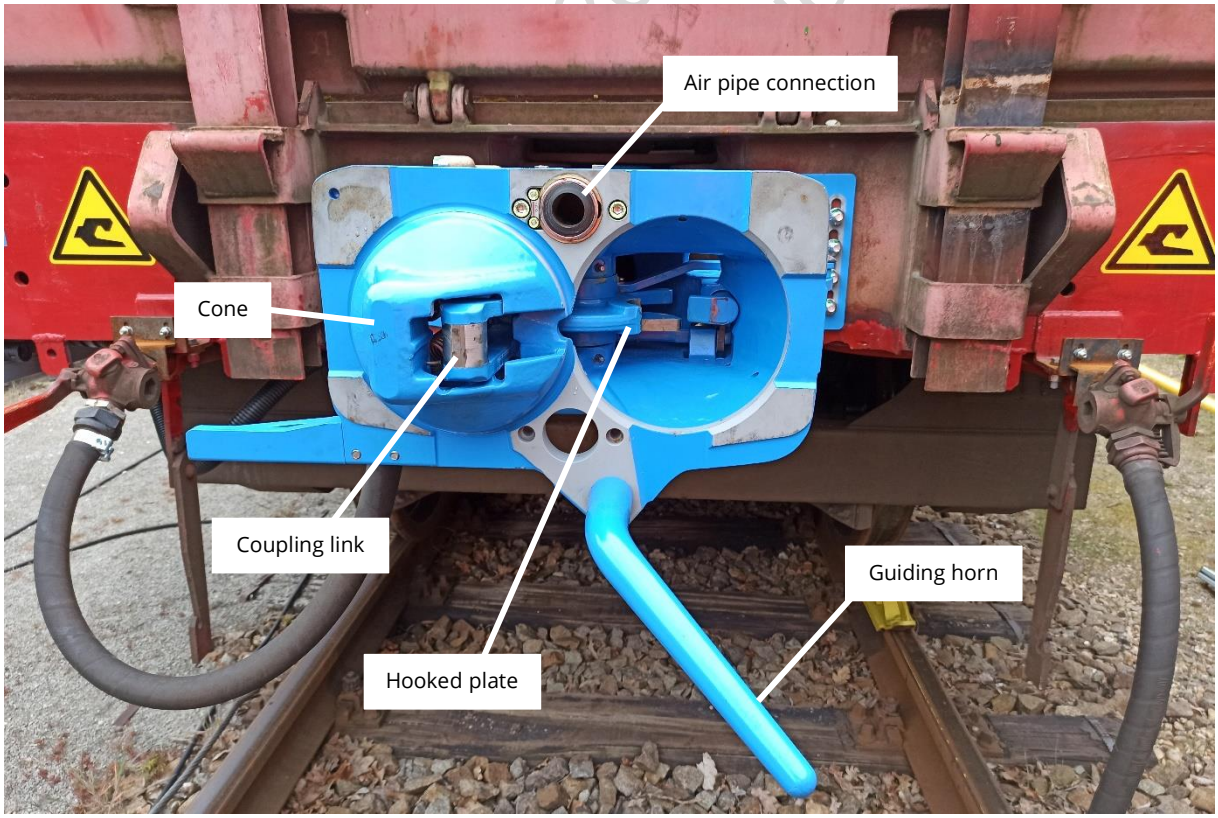

Figure 2: Front plate of a Dellner DAC.

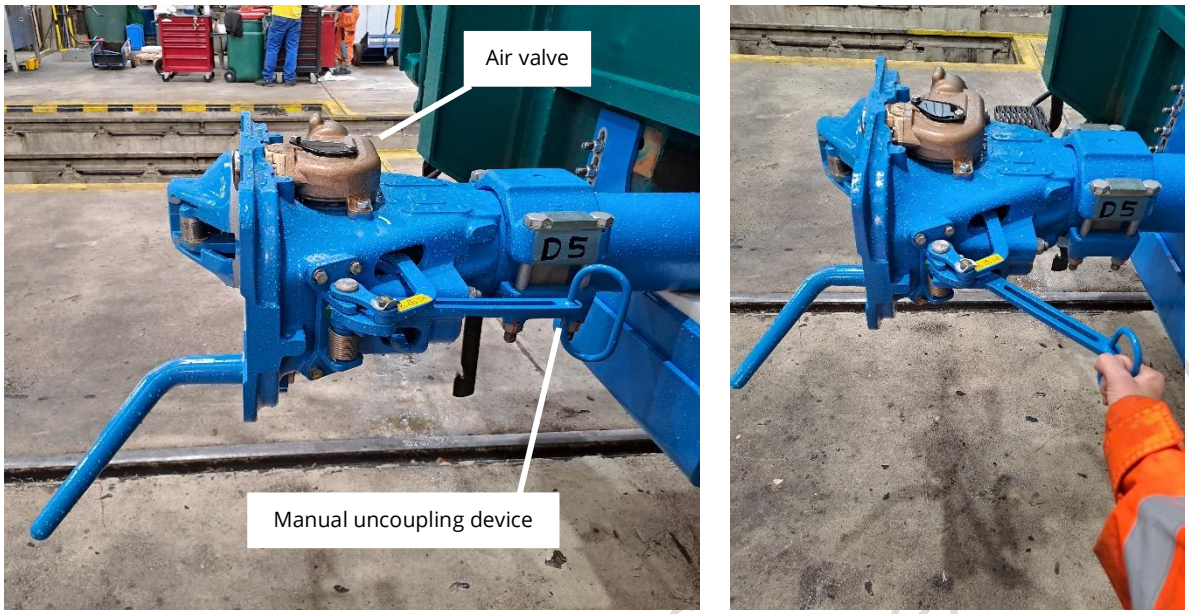

Figure 3: Left: Coupler head of a Dellner DAC (with air valve and manual uncoupling device). Right: Actuation of the manual uncoupling device.

Figure 4: Draft gear of a Dellner DAC.

Figure 5: Vertical support of a Dellner DAC.

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1.1.2 Couplers under test

1.1.2.1 D1

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
23.04.2024	#001	Initial status	**(M):** Type: 9029; SN: 002 2004268; Year: 2023		**(L):** HVLE **(W):** Samms_1781, side A
26.04.2024	#002	Compression force indication pin sheared off at ~1.400 kN.		**(D):** Compression force indication pin fell off.	

1.1.2.2 D2

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
23.04.2024	#001	Initial status	**(M):** Type: 9029; SN: 001 2004268 ; Year: 2023 DMS installed.		**(L):** HVLE **(W):** Samms_1781, side B
30.04.2024	#002	Compression force indication pin sheared off at ~1.000 kN.		**(D):** Compression force indication pin fell off.	
14.05.2024	#003	Change of coupler head.		**(V) + (D) + (C):** New	**(W):** Shimmns_6025, side B

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1.1.2.3 D3

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
14.05.2024	#001	Initial status and installation	**(M):** Type: 9029; SN: 004 2004268 ; Year: 2023 DMS installed. Attechment-bump for the type plate not existent.		**(L):** HVLE **(W):** Samms_9383, side B
16.05.2024	#002	Compression force indication pin sheared off at ~1.400 kN.		**(D):** Compression force indication pin fell off.	

