



D7.2

DAC Level 5 ready Interoperability Report

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1 Executive Summary

This deliverable presents the results of the **first interoperability laboratory tests up to Functional Level 5 (FL5)** carried out jointly by the four DAC supplier beneficiaries - Dellner, Knorr-Bremse, Voith, Wabtec - within **FP5-TRANS4M-R**. These tests represent the second interoperability campaign performed in laboratory conditions. The previous one was conducted with DAC Functional Level 4 (FL4) in WP 6 within the project and reported in Deliverable D6.2. Earlier individual component qualification activities for DAC FL5 were documented in D7.1.

The primary objective of the test campaign was to **verify interoperability and functional readiness of DAC Level 5 solutions**, including mechanical, pneumatic, electrical, and digital interfaces. Each supplier provided a functional FL5-ready coupler equipped with a simulation box for automated uncoupling, enabling comparable and repeatable testing across all cross-supplier configurations.

The tests followed the procedures defined in Deliverable D5.3 and relevant European standards (e.g., EN 16019, EN 60512). Test categories included:

- Mechanical coupling and decoupling performance
- Gathering range verification under defined deflection conditions
- Pneumatic leakage and functional checks
- Electrical and digital communication tests using the Voith E-Coupler
- Actuator performance, including automated uncoupling under braked and unbraked conditions

The testing confirmed that **all four DAC solutions demonstrate FL5 readiness under laboratory conditions**, meeting the requirements needed to progress toward train integration and field testing in WP14. The successful outcomes also demonstrate significant progress in the **harmonization of mechanical and functional interfaces**, achieved through close coordination and standardization efforts within the DAC Core Group.

The validated test results support **Quality Gate 1 (Component Qualification)** and provide the basis for upcoming interoperability tests in operational environments, which will be reported in **Deliverable D7.3**.

Keywords: Functional level, mechanical, interoperable, DAC, testing, coupler

2 Abbreviations & Acronyms

Abbreviation / Acronym	Description
CEN	Comité Européen de Normalisation
DAC	Digital Automatic Coupler
DEL	Dellner
DIN	Deutsches Institut für Normung
EDDP	European DAC Delivery Program
EN	European Norm
ERA	European Union Agency
FA	Flagship Area
FKM	Forschungskuratorium Maschinenbau e.V (7 th edition 2020)
FT	Faiveley Transport
KB	Knorr Bremse
N/A	Not applicable
OEBB-RC	Österreichische Bundesbahnen Rail Cargo
SMO	Siemens
TC	Technical Committee
VT	Voith
WG	Working Group

Functional levels (FL)

Functional level 5 ready: FL 4 plus full automated uncoupling of each beneficiary

Note: The fully automated uncoupling function can be achieved consist control unit by means of remote access.

3 Background

The present document constitutes the Deliverable D7.2 “Laboratory interoperability testing of DAC up to Level 5” in the framework of the Flagship Project FP5- TRANS4M-R as described in the EU-RAIL MAWP and contributes as well to the Flagship Project 5 - TRANS4M-R.

The project aims to boost innovation for the European rail freight sector, concretely by developing, validating, and demonstrating FP5-TRANS4M-R technical enablers. The work to reach this level of TRL is complex and thus divided into several work packages which are highly dependent on each other.

