

Climate chamber

Test scenario

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Abbreviations & Acronyms

Abbreviation / Acronym	Description
AAR	Association of American Railroads
BP	Brake Pipe
DAC	Digital automatic coupler
DBC	DB Cargo AG
DBST	DB Systemtechnik GmbH
DC	Dellner Couplers
DMS	Strain gauge (ger.: DehnungsMessStreifen)
e-coupler	Electrical coupler
eLCF	Endurable Longitudinal Compressive Forces
ERJU	Europe's Rail Joint Undertaking
FDFT	Full Digital Freight Train
FP5	Flagship Project 5 of the ERJU project
FT	Faively Transport - Wabtec
HBK	Hottinger Brüel & Kjaer GmbH
KB	Knorr-Bremse AG
LCF	Longitudinal Compressive Forces
oLCF	occurring Longitudinal Compressive Forces
P/F	Pass / Fail - criteria
ToR	Top of rail
TRL	Technology Readiness Level
TTL	Train Test Lab
VT	Voith GmbH & Co. KGaA
WP4	Working Package 4 of the FP5 – Authorisation requirements
WP13	Working Package 13 of the FP5 – Test management
WP14	Working Package 14 of the FP5 – Train Test Lab

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

1 Project description

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). Couplers are produced by various suppliers and sent to testing in accordance with the V-model process for validation.

The tests are coordinated by the test management (WP13) within TRANS4M-R and distributed across several test instances. This test scenario covers the tests that were executed by TRANS4M-R WP14 in the Train Test Lab. The objective of the tests within WP14 is to validate technical enablers in a safe, closed test environment (TRL 5 to TRL6). The systems under test must have been previously tested on test rigs and the corresponding verifications described in Quality Gate 1 must be available. The purpose of the tests in the Train Test Lab is to generate further evidence for quality gate 2 for operating demonstrator trains on public infrastructure (TRL 6 to TRL 7). [DEL13.2]

The test scenario described here involves tests that are to be used as verification for further trains and the general operation of vehicles on public infrastructure.

2 Test objective

The objective of tests described in this document is to demonstrate the selected DAC's behavior under certain environmental conditions, especially within a definite temperature range and under influence of snow and ice. The basis for the assumption of environmental conditions is EN 50125:2014 chapter 4.3 (temperature), 4.7 (snow) and 4.8 (ice). The tests described focus on temperature class T1 described in chapter 4.3.

Basis for the execution of the testing can be found in DIN CEN/TR 16251:2016 and SFS-INSTA 851:2023 respectively. However, capabilities of the infrastructure used or efficiency of test conduction may have an influence on the realization of the tests.

Focus of the climate chamber testing is the demonstration of performance of coupling and uncoupling functions under described conditions. Performance of coupling function include the mechanical, pneumatic and electric coupling of DACs.

3 Fundamentals, definitions and technical principles

The aim of this section is to explain the technical mechanisms involved in coupling and uncoupling DACs under described environmental conditions. Learnings from [DAC4EU] have shown that the influence of temperature range had proven to have a minor effect in their testing, however the influence of ice and snow may have significant effect of the performance of coupling and uncoupling functions. Presence of ice and snow had influenced the mechanical, electric and pneumatic coupling of a significant number of tests executed.

Assumed issues occurring with snow and ice applied to the coupler are the effect that the approachment of coupler planes may be hindered by compressed snow on the cone/funnel of the Scharfenberg head and on the coupler planes. This effect may be significant to the principal design of the mechanical coupler head (Scharfenberg). Different solutions to overcome this effect are in place for the different DAC designs of the tested suppliers. The testing described may help provide clarity on the effectiveness of the different solutions, also when coupling interoperable with mating DACs of different suppliers.

In addition to the above, the effect of ice is assumed to be able to block movement of mechanical parts while uncoupling.

On top of that, the effect of snow and ice conditions to the electric and pneumatic coupling could include various effects, e.g. pieces of ice interfering with the pneumatic and electric interfaces while coupling or uncoupling, in the worst case damaging components of the coupler, e.g. sealing of pneumatic coupler.

4 Test procedure

On the basis of the normative boundary conditions and the assumed failure modes presented, a test procedure according to DIN CEN/TR 16251:2016 respectively SFS-INSTA 851:2023 is proposed. Boundary condition according to T1 described in EN 50125:2014 chapter 4.3 will be applied.

