



FP5TRANS4M-R

Transforming
Europe's Rail Freight

D5.3

Validation/Test Procedures of Wagon and Locomotive DAC up to Level 5

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1 Executive Summary

D5.3 shall define tests for wagon- and hybrid couplers needed to achieve TRL8 of the described products. The content and structure of tests is made to validate compliance to requirements in D5.2. The methodology involves 3 different types of tests:

Type tests shall be used to validate if the products are meeting the overall strength requirements.

Functional tests on test bench level shall validate general functionality of the products and first level of interoperability.

Train lab test shall be performed to confirm functionality, interoperability and safety on train/wagon level.

Specific tests demanded in relation to train functions and power and data functionality are part of documents D 5.1 and D 5.4

The reliability aspect can only be tested on a test bench level and thus showing the fatigue behavior of the products. A full range of product related experience and reliability as well as some maintenance aspects can only be gathered in specific field tests and is not a target of this document.

Operation of demo trains shall be used to collect field data in regards of reliability. A list of reliability assessment criteria shall be prepared before testing. A theoretical assessment based to requirements shall lead to adaptions if feasible.

Test facilities, capabilities and or available rolling test might not be available to perform all specified test. In case an expert team shall define how the required performance can be tested according to an equal level to achieve full TRL target.

Based on the need of specific and detailed test specifications acceptance criteria (i.e. number of repeat cycles, ...) are clearly defined in these documents.

Keywords: Safety, test, compliance, strength, functionality, interoperability;

2 Abbreviations & Acronyms

Abbreviation / Acronym	Description
ADIF	Administrador de Infraestructuras Ferroviarias
CAN	Controller Area Network
CEN	Comité Européen de Normalisation
DAC	Digital Automatic Coupler
DB	Deutsche Bahn
DEL	Dellner
DIN	Deutsches Institut für Normung
EDDP	European DAC Delivery Program
EN	European Norm
ERA	European Union Agency
FA	Flagship Area
FT	Faiveley Transport
KB	Knorr Bremse
OEBB-RC	Österreichische Bundesbahnen Rail Cargo
SC	Subcommittee
SMO	Siemens
TC	Technical Committee
TRV	Trafikverket
UIRR	International Union for Road-Rail Combined Transport
VT	Voith
WG	Working Group

3 Background

The present document constitutes the Deliverable D5.3 "Validation Test Procedures of Wagon and Locomotive DAC up to level 5" in the framework of the Flagship Project FP5-TRANS4M-R as described in the EU-RAIL MAWP. This document reflects the current status of D5.2. Modification and open aspects will be collected according to appendix in D5.2 and defined with the revision of this document.

4 Objective/Aim

This document aims to close document deliverable 5.3. Which are based on work in task 5.1, 5.2 and 5.3.

Task 5.1: Technical Specification and Validation/Test DAC Level 4

Based on the operational procedures, and EDDP definition, system vision and architectures, VOI will lead the work with the partners (KB, DEL, FT) and define the technical specification and minimum interfaces necessary for interoperable operation of a DAC functional level 4: mechanical, pneumatic, power and data connection. Level 4 shall demonstrate a full mechanical, pneumatic and electrical interoperable equivalent to the level of complexity of the current system of screw and buffer systems. KB will lead the work to define the minimum required tests procedures, required to show the fulfilment of the functional requirements and their interoperability, since such tests are not existing yet. The operators will verify if the technical specifications meet the use cases and the functional requirements derived from the operational procedures.

The outcomes documented in the deliverables will be fed to finalize the CEN standard for the DAC under the work of CEN/TC 256/SC 2 WG 33 subgroup 3 and providing inputs for CLC/TC 9X/WG 15-10. The pass-fail criteria will be harmonized across relevant stakeholders incl. authorization authorities (e.g., ERA and/or EDDP).

Task 5.2: Technical Specification and Validation/Test Plan DAC Level 5

Based on the technical specification defined in Task 5.1 for a DAC level 4FT lead the activity to extend specification for a DAC level 5. The necessary interface definition is led by DEL. The function definition to ensure digital compatibility and interoperability is led by VOI. Out of the specification KB will elaborate the required test specification and the validation plan to demonstrate the fulfilment of functional and interoperability requirements. The operators will verify that the functional requirements meet the use case, specification and the set of the test procedures are sufficient for qualifying and certifying the equipment for train integration. The deliverables will be used as input for standardisation for the DAC Level 5 under the work of CEN/TC 256/SC 2 WG 33 subgroup 3.

Task 5.3: Technical Specification and Validation/Test Plan Hybrid (Wagon/Loco) DAC Level 5

VOI will lead the work and define the functional requirements and minimum standardised interfaces necessary for interoperable operation of a Hybrid Coupler Locomotive-Wagon starting at functional level 2 (mechanical and pneumatic), level 4 (electrical) and level 5 readiness. KB will lead the work to create a list of tests needed to show the fulfilment of functional requirements and interoperability. The operators participating in the Task will verify that the functional requirements meet the user requirements, and that defined testing procedures correspond with the required authorization procedures and strategies (WP4). The deliverables will be used to finalize the CEN standard for the Hybrid Coupler

under the work of CEN/TC 256/SC 2 WG 33 subgroup 3 (not sure which group is dealing with Hybrid Coupler). The pass-fail criteria shall be discussed and aligned with relevant stakeholders, such as the authorisation authority(s) e.g. ERA and/or EDDP.

5 Terms and definitions

Digital Automatic Coupler (DAC)

a central buffer end coupling system for freight applications that couples automatically.

Note 1: The degree of automation is defined in DAC functional levels 1-5. See functional levels.

Note 2: The requirements described in this standard are valid for digital automatic couplers for use in freight trains. For digital automatic couplers for use in passenger trains there exist different or additional requirements.

Note 3: An additional electrical contact coupling for the transmission of voltages and data/signals is out of scope of this standard.

Note 4: The mechanical housing for the electrical coupler will be covered in this document.

Electrical Coupler

A system that is used for connecting or disconnecting the electrical lines automatically which transfer control signals or power supply / current from one railway vehicle to another within a train.

Note 1 If relevant the Electrical coupler will also house data connections and lines. The electrical components of the electrical coupler are defined in CENELEC.

Note 2 For clarity -the mechanical interfaces but not the transmission conduits (pins) and their configuration of the electrical coupler are covered in this standard.

Horizontal and Vertical Support

A system that moves or aids - in the uncoupled condition - the complete coupler back into the central position after being deflected

Split Collar

A fastening element consisting of two metal half-shells that are joined by fasteners.

Note: This is not an interface covered here.

Draft gear

An element of the coupler that can transfer compressive and tensile forces into freight wagon or locomotive.

Note The draft gear can handle regenerative and non-regenerative energy.

Crash element

A non-regenerative energy absorption device that absorbs energy in the event of a collision.

Note: These devices are used to protect the main structure of the wagon or other rail device it is attached to. These elements may be sacrificial.

Coupler shank

Connection between the coupler head and the draft gear

Pivot pin

Pin used to connect the coupler shank to the draft gear.

Manual uncoupling mechanism

Device which provides manual rotation of the locking mechanism from the coupled position in to the ready to couple position.

Note: It can be a lever, handle, rope, or other tool which is connected to the coupling mechanism and is pulled until the ready to couple position is attained.

Uncoupling actuator

Device which provides automatic rotation of the locking mechanism from the coupled position in to the ready to couple position.

Prevent coupling

State when the mechanical mechanism of the coupler is retained in an uncoupled state preventing coupling of the couplers even if two couplers are put in contact (buffed) with each other – which normally would result in coupling.

Note this enables buffing in hump and yard operations.

