

FP5TRAN S4M-R
Transforming
Europe's Rail Freight

Running ability tests

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
NNTR	Notified national technical rules
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
	Screw coupler – Air pipes coupled
	Screw coupler – Air pipes uncoupled

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 the tests described in this document is to demonstrate that vehicles with a DAC meet the functional requirements for the running ability. This document specifically focuses on functional tests proving that vehicles with a DAC can be operated without restrictions regarding track geometries. Tests regarding the derailment safety requirements are covered by the test specification [TS_DAC_013].

The described tests focus on the mechanical and pneumatical connections. Regarding the e-coupler only a connection loss will be investigated. Further investigations on train function systems and steadiness of data communication need to be carried out, as these systems are not available at the time.

The tests complement the manufacturer's tests on test benches (e.g. vibration tests, durability tests, strength tests).

The basis for the requirements regarding the use of a DAC is the EU regulation concerning the technical specification for interoperability relating to the subsystem 'rolling stock – freight wagons' of the rail system in the European Union [TSIWAG].

Section 4.2.3.5 of this regulation describes the requirements regarding running safety. Requirements regarding the safety against derailment (section 4.2.3.5.1) are covered in the [TS_DAC_013]. Regarding the running dynamic behaviour (section 4.2.3.5.2) it is specified that the unit shall be designed to provide safe movement up to the maximum design speed. The running dynamic behaviour of a unit shall be proven by:

- following the procedures set out in the specification EN 14363:2016+A2:2022 [EN14363], points 4,5,7
- performing simulations using a validated model.

The demonstration of conformity is furthermore described in section 6.2.2.3.

The running dynamic behaviour is also permitted to be assessed at interoperability constituent level in accordance with point 6.1.2.1. In this case a specific test or simulation at subsystem level is not required.

As the [EN14363], chapter 7 defines a procedure for the evaluation of the running dynamic based on a single wagon, the results are defined by the running gear and independent of the coupler – in this case the DAC. Therefore, an evaluation regarding the running dynamic behaviour according to [EN14363], chapter 7 is not required.

Further specific requirements for the running ability of vehicles with a DAC are described in [DEL5.2] and relevant test procedures are described in [DEL5.3]. Further test procedures that have been implemented so far were realised in the DAC4EU project and are described in [DAC4EU01].

Notified national technical rules (NNTR) are not referred to in this document.

3 Fundamentals, definitions and technical principles

3.1 Design characteristics of the DAC

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)
- 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)

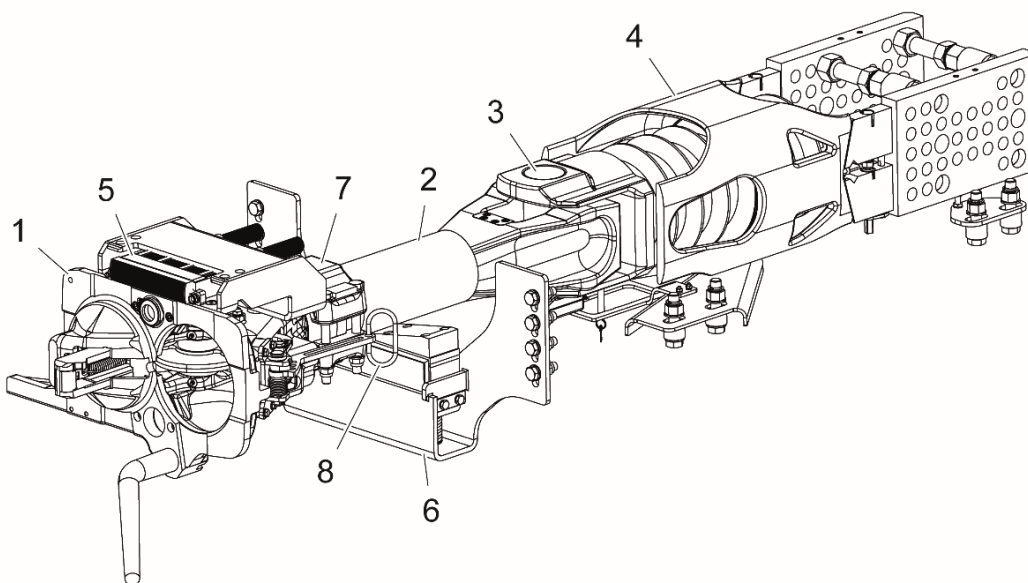


Figure 1: Scheme of the DAC. 1: mechanical coupler / coupler head, 2: coupler shank, 3: pivot pin, 4: draft gear (with compression force stop on the right end), 5: electrical coupler, 6: vertical support, 7: split collar, 8: manual uncoupling device; Source: [DEL5.3], edited.