1.1.2.4 D4

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
14.05.2024	#001	Initial status	**(M):** Type: 9029; SN: 018 2004268 ; Year: 2024 DMS installed.	**(V) + (D) + (C):** From D2 (change of coupler head) **(D):** Compression force indication pin broken	**(L):** HVLE **(W):** Samms_1781, side B

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1.1.2.5 Photo documentation

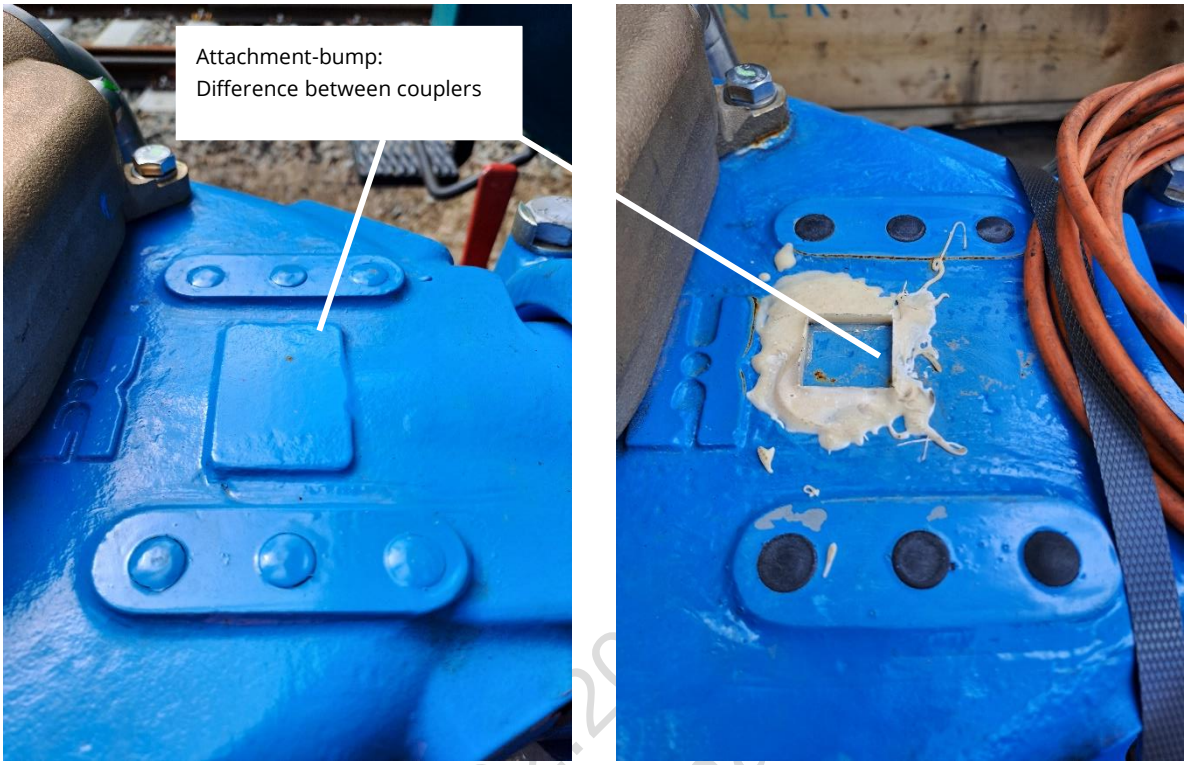

Figure 6: Left: Attachment-bump for type plate existent on couplers D1, D2 and D4. Right: Attachment-bump for type plate not existent on coupler D3. White: glue for attachment of acceleration sensor.

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1.2 Knorr-Bremse

1.2.1 Overview of the coupler

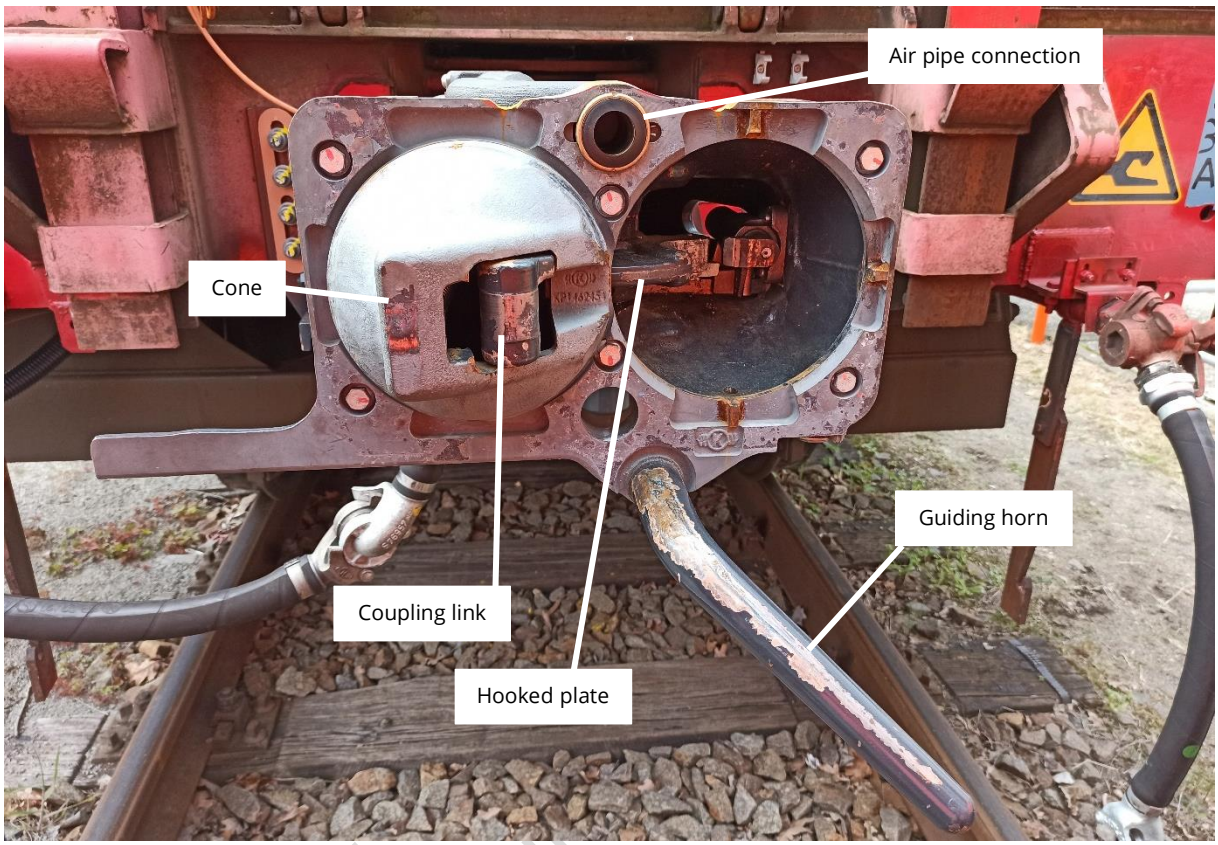

Figure 7: Front plate of a Knorr-Bremse DAC.

Figure 8: Left: Coupler head of a Knorr-Bremse DAC (with e-coupler and manual uncoupling device). Right: Actuation of the manual uncoupling device.