Berne or Berner rectangle

Area between the vehicles ends defined by EN 16839:2022-10 App F

Functional levels (FL)

Functional level 1:

automated coupling of the mechanical connection; manual uncoupling possible

Functional level 2:

FL 1 plus automatic coupling of air pipe

Functional level 3:

FL 2 plus automatic coupling of electrical power line(s)

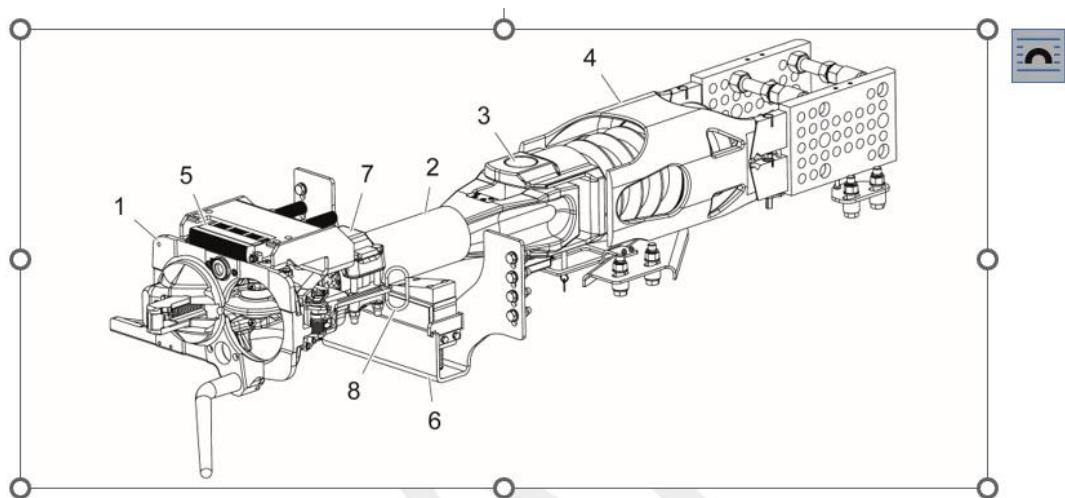
Functional level 4:

FL 3 plus automatic coupling of data line(s)

Functional level 5:

FL 4 plus full automated uncoupling

Note The full automated uncoupling can be achieved by means of remote access.



Key

- 1 Mechanical coupler
- 2 Coupler shank
- 3 Pivot pin
- 4 Draft gear
- 5 Electrical coupler
- 6 Support
- 7 Split Collar
- 8 Manual uncoupling

Figure 1 Schematic view of the coupler components

6 DAC Supplier Testing

The definitions of testing are in accordance with the requirements provided within draft for CEN standardization about the DAC and shall be applicable to show product compliance to characteristics specified in D 5.2.

6.1 Type Testing

Type testing includes measurements of general properties (e.g., dimensional and weight/mass measurements), functional testing, strength validation and draft gear performance. Measurements specifications only apply if installation pocket is according to UIC530. DAC functionalities and strength requirements must, during validation, take into account at least the temperature range T1 and the influence of snow, ice and solar radiation in accordance with EN 50125-1:2014.

Note: The standard EN50125-1:2014 for rolling stock and on-board equipment, as well as EN50125-2: 2002 and EN50125-3:2003 for fixed electrical installations and equipment for signalling and telecommunications will be abolished and replaced by the single standard EN 50125 in order "to update the environmental and climate topics related to railway equipment and rolling stock". "This update is done by taking into account a possible impact of climate change". EN 50125 is currently in the draft stage as prEN 50125:2025 and provides, among other things, for a change in the limit range for the T1 temperature range from the current [-25 to +40 °C] to [-25 to +45 °C] in the future. Once prEN 50125:2025 has been approved and released, it will be necessary to check whether the current criteria for the environmental conditions for the DAC need to be updated by the CEN standards committee.

6.1.1 General measurements

Before installing the DAC and performing any tests the following measurements must be performed on representative couplers as a first article inspection:

- Dimensional checks on the coupler head according to prEN 18171:2025
- Conformity with the requirements in D 5.2 of the geometric design of the DAC:
 - o The coupler arm's articulated length in maximum extended position (from the pivot up to the coupler front face level) for a DAC equipped with standard draft gear type A or C.
 - o The distance of pivot point behind the headstock. The measurement can be taken as 150 +/-5mm from draw stop to the pivot point.
 - o The distance between the center line of the coupler and the height of the coupler.
- Geometric check of the arrangements and dimensions of the contacts and their contact carrier on the electrical coupler according to chapter 6.2; 6.3; 6.4; 6.6; in D5.2.
- The weight of the DAC shall be measured and documented D5.2, chapter 6.1).

6.1.2 Corrosion protection

The surface protection shall be tested based on sample plates to achieve 480 h neutral salt spray based on ISO 9227:2022.

6.1.3 Fire and smoke testing

According to TSI-WAG, materials with a potentially high fire risk must be identified in advance, and the design must then aim to prevent fires and mitigate the consequences in the event of a fire. Based on the list of materials for each component, tests of the fire and smoke behavior of combustive materials shall be performed according to EN 45545 protection class 2. The fire protection concept must be validated, especially for batteries and electrical installations.

The tests to be carried out serve to evaluate the effectiveness of measures to prevent fires and to test the effectiveness of measures to mitigate the consequences of a fire. Test result documents shall be provided with the product and kept valid.

6.1.4 Climate chamber test

Appropriate coupler function shall be tested under extreme climate conditions in a climate chamber.

Min. and maximum temperatures as specified in CEN EN_DAC 2023 (WI 00256A0K) shall be applied.

- Coupling and uncoupling test at -25 °C
- Coupling and uncoupling test at 40 °C
- Coupling and uncoupling test at -25 °C with 3 mm Ice layer (to the top and front)

Coupling and uncoupling activate and de-activate prevent coupling position of all functions shall be achieved without manual intervention (except release of decoupling)

6.2 Functional testing

The acceptance criteria for each function are described in D5.2 and in prEN 18171:2025. In addition to the "pass" and "fail" assessments, there are also tests that can be evaluated based on the degree of fulfillment of the requirements. However, it is important that the test results are statistically validated. The RAMS Working Group was established for this purpose. It is tasked with determining the number of test iterations to be conducted and the pass/fail ratio for each RAMS objective per function.

6.2.1 Mechanical Coupler

6.2.1.1 Dimension check

- Check coupler lock play using main control gauge.
- Check male cone height.

6.2.1.2 Visual checks

- Check if the coupler is completely and correctly assembled in compliance with the drawing.
- Check if the coupler lock moves freely.
- Check if the coupler lock elements are sufficiently greased.
- Check if the contact surfaces of the coupling link, hook plate and front face are free of dirt, paint, and paint splashes.

6.2.1.3 Mechanical functions check

Check of manual and automatic mechanical coupling functions by coupling and uncoupling the mechanical and electrical coupler. The following tests shall be repeated min. 5 times.

Coupling:

- a. Coupling mechanism shall audibly latch when coupling.
- b. Check free movement of the electrical coupler incl. cables.
- c. The release bar shall be retracted inside the coupler head when coupled.
- d. Visual check of visual indicator in coupled position.
- e. Visual check of the sealed front lid.
- f. Check if sensors are providing the correct signal as specified.
- g. Check function of the prevent-coupling-position.

Uncoupling:

- a. The release bar shall be locked towards the trigger mechanism housing when uncoupled.
- b. Check the free movement of the electrical coupler including cables.
- c. Check if the electrical coupler lid is completely closed.
- d. The coupling mechanism shall be in the ready-to-couple position when the couplers are moved apart after uncoupling.
- e. The release bar shall protrude outside the coupler head when uncoupled.
- f. Visual check of the visual indicator in uncoupled position.
- g. Check if sensors are providing the correct signal as specified.
- h. Check the function of the prevent-coupling-position.

6.2.1.4 Gathering Range

The deflection cases for the gathering range test are shown in table 1 based on definitions in D5.2. The coupler shall be deflected parallel to its longitudinal axle to achieve the specified positions. At all positions, successful coupling and uncoupling shall be achieved. Between each load case a visual inspection should be done. After the test an overall evaluation of the specimen should be done. No repetition of this test is required.

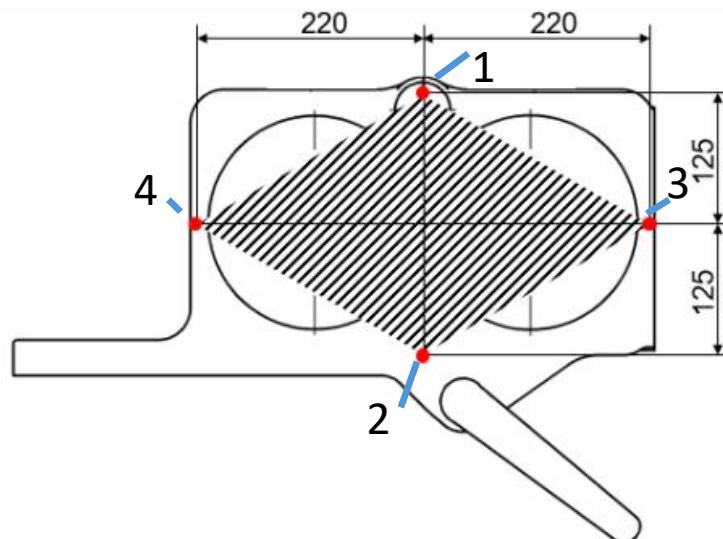


Figure 2: Test positions on latch type coupler head and type 10 gathering range

Table 1 Test Procedure Coupling Test

Case	Horizontal Deflection [mm]	Vertical Deflection [mm]	Cycles [-]
1	0	+ 125	2
2	0	- 125	
3	+ 220	0	
4	- 220	0	

6.2.1.5 Lateral and vertical displacement test

Coupler lateral and vertical displacement tests are to be performed in relation to applicable longitudinal strokes (in the draft gear) determined on the test bench. The mounting device for the installation of the draft gear and the support onto the test bench must correspond to the dimensions of the installation space of the wagon. Movements of the coupler cannot be performed by manual force if the spring elements are present due to the preload of the draft gear working against the tensile and compressive forces occurring during coupler movements. To realize the test, the spring elements of the draft gear and vertical support (incl. centering device) can be replaced by placeholders with very low stiffness or can be removed. As this test has the target to verify the general design no repetition is required.