The test procedure, however, may be adapted to account for the capability of the infrastructure used and the learnings from [DAC4EU].

4.1 Environmental conditions

Based on the experiences that were made during the climate chamber testing of DACs in [DAC4EU], the cases for environmental conditions are chosen to include minimum and maximum temperature, ice and different snow conditions. The cold temperature condition may be impacted by different factors during the execution of testing (weather conditions, sequence of testing, efficiency considerations), so that a temperature of -25°C will be approached but cannot be guaranteed at all times. The aim of the testing should be to approach the temperature of -25°C as good as possible.

The environmental conditions chosen for this testing are:

1. +45°C dry air
2. -25°C dry air (see comment above)
3. Ice layer of minimum 3mm
4. Wet snow layer of 50mm
5. Dry snow layer of 20mm

4.2 Test objects

Climate chamber testing will test the couplers of all four DAC suppliers involved. Following components are needed from each of the DAC suppliers (Voith, Knorr-Bremse, Wabtec and Dellner):

- Coupler Head
- Uncoupling Actuator
- Push Button Control Unit incl connection/cabling to Actuator
- Shank
- E-coupler
- Draft gear
- Spacer Plates
- Vertical Support
- Fastening material

All components shall be installed on the test wagons according to respective supplier's manual/instruction. Confirmation for correct installation shall be given by suppliers.

4.3 Procedure for coupling function according to DIN CEN/TR 16251:2016

Independent of the environmental conditions described in chapter 4.1, the actual test procedure does not vary. The test procedure describes the actions to be performed as follows:

- Establish environmental condition (this may include preparatory work like cooling of test objects over night or create snow/ice condition)
- Couple objects under tests
- Check for completeness of mechanical, pneumatic and electric coupling according to DIN CEN/TR 16251:2016
- Recording of results

Further details regarding the execution of the tests are described in the following chapters.

4.4 Procedure for uncoupling function

Independent of the environmental conditions described in chapter 4.1, the actual test procedure does not vary. The test procedure describes the actions to be performed as follows:

- Establish environmental condition (this may include preparatory work like cooling of test objects over night or create snow/ice condition)
- Power on objects under test
- Uncouple objects under tests
- Recording of results

The test shall be repeated for different types of uncoupling:

- Manual uncoupling (uncoupling by utilization of mechanical emergency decoupling mechanism)
- Automatic uncoupling (uncoupling by application of "prevent coupling position" on the electric interface)

Further details regarding the execution of the tests are described in the following chapters.

4.5 Infrastructure and setup

To conduct the described testing, a climatic chamber is used with the following properties:

- Accommodate 3 freight wagons
- Possibility of shunting at low speeds
- Compressed air supply in chamber (5 bar)
- Temperature range -25°C to $+45^{\circ}\text{C}$ ¹
- Equipment to create ice layer
- Equipment to create dry snow
- Equipment to create wet snow

Such a climatic chamber is for example available at the site of DB Systemtechnik in Minden.

The aim of the test setup is to efficiently conduct the described testing in the given infrastructure. Number of test days shall be minimized while accommodating a possibly large number of single tests within the test schedule. Therefore, the execution of both coupling and uncoupling tests will be performed within one test setup by the use of three wagons in the climatic chamber.

The test setup is shown in Figure 1.

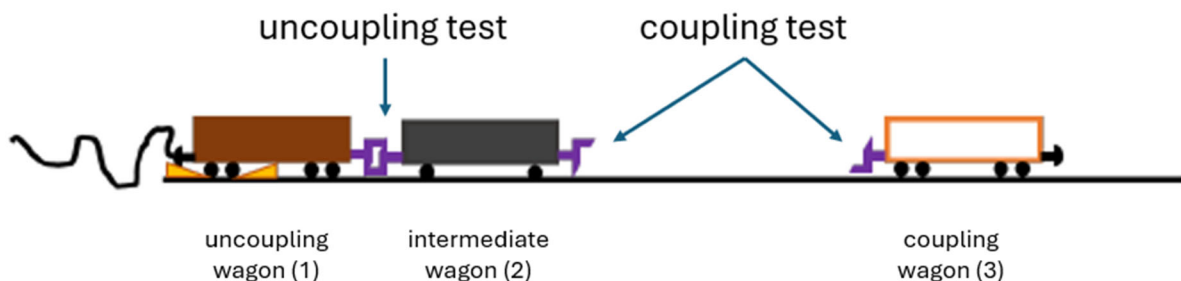


Figure 1: Setup of wagons in climatic chamber for efficient testing (Source: [DAC4EU])

¹ Cold temperature value may vary depending on weather conditions and other boundaries. Aim is to approach the cold temperature of -25°C as closely as possible.