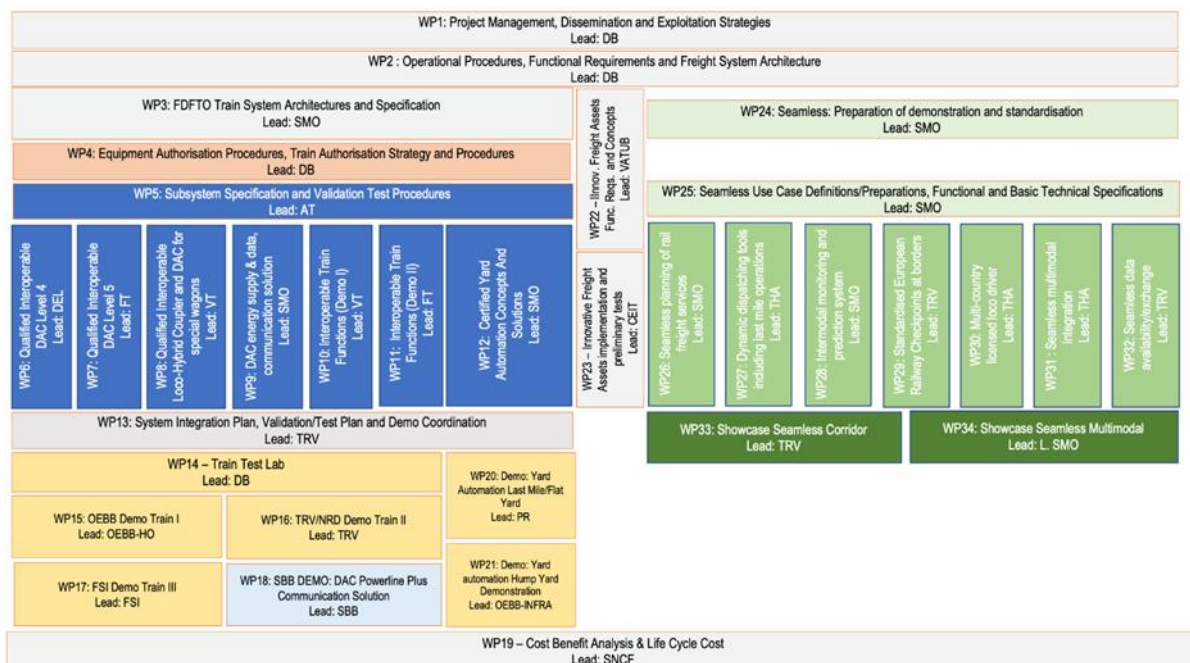


Figure 1: TRANS4M-R DAC Level Structure

The work on deliverable D7.2 has been achieved in Work Package 7 “Laboratory interoperability testing of DAC up to Level 5”.

Due to availability of CCU software and hardware components for the end of July 2026, synchronization for uncoupling could not be tested for D7.2 in December 2025. Therefore, the presented test results relate to “DAC 5 ready”.

3.1 Methodology

The work has been carried out by experts from the DAC core group in December 2025 after defining and aligning a test plan including timings.

Date	Day	Task	DAC 1	DAC 2	Electric coupler	Starting Time	Duration	Ending Time
05.12.2025	Friday	Installation on test bench	Knorr-Bremse		Voith	tbd	before	
05.12.2025	Friday	Installation of draftgear into adapter	Knorr-Bremse			tbd	before	
05.12.2025	Friday	Installation of DFT components	Knorr-Bremse			tbd	before	
08.12.2025	Monday	Installation on test bench		Voith	Voith	10:30	01:30	12:00
08.12.2025	Monday	Installation of draftgear into adapter		Voith				
08.12.2025	Monday	Installation of DFT components		Voith				
08.12.2025	Monday	Test 1	Knorr-Bremse	Voith	Voith	13:00	04:00	17:00
08.12.2025	Monday	Installation of DFT components	-	Wabtec		17:00	01:30	18:30
08.12.2025	Monday	Installation of draftgear and headshank into adapter on testbench	-	Wabtec	Voith	17:00	01:30	18:30
09.12.2025	Tuesday	Test 2	Knorr-Bremse	Wabtec	Voith	09:00	04:00	13:00
09.12.2025	Tuesday	Installation of DFT components	-	Dellner		13:00	01:30	14:30
09.12.2025	Tuesday	Installation of draftgear into adapter on testbench	-	Dellner	Voith	13:00	01:30	14:30
09.12.2025	Tuesday	Test 3	Knorr-Bremse	Dellner	Voith	14:30	04:00	18:30
10.12.2025	Wednesday	Installation of DFT components	Voith	-		08:00	01:30	09:30
10.12.2025	Wednesday	Installation of draftgear into adapter on testbench	Voith	-	Voith	08:00	01:30	09:30
09.12.2025	Wednesday	Test 4	Voith	Dellner	Voith	09:30	04:00	13:30
10.12.2025	Wednesday	Installation of DFT components	Wabtec	-	Voith	13:30	01:30	15:00
10.12.2025	Wednesday	Installation of draftgear into adapter on testbench	Wabtec	-	Voith	13:30	01:30	15:00
11.12.2025	Thursday	Test 5	Wabtec	Dellner	Voith	08:00	04:00	12:00
11.12.2025	Thursday	Installation of DFT components	-	Voith	Voith	12:00	01:30	13:30
11.12.2025	Thursday	Installation of draftgear into adapter on testbench	-	Voith	Voith	12:00	01:30	13:30
12.12.2025	Friday	Test 6	Wabtec	Voith	Voith	09:00	04:00	13:00
12.12.2025	Friday	Disassembly and packaging	all	all		13:30		17:00

Figure 2: Overview Test Planning

Each DAC supplier provided a Level 5 DAC coupler with an additional control unit for the uncoupling process, enabling standardized testing.

As far as possible, the tests referred to are from standards, or Deliverable D5.3: "Validation/Test Procedures of Wagon and Locomotive DAC up to Level 5 ready" for Flagship Project 5 - TRANS4M-R from January 2024.