At the time DACs with actuators are present. Synchronization messages, data transmission protocols and train functions are not available. Therefore, train functions and steadiness of data transmission are not in scope of testing. The tests focus on the mechanical and pneumatical connections. Regarding the e-coupler only a connection loss will be investigated.

The suppliers are currently providing DACs which might differ in:

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

Due to these differences, also the interoperability between the DACs of different suppliers must be tested - besides the testing of matching couplers of one supplier.

3.2 Importance of running ability tests

As stated in chapter 2, neither the [TSIWAG] nor the [EN14363] define requirements regarding the running ability that are dependent of the type of coupler installed into a wagon. This is due to a focus of these standards on the wagon as test object.

Still, the functional safety of the DAC during train runs must be proven and it must be verified that the DAC is able to be operated with no restrictions regarding track geometries. Therefore, an assessment of the technical parts of the DAC and their requirements during a train run must be made.

These tests complement the manufacturer's tests on test benches (e.g. vibration tests, durability tests, strength tests) and show the DACs behaviour in the field.

3.3 Assessment of [DAC4EU01] and [DEL5.3]

The phase 1 of the DAC4EU project [DAC4EU01] focused on providing the foundation of technical data of the DAC. It was one of the first projects carrying out field tests with DAC couplers. As the design fix of the Scharfenberg coupler was done after the project, the aim of the project was to compare the performance of different coupler systems.

During the DAC4EU project different running ability tests were executed (together with coupling tests). The aim of these tests was to cover a wide variety of operational scenarios. Therefore, the DAC was tested in a variety of wagons in different infrastructures.

In general, the tests were done with the following wagons:

- Eanos-x 059
- Hbbins 306
- Zags 119

The load state of the H-wagon was changed to reach different vertical offsets during coupling tests. The E-wagon was fully loaded (90 t), the Z-wagon was empty (32 t).

The tested track geometries were:

- Straight track (only couple tests)
- 190 m curve
- 150 m curve
- 190 m S-curve
- 150 m S-curve with 6 m intermediate straight
- 100 m curve
- 75 m curve
- Ferry boat ramp (3.5° slope)

Every test was executed 5 times with a speed of 5 km/h. The wagon group was pushed and pulled through the track geometries.

The [DEL5.3] defines tests needed to achieve TRL8 of the DAC. The running ability tests stated in this document echo the procedure done within the DAC4EU project.

The main differences are:

1. the track geometries are reduced to:
 - 150 m curve
 - 150 m S-curve with 6 m intermediate straight
 - 75 m curve
 - Ramp with 2.5° inclination
2. A minimum of 3 repetitions is needed (DAC4EU: 5 repetitions)
3. Wight of the wagons:
 - E-wagon: 90 t
 - H-wagon: 45 t (DAC4EU: changing load)
 - Z-wagon: 32 t

In summary the described test cases aim to test a wide variety of scenarios. As for the validation of the DAC only the worst-case scenarios are relevant, the test cases are adapted within this test specification.

4 Test procedure

4.1 Adaptation of [DEL5.3] and [DAC4EU01]

In this chapter, the tests defined in [DEL5.3] are adapted to test the worst-case scenarios in terms of the running ability.

From a technical perspective the stress on the mechanical coupler, the pneumatical connection and the e-coupler connection increase with a larger coupling angle, due to higher bending moments and shear forces.

For this reason, the scenarios with the largest coupling angles can be seen as the worst-case scenarios and should be tested.

In the following chapters the influence of the infrastructure and the vehicle characteristics on the coupling angle is examined.