In the zero position the center line of the coupler must coincide with the longitudinal axis of the wagon and the length of the coupler from the head stock (buffer fastening plane) to the coupler plane shall be 620 mm.

Table 2 summarizes the coupler movements that are to be performed. Within the specified range stroke values depend on individual draft gear designs.

Table 2 Coupler displacement test angles

Movements	Stroke in pressure direction	Stroke in tension direction	Minimal rotation around vertical axis	Minimal rotation around horizontal axis
1	105 – 120 mm	0	0	0
2	0	50 - 70 mm	0	0
3	0	0	+17°	0
4	0	0	-17°	0
5	0	0	0	+6°
6	0	0	0	-6°
7	0	0	+ 17°	+ 6°
8	0	0	- 17°	+ 6°
9	0	0	+ 17°	- 6°
10	0	0	- 17°	- 6°
11	50 - 70 mm	0	+12°	0
12	50 - 70 mm	0	-12°	0
13	105 - 120 mm	0	+ 4°	0
14	105 - 120 mm	0	- 4°	0
15	105 - 120 mm	0	0	+ 4°
16	105 - 120 mm	0	0	- 4°
17	0	50 - 70 mm	+17°	0
18	0	50 - 70 mm	-17°	0
19	0	50 - 70 mm	0	+6°
20	0	50 - 70 mm	0	- 6°

The type and direction of coupler movements can be seen in Figure 3.

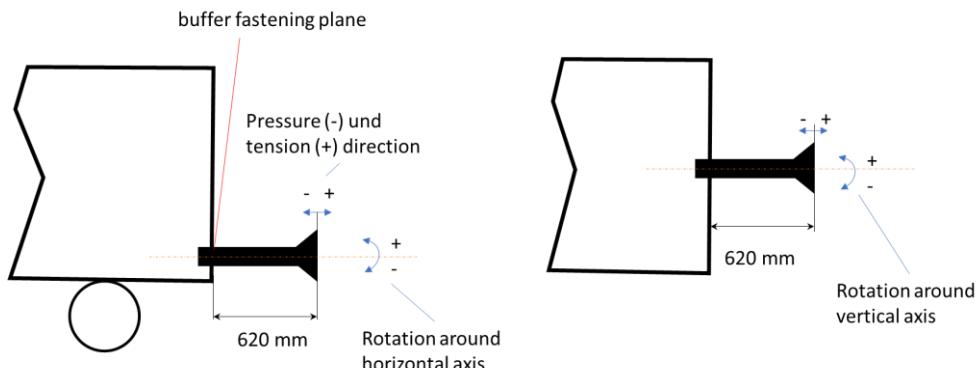


Figure 3: Type and direction of coupler movements

6.2.1.6 Manual Uncoupling Device

Check that the needed uncoupling and prevent coupling force of one of the coupler heads do not exceed the maximum force level (reference to D5.2), without any residual tensile load on the coupler and without air pressure. The value is defined by the average of at least 3 measurements.

Check if the mechanical prevent uncoupling position will be maintained stable by separating and connecting two coupler heads in active "prevent coupling position" at least 5 times. The deactivation of the "prevent coupling position" shall be achieved by simulating a trackside device.

6.2.1.7 Automatic Uncoupling

- Check if maximum time for rotating the coupling mechanism to uncoupled position is within 3 seconds
- Visual check simultaneous function of two mating uncoupling devices

6.2.1.8 Centering of Coupler

- Displace the coupler angular to its maximum displacement position.
- Check the recentering function without manual assistance.
- Apply vibration (manual) to the coupler head thus simulating the vibration of moving wagons to achieve final recentered position. This position shall be within +/- 2° to the centerline.
- Check that the coupler can be horizontally deflected up to 6° +/- 1° (coupling in tight curves) before releasing it and check that the coupler will stay in that position without self-centering. The deflection force shall not exceed 400 N.

(Note: 6° under revision-depending on final spec of the interface)

6.2.2 Pneumatic Coupler

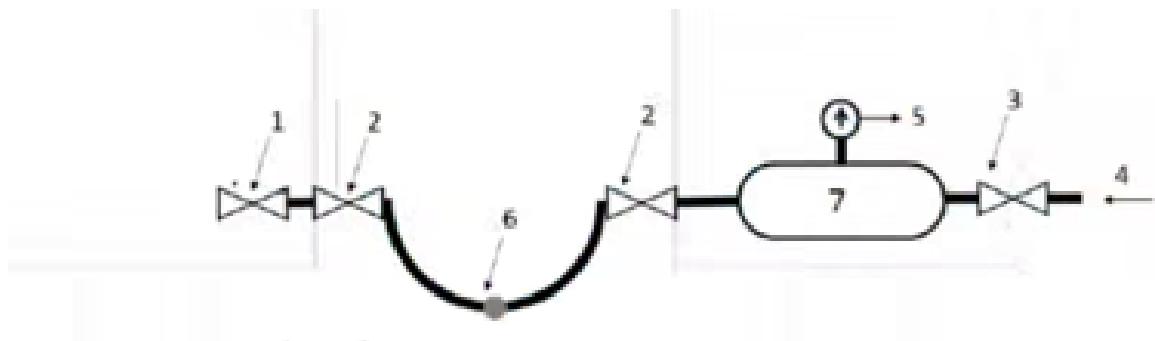
6.2.2.1 Leakage test

To ensure appropriate train operation a leakage test according to EN 16019:2014 (Leakage test) on lab level shall be performed

Note: No additional leakage test on train level to verify coupler system performance.

6.2.2.2 Brake pipe propagation speed test

The brake pipe propagation speed test shall be performed to validate brake performance of a freight train equipped with the DAC. The fall time in pressure should not be longer than that for the reference system in Figure 4, based on the description of the test setup and procedure for end cocks in EN 14601:2024.



- 1: Cut off cock (bigger diameter than 2)
- 2: End cock (EN 14601:2024)
- 3: Cut off cock (reservoir filling)
- 4: Air for filling the reservoir (10 bar)
- 5: Pressure sensor
- 6: 2 Air hose – pneumatic half coupling (EN 15807:2021)
- 7: Reservoir 400 l (recommended)

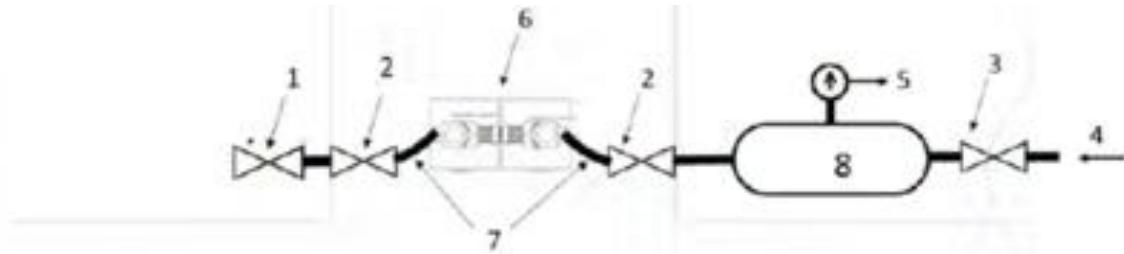
Figure 4: Brake pipe propagation speed test (described in EN 14601:2024)

An air reservoir with a volume of 400 l (recommended) shall be connected to the string hose components to be tested via a valve (2) and a hose. The inner diameter of reservoir exhausting hose shall be at least 2". The total length of valve and hose shall be 1 m at most. The air reservoir shall be equipped with a pressure sensor (5).

Initially, valve V3 is open and valve V2 is closed. The air reservoir shall be filled with compressed air to a pressure of approx. 10 bar through valve V3. When this pressure is reached, valve V3 shall be closed. Valve V2 shall then be opened abruptly. It shall be fully open before the pressure in the reservoir has dropped to 9 bar. The reservoir shall be

depressurized entirely. The relevant time span for venting the reservoir (venting time) shall be determined from the moment where the pressure drops below 9 bar to the moment where the pressure drops below 1 bar.