3.2 Structure of testing approach

The structure of the interoperability tests is based on the following subtest areas:

1. Dimensional Checks
2. Functional Checks
3. Gathering Range
4. E-Coupler Testing
5. Functional and Visual Checks Pneumatics
6. Actuator testing

4 Objective/Aim

The objective of this deliverable is to demonstrate that the couplers are interoperable and meet the requirements for use in rail freight transport applications. To demonstrate DAC Level 5 readiness functionality, the aim is to test and demonstrate the interoperability of the couplers in laboratory environment & provide qualified technology for train tests under controlled environment and large-scale validation and demonstration.

The secondary objective is to verify that the data and electrical performance meet the requirements set out in Deliverable D5.2 "Technical Specifications of Wagon and Locomotive DAC up to Level 5 ready", Flagship Project FP5- TRANS4M-R."

Thirdly, this report can be used for quality gate 2 "tested assets (test approvals) – vehicle testing".

See WP13 "System Integration Plan, Validation/Test Plan and Demo Coordination" Deliverable D13.1 chapter 6.1 "Quality Gates" for more information.

	Task definition	Deliverable output
Task 7.2	Once the interoperability maturity of at least two DACs solutions has been reached KB will lead the work of small-scale testing of prototypes by arranging a round robin test according to the validation and verification plan set in Task 5.2 and documented in Deliverable D5.2 (e.g: synchronization tests). Each partner will contribute with their interoperable solution for the functional tests and interoperability validation. The tests will be executed in a controlled laboratory environment at one or more of the industry partners facilities. The results of the tests will be presented and validated with the targeted user group (operators) as	Couplers tests were performed by beneficiaries according to tests documented in D5.3 (task 5.1) on couplers up to level 5. The test shows that maturity is high enough to proceed to interoperability testing between different suppliers according to task 7.3. The tests also show that the couplers pass quality gate 1 "component qualification – pre vehicle testing of D13.1. The background documents are of a quality that can be used in a future authorization process.

	Task definition	Deliverable output
	at least pass/fail and used as benchmarks for further work. Once interoperability is proven under laboratory environment, the coupler samples are considered ready for train integration and field tests in closed environment i.e. ready for WP14 train lab.	The results of the tests were presented to the operators in the monthly WP6/7 meeting on the 29th of January as well as on the 9th of February during the FP5 FDFTO Sounding Board meeting.