4.1.1 Infrastructure

From an infrastructural point of view, large coupling angles occur while running through curves with a small radius or entering tracks with high inclination.

Therefore, regarding the track geometry listed in the [DEL5.3], tests should be executed on:

- 75 m curve
- Ferry boat ramp with 3.5° inclination

As stated, the functional running ability tests are thematically linked to the derailment tests presented in [TS_DAC_013]. These derailment tests are carried out on a 150 m S-curve with 6 m intermediate straight. Therefore, functional running ability tests on this infrastructure (150 m S-curve with 6 m intermediate straight) should also be considered.

4.1.2 Vehicles

From a wagon perspective, the coupling angle will increase the longer the overhang and the wider the distance between bogie pivots / axles are.

The same characteristics are also important for the derailment safety tests (see [TS_DAC_013] and [EN15839]), for which the wagon Rs 680 is used. Therefore, wagons with approximately equal characteristics can be chosen for the tests.

An exemplary selection of wagons is shown below:

Table 1: Exemplary selection of wagons.

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

As the coupling angle is not influenced by further wagons in a train set, the tests can be carried out with two coupled wagons, instead of three as stated in [DEL5.3].

It is estimated that the vertical offset of the wagons has a minor impact on the coupling angle. Therefore, the load state of the wagons is irrelevant.

The same type of wagons should be used for all running ability tests.

4.1.3 Hypothesis and requirements

As no requirements are defined in the standards and the [DEL5.3], the following requirements are extracted from the [DAC4EU01]:

During the functional running ability tests the DAC should meet the following requirements:

1. General requirements:
 - The DAC shall not have a negative effect on the operation of the wagons on the test-infrastructure.
 - No damages on any part of the DAC occur during a test run
 - No damages on any part of the wagon occurs by the DAC
2. Mechanical coupler:
 - The couplers shall not decouple during a test run
3. Pneumatical connection:
 - No leakage shall occur during a test run
4. E-Coupler:
 - No connection loss shall occur during a test run

4.1.4 Measurement parameters

During the tests the following parameters must be measured:

1. To verify the requirements:
 - Connection of e-couplers
 - Connection of mechanical couplers
 - Pressure loss in the brake pipe
2. To examine under which circumstances a requirement is not met:
 - Speed of the wagons
 - Longitudinal force on the coupler
 - Travel of the draft gear spring
 - Location on the track (GPS location)

4.2 Test objects

Within the running ability tests, the couplers of all four DAC suppliers involved will be tested. 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 the suppliers.

5 Test execution

5.1 Description of test case

This chapter summarizes the test procedure into a defined test execution.

Running ability tests are to be executed on different track geometries with couplers of different suppliers. During a test two wagons with a DAC coupling are pushed and pulled through a defined infrastructure.

The following individual tests are to be executed:

Table 2: Testing-Infrastructure.

Infrastructure	Pushed / Pulled	Velocity
75 m curve	Pushed + Pulled	5 km/h
Ferry boat ramp (3.5° inclination)	Pushed + Pulled	5 km/h
150 m S-curve with 6 m intermediate straight	Pushed + Pulled	5 km/h

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

Table 3: Combinations of coupler configurations.

		Wagon 1			
		DC	FT	KB	VT
Wagon 2	DC	3	-	-	-
	FT	3	3	-	-
	KB	3	3	3	-
	VT	3	3	3	3

To be evaluated:

Table 4: Evaluation - Criteria.

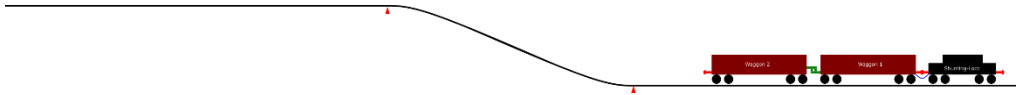
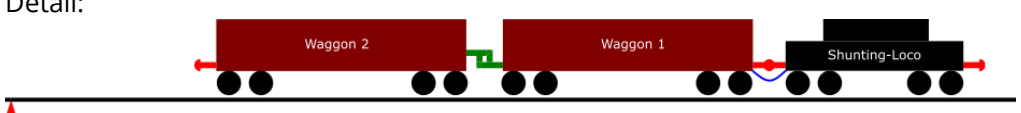
To evaluate	Criteria
General	
Operation without restrictions	The DAC must not adversely affect the operation of the wagons on the test-infrastructure.
Critical damages coupler	The coupler must stay functional and not be critically damaged during the test.
Critical damages wagon	The wagon must stay functional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