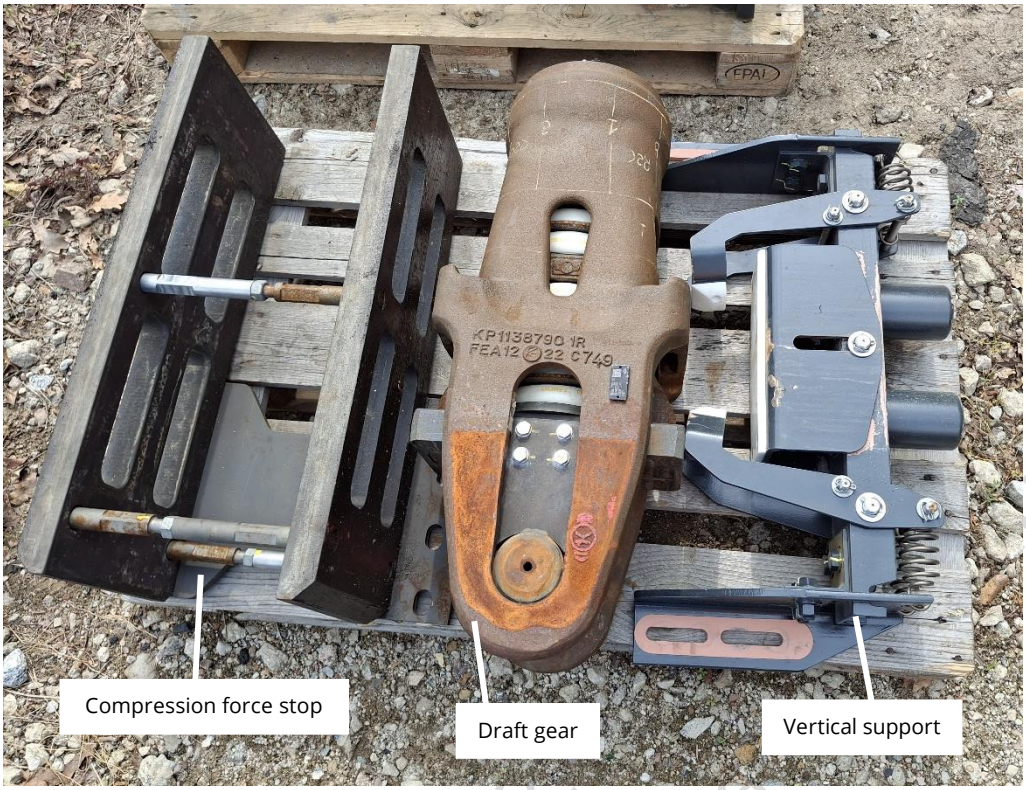

Figure 9: Further parts of a Knorr-Bremse DAC.

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1.2.2 Couplers under test

1.2.2.1 K1

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
23.04.2024	#001	Initial status	**(M):** DAC E-Coupler PROTOTYPE 10/2023 3523420020 DMS installed. **(A):** KP1528372#3523040002#	**(V):** (01)04061272309112 (21)3523040004 (240)KP1835697-MX DACV2 Plastic cut out to save DMS cables.	**(L):** HVLE **(W):** Shimmns_9383, side B
29.04.2024	#002	Front plate needed to continue tests.	**(M):** Front plate exchanged with K2.		
30.04.2024	#003	Front plate changed back.	**(M):** Front plate exchanged back.		
13.05.2024	#004	Demounting from wagon. Front plate needed to continue tests.	**(M):** Front plate exchanged with K2.		**(L):** HVLE **(W):** -

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1.2.2.2 K2

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
23.04.2024	#001	Initial status	**(M):** DAC E-Coupler PROTOTYPE 10/2023 3523420019 **(A):** KP1528372#3523040001#		**(L):** HVLE **(W):** Samms_3779, side A
29.04.2024	#002	Greasing of mechanical coupler parts.	**(M):** Greasing of coupler parts.		
29.04.2024	#003	Front plate changed with K1, due to loose locking ring of cone.	**(M):** Front plate exchanged with K1.		
30.04.2024	#004	Front plate changed back.	**(M):** Front plate changed back.		
13.05.2024	#005	Front plate changed with K1.	**(M):** Front plate exchanged with K1.		

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1.2.2.3 Photo documentation:

Figure 10: Coupler K1 (chapter 1.2.2.1): Plastic-plate of the vertical support was cut out to save DMS cables.

Figure 11: Detached front plate that was exchanged between the couplers K1 (chapter 1.2.2.1) and K2 (chapter 0).

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1.3 Voith

1.3.1 Overview of the coupler

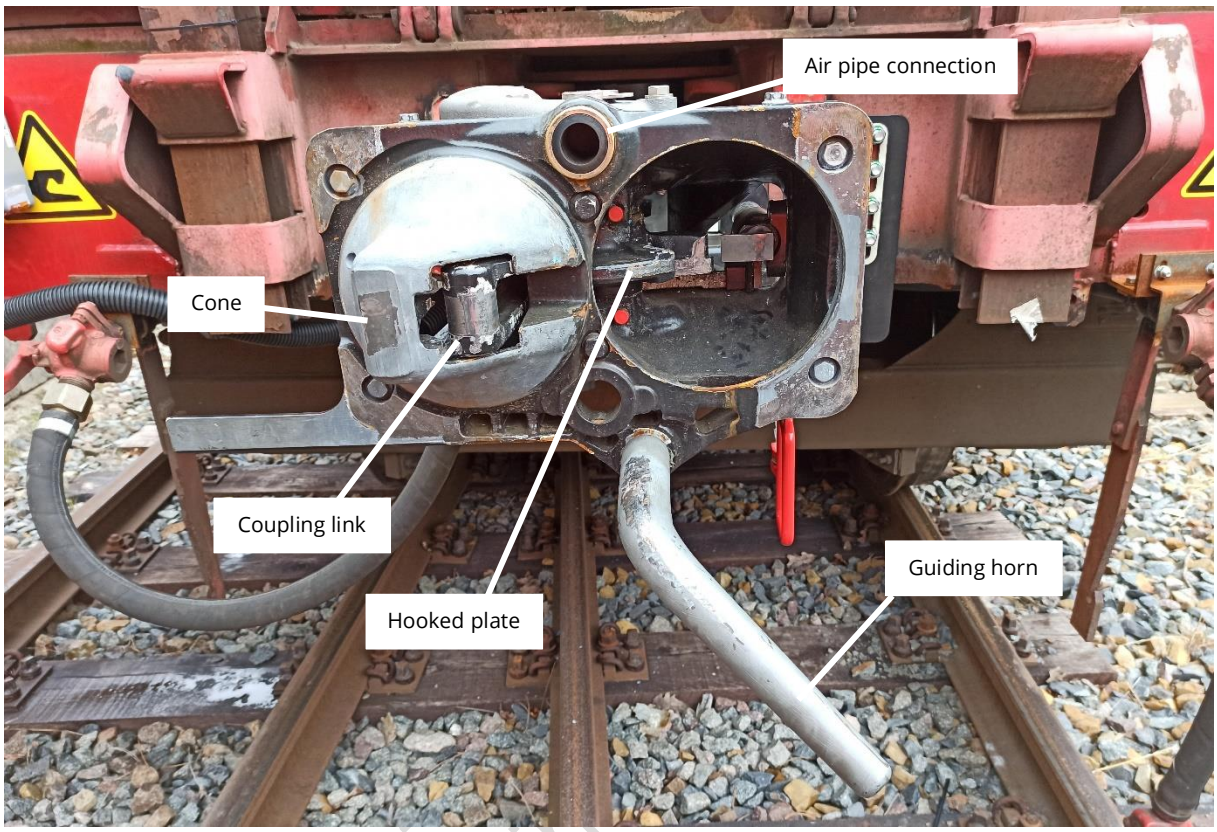

Figure 12: Front plate of a Voith DAC.

Figure 13: Left: Coupler head of a Voith DAC (with e-coupler and manual uncoupling device). Right: Actuation of the manual uncoupling device.

Figure 14: Draft gear of a Voith DAC.