5 Assets and Test Set-up

5.1 Assets

5.1.1 DELLNER

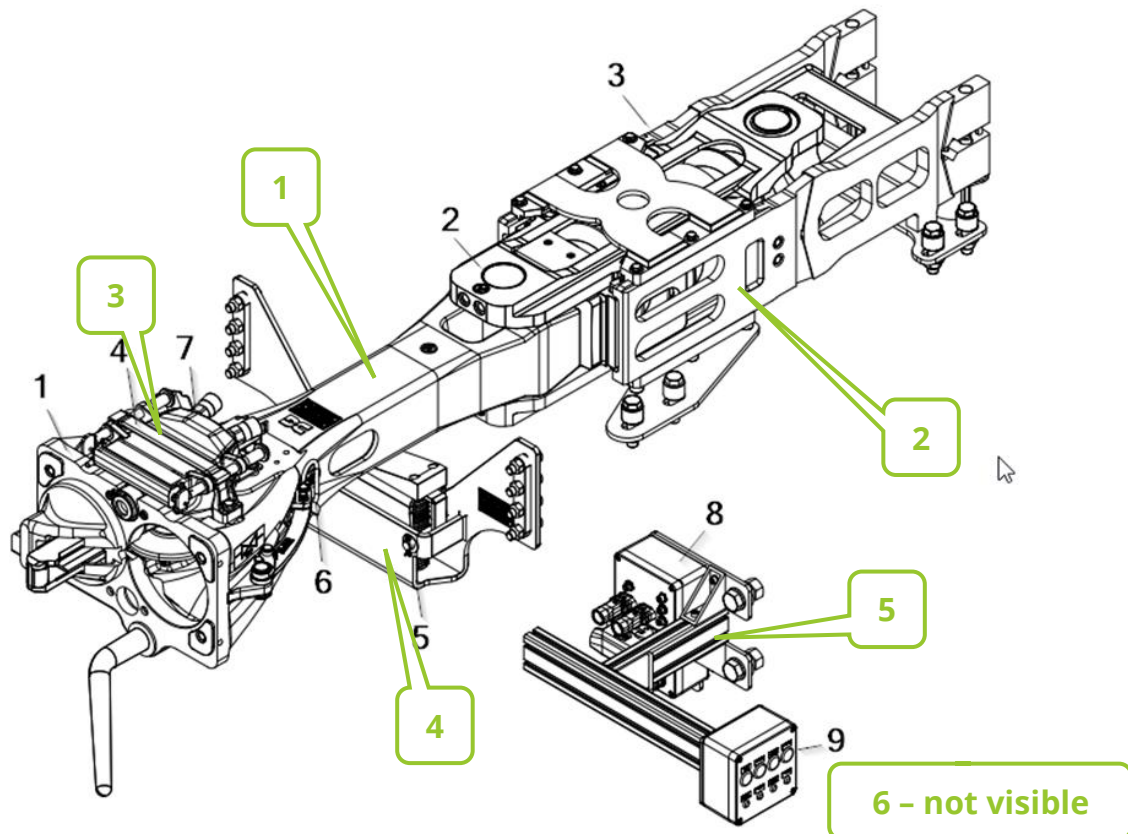


Figure 3: 3D View of the DELLNER DAC

Table 1: Components of the DELLNER DAC

	Designation	Item Number	Serial Number	Production Date
1	Coupler Head	2011010	13	2025
2	Draft Gear	2013768	14	2025
3	Electric Coupler	VOITH	230.101203-001	2025
4	Vertical Support	2015202	13	2025
5	Simulations Box	2017602	3011	2025
6	Actuator	2017728	2500021	22.09.2025

5.1.2 KNORR-BREMSE

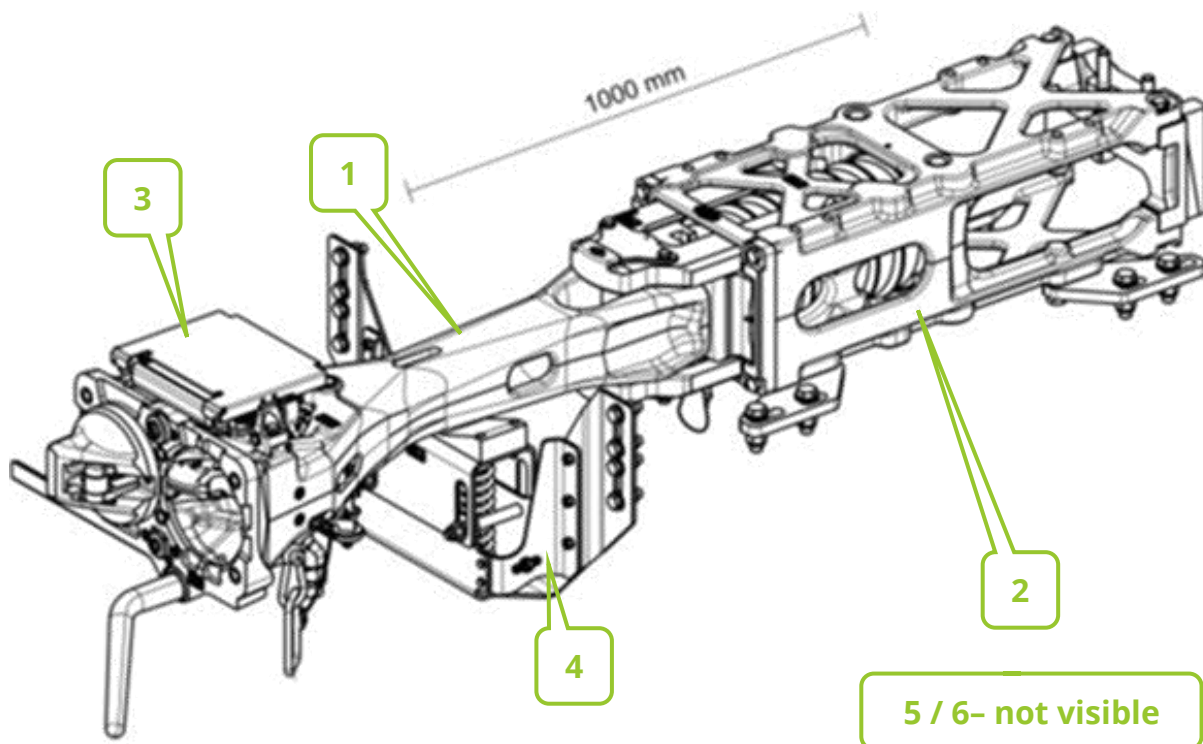


Figure 4: 3D View of the KNORR DAC

Table 2: Components of the KNORR DAC

	Designation	Item Number	Serial number	Production Date
1	Coupler Head	KP6948598-1MX	3525490045	2025
2	Draft Gear	KP5311349-3MX	3525490043	2025.08.07
3	Electric Coupler	VOITH	230.101203-001	2025
4	Vertical Support	KP1835697-1MX	3525390047	2025
5	Simulations Box	K1/K2	1190610	2025
6	Actuator	KP1001040-3	3525150007	2025