5.2 Test procedure

5.2.1 Preparation and initial situation

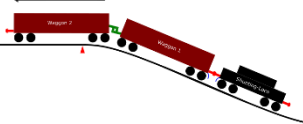
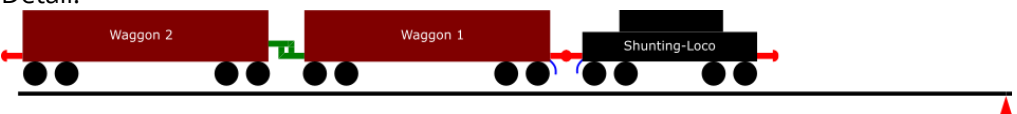
Remark: The schematic

ID	
1	Preparation
1.1	Continuously measured parameters
1.2	Speed of the wagons
1.2.1	Longitudinal and compression force on the coupler
1.2.2	Spring deflection of draft gear
1.2.3	Brake pipe pressure
1.2.4	Location on the track (GPS)
1.2.5	Connection of the e-couplers
1.2.6	Connection of the mechanical couplers
1.3	Additionally measured parameters
1.3.1	Coupler heights in uncoupled state
1.3.2	A regular examination of the couplers (see point 0) should be executed in advance to a test series.
1.4	To document
1.4.1	Vehicles – Vehicle number – Vehicle type – Direction – Loading condition – ...
1.4.2	Couplers – Supplier – DAC Type – ID / Serial Number – Parts – ...
1.4.3	Weather conditions – Temperature – Rain / Snow – ...
1.4.4	Infrastructure – Location – Geometry
1.4.5	Abnormalities and deviations from procedure
1.4.6	Time and date

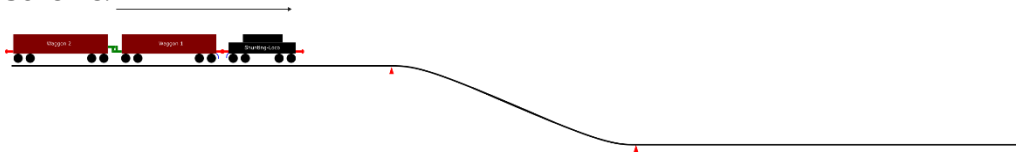
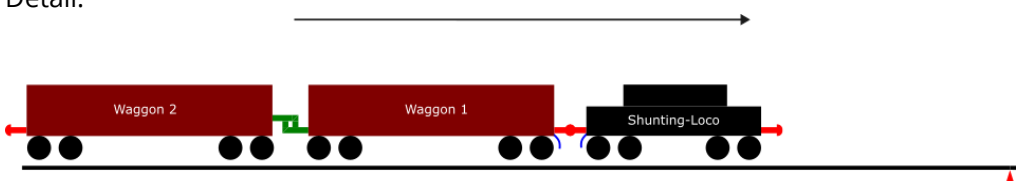
2	Initial Situation
2.1	Description
2.1.1	The wagons are coupled via a DAC.
2.1.2	Wagon 1 is coupled with a shunting loco.
2.1.3	The wagon setup is located in front of the test-infrastructure. The distance must be long enough to accelerate to the defined running speed.
2.1.4	The brake pipe is filled by the loco.
2.1.5	Wagon 1 and 2: – Brakes deactivated – Coupled via DAC – Brake pipe filled
2.1.6	Scheme:  Detail:  <i>Figure 2: Running ability tests: Initial setup. (Exemplary for ferry boat ramp).</i>
2.2	To document
2.2.1	Abnormalities and deviations from procedure.
2.3	To measure additionally to 1
2.3.1	If the air tightness of the wagons is not sufficient: – Measure the air tightness in advance, to subtract the initial leakage from potential leakage during the tests