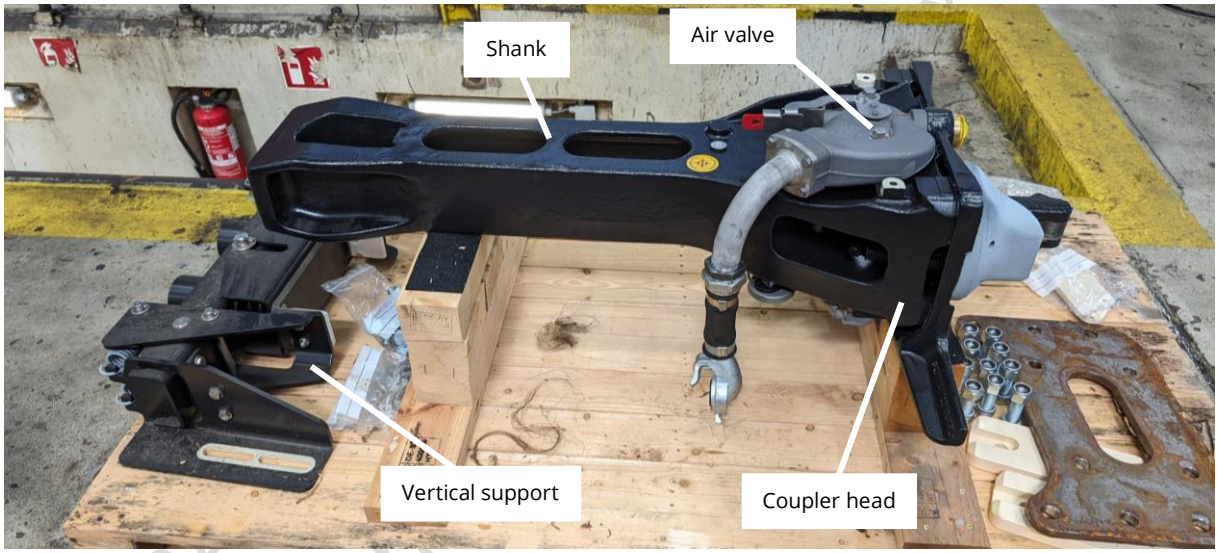

Figure 15: Further parts of a Voith DAC.

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1.3.2 Couplers under test

1.3.2.1 V1

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
23.04.2024	#001	Initial status	**(M):** 1000009315 2023 230.101422-001 DMS installed.	**(V):** 0010 2022 230.043171109DCO	**(L):** HVLE **(W):** Shimmns_6025, side B
26.04.2024	#002	Lost splint of mechanical uncoupling device.	**(M):** Mechanical uncoupling broke (splint got lost and was replaced by HVLE)		
29.04.2024	#003	Greasing of mechanical coupler parts.	**(M):** Greasing of coupler parts.		
14.05.2024	#004	Deinstallation			**(L):** HVLE **(W):** -

1.3.2.2 V2

Configurations:

Date	Config.	Description	(M) Mechanical coupler (A) Air valve	(V) Vertical centration (D) Draft gear (C) Counter plate	(L) Location (W) Wagon
23.04.2024	#001	Initial status	**(M):** 1000009314 2023 230.101422-001	**(V):** 0020 2022 230.043171109DC6	**(L):** HVLE **(W):** Samms_3779, side B

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Annex 2

Interoperability - Impact tests

Test report:	2024-006-WP14-TR03
Annex No.:	Annex 2
Annex - Version:	V01

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

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"The project is supported by the Europe's Rail Joint Undertaking and its members."

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Abbreviations and acronyms

Abbreviation / Acronym	Description
BoB	Best of both – criteria
CL	Coupling link
DAC	Digital automatic coupler
DBST	DB Systemtechnik GmbH
DL	Dellner Couplers AB
DMS	Strain gauge (ger.: Dehnungsmessstreifen)
e-coupler	Electrical coupler
ERJU	Europe's Rail Joint Undertaking
HBK	Hottinger Brüel & Kjaer GmbH
HVLE	Havelländische Eisenbahn
IFB	Institut für Bahntechnik GmbH
KB	Knorr-Bremse AG
P/F	Pass / Fail - criteria
TOR	Top of rail
TTL	Train Test Lab
VT	Voith GmbH & Co. KGaA

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

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1 Description of test case

This annex is focusing on the interoperable impact tests. Objective of the tests is the evaluation of the mechanical and pneumatical parts of the DACs regarding the interoperability in terms of coupling of couplers from different suppliers.

Impact tests with different speeds, different loading conditions and on different track geometries shall be performed.

The following individual tests were to be executed:

Case	Moving wagon	Standing wagon	Velocity [km/h]	Infra. / Curve	Amount
1xx	empty	empty	Expectation: Too low impact force for a correct coupling. Slow speeds are the most relevant. → Tests from slow speeds.		
111	empty	empty	0,6	straight	5
121	empty	empty	0,6	190 m right	5
2xx	full	empty	Expectation: The moving wagon pushes the standing wagon away too fast for a correct coupling. A relevant speed cannot be defined, as the coupling process is highly dependent on the interaction of the hooked plates, coupler links and spring characteristics. → Different speeds from 2 to 12 km/h.		
211	full	empty	2	straight	5
212	full	empty	8	straight	5
213	full	empty	12	straight	5
221	full	empty	4	190 m right	5
3xx	full	full	Expectation: High impact forces leading to damages. High speeds are the most relevant. → Tests from high speeds. → 12 km/h not possible, as too high impact forces (> 2.000 kN) are expected.		
311	full	full	6	straight	5
312	full	full	8	straight	5
313	full	full	10	straight	5
321	full	full	6	190 m right	5

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

		Moving wagon		
		DL	KB	VT
Standing wagon	DL	All	All	All
	KB	Only 2xx	1xx 2xx [1)]	All
	VT	Only 2xx	Only 2xx	1xx 2xx [1)]

[1)] Tests 3xx were executed during e-coupler assessment tests. See [WP14_001].

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To be evaluated:

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

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2 Test execution – Impact tests

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”
- Brake pipe exhausted

Moving wagon:

- Brakes deactivated
- Coupler centred
- Coupler in status “ready to couple”
- Brake pipe filled to ~5bar

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.

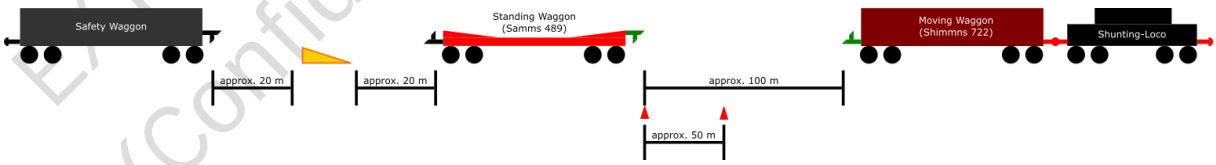

Figure 1: Impact tests: Initial setup.

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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.

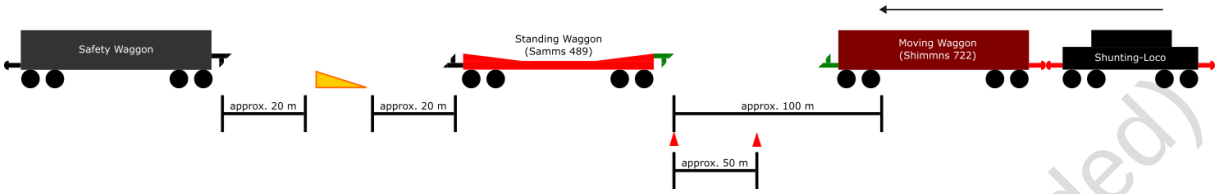

Figure 2: Impact tests: Push-off operation – acceleration phase.

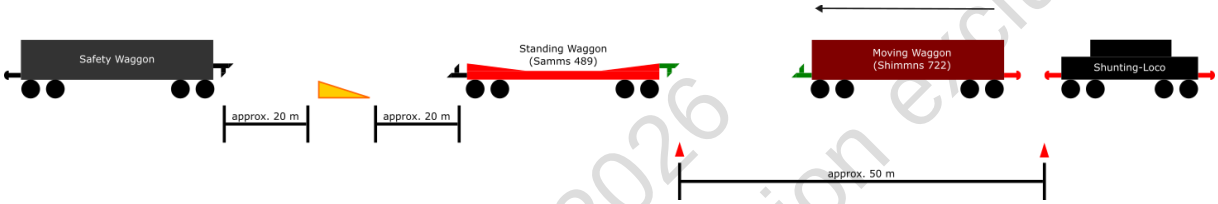

Figure 3: Impact tests: Push-off operation – push-off.

2.1.3 Impact

The moving wagon impacts on the standing wagon. Both wagons move further and are braked by the brake shoe. Air pressure in the brake pipes is equalized between the wagons.