4.6 Vehicles

Vehicles shall have an installation space according to UIC 530-1. DAKs shall be installed on the test wagons according to respective supplier's manual/instruction. Confirmation for correct installation shall be given by suppliers (also see 4.2).

Types and loading condition of vehicles used for this testing are irrelevant to the test result.

In order to support efficient testing, following guidelines should be taken into account for the selection of vehicles:

- Short vehicles will support easy placement in climatic chamber
- Empty vehicles will support handling and heating/cooling of equipment (energy and time) in climatic chamber

4.7 Measurement values

The following events/conditions need to be assessed by means of measurement:

- Success of mechanical coupling
- Success of pneumatic coupling
- Success of electric coupling
- Success of uncoupling
- Success of prevent coupling position position

Recording of following events/measurands will allow the evaluation of the above cases:

- Status of mechanical coupling indicator
- E-coupler contacting
- Pressure in brake pipe
- Electric power consumption of actuator

For reproducible execution of the tests, an additional measurement is needed:

- Speed of impacting wagon

Additional measurements are recommended to support test execution and evaluation of results:

- Movement of coupler head
- Force in coupler shank
- Wagon acceleration
- Wagon position (GPS)
- Environmental conditions (Air temperature, air humidity)
- Cameras

All measurement equipment shall be assembled to the coupling wagon ((3) in Figure 1), except the measurement of electric power consumption of the actuator shall be equipped to the uncoupling wagon ((1) in Figure 1).

4.8 Hypotheses

Coupling and uncoupling functions shall work reliably under high and low temperature conditions and under the influence of ice and snow. While previous tests have not revealed serious issues under the influence of high and low temperature, ice and snow conditions may have an impact on the proper function of the mechanical, pneumatic and electric coupling as well as on uncoupling. The tests described in this document shall give an indication of the reliable function under conditions described.

5 Test execution

5.1 Description of test case

This chapter describes the interoperable coupling and uncoupling tests under different environmental conditions. Each test needs to be performed under the different environmental conditions described in Environmental conditions 4.1.

Coupling tests will be performed on straight tracks only, at moderate impact speeds with a target of 4 km/h and with empty wagons.

Objective of the tests is the evaluation of the function of the mechanical, pneumatic and electric coupler of DACs, also regarding the interoperability in terms of coupling of couplers from different suppliers.

The following individual tests shall be executed:

Table 1: Overview of test cases.

Moving wagon	Standing wagon	Infrastructure	Velocity [km/h]	Amount of tests
empty	empty	Coupling Test. Expectation: Environmental conditions may hinder the function of the coupler		
empty	empty	straight	4	at least 2
empty	empty	Manual Uncoupling Test (via manual emergency uncoupling). Expectation: Environmental conditions may hinder the function of the coupler		
empty	empty	straight	n/a	at least 1
empty	empty	Electric Uncoupling Test (via actuator) – Set coupler in prevent coupling position Expectation: Environmental conditions may hinder the function of the coupler		
empty	empty	straight	n/a	at least 1

All tests shall be executed with the following coupler configurations:

Table 2: Combinations of coupler configurations.

		Moving wagon			
		DC	KB	VT	FT
Standing wagon	DC	x	x	x	x
	KB		x	x	x
	VT			x	x
	FT				x

It is not relevant, which one is the standing and which one the moving wagon during the coupling test.

Manual decoupling operation shall always be executed on the intermediate (2) wagon in Figure 1.

Electric uncoupling / buffer position shall always be executed on the uncoupling wagon (1) in Figure 1.

During the tests and functional coupling tests the following parts needs to be evaluated:

Table 3: Evaluation - Criteria.

To evaluate	Criteria
Impact / Coupling	
Mechanical coupling	The couplers are mechanically coupling during each impact test. Remark: After a failed coupling the wagons will impact again with lower speeds due to a braking of the standing wagon. Only the first impact shall be evaluated.
Pneumatic coupling	The brake pipes of both wagons must couple during each impact test. No major leakage of the brake pipe shall be detected.
Electric coupling	The e-coupler must couple during each impact test.
Critical damages coupler	The coupler must stay functional and not be critically damaged during or after the tests.
Critical damages wagon	The wagon must stay functional and not be critically damaged by the DAC during the tests.
Wear and tear	The wear of parts should be noted. Remark: The wear should not lead to failure of the parts, considering the amount of tests.
Uncoupling	
Uncoupling	By uncoupling on one coupler, both couplers reach the "ready-to-couple" resp. "prevent coupling" position. This shall be evaluated for all uncoupling operations, not only between uncoupling wagon (1) and intermediate wagon (2) according to Figure 1.