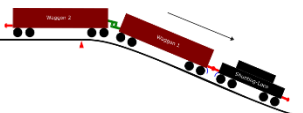
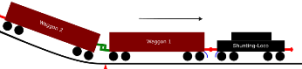
5.2.2 Pushing through the infrastructure

3	Decouple air pipes
3.1	Description
3.1.1	The air pipes are decoupled.
3.1.2	Remark: – Due to the decoupling, the pressure in the air pipes will drop. – The pressure in the air pipes shall be high enough to measure potential leakages during the test.
3.1.3	Scheme:  ▲ <i>Figure 3: Running ability tests: Decoupling of air pipes.</i>
3.2	To document
3.2.1	Abnormalities and deviations from procedure.
4	Accelerate to running speed
4.1	Description
4.1.1	The wagon setup is accelerated to the defined running speed. This speed shall be reached before the test-infrastructure is entered.
4.1.2	Scheme:  ▲ <i>Figure 4: Running ability tests: Pushing - Accelerate to running speed.</i>
4.2	To document
4.2.1	Abnormalities and deviations from procedure.

5	Pushing through the test-infrastructure
5.1	Description
5.1.1	The wagon setup is running through the infrastructure with the defined running speed.
5.1.2	Scheme: Entering:  Running through:  Exiting:  <i>Figure 5: Running ability tests: Pushing through the test-infrastructure. (Exemplary for ferry boat ramp).</i>
5.2	To document
5.2.1	Abnormalities and deviations from procedure.
6	Stopping
6.1	Description
6.1.1	The wagon setup is stopped behind the test-infrastructure. The distance must be long enough to accelerate to the defined running speed for the pulling through the infrastructure.
6.1.2	Scheme:  Detail:  <i>Figure 6: Running ability tests: Pushing - Stopping. (Exemplary for ferry boat ramp).</i>
6.2	To document
6.2.1	Abnormalities and deviations from procedure.

5.2.3 Pulling through the infrastructure

7	Refill air pipes
7.1	Description
7.1.1	If the air pipes are exhausted, a refilling of the air pipes is needed. If the air pipes contain enough pressure to measure a leakage during the test, the test can be continued without refilling.
7.1.2	The air pipes must be disconnected after refilling.
7.2	To document
7.2.1	Refilling of air pipes.
7.2.2	Abnormalities and deviations from procedure.
8	Accelerate to running speed
8.1	Description
8.1.1	The wagon setup is accelerated to the defined running speed. This speed shall be reached before the test-infrastructure is entered.
8.1.2	Scheme:  Detail:  <i>Figure 7: Running ability tests: Pulling - Accelerate to running speed. (Exemplary for ferry boat ramp).</i>
8.2	To document
8.2.1	Abnormalities and deviations from procedure.

9	Pulling through the test-infrastructure
9.1	Description
9.1.1	The wagon setup is running through the infrastructure with the defined running speed.
9.1.2	Scheme: Entering:  Exiting:  <i>Figure 8: Running ability tests: Pulling through the test-infrastructure. (Exemplary for ferry boat ramp).</i>
9.2	To document
9.2.1	Abnormalities and deviations from procedure.
10	Stopping
10.1	Description
10.1.1	The wagon setup is stopped behind the test-infrastructure.
10.1.2	The test run is officially stopped.
10.1.3	Scheme:  <i>Figure 9: Running ability tests: Pulling - Stopping.</i>
10.2	To document
10.2.1	Abnormalities and deviations from procedure.

5.2.4 Regular examination

11	Visual examination
11.1	Description
11.1.1	A visual examination of the couplers and draft gear should be done regularly. It must not be executed after each test, but approx. after a test series.
11.1.2	The following should be checked in detail: – Draft gear – E-coupler contacts – Screws – Wear – Air seal
11.2	To document
11.2.1	Photo documentation
11.2.2	Abnormalities
12	E-coupler contacts
12.1	Description
12.1.1	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.
12.2	To document
12.2.1	Abnormalities
12.3	To measure additionally to 5.2.11
12.3.1	Measurement of the insulation-resistance between contacts and housing.
12.3.2	Measurement of the insulation-resistance between each contact.
12.3.3	Measurement of the resistance over the coupler.