To check if a correct connection of the brake pipes is given and the air valves are opened, the standing wagon is exhausted. A pressure drop in the moving wagon is expected.

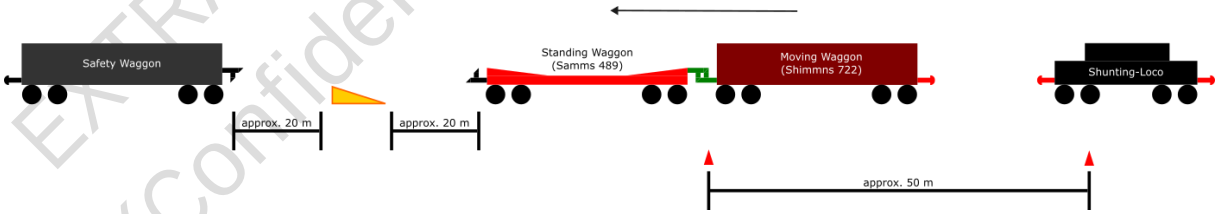

Figure 4: Impact tests: Impact.

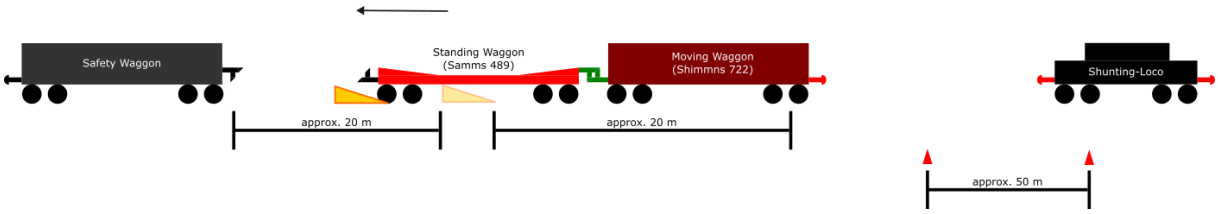

Figure 5: Impact tests: Braking after impact.

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Remark:

It is expected that both couplers couple on impact. If this is not the case, the wagons will move on. Latest when the previously standing wagon is braked by the brake shoe, the wagons will impact again with slower speed. Only the first impact is evaluated.

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.

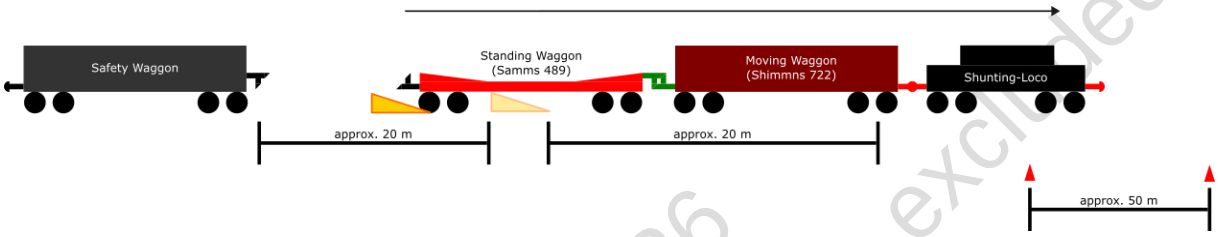

Figure 6: Impact tests: Pull wagons back.

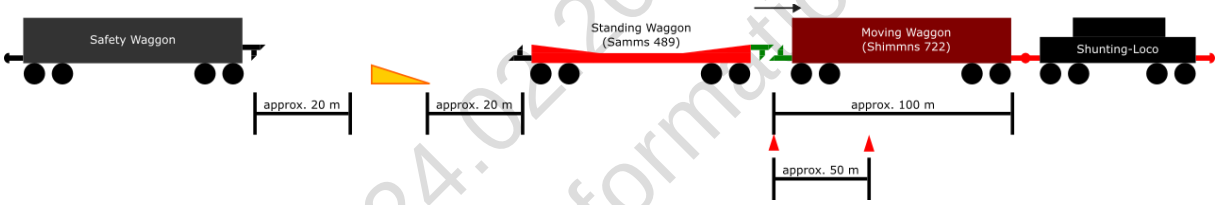

Figure 7: Impact tests: Uncouple and reset to initial setup.

Remark:

The couplers are uncoupled by means of the mechanical uncoupling device. It is expected that both couplers are reset to the “ready-to-couple”-position.

If a coupler stays in the “not-ready-to-couple” position, it is reset by means of the mechanical uncoupling device on the specific coupler.

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2.1 Infrastructure

2.1.1 Wagons and couplers

The couplers were installed on two different wagon types:

- Shimmns, type 722
- Samms, type 489

The Shimmns wagons were equipped with measurement systems 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 1.

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 and switch 22, depending on the push-off direction.

The tested coupler of the standing wagon was placed in the middle of the switch, while the moving wagon was pushed off on:

- track 1 (from the direction of switch 13), in case of tests on switch 12
- track 2a (from the direction of switch 21), in case of tests on switch 22

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

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

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

Figure 11: Test setup for impact tests on the switch 22 (190m-right-curve).

Figure 12: Positioning of standing wagon on the switch 22 (190m-right-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 2.2.1.2.1)
- Photo documentation of the couplers on a regular basis (approx. every 5 tests)

Measured by measurement systems:

- Every test was recorded by the DBST on-wagon system (see chapter 2.2.1.1) on the moving wagon (Shimmns_6025 and Shimmns_9383).

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2.2.1 Measurement equipment

The measurement equipment consisted of different parts: systems installed on the Shimmns_6025 and Shimmns_9383 wagons by DBST (chapter 2.2.1.1), an additional setup of cameras (chapter 2.2.1.2.1) and a system for measurement of the coupler heights (chapter 2.2.1.2.2).

2.2.1.1 On-wagon system (DBST-system)

On-wagon measurement systems were installed on the Shimmns wagons. They consisted of a Datalogger and two measuring amplifiers. Calibrated measurement chains were used to record the data of the on-board system. The location of installation of the sensors, signal names, identifiers and descriptions are shown in the following tables:

Shimmns_6025:

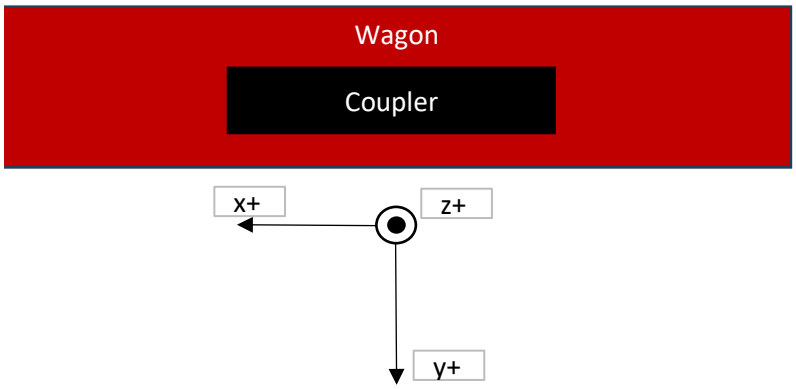
Name	A = analogue D = digital	Description	Source / Installation	Connection	Range	Sampling Frequency [Hz]
Time	A	Time	Data-logger			
F_z	A	Force on coupler	Calculated from Raw-Data	DMS on coupler	-2.000 to 2.000 kN	1000
S_x	A	Displacement (x-axis -> Sideways)	Wire sensor	On rack -> rights side of coupler	0 to 1.000 mm	100
S_y	A	Displacement (y-axis -> Up/Down)	Wire sensor	On rack -> above coupler	0 to 1.000 mm	100
S_z	A	Displacement (z-axis -> Forward/Backward)	Wire sensor	On rack -> behind coupler	0 to 1.000 mm	100
Imp	A	Impulses (Distance)	Incremental Encoder	Pushed on left wheel	0-70.000.000	1000
ax_Coup_WCS	A	Acceleration Coupler (x-axis - Sideways)	Acceleration Sensor (3ax)	Glued onto coupler	1000g	5000
ay_Coup_WCS	A	Acceleration Coupler (y-axis - Up/Dpwn)	Acceleration Sensor (3ax)	Glued onto coupler	1000g	5000
az_Coup_WCS	A	Acceleration Coupler (z-axis - Forward/Backward)	Acceleration Sensor (3ax)	Glued onto coupler	1000g	5000
ax_Wag_WCS	A	Acceleration Coupler (x-axis - Sideways)	Acceleration Sensor (3ax)	Screwed into middle of wagon	10g	5000
ay_Wag_WCS	A	Acceleration Coupler (y-axis - Up/Dpwn)	Acceleration Sensor (3ax)	Screwed into middle of wagon	10g	5000
az_Wag_WCS	A	Acceleration Coupler (z-axis - Forward/Backward)	Acceleration Sensor (3ax)	Screwed into middle of wagon	10g	5000
pBP	A	Brake Pipe Pressure	Pressure Sensor	Stäubli-socket screwed into Distributor valve	0-10 bar	100
pC	A	Brake Cylinder Pressure	Pressure Sensor	Stäubli-socket screwed into Distributor valve	0-7 bar	100
s	A	Distance	- calculated			
v_kmh_filt	A	Speed, filtered (over 0.1 s)	- calculated			