5.1.3 VOITH

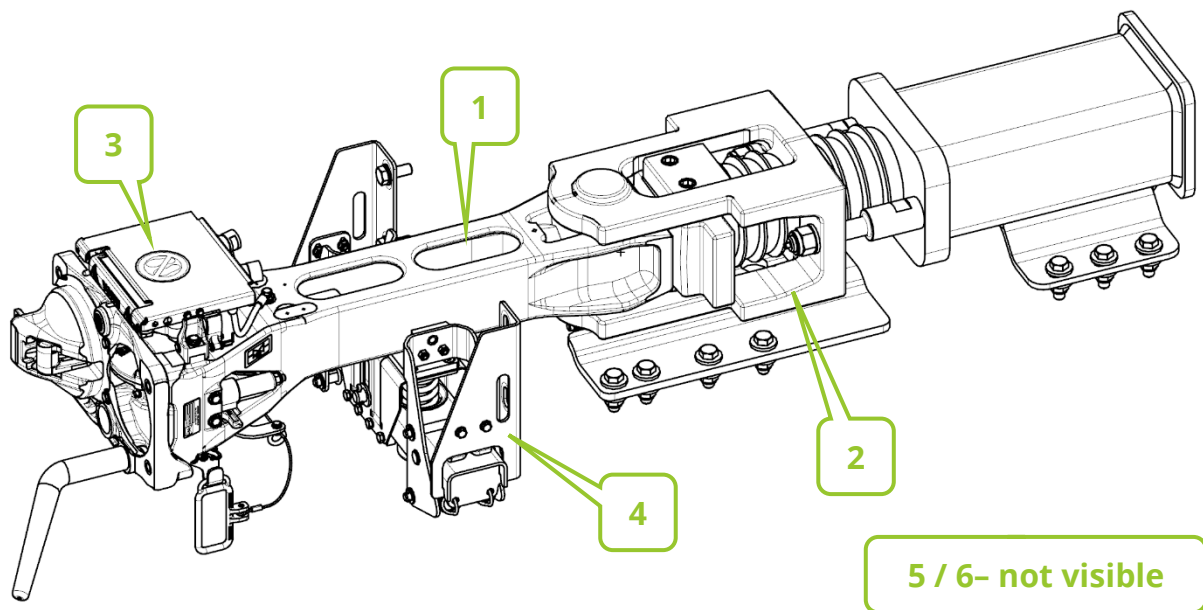


Figure 5: 3D View of the VOITH DAC

Table 3: Components of the VOITH DAC

	Designation	Item Number	Serial Number	Production Date
1	Coupler Head	230.103455-001	1000028654	2025
2	Draft Gear	FN-RP2-KS-00.02.00	24/45391712	2025
3	Electric Coupler	VOITH	230.101203-001	2025
4	Vertical Support	230.054751-001	100000104	2024
5	Simulations Box			2025
6	Actuator	42044100_rev 7.8	20006-PT009	2025