This test is to be repeated with the DAC system as detailed in Figure 5



- 1: Cut off cock (bigger diameter than 2)
- 2: End cock (EN 14601)
- 3: Cut of cock (reservoir filling)
- 4: Air for filling the reservoir (10 bar)
- 5: Pressure sensor
- 6: 2 Coupler valves connected
- 7: 2 connecting hoses
- 8: Reservoir (recommended: 400 l)

Figure 5: Brake pipe propagation speed test with DAC system

Venting time in test shall be equal or better than defined in D5.2 to pass the test. If no mating main reservoir pipe (MRP) exists, the valve shall remain closed.

6.2.3 Electrical coupler testing

6.2.3.1 Energy connection

The electrical continuity and contact resistance tests shall be performed according to EN 60512-2-1: 2002 (identical to IEC 60512-2-1:2002). For the Contact resistance the Millivolt level method can be used. A resistance < 2 mOhm shall be achieved for all type of contacts.

General measuring requirements

Measurements may be carried out with direct current or alternating current. For AC measurements, the frequency shall not exceed 2 kHz. In case of dispute, the DC measurements shall govern.

The accuracy of the measuring apparatus shall be such that the total error does not exceed 1%.

Measurement details

The contact resistance shall be derived normally from the voltage drop measured between the zones intended for connection of the wiring to the contacts.

The contact shall not be operated while the measuring voltage is applied.

Care must be taken during the measurement to avoid exerting abnormal pressure on the contacts under the test and to avoid movement of the test cables.

Where the connection points specified in the detail specification are not directly accessible, the resistance of the cable or wire used shall be subtracted from the measured value. The corrected value shall be recorded.

The contacts to be measured shall be chosen in accordance with the detailed specification.

Test current and voltage

The test voltage shall not exceed 20 mV DC. or peak voltage AC. In order to prevent the breakdown of possible insulating films on the contacts.

The test current shall not exceed 100 mA, AC or DC.

6.2.3.2 Data connection

The Single-Pair Ethernet standard defines the following types: 10BASE-T1S, 10BASE-T1L, 100BASE-T1 and 1000BASE-T1. The focus is currently on 10BASE-T1L. 10BASE-T1L was first defined by IEEE802.3cg in 2019, the most recent version of this standard is IEEE802.3 published in 2022.

The standard defines 10BASE-T1L theoretical maximum speed as 10 Mbps.

A resistance < 2 mOhm shall be achieved for all type of contacts.

6.2.3.3 IP protection level

The electrical coupler shall be tested against ingress of dust and water according to EN 60529:2014 (identical to IEC 60529:1989 + A1:1999 + A2:2013). Target is to achieve a degree of protection of minimum IP55 when coupled and minimum IP54 when uncoupled.

6.2.4 Strength testing - Compression and tension strength and fatigue validation.

The test consists of the determination of the minimum static load of the coupler, or components of the coupler. It shall be demonstrated by means of static tests that the coupler head of the DAC withstands the loads stated in EN 12663-2:2010+A1:2023, section 5.2.2. The tests shall in each case be performed on unstressed couplers which have not been tested before.

Two couplers shall be coupled to conduct the tensile/compression test.

The position of the strain gauges shall be defined based on FEA detected critical areas.

Draft gear tests shall be made accordingly but as a separate module.

Test procedure for static yield-strength test

The loads shall be applied gradually up to the maximum value and held for 1 min.

The maximum tensile and compressive loads shall not cause permanent deformation ($\leq R_{p0,2}$ limit).

It is recommended that:

- The couplers used for the type test are preloaded to stabilize the overall structure.
- The maximum force is applied incrementally at least twice.
- The measurement equipment is to be reset to 0 before the final test.
- The results of the final test shall be considered in the validation.
- The strains measured under the maximum applied loads, shall be $\epsilon \leq \epsilon_{\text{limit}} = R_{p0,2}/E$.

ϵ	measured strain
E	Young's modulus of the material;
$R_{p0,2}$	is the stress at which the material undergoes a 0,2 % non-proportional (permanent) extension during a tensile test as defined in EN ISO 6892-1;
ϵ_{limit}	is the limit of elongation of the material.

Evaluation of local stress concentrations may be done according to EN 12663-1:2010+A1:2014, section 5.4.2.

After applying and removing the maximum tensile load, the coupler locks of the coupler heads and the draft gear shall move freely. This can for example be demonstrated by manually uncoupling the coupler heads. Visual damages shall be noted and evaluated against safety.

6.2.4.1 Static tension

Test procedure tension load

- Test components shall be preloaded at approximative 30 kN to stabilize the overall structure.
- The measurement equipment is to be reset to 0.
- Increase the forces in min. 200 kN steps with a minimum of 3 steps in total up to 1 000 kN and maintain the force for 1 min. Repeat the procedure 2 times.

Note: The test procedure specified here supplements the test procedure in EN16019:2014 regarding the method of force application during testing and considers

the fact that DACs for rail freight transport are pre-tensioned. The assessment procedures according to 16019:2014 or EN12663-1:2010 apply.

The maximum tensile load shall not cause permanent deformation ($\leq R_p0,2$ limit) of the test components.

Note: After applying and removing the maximum tensile load, the coupler locks of the coupler heads shall move freely.

6.2.4.2 Static compression

- Test components shall be preloaded at approximative 30 kN to stabilize the overall structure
- The measurement equipment is to be reset to 0.
- Increase the forces in min. 200 kN steps with a minimum of 3 steps up to 2 000 kN and maintain the maximum force for 1 min. Apply the maximum force twice

Note: The test procedure specified here supplements the test procedure in EN16019:2014 regarding the method of force application during testing and considers the fact that DACs for rail freight transport are pre-tensioned. The assessment procedures according to 16019:2014 or EN12663-1:2010 apply.

The maximum compression load shall not cause permanent deformation ($\leq R_p0,2$ limit) of the coupler components. Elastic pads may be permanently deformed or replace by means of stiff structure.

After applying and removing the maximum compressive load, the coupler locks of the coupler heads shall move freely.

6.2.4.3 Fatigue/ endurance testing under service load

The fatigue strength test shall demonstrate that the DAC can withstand the specified loads until the end of the target service life. The main components of the DAC that are in the main force flow (up to 1 000 kN in tension and 2 000 kN in compression) during travel and coupling operations must have a service life of 30 years if the appropriate maintenance is observed.

The description of the experimental proof for a service live of 30 years is as follows:

The service life is verified with a fatigue test. The tests are carried out on unloaded/untested coupler front parts and draft gear. Tests can be carried out on a complete system or on partial components. Spring elements can be replaced by spacers. The force applied onto the test objects must be induced according to the force flow in the complete DAC. Strain gauges must be applied to positions with expected high strains and stresses according to FEA results.

The procedure for the fatigue strength test of the DAC is based on the procedure for testing the screw coupler according to Annex A, EN 15566:2022. The following test steps,

which are carried out one after the other, must be observed during the dynamic testing of the DAC:

- The fatigue test must be carried out on three samples of the DAC components
- Conditioning of the DAC with a tensile force of 60% of the minimum breaking load.
- Non-destructive testing: Before the endurance test, the DAC must pass a magnetic particle test or dye penetrant test according to EN 10228-1:2016 and EN 10228-2:2016. Any sign of a surface defect that appears must be recorded in size and shape.
- Dynamic testing
 - o Stage 1: Delta F1 = 0 kN ± 300 kN and N1 = 1,5 x 10⁶ cycles

The load frequency should not exceed 4 Hz.

- Non-destructive testing after the endurance test
- Analysis of the residual strength by carrying out a static test. 95% of the minimum breaking load must be withstood for three minutes. The test component must not fracture during this static test.
- Macroscopic and microscopic tests according to the specifications in Annex E, EN15566:2022

Note: Each individual test must be performed in a single laboratory. EXAMPLE: Dynamic tests from start to finish shall be carried out in one laboratory.

Wear parts are to be exchanged during the test.

6.2.4.4 Nominal breaking force

The coupler shall not lead to apply major damages on wagons due to excessive tension loads. A test shall determine the minimum breaking force at tensile loads to the coupler, or components of the coupler.