5.3 Detailed overview of measurement equipment

The measurement equipment can be installed on one of the two wagons. In the following the sensors currently used for measurement of the different parameters by the TTL (WP14) and during the DAC4EU project [DAC4EU01] are described:

Table 5: Overview of measurement equipment.

Measured parameter	Sensor and installation	Used in projects
Speed of the wagons	Incremental encoder pushed on the wheel	TTL – WP14
	Incremental encoder installed into the axle	[DAC4EU01]
Longitudinal force on the coupler	Strain gauge on the coupler shank	TTL – WP14 [DAC4EU01]
Travel of the draft gear	Wire sensor installed on the wagon, measuring the distance to the coupler head	TTL – WP14 [DAC4EU01]
Location on the track	GPS sensor	TTL – WP14 [DAC4EU01]
Connection of mechanical coupler	Wire sensor connected to the couple indicator	Not measured in any project so far
Connection of e-couplers	Measurement of a voltage over all pins of the e-coupler.	TTL – WP14
Pressure loss in brake pipe	Pressure sensor at the distributor valve or at the brake pipe	TTL – WP14 [DAC4EU01]

5.4 Evaluation

The given criteria are evaluated the following way:

Table 6: Evaluation - Way of evaluation.

To evaluate	Way of evaluation
General	
Operation without restrictions	→ Documentation of abnormalities in operation of the wagon due to the DAC in the test protocol
Critical damages coupler	→ Documentation of abnormalities in the test protocol → Regular photo documentation
Critical damages wagon	→ Documentation of abnormalities in the test protocol → Regular photo documentation
Mechanical coupler:	
Connection	→ Documentation of abnormalities in the test protocol Measurement of coupler status with on-wagon system: → Analysis of changes of coupler status during the test
Pneumatical coupling:	
Leakage	Measurement of brake pipe pressure with on-wagon system: → Analysis of sudden pressure drops while running through the infrastructure. → Comparison of leakage during test with nominal leakage measured in advance.
E-Coupler:	
Connection	Measurement of e-coupler connection with on-wagon system: → Analysis connection-losses during test.

6 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[DAC4EU01]	60226-TT.TVP22-PR01-V2	Testing: Digital automatic coupler Phase I Coupling and running tests	DB Systemtechnik – Tests of running dynamics	03.12.2021	2
[DEL5.2]	-	TRANS4M-R – D5.2 Technical Specifications of Wagon and Locomotive DAC up to Level 5	Johan Ahman	20.12.2023	1
[DEL5.3]	-	TRANS4M-R – D5.3 Validation/Test Procedures of Wagon and Locomotive DAC up to Level 5	Andreas Schuhmacher	31.10.2023	4
[DEL13.2]	-	TRANS4M-R - D13.2 Consolidated full system integration plan, test concept & validation concept and plan	Anna Åkerman	11.04.2024	4
[EN14363]	EN 14363:2016 +A1:2028	Railway applications Testing and simulation for acceptance of running characteristics of railway vehicles – Running behaviour and stationary tests; German version EN 14363:2016+A1:2018	DIN-Normenausschuss - FSF	01.11.2019	1
[EN15839]	EN 15839:2012 +A1:2015	Railway applications Testing for the acceptance of running safety under longitudinal compressive forces; German version EN 15839:2012:A1:2015	DIN-Normenausschuss - FSF	01.01.2016	-
[TS_DAC_013]	2025-013-DAC-TS01	Running safety under longitudinal compressive forces – Test scenario	Daniel Wolfram	-	01
[TSIWAG]	321/2013	TSI Wagon COMMISSION REGULATION (EU) No 321/2013 of 13 March 2013 concerning the technical specification for interoperability relating to the subsystem 'rolling stock - freight wagons' of the rail system in the European Union and repealing Decision 2006/861/EC (Text with EEA relevance)	European commission	13.03.2013	1

7 Appendices

Annex	Vn.	Title	Content