5.1.4 WABTEC

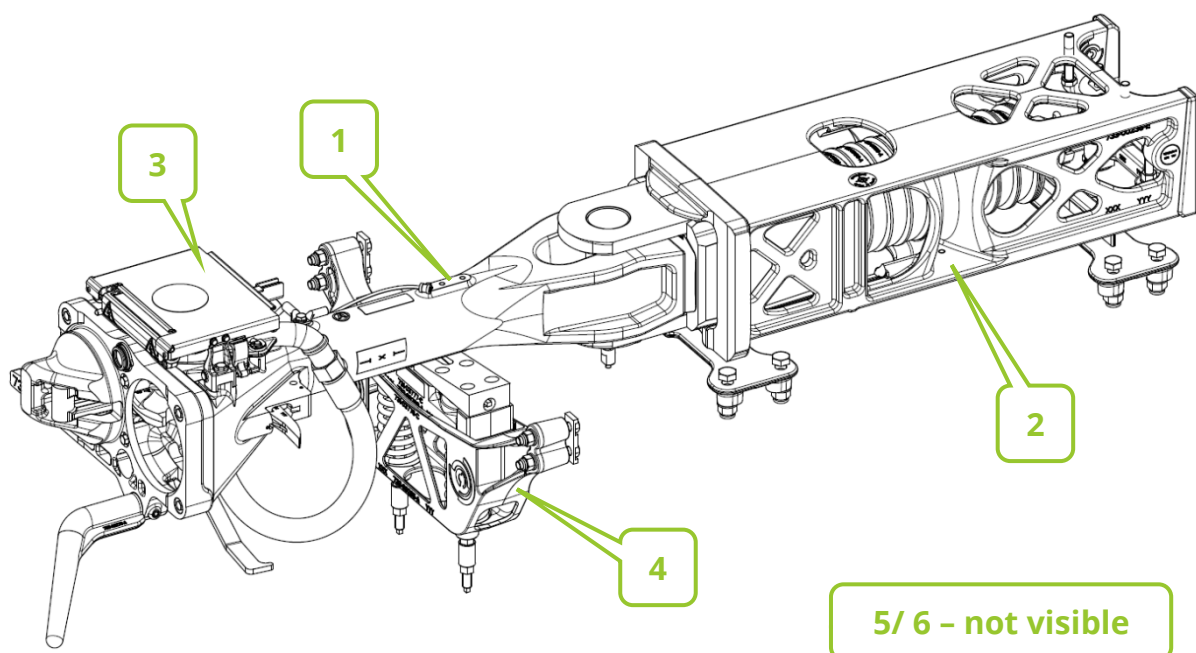


Figure 6: 3D View of the WABTEC DAC

Table 4: Components of the WABTEC DAC

	Designation	Item Number	Serial Number	Production Date
1	Coupler Head	730-02067-B	BS39580	09/2025
2	Draft Gear	730-02045-E	BS38381	07/2025
3	Electric Coupler	VOITH	230.101203-001	2025
4	Vertical Support	730-02046-C	BS39490	09/2025
5	Simulations Box	FT0293800-100-A	SCN0002	2025
6	Actuator	821-01242-B	SCN0002	2025

5.2 Test Set-Up

The interoperability coupling tests were conducted on the RENK coupling test bench at Knorr-Bremse in Budapest. The setup included two installation positions, DAC1 and DAC2, with the DAC1 position being adjustable for achieving the required deflection angles.

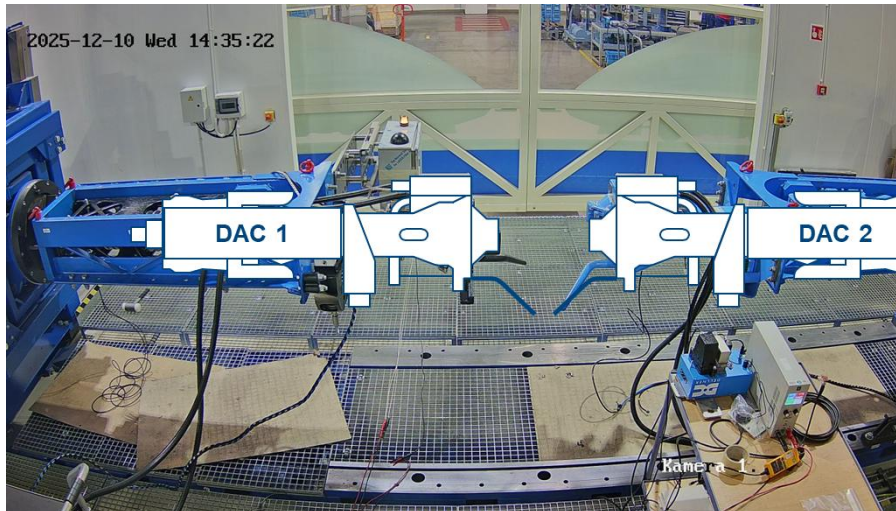


Figure 7: Test bench set-up

5.2.1 Knorr-Bremse – Wabtec (with Voith E-coupler)



Figure 8: Test set-up Knorr-Bremse - Wabtec

5.2.2 Knorr-Bremse – Voith (with Voith E-coupler)



Figure 9: Test set-up Knorr-Bremse - Voith

5.2.3 Knorr-Bremse – Dellner (with Voith E-coupler)



Figure 10: Test set-up Knorr-Bremse - Dellner

5.2.4 Wabtec - Dellner (with Voith E-Coupler)



Figure 11: Test set-up Wabtec - Dellner

5.2.5 Wabtec - Voith (with Voith E-Coupler)

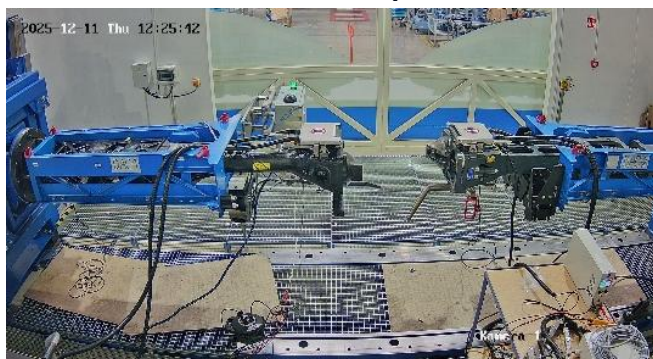


Figure 12: Test set-up Wabtec - Voith

5.2.6 Voith - Dellner (Voith E-Coupler)



Figure 13: Test set-up Voith – Dellner

6 Interoperability test planning

The following chapter provides a comprehensive overview of the tests considered and conducted during the test week with the different coupler pairings.

6.1 Dimensional Checks

The dimensional checks have been conducted in D7.1 chapter 5.2.

6.2 Functional Checks

The functional checks have been conducted in D7.1 chapter 5.3.