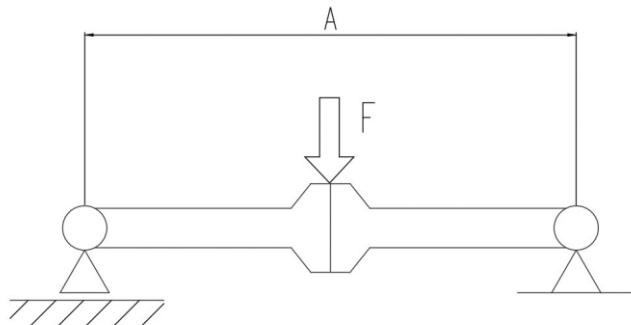
The test system elasticity shall be similar or equal to the elasticity of a complete coupler.

Static test procedure:

- Apply tension load to two coupled coupler heads up to the breaking point.
- Please see ch 5.1 in Deliverable 5.2 for min. breaking load of coupler/coupler parts test temperature shall be between 15 °C and 25 °C.

6.2.4.5 Vertical strength test

The coupler shall withstand a vertical load of minimum 150 kN without fracturing to prevent climbing of two impacting wagon. The test conditions shall be applied according to the figure below.



F: Vertical climb load: 150 kN.

A: Length of two coupled couplers: 2000 mm

Figure 6: Test conditions of vertical strength test

6.2.5 Derailment test on test bench

During curves and/or if wagons have a height difference deflection angle between the longitudinal axis of the coupler and the longitudinal axis of the wagon can be observed. Under longitudinal compressive forces, the angles cause transversal forces in the car body. These transversal forces in interaction with the torsional stiffnesses of the wagon body, the stiffnesses of the running gear and the secondary stiffnesses lead to wheel force changes. In unfavorable cases, this can lead to wheel lifting and thus to derailment.

On the test bench, the transversal force component is to be determined as a function of the coupler angle and the longitudinal compressive force. The values shall be equal or higher than table 2 "derailment min values of reference system".

6.2.5.1 Data acquisition prior the test

- Prior to the test the specimen shall be dimensionally checked against relevant measurement.

6.2.5.2 Test the guidance of the pressure plate according to UIC 524:1978

Note: This test shall be performed mandatory as long as not all defining factors to the running safety of wagons are developed and validated. In future a new method or other parameters might replace the following.

Test procedure

The angular deviation of the pressure plate depends on the point of force application on the pressure plate and on the force. The angle deviation under compressive force and eccentricity must be determined on the test bench based on Figure 8: Test set-up for guidance. The installation situation of the draft gear on the test bench must correspond to the installation conditions on the vehicle. The spring assembly must be pretensioned.

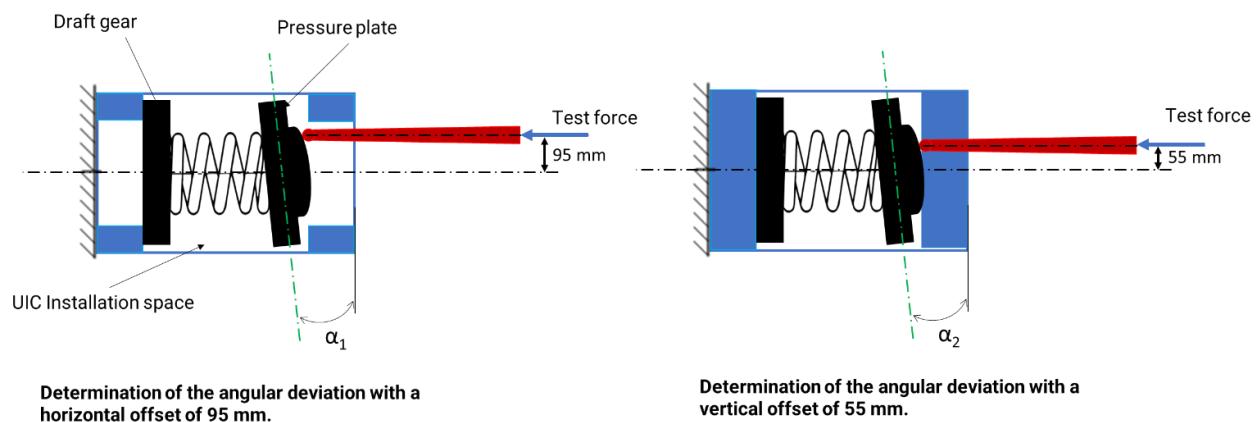


Figure 7: Test set-up for guidance test

The test is carried out with a static force. The test force must be varied between 0 and 800 kN in 50 kN steps according to UIC 524:1978 (the limitation of the force to 600 kN in the first version submitted was due to the maximum force that the test bench at DB Systemtechnik could withstand at that time. According to UIC 524:1978, the test must be carried out up to a force of 800 kN).

The angles α_1 and α_2 are to be measured for the respective offset and force and entered in the Table 3. The angle is measured via four stroke sensors placed in each corner to evaluate the deflection angles α_1 and α_2 .

Table 3 Result Overview

Force [kN]	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
α_1 [°]																	
α_2 [°]																	

The results can also be presented graphically as shown according to UIC 524.

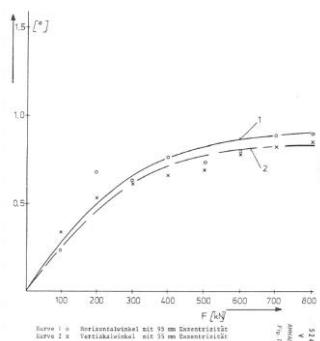


Figure 8: Graphic sample to show a test result

Test criteria

To achieve an optimum effect of the all-round stabilizing coupler joint, the pressure plate of the spring apparatus must be well guided vertically and horizontally (see UIC 524:1978 Annex 2.2).

- The transverse displacement of the thrust piece a1 (horizontal) and a2 (vertical) relative to the center line of the spring apparatus must be within the following limits during operation:
[$a1 = a2 = \pm 3,5 \text{ mm}$]².
- The transverse displacement of the thrust piece a3 (horizontal) and a4 (vertical) relative to the center line of the carriage must be within the following limits during operation:
[$a3 = a4 = \pm 6 \text{ mm}$]².

The guide length should be selected so that the pressure plate does not exceed the following angular deviation:

- The angular deviation of thrust piece plate a1 (horizontal) and a2 (vertical) perpendicular to the center line of the vehicle mounting space shall not exceed the limits $a1 = a2 = \pm [1,25^\circ]$ ² during operation under the following conditions:
 - Longitudinal force 800 kN: eccentricity 55 mm vertical
 - Longitudinal force 800 kN: eccentricity 85 mm horizontal

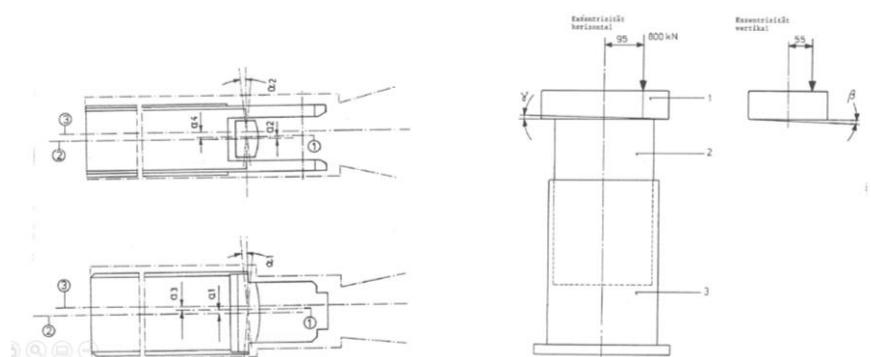


Figure 9: Overview test setup

²: This value should be redefined on the basis of the newly specified permissible longitudinal compressive force of 500 kN for derailment safety, as this value was defined for a permissible longitudinal compressive force of 600 kN. A final decision on this issue should be found in the FP5-DACtivate report on propelling tests for safety against derailment.

6.2.6 Draft Gear / Energy Absorption Performance

6.2.6.1 Static

Test principle

The test consists of the determination of the force-stroke diagram during the compression and tension of the complete draft gear.

Test procedure

- The test shall be carried out at least **72 h after assembly**, if rubber or other elastomer elastic are to be tested.
- Test temperature of the draft gear shall be between **15 °C and 25 °C**. (normal temperature $\pm 5^{\circ}\text{C}$)
- The compression and tension phase shall be followed immediately by the decompression phase. The maximum displacement speed of the press in both directions shall be less than or equal to 0,05 m/s according to EN15551:2022, Appendix D (since different curve profiles can occur, particularly with elastomer spring systems, due to the different displacement speeds, testing can optionally be carried out with a displacement speed between 8 and 10 mm/s, provided that the test equipment allows this, in order to be able to compare draft gear characteristics from different suppliers). When fully release, the draft gear shall be found to be in the same condition as initially.
- **Three cycles** up to the maximum stroke according to Table 1 are made. The test shall be arranged in such a way that the draft gear system will not be exposed to unacceptable thermal loads. A break after two complete cycles is allowed if the **break is less than 10 minutes**.
- A force-stroke diagram is recorded during the **three cycles**, all curves shall be included in the tolerance defined in Table 1.
- Draft gear system with **hydrodynamic or hydrostatic** shall go through an additional test that show the draft gear **reaction remains virtually constant within** $[\pm 5\%]$ of the nominal value for **10 min** with compression and tension values of 30 mm, 60 mm and 100 mm.