5.2 Test procedure

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 (intermediate wagon (2)) is positioned on a defined location. A moving wagon (coupling wagon (3)) is accelerated and pushed-off.

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

The detailed procedure of climate chamber tests is schematically shown in Figure 2.

- Uncoupling of (1) and (2)
- Moving of (2) to initial position for coupling test
- Accelerate (3)
- Push off (3)
- Coupling of (3) and (2)
- Coupling of (2) and (1)

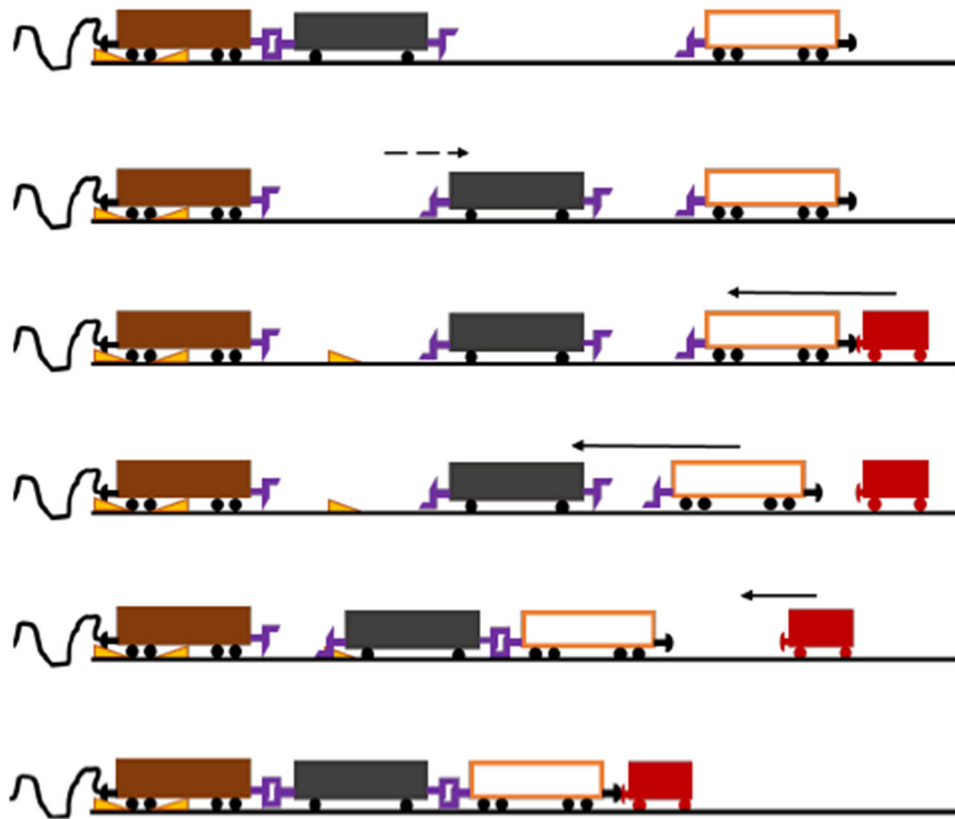


Figure 2: schematic procedure of climate chamber tests (Source: [DAC4EU])

Leakage test can be performed after coupling of all 3 wagons.

Regarding the coupling test, detailed steps are described in the following subchapters.

5.2.1 Preparation and initial situation

ID	
1	Environmental conditions
1.1	Prepare environmental conditions according to 4.1
2	Preparation
2.1	Measure/document
2.1.1	– Continuously measured oparameters according to 4.7
2.1.2	Vehicles – Vehicle number – Vehicle type – Direction – Loading condition – ...
2.1.3	Couplers – Supplier – DAC Type – ID / Serial Number – Parts ...
2.1.4	Climatic conditions – Air temperature – Air humidity ...
2.1.5	Operator For protection of data privacy an „operator-ID“ is sufficient
2.1.6	Infrastructure – Location – Geometry
2.1.7	Abnormalities and deviations from procedure
2.1.8	Time and date
2.1.9	Height difference of the couplers