6.3 Gathering Range

The test procedure for the gathering range test is described in deliverable D5.3 chapter 6.2.1.4 "Gathering range". Between each test case, a visual inspection shall be performed to ensure that no damage affecting the function of the mechanical coupler has occurred. In case of damage, it must be described and documented. After the test, an overall evaluation of the specimen shall be performed.

This test shows the range in which couplers can couple to each other.

Table 5: Deflection Angles Coupling Test

Test Case	Horizontal Deflection [mm]	Vertical Deflection [mm]	Cycles [-]
1	0	+ 125	1
2	0	- 125	
3	+ 220	0	
4	- 220	0	
5	0	+ 125	2
6	0	- 125	
7	+ 220	0	
8	- 220	0	

6.4 E-Coupler Testing

The e-coupler is to be

actuator is described in deliverable D5.3 chapter 6.2.8 "Actuator testing".

Two couplers with actuators tested according to procedures outlined in Deliverable D5.3 chapter 6.2.3. EN 60512-2-1 IEC:2002 "Electrical continuity and contact resistance tests Contact resistance – Millivolt level method."

Testing for Data connections 10 Mbps according to deliverable D 5.3 chapter 6.2.3.2.

6.5 Functional and Visual Checks Pneumatics

The functional testing of the pneumatic connections is performed in accordance with EN16019 Chapter 5.2.4.2, specifically "The Leakage Test". For each coupler pairing one leakage test was performed.

6.6 Actuator testing

The functional testing of the are installed and connected to control and power units. Decoupling tests are carried out under three conditions—single actuator, both actuators on braked (compression force on couplers) couplers, and both actuators on non-braked couplers—with power consumption and rotation angle recorded, each repeated five times. Each control unit was checked if the uncoupling signal was transmitted.

7 Results

All tests were successfully performed without major issues. The summary of the tests can be found below.

7.1 Coupling and Actuator Test

Repeated mechanical coupling and decoupling was conducted for the different DAC pairings and gathering ranges. Results are shown in table 6.

The coupling und decoupling took place without major restrictions or problems for all DAC combinations. The results are shown in the tables below.

Table 6: Mechanical Tests – Coupling

Beneficiaries	Knorr-Bremse (Coupling)	Wabtec (Coupling)	Voith (Coupling)	Dellner (Coupling)
Knorr-Bremse	D7.1	Pass	Pass	Pass
Wabtec		D7.1	Pass ¹	Pass
Voith			D7.1	Pass
Dellner				D7.1

¹ Attempts to couple with negative vertical deflection were repeatedly unsuccessful. Voith draft gear lifted within the test set-up, causing the head to become misaligned. Following realignment of both the draft gear and the coupler heads, the tests were repeated and successful coupling was subsequently achieved.

The decoupling of the actuators was tested in three conditions—single actuator, both actuators on braked couplers, and both actuators on non-braked couplers. All de-couplings were conducted successfully. The results of the de-coupling tests for the different scenarios are shown in the tables 7,8 and 9 below. Power consumption of actuators for de-coupling for all couplers with single actuator activated and both actuators activated on braked couplers was measured. According to test specification in D5.3 chapter 6.2.1.7 the requirement for a de-coupling process of 3 seconds has been fulfilled for each scenario.

Table 7: Mechanical Tests – Decoupling – Scenario 1 singular actuator

Beneficiaries	Knorr-Bremse (De-Coupling)	Wabtec (De-Coupling)	Voith (De-Coupling)	Dellner (De-Coupling)
Knorr-Bremse	D7.1	Pass	Pass	Pass
Wabtec	Pass	D7.1	Pass	Pass
Voith	Pass	Pass	D7.1	Pass
Dellner	Pass	Pass	Pass	D7.1

Table 8: Mechanical Tests – Decoupling – Scenario 2 both actuators decoupling on braked couplers (compression forced applied)

Beneficiaries	Knorr-Bremse (De-Coupling)	Wabtec (De-Coupling)	Voith (De-Coupling)	Dellner (De-Coupling)
Knorr-Bremse (De-Coupling)	D7.1	Pass	Pass	Pass
Wabtec (De-Coupling)		D7.1	Pass	Pass
Voith (De-Coupling)			D7.1	Pass
Dellner (De-Coupling)				D7.1

Table 9: Mechanical Tests – Decoupling – Scenario 2 both actuators decoupling unbraked coupler

Beneficiaries	Knorr-Bremse (De-Coupling)	Wabtec (De-Coupling)	Voith (De-Coupling)	Dellner (De-Coupling)
Knorr-Bremse (De-Coupling)	D7.1	Pass	Pass	Pass
Wabtec (De-Coupling)		D7.1	Pass	Pass
Voith (De-Coupling)			D7.1	Pass
Dellner (De-Coupling)				D7.1

Explanation of key:

Green: No issues

Yellow: Minor – works satisfactory but small adaptations are needed

Orange: Issues – Principals demonstrated but improvements needed

Red: Fail

7.2 Pneumatic Test

One pneumatic test was successfully conducted for each DAC combination. Pass/Fail results are shown in table 8.