Measurements

Measurements are the following:

- Stroke
- Force
- Temperature
- Time

All the parameters shall be recorded. Additionally, the parameters stroke of the spring system and force are recorded on a force-stroke diagram. Stored energy W_{es} and absorbed energy W_{as} are calculated with the diagram.

A stroke-force diagram is recorded during the three cycles, all curves shall be within the tolerances defined in D5.2.

6.2.6.2 Endurance

Test principle

The aim of this test is to verify the fatigue performance of the whole draft gear when working under short stroke conditions (behavior in curves and S-curves and during braking).

Test procedure

The test shall be done according to EN15551:2022, Annex F.

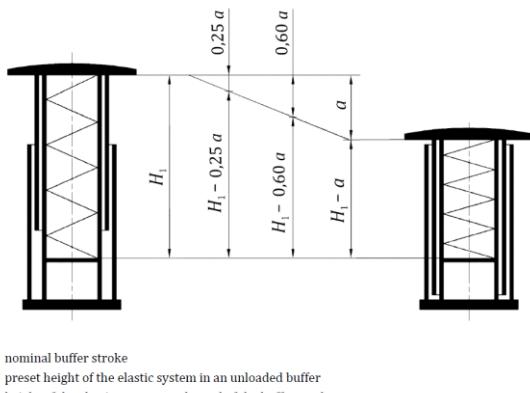


Figure 10: Definition of heights

6.2.6.3 Dynamic

Test principle

The dynamic tests specified in the following clauses are certification tests of draft gear systems and could be carried out as wagon impact test, on a pendulum test stand, as drop hammer test, or similar appropriate test facilities to achieve test target results as below.

Test procedure

The test consists of subjecting an elastic system to 13 200 compression cycles repeated at three stroke levels and afterwards verifying that its static characteristics are maintained.

- The stored energy (W_e) shall be at least equal to 80 % of the value measured under the same conditions during the static compression test carried out before and at least 24 h after the three endurance test cycles.
- The absorbed energy (W_a) shall be at least equal to 80 % of the corresponding value measured before and at least 24 h after the three cycles of the endurance test (under the same conditions).
- With the elastic system being kept flanged in its assembly at height H_1 for a minimum of 72 h, the stroke-force diagram is plotted under the conditions of the static test.

- Three sequences each consisting of 3 000 cycles at C_1 followed by 1 200 cycles at C_2 and 200 cycles at C_3 are performed. In the end 13 200 cycles are performed within the three phases compression, decompression, and a rest period according to EN15551:2022.
 - Stroke C_1 : One cycle per 60 s
 - Stroke C_2 : One cycle per 90 s
 - Stroke C_3 : One cycle per 120 s
- The maximum temperature of the elastic system during the test shall be defined by agreement with the supplier. This maximum permissible value shall exceed 40 °C and if needed a ventilation can be used.
- If applicable: An additional test is required for spring elements for which the elastic force is mainly related to the compression speed, and which are fitted with tightness elements (e.g., sealings). For the examination of the behavior of the tightness elements, it is necessary to carry out, in addition to the above-described main cycles, the following cycles, which shall also be repeated three times with speeds between 0.05 m/s to 0.3 m/s:
 - 15 000·cycles with 10 % of the stroke
 - 15 000·cycles with 25 % of the stroke

It is permissible to use a second spring element for these tests. Before and after each series of three cycles, the dimension of the cylinder and piston, as well as those of the tightness elements, shall be measured. The wear noted shall not adversely affect the operation.

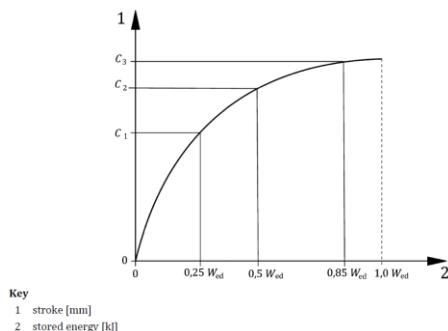


Figure 11: Determination of buff strokes for endurance test

6.2.7 E-coupler testing

6.2.7.1 Electrical coupler IP Test

- Check IP protection specification from D5.2 in uncoupled and coupled position.
- Test procedure to be taken from EN 60529:2014 (identical to IEC 60529:1989 + A1:1999 + A2:2013).

- IP test in coupled position shall be done with two couplers.
- Due to the UIC position of hybrid couplers the e-coupler IP test in uncoupled position shall be repeated with the e-coupler representing applicable orientation (i.e. turned 90° upwards)

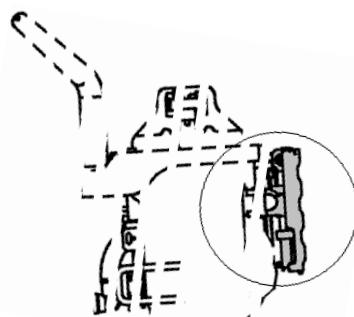


Figure 12: E-coupler IP protection test for Hybrid application

6.2.7.2 Electrical coupler endurance test

The endurance test shall consider lifecycles as defined in D5.2 wagon coupler. Coupling speeds shall be between 0,6 km/h and 5 km/h.

6.2.7.2.1 Test principle

The test shall simulate the life cycle of the mechanical e-coupler and find out the reliability of the coupler during the coupling and decoupling.

6.2.7.2.2 Test procedure

- Measurement and documentation of wear parts before final assembly (cam, plunger/lever, curve plate, contacts, gears etc.)
- 2 e-couplers to be mounted on the 2 coupler heads, or a test rig with same mechanical stop as 2 coupled couplers.
- The measurement to check signaling and voltage after the defined cycles
- After each 4 500 which include followed cycles at defined temperatures:
 - o 540 cycles at +40°C
 - o 540 cycles at - 25°C
 - o 45 cycles at - 40°C
 - o 3 375 cycles + 20°C

- Test procedure will be repeated until the service life is reached.
- After 4 500 cycles the electrical coupler endurance test to be interrupted and both electrical couplers have to be visually checked and maintained according to user manual. A resistance check shall be performed in the same cycle against the value as defined in 6.2.3.1.

6.2.7.3 Electrical coupler vibration test

Vibration test at least according to EN 61373:2010 ((identical to IEC 61373:2010), Category 2.

6.2.7.4 Electrical coupler shock test

Shock test according to EN 61373:2010 ((identical to IEC 61373:2010), Category 2 (boogie mounted equipment).

6.2.7.5 Electrical coupler EMC test

The EMC test to be done according to standard EN50121-3-2:2016

6.2.7.6 Electrical coupler test of communication and power lines

The test plans for power system and communication system can be found in chapter 10.1 and 10.2 of D 5.4 Version V3.0. The requirements to be met are listed in D 5.4 Version V3.0, Chapters 7.2 and 7.3.

6.2.8 **Actuator testing**

6.2.8.1 Functional test

Actuator device opens the locking mechanism of both couplers simultaneously.

Test procedure:

- 2 freight couplers with BP valve and actuator in each coupler to be installed into the test bench.
- Control/operation unit to be connected with the actuator and power supply. If possible, synchronization of both actuators to be aligned.
- The first decoupling test with only one actuator to be done on so called "braked couplers" no tension on couplers. Power consumption analysis on one actuator to be measured, rotation angle of the main bolt. Repeat the test 5 times.
- The second decoupling test with both actuators (synchronized) to be done on so called "braked couplers" no tension on couplers. Power consumption analysis on one actuator to be measured. Repeat the test 5 times.
- The third decoupling test with both actuators (synchronized) to be done on so called "not braked couplers" tension on couplers because of the BP valves. Power consumption analysis on one actuator to be measured. Repeat the test 5 times.
- Controller test to be done to measure signaling.

- Temperature behavior test (function from -25°C to + 40°C)
- It shall be tested, that two mating couplers can be uncoupled and kept in prevent uncoupling position. During the test the mating coupler heads shall be separated connected at least 5 times with engaging the couplers locking devices. The prevent coupling position shall be deactivated by means of an active signal.