Shimmns_9383:

Name	A = analogue D = digital	Description	Source / Installation	Connection	Range	Sampling Frequency [Hz]
Time	A	Time	Data-logger			
F_z	A	Force on coupler	Calculated from Raw-Data	DMS on coupler	-2.000 to 2.000 kN	1000
S_x	A	Displacement (x-axis -> Sideways)	Wire sensor	On rack -> rights side of coupler	0 to 1.000 mm	100
S_y	A	Displacement (y-axis -> Up/Down)	Wire sensor	On rack -> above coupler	0 to 1.000 mm	100
S_z	A	Displacement (z-axis -> Forward/Backward)	Wire sensor	On rack -> behind coupler	0 to 1.000 mm	100
Imp	A	Impulses (Distance)	Incremental Encoder	Pushed on left wheel	0-70.000.000	1000
ax_Coup_WCS	A	Acceleration Coupler (x-axis - Sideways)	Acceleration Sensor (3ax)	Glued onto coupler	1000g	5000
ay_Coup_WCS	A	Acceleration Coupler (y-axis - Up/Dpwn)	Acceleration Sensor (3ax)	Glued onto coupler	1000g	5000
az_Coup_WCS	A	Acceleration Coupler (z-axis - Forward/Backward)	Acceleration Sensor (3ax)	Glued onto coupler	1000g	5000
ax_Wag_WCS	A	Acceleration Coupler (x-axis - Sideways)	Acceleration Sensor (3ax)	Screwed into middle of wagon	10g	5000
ay_Wag_WCS	A	Acceleration Coupler (y-axis - Up/Dpwn)	Acceleration Sensor (3ax)	Screwed into middle of wagon	10g	5000
az_Wag_WCS	A	Acceleration Coupler (z-axis - Forward/Backward)	Acceleration Sensor (3ax)	Screwed into middle of wagon	10g	5000
pBP	A	Brake Pipe Pressure	Pressure Sensor	Stäubli-socket screwed into Distributor valve	0-7 bar	100
s	A	Distance	- calculated			
v_kmh_filt	A	Speed, filtered (over 0.1 s)	- calculated			

The following coordinate system was defined:

Front view on the coupler:



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2.2.1.1.1 Force on the coupler

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

Figure 13: Strain gauge on a Knorr-Bremse couple.

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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 14: Wire sensor for forward/backward movement S_z.

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Figure 15: Wire sensor for vertical movement S_y.

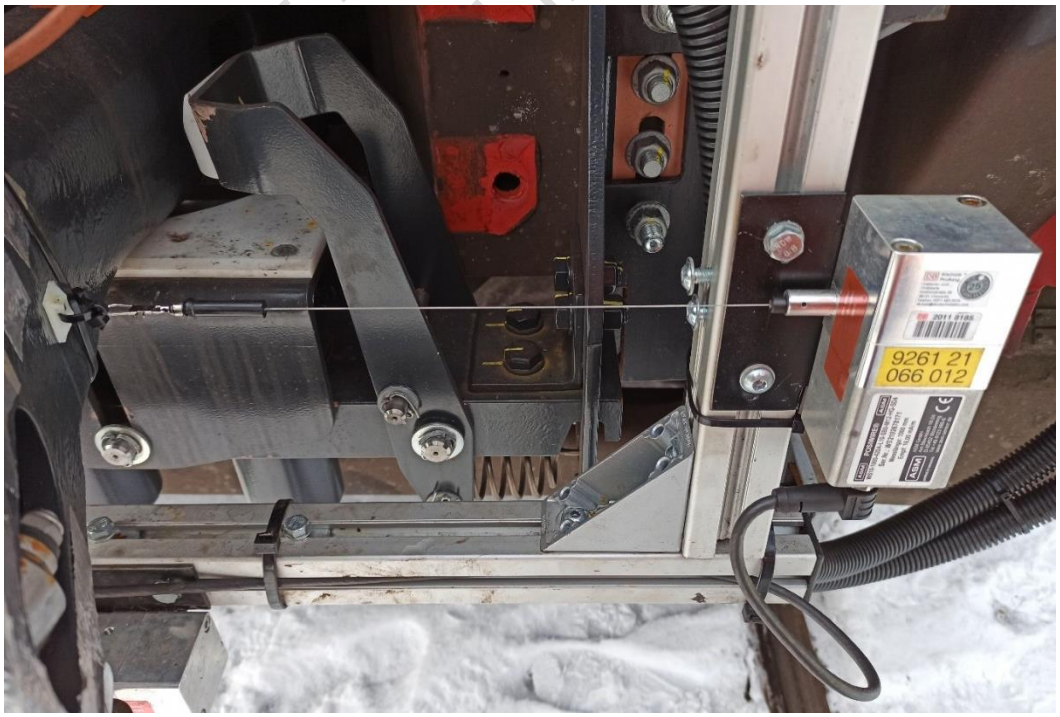

Figure 16: Wire sensor for horizontal movement S_x.

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 17: Incremental encoder with wheel, attached to the wagon wheel.

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2.2.1.1.4 Brake pipe pressure and brake cylinder pressure

The brake pipe and brake cylinder pressure were measured with a pressure sensor, which was attached to the test-points of the distributor valves.

The brake cylinder pressure of the Shimmns_9383 could not be measured, as the distributor valve was defect. Only the brake pipe pressure was measurable.

Figure 18: Pressure sensors attached to the distributor valve on test-points of brake pipe and brake cylinder.

2.2.1.1.5 Acceleration of coupler and wagon

Acceleration-sensors (3ax) were installed on the coupler and on the wagon. The sensor on the coupler was glued onto the coupler. Additionally, it was fixed with tape from above. The sensor on the wagon was screwed onto the wagon, positioned in the middle of the wagon.