Table 10: Pneumatic Tests

Beneficiaries	Knorr-Bremse	Wabtec	Voith	Dellner
Knorr-Bremse	D7.1	Pass	Pass	Pass
Wabtec		D7.1	Pass	Pass
Voith			D7.1	Pass
Dellner				D7.1

Explanation of key:

Green: No issues

Yellow: Minor – works satisfactory but small adaptations are needed

Orange: Issues – Principals demonstrated but improvements needed

Red: Fail

7.3 E-Coupler Testing

For all DAC combinations equipped with the Voith E-Coupler the electrical connection was successfully established. Data connection was continuously monitored during all couplings and was established without issues at all successful couplings. The results of the testing are shown in table 9. The data connection was measured on the Single-Pair Ethernet contacts as defined in D5.3 chapter 6.2.3.2: 10BASE-T1S, 10BASE-T1L, 100BASE-T1 and 1000BASE-T1. Figure 15 shows an example of the continuous data connection measurement for the testing.

Table 11: Electrical & Digital Tests

Beneficiaries	Knorr-Bremse	Wabtec	Voith	Dellner
Knorr-Bremse	D7.1	Pass	Pass	Pass
Wabtec		D7.1	Pass	Pass
Voith			D7.1	Pass
Dellner				D7.1

Explanation of key:

Green: No issues

Yellow: Minor – works satisfactory but small adaptations are needed

Orange: Issues – Principals demonstrated but improvements needed

Red: Fail

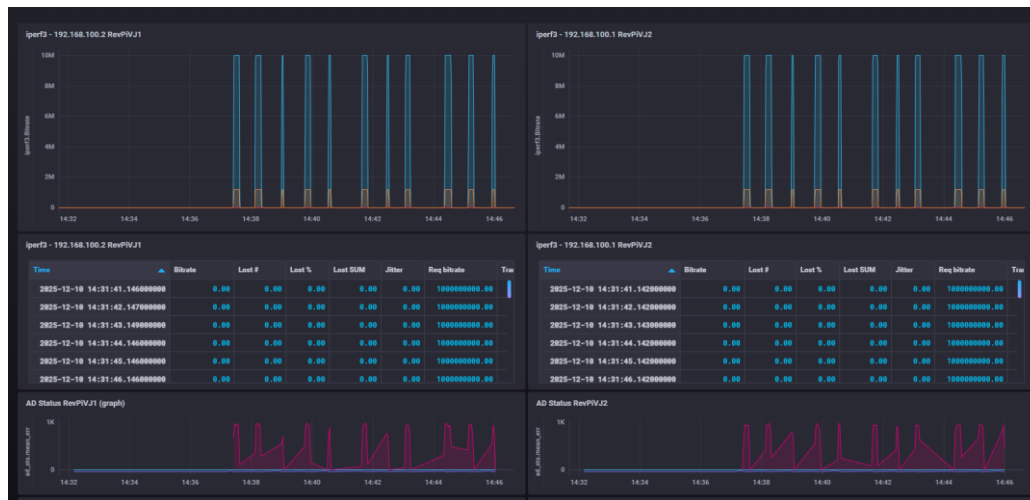


Figure 14: Example for continuous data connection measurement for Wabtec-Dellner

8 Conclusion

The couplers tested successfully in D7.1 have been used for interoperability test between the 4 DAC suppliers. Interoperability test for mechanical, pneumatical and electrical connection has successfully been executed. Functional Level 5 ready has been proven in laboratory conditions. The control of the actuators was realized with actuator simulation boxes and synchronization was manually realized by pressing the uncoupling button at the same time. Testing with full synchronization by CCU will be part of WP10.

The minor issue due to the test set-up encountered during the tests was effectively resolved, and actuator testing confirmed reliable uncoupling across various scenarios, including both braked and unbraked couplers and different deflection angles. Previous challenges related to mechanical interoperability have been eliminated by reduction of geometric variations in the coupling head and locking mechanisms among the four DAC beneficiaries. This achievement was made possible through effective coordination and further standardization by the DAC Core group, leading to a step forward in interoperability.

The next development step is to prove the functionality of the systems on the real wagons. The achieved positive results during the interoperability tests in lab allows all DAC beneficiaries to deliver DAC level 5 ready couplers required for the Train Test Lab (WP14). These results will be documented in deliverable D7.3.

9 References

1. EN16019 - EN 16019:2014-06 "Railway applications - Automatic coupler - Performance requirements, specific interface geometry and test method"
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