5.2.2 Coupling test

3	Uncoupling test
3.1	Description
3.1.1	Air cocks of affected wagon ends: closed
3.1.2	Uncoupling or set "prevent coupling" position of intermediate wagon (2) (alternate electrical and pneumatic coupling to reach target quantity for each type per supplier described in 5.1)
3.2	To document
3.2.1	Abnormalities and deviations from procedure.
3.2.2	Coupler status of both couplers after uncoupling.
4	Initial situation for coupling test
4.1	Description
4.1.1	Intermediate wagon (2): – Brakes deactivated – Coupler centred – Coupler status: „ready to couple“ – Air cocks of affected wagon ends: closed
4.1.2	Coupling wagon (3): – Brakes deactivated – Coupler centred – Coupler status: „ready to couple“ – Air cocks of affected wagon ends: closed
4.1.3	The coupler of the intermediate wagon (2) is placed on a defined location (couple location).
4.1.4	To brake the wagons after impact a brake shoe is placed behind the intermediate wagon (2).
4.2	To document
4.2.1	Abnormalities and deviations from procedure.
5	Push-off operation
5.1	Description
5.1.1	Screw-coupler and brake pipe of coupling wagon (2) is uncoupled.
5.1.2	Coupling wagon (2) is accelerated to target push-off speed.
5.1.3	A steady moving phase might be necessary to reduce the energy input into the loco-wagon system during acceleration phase.
5.1.4	As the coupling 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.
5.2	To document
5.2.1	Abnormalities and deviations from procedure.
6	Impact - with coupling
6.1	Description
6.1.1	Impact and coupling of intermediate (2) and coupling (3) wagon.
6.1.2	Both wagons move further and are braked by the brake shoe.
6.1.3	The closed air cocks on the respective wagon ends involved in coupling are

	opened.
6.1.4	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.
6.2	To document
6.2.1	Abnormalities and deviations from procedure.
6.2.2	Coupling status.
7	Leakage test
7.1	Description
7.1.1	Remove brake shoe behind intermediate wagon (2)
7.1.2	Push intermediate wagon and coupling wagon onto uncoupling wagon with loco
7.1.3	Execute leakage test according to DIN CEN/TR 16251:2016
8	Reset to initial position
8.1	Description
8.1.1	Uncouple intermediate wagon (2) and coupling wagon (3)
8.1.2	Pull the coupling wagon (3) back to initial position.
8.1.3	Remark: The couplers are uncoupled. It is expected that both couplers are reset to the "ready-to-couple"-position. If a coupler stays in the "coupled" position, it should be reset on the specific coupler.
8.2	To document
8.2.1	Abnormalities and deviations from procedure.
8.2.2	Coupling status.
8.2.3	Actuated coupler.

5.2.3 Regular examination

9	Visual examination
9.1	Description
9.1.1	A visual examination of the couplers and draft gear should be done regularly. It is not to be executed after each test, but approx. after each test block.
9.1.2	The following is to be checked in detail: – Draft gear – E-coupler contacts – Screws – Wear – Air seal –
9.2	To document
9.2.1	Photo documentation

9.2.2	Abnormalities
10	E-Coupler contacts
10.1	Description
10.1.1	A measurement of the insulation-resistance and the resistance of the contacts of the e-coupler should be done regularly. It must not be executed after each test, but approx. once a day.
10.2	To document
10.2.1	Abnormalities
10.3	To measure additionally to 1
10.3.1	Measurement of the insulation-resistance between contacts and housing.
10.3.2	Measurement of the insulation-resistance between each contact.
10.3.3	Measurement of the resistance over the coupler.

5.3 Evaluation

The given criteria are evaluated the following way:

Table 4: Evaluation - Way of evaluation.

To evaluate	Way of evaluation
Impact / Coupling:	
Mechanical coupling	→ Documentation of coupler status after impact in protocol.
Compression force	Measurement of force on the coupler with on-wagon system: → Max. compression force during test evaluated.
Pneumatic coupling	Measurement of brake pipe pressure with on-wagon system: → Connection: Pressure 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

6 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[DAC4EU]	60226-TT.TVP21-PR02-V1.1-192843	Testing: Digital automatic couplers Phase I Climate chamber tests	Dr. Daniel Jobstfinke	05.01.2022	1.1

7 Appendices

Annex	Vn.	Title	Content