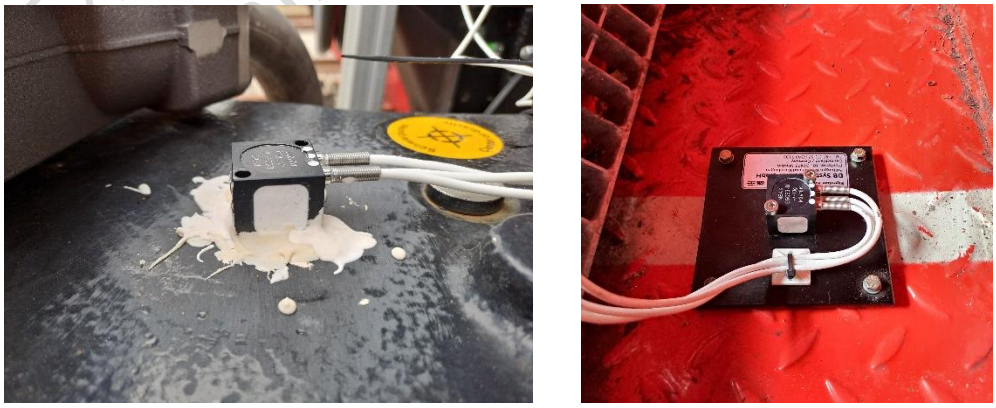

Figure 19: Left: 1000g-acceleration sensor glued onto the coupler. Right: 10g-acceleration sensor screwed onto the middle of the wagon.

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2.2.1.1.6 Data acquisition

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

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

The measurement frequency is shown in chapter 2.2.1.

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

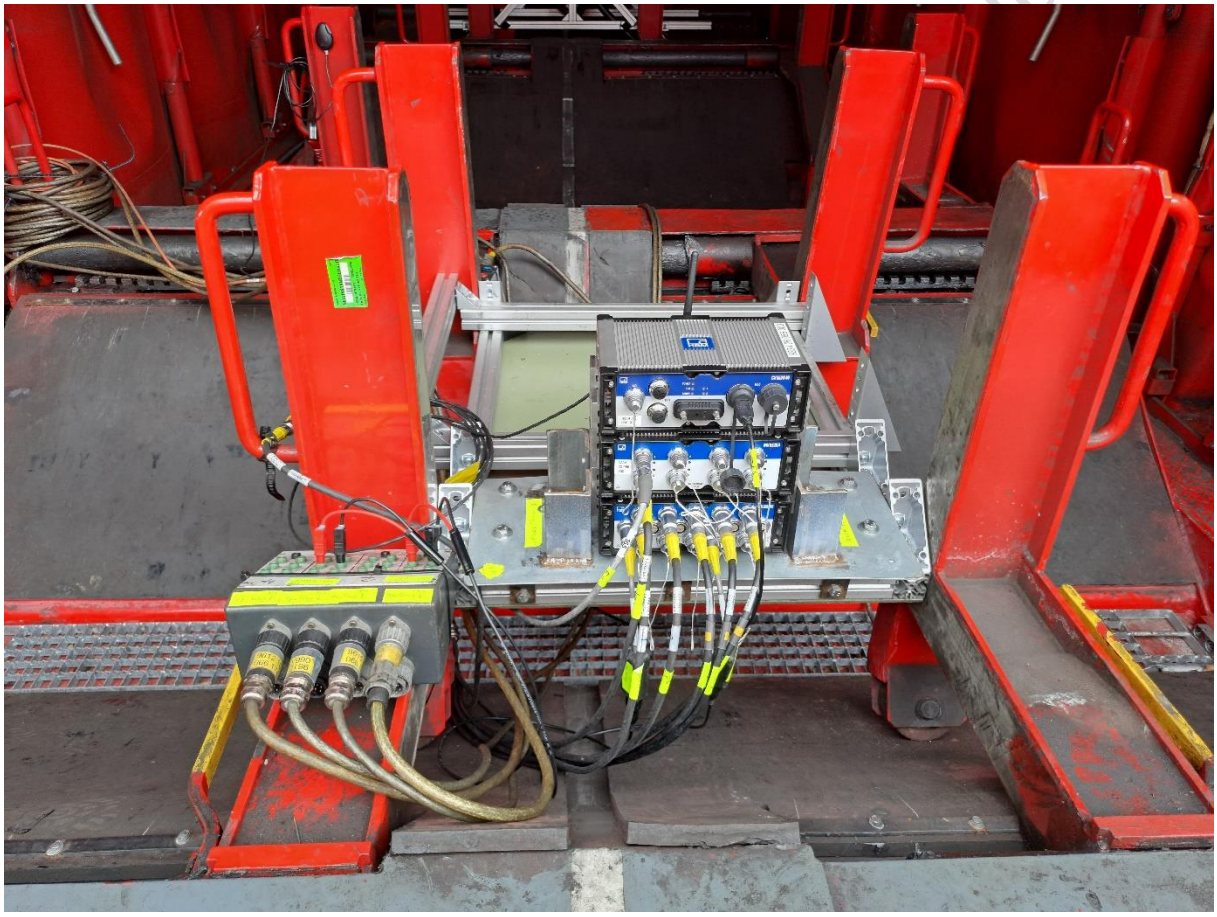

Figure 20: DBST on-wagon measurement system: Data-logger and measuring amplifiers.

Figure 21: DBST on-wagon measurement system: Battery pack with different voltage outputs.

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2.2.1.1.7 Data processing

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

2.2.1.2 Further systems

2.2.1.2.1 Camera system

The camera system consists of GoPro cameras set up in different positions. Following camera views were installed:

- Couplers at couple-position from right side
- Couplers at couple-position from left side
- Couplers at couple-position from below
- View of the coupler of the moving wagon from wagon side (installed on the wagon)
- View of the coupler of the standing wagon from wagon side (installed on the wagon)

Due to the duration of the tests and charging errors, not every view could be recorded for every test.

2.2.1.2.2 Measurement of coupler heights

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

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

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

The distance between the top of rail and the bottom of the coupling link was measured with a laser-distance-sensor (Milwaukee LDM 30 [Milwaukee_LDM30]) fixed inside a rack of aluminium-profiles (see Figure 22 and Figure 23).

The heights of the coupling links were measured with a calliper gauge (see Figure 24).

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

$$Coupler\ height = Distance_{TOR\ to\ bottom\ of\ CL} + \frac{1}{2} Height_{CL}$$

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Figure 22: Left: Laser distance sensor for coupler height measurement [Milwaukee_LDM30]. Right: Laser point on the coupler link.

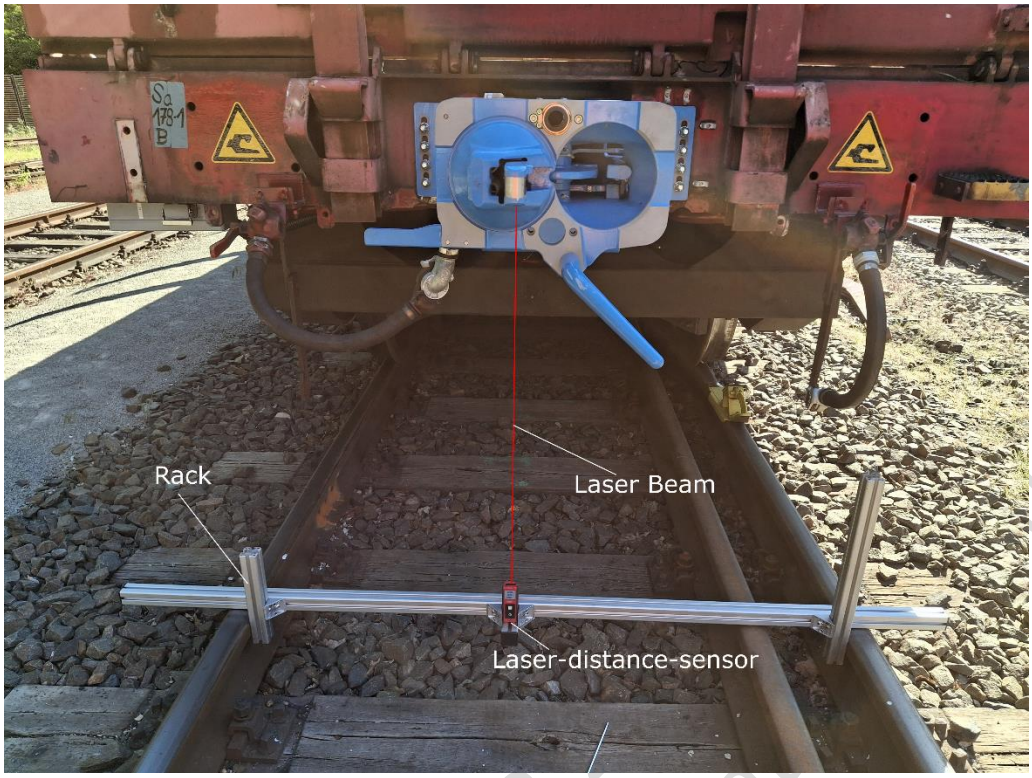

Figure 23: Aluminium rack with laser sensor for height measurement of the couplers.