6.2.8.2 Actuator IP test

- Check IP specification from D5.2 in uncoupled and coupled position.
- Test procedure to be taken from EN 60529:2014 (identical to IEC 60529:1989 + A1:1999 + A2:2013).

6.2.8.3 Actuator endurance test

The endurance test shall show the wear and reliability of the actuator.

The test shall simulate the life cycle of the actuator and find out the reliability of the coupler during the coupling and decoupling. Life cycles taken from D 5.2 wagon coupler.

Procedure:

- Measurement and documentation of wearing parts before final assembly.
- 2 actuators to be mounted on the 2 coupler heads, or a test rig with same mechanical stop as 2 coupled coupler.
- Check energy consumption and uncoupling time after defined cycles.
- After each 4 500 which include followed cycles at defined temperatures:
 - o 540 cycles at + + 40°C
 - o 540 cycles at - 25°C
 - o 45 cycles at - 40°C
 - o 3 375 cycles + 20°C
- Test procedure will be repeated until the service life is reached.
- After 4,500 cycles the actuator endurance test to be interrupted and both actuators have to be visually checked and maintained according to user manual.

6.2.8.4 Actuator vibration test

Vibration test at least according to EN 61373:2010

- o Category 2 (in coupler head)
- o Category 1A (on wagon)

6.2.8.5 Actuator shock test

Shock test at least according to EN 61373:2010

- Category 2 (in coupler head)
- Category 1A (on wagon)

6.2.8.6 Actuator EMC test

The EMC test to be done according to standard EN 50121-3-2:2016.

6.2.9 Environment testing

Testing & requirements acc. to SS-INSTA 851:2023

6.2.10 Interoperability testing

The test is to demonstrate Interoperability of couplers from different suppliers. In conjunction with chapter 6.2 the functionality of pneumatic, electric and mechanic coupler shall be tested. These tests shall be performed on a test bench. The wagon control unit function shall be taken or simulated.

Focus shall be:

- Correct mechanical coupling and uncoupling including gathering range.
- Correct pneumatic coupling and uncoupling.
- Correct electrical coupling and uncoupling.
- Tightness of the air and the e-coupler sealing system.
- Simultaneous uncoupling of all functions
- Manual uncoupling of the system released on both types.
- Electrical uncoupling of the system released by external control.

6.2.11 Protection against electrical hazard and Compatibility with train detection systems

The effectiveness of protective measures against indirect and direct contact and compatibility with train detection systems must be tested. The test specifications for this are defined by WP 9, D5.4 and the CENELEC working group.

7 Testing on vehicle and train level

7.1 Impact System Tests

The aim of the different impact tests is to prove the interoperable coupling scenarios on the track. Before the installation all laboratory tests must be successfully done. Those impact test are to be carried out with the following freight wagons:

- Fully loaded wagon with 90 T (i.e., Eanos)
- Fully loaded wagon with 45 T (i.e., Hbbins)
- Empty wagon with 32 T (i.e., Zagns)
- Loaded wagon with 80 T to validate the draft gear.
- Additional wagons can be applied for testing.

Different wagon type shall enable coupling test under height differences of coupler center lines (max. refer to gathering range) and shall be measured after installation before testing. Loaded wagons (80t and 90t) are used to test out the draft gear capacities under the defined impact speed conditions.

The below listed measurement equipment should be mounted on the freight wagon Hbbins or on the DAC. Interfaces (two mating DAC) of interest shall be equipped with one measuring device:

- Longitudinal force on DAC shank.
- Longitudinal DAC head displacement.
- Accelerations in the middle of the car body in all three directions.
- Pressure in brake pipe.
- Environmental temperature.
- Speed of the driving wagon.
- Coupling status of both DAC shall be documented after each coupling and uncoupling procedure.

The acceleration measurements shall be filtered with 32 Hz and all others with 100 Hz according to EN15551 E.2.

Each impact test according to Table 4 must be carried out five times and each driving tests according to Table 5 three times. During the impact tests the freight wagon Habbins is always the standing wagon. The order of the wagons shall be defined upfront and kept identical for all supplier tests.

Tests to validate the performance of non- regenerative energy absorbing devices (Cat: AX) shall be performed according to RID specification requirements. Such a test can be performed dynamically on component level. The aim is to measure the specified energy absorption and force values tested within the agreed tolerance levels.

Coupling in curve test shall be repeated with couplers aligned in:

- Nominal centered position
- Deflected position within its re-centering tolerance angle.
- Both orientations of S curves (if not available on theoretical level)

Table 4 Overview Impact Tests

Infrastructure	Used Wagons	Impact Speed
Coupling Test	Eanos and Hbbins	0.6 kph
	Hbbins and Zagns	0.6 kph
Straight Track	Eanos and Hbbins	2 kph
		8 kph
		12 kph
	Hbbins and Zagns	2 kph
		8 kph
		12 kph
	Eanos and 80 t wagon	12 kph
DAC with AX draft gear	Eanos and 80 t wagon	Impact speed defined to achieve >80% of energy absorption
DAC with AX draft gear	30 t into 80 t not braked ³	36 kph
150 m Curve	Eanos and Hbbins	2 kph
		4 kph
	Hbbins and Zagns	2 kph
		4 kph
150 m S-Curve with 6 m intermediate straight	Eanos and Hbbins	2 kph
	Hbbins and Zagns	2 kph
75 m Curve (with manual adjustment)	Eanos and Hbbins	2 kph
	Hbbins and Zagns	2 kph

Table 5 Overview Driving Tests

Infrastructure	Used Wagons	Driving
150 m Curve	All	Pulled
		Pushed
150 m S-Curve with 6 m intermediate straight	All	Pulled
		Pushed
75 m Curve	All	Pulled
		Pushed
Ramp with 2°30' inclination	All	Pulled
		Pushed

³: The weight of impacting and impacted wagons are chosen in a manner to achieve app. 80% of capacities of acting elements (2 AX draftgear types).

7.2 Running Safety Tests

Note: This test shall be performed to support the theoretical approach calculating the running safety of the wagons. As soon as the methods are developed and validated, this test shall be replaced.

Based on D5.2 the derailment safety of freight wagons with automatic couplers shall be tested accordingly:

The investigation for assessing the running safety under longitudinal compressive forces must be carried out experimentally by driving tests in S-curves.

Note: Complementary a simulation tool which will be developed in parallel can be used to perform further investigation based on theoretical figures.

Proof of the endurable longitudinal compressive force is provided experimentally by driving tests in curves. For freight wagons with side buffers and screw couplers, the test conditions for carrying out and evaluating such driving tests are specified in UIC 530-2:2008 and EN 15839:2012+A1:2015

As there is currently no defined test procedure for wagons with automatic coupler, they are tested according to the same test procedure as wagons with side buffers. The freight wagons will have automatic couplers instead of side buffers and screw couplers.

The test track and the wagon configuration can be seen in the following Figure 12.

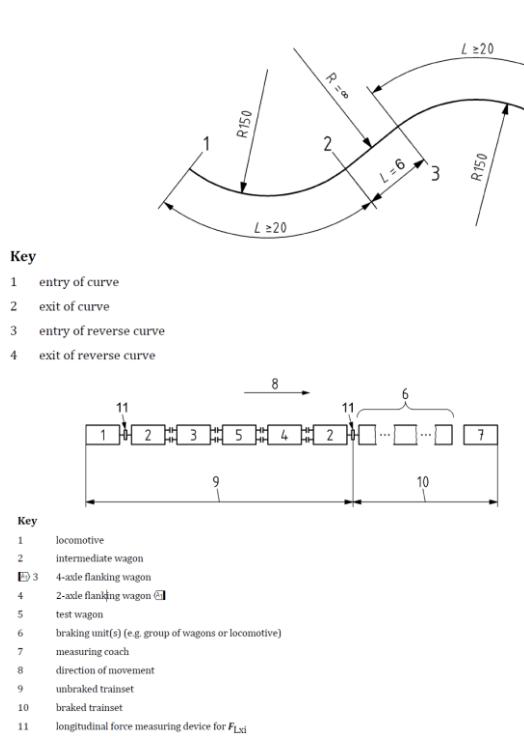


Figure 13: Layout of the test track and example for a test train configuration based on EN 15839

Preconditions:

- The test shall be performed on a standardized reference track geometry. As an alternative the used track shall be measured against the reference track. Deviation from standard and its influence on expectable test result shall be described and considered.
- The positions of the wheels of the test wagon along the test track must be clearly determined during the tests. Wheel geometry shall be compared against applicable standard.
- The coupler angles of the test vehicle relative to the longitudinal axis of the vehicle must be measured during the tests.
- The torsional stiffness of the test wagon must also be determined experimentally before the tests. For this purpose, the torsion diagram of the test wagon must be drawn up.