Figure 24: Measurement of the height of the coupler link with a calliper gauge.

2.3 Criteria for a valid test execution

The test execution was defined as valid in case of:

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

2.4 Evaluation

The given criteria are evaluated the following way:

To evaluate	Way of evaluation
Impact / Coupling:	
Mechanical coupling	→ Documentation of coupler status after impact in protocol.
Compression force	Measurement of force on the coupler with on-wagon system: → Max. compression force during test evaluated.
Pneumatic coupling	Measurement of brake pipe pressure with on-wagon system: → Connection: Pressure drop during coupling (due to equalization of brake pipe pressures) evaluated (Automatic evaluation: drop of 2 bar) → Leakage: Pressure drop after coupling evaluated (Automatic evaluation: drop of max 0.1 bar in 10s – period: 2s to 12s after impact) → Open air valve: Pressure drop after exhausting on standing wagon evaluated (Automatic evaluation: drop to <0,2 bar)
Critical damages	→ Documentation of abnormalities in protocol → Photo documentation
Wear and tear	→ Documentation of abnormalities in protocol → Photo documentation
Uncoupling:	
Uncoupling	→ Documentation of coupler status after uncoupling in protocol → Measurement of force on the coupler with on wagon-system. Force when uncoupling evaluated.

The graphical representation of the measured data of an exemplary coupling test is shown in Figure 25.

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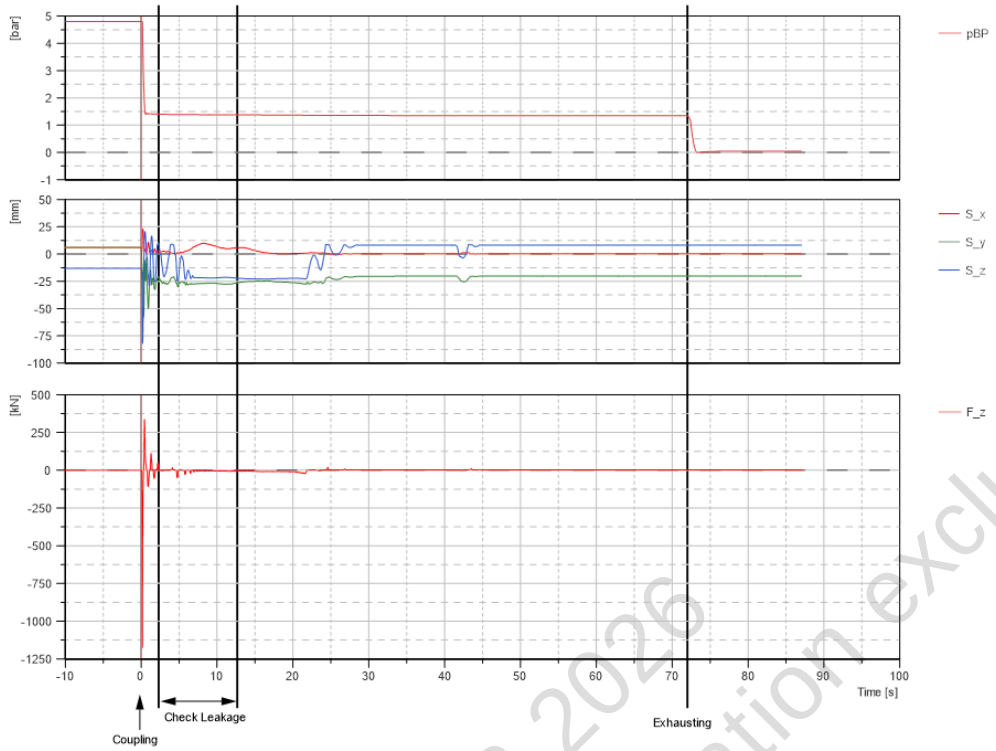

Figure 25: Graphical presentation of an exemplary coupling test.

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3 Results

3.1 Impact tests

Due to reasons of confidentiality, the results are presented per supplier in the annexes listed in chapter 5.

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3.2 Coupler heights

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

Coupler	Date	Waggon	Load state	Height CL	Height TOR – CL Mean of 3	Coupler height
				[mm]	[mm]	[mm]
D1				70,3		
	25.04.2024	Samms_1781, Side A	Empty		1003	1038
	26.04.2024	Samms_1781, Side A	Empty		968	1003
	06.05.2024	Samms_1781, Side A	Full		960	995
D2				70,3		
	24.04.2024	Samms_1781, Side B	Empty		985	1020
	25.04.2024	Samms_1781, Side B	Empty		995	1030
	29.04.2024	Samms_1781, Side B	Full		972	1007
	17.05.2024	Shimmns_6025, Side B	Full		924	959
D3				70,3		
	15.05.2024	Shimmns_9383. Side B	Full		916	951
	15.05.2024	Shimmns_9383. Side B	Full		899	934
	16.05.2024	Shimmns_9383. Side B	Full		895	930
D4				70,3		
	15.05.2024	Samms_1718, Side B	Empty		987	1022
K1				71,6		
	24.04.2024	Shimmns_9383, Side B	Full		937 (Mean of 2)	973
	24.04.2024	Shimmns_9383, Side B	Full		931	967
	25.04.2024	Shimmns_9383, Side B	Empty		991	1026
	29.04.2024	Shimmns_9383, Side B	Full		938	974
K2				71,6		
	25.04.2024	Samms_3779, Side A	Empty		1014	1050
	29.04.2024	Samms_3779, Side A	Empty		1000	1036
	14.05.2024	Samms_3779, Side A	Full		986	1022
	17.05.2024	Samms_3779, Side A	Empty		994	1030
V1				70,5		
	25.04.2024	Shimmns_6025, Side B	Empty		972	1007
	26.04.2024	Shimmns_6025, Side B	Full		938	973
	29.04.2024	Shimmns_6025, Side B	Full		940	976
	06.05.2024	Shimmns_6025, Side B	Full		937	972
	14.05.2024	Shimmns_6025, Side B	Full		938	973
V2				70,5		
	24.04.2024	Samms_9383, Side B	Empty		980	1015
	15.05.2024	Samms_9383, Side B	Empty		980	1015
	16.05.2024	Samms_9383, Side B	Empty		979	1014

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4 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[HBK_CM]	B04486	Catman Universal data acquisition and analysis software Data Sheet	HBK	14.07.2023	06
[HBK_CX22]	B04717	Somat^{XR} CX22B-R-W Data recorder Data Sheet	HBK	23.05.2023	04
[HBK_MX840]	B04309	Somat^{XR} MX840B-R Rugged universal amplifier Data Sheet	HBK	27.07.2022	04
[HBK_MX1601]	B04019	Somat^{XR} MX1601B-R Ultra-rugged Standard Amplifier Data Sheet	HBK	07.05.2024	05
[Milwaukee_ LDM30]	-	Milwaukee – LDM 30 Original Instructions	Milwaukee	-	-
[WP14_001]	2024-001-WP14-TR01	E-coupler assessment TTL Test report	WP14 Julian Beck	22.02.2024	01

5 Appendices

Annex	Vn.	Title	Content
Annex 2.1	V01	Results – Impact tests - Voith	Presentation of the results from interoperability – impact tests with participation of Voith

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