During the first driving tests, an attempt must be made to identify tendencies for changes in the wheel forces in the range from 0 to 600 kN and stopped before a derailment is initiated. The derailment criteria must be evaluated simultaneously during the tests. At least 20 suitable tests to be carried out where at least 10 of these tests, the minimum endurable longitudinal compressive force of 500 kN should be exceeded by 10 %.

7.3 Interoperability Tests

To prove the interoperability between to different DAC types, the described tests in the chapters 7.1 and 7.2 shall be done with a DAC from at least one other supplier.

7.4 Installation Tests

To prove the installation of the DAC on a freight wagon type the following points should be verified.

- Measurement of the UIC pocket based on sketch in D5.2; 6.5.1 Figure 4.
- Measurement of the weight of the following components
 - Draft gear incl. fixing material (spacer, plates, screws)
 - Vertical support incl. fixing material
 - Coupler head including electric coupler
 - Manual uncoupling including all fixing material
- Record all necessary preparation work at the freight wagon like rework activities or movement of brake pipe connection.
- Evaluation of the needed special assembly tools like lifting devices or other needed tools
- Measurement the necessary DAC installation time by two people
- Measurement the needed time for replacement of DAC head with and without electric coupler by two people

7.5 Uncoupling tests

7.5.1 General

Described uncoupling tests for wagons and Locos shall be performed under different operational conditions as stated below:

- a) Flat yard shunting: Wagons are in stand still situation, braked or without pressure (secured with brake shoe). This test has to be performed in straight track and specified curve geometries the wagon shall pass.
- b) Hump yard shunting: Wagons will be pushed over the hump. Manual uncoupling can be performed up to speeds of max. 5,6 km/h. Remote uncoupling can be tested up to max operational speed of the yard.
- c) Fly shunting: Wagons will be pushed away by the loco.
- d) With wagons containing swapping loads

7.5.2 Manual uncoupling tests

Manual uncoupling and prevent coupling position shall be tested up to a maximum wagon speed of 5,6 kph. The manual uncoupling shall be tested under all conditions defined in 6.5.1. Wagons must not be under tension load.

To be checked:

- Force to uncouple two couplers (only straight track).
- Safe uncoupling in specified track geometries
- Safe ergonomic to uncouple two couplers with wagons in motion.
- Safe engagement of prevent coupling position.
- Prevent coupling position shall be held in case of interruptions during shunting operations.
- Check that when releasing the prevent recoupling position the coupler head will return to ready to be coupled position.
- Repeat the test 10 times.

7.5.3 Remote uncoupling tests

Remote uncoupling and prevent coupling position shall be tested up to a maximum operational wagon speed. The remote uncoupling shall be tested under all conditions defined in 6.5.1. Wagons must not be under tension load.

To be checked:

- Time to uncouple two couplers (only straight track, $\leq 3s$)
- Safe uncoupling in specified track geometries
- Safe ergonomic to uncouple two couplers with wagons in motion.
- Safe engagement of prevent coupling position.
- Prevent coupling position shall be held in case of interruptions during shunting operations.
- Test release function of the prevent coupling position (the coupler head will return to ready to be coupled position)
- Repeat the test 10 times.

The remote uncoupling test shall be performed with increasing tensile loads up the system limit (uncoupling cannot be completed)

- Load steps 10 kN
- Flat yard shunting on straight track (standstill wagons)

7.6 Communication and power lines tests.

Test requirements for train lab test to be added based on WP9 definition.

7.7 Functional tests under severe environmental conditions

Coupler train tests under different environmental conditions shall be performed using Demo trains running in different climatic areas (Sweden, Switzerland, Austria, Italy...). Special focus shall be made to the electrical coupler. The electrical coupler shall be tested as type test.

8 Hybrid coupler testing

- The definitions of testing are in accordance with the requirements provided within draft for CEN standardization about the DAC and shall be applicable to show product compliance to characteristics specified in D 5.2.
- Full functional interoperability between Hybrid – Hybrid and Hybrid – wagon according to chapter 6 are to be performed.

8.1 Lab strength testing

8.1.1 Static tension test

Test procedure tension load

- 2 coupler heads have to be coupled and preloaded at approximative 30 kN to stabilize the overall structure (EN 16019:2014).
- The measurement equipment is to be reset to 0.
- Increase the force in min. 200 kN steps with a minimum of 3 steps in total up to 1 000 kN and hold the force for 1 min. Repeat the procedure 2 times (EN 16019:2014, chapter chapter 5.1.2).

The maximum compression load shall not cause permanent deformation ($\leq R_{p0,2}$ limit) of the coupler head. (EN 16019:2014)

After applying and removing the maximum compressive load, the coupler locks of the coupler heads shall move freely.

Draft gear tests shall be made accordingly but as a separate module.

8.1.2 Static compression test

- 2 coupler heads must be coupled and preloaded at approximative 30 kN to stabilize the overall structure. (EN 16019)
- The measurement equipment is to be reset to 0.
- Increase the force in min. 200 kN steps with a minimum of 3 equal steps up to 2 000 kN and maintain the maximum force for 1 min. Apply the maximum force twice (EN 16019:2014, Chapter 5.1.2).
- The maximum compression load shall not cause permanent deformation ($\leq R_{p0,2}$ limit) of the coupler head. (EN 16019:2014).

Draft gear tests shall be made accordingly but as a separate module.

8.1.3 Fatigue load test

The fatigue strength test shall demonstrate that the DAC can withstand the specified loads until the end of the target service life. The main components of the DAC that are in the main force flow (up to 1 000 kN in tension and 2 000 kN in compression) during travel and coupling operations must have a service life of 30 years if the appropriate maintenance is observed.

The description of the experimental proof for a service live of 30 years is as follows.

The service life is to be verified with a fatigue test. The tests are carried out on unloaded/untested coupler front parts and draft gear. Tests can be carried out on a complete system or on partial components. Spring elements can be replaced by spacers. The force applied onto the test objects has to be induced according to the force flow in the complete DAC. Strain gauges must be applied to positions with expected high strains and stresses according to FEA results.

The procedure for the fatigue strength test of the DAC is based on the procedure for testing the screw coupler according to Annex A, EN 15566:2022. The following test steps, which are carried out one after the other, must be observed during the dynamic testing of the DAC:

- The fatigue test must be carried out on three samples of the DAC components.
- Conditioning of the DAC with a tensile force equivalent to approximately 60% of the minimum breaking load).
- Non-destructive testing: Before the endurance test, the DAC must pass a magnetic particle test or dye penetrant test according to EN 10228-1:2016 and EN 10228-2:2016. Any sign of a surface defect that appears must be recorded in size and shape.
- Dynamic testing on DAC head:
 - o Stage 1: $\Delta F_1 = 0 \text{ kN} \pm 300 \text{ kN}$ and $N_1 = 1,5 \times 10^6$ cycles
- Dynamic testing on screw coupler against 10 years:
 - o Stage 1: $\Delta F_1 = + 300 \text{ kN}$ and $N_1 = [0,5 \times 10^6]^4$ cycles
 - o Stage 2: $\Delta F_2 = + 1 015 \text{ kN}$ and $N_2 = [720]^4$ cycles (load cycle to be checked)

⁴: load cycles to be reviewed

In the dynamic test, the load changes of "Stage 1" must be interrupted at regular intervals by load changes of "Stage 2". The "Level 2" load changes can also be combined into blocks (by dividing the total number of load changes into at least 30 blocks). The load frequency should not exceed 4 Hz.

- Non-destructive testing after the endurance test

- Analysis of the residual strength by carrying out a static test. 95% of the minimum breaking load must be withstood for three minutes. No fracture of test component shall be allowed
- Macroscopic and microscopic tests according to the specifications in Annex E, EN15566:2022

Note: Each individual test must be performed in a single laboratory. EXAMPLE: Dynamic tests from start to finish shall be carried out in one laboratory.

Wear parts are to be exchanged during the test.

The hybrid coupler with its draft gear must undergo the same tests with regard to strength and service life as the DAC. For the UIC mode, the screw coupler must be tested using the test method according to EN15566:2022.

8.2 Test of specific coupler functions

8.2.1 DAC mode

All functional test in DAC mode shall be carried out as specified for the wagon DAC in chapter: 6.3; 6.4; 6.5; 6.7; 6.8.

8.2.2 Impact tests in DAC mode

This test is to be carried out with the individual locomotives equipped with hybrid couplers. Before the installation all laboratory tests for strength, freedom of movement and energy absorption capacity must be successfully completed. This coupling test is performed with a fully loaded 90-ton freight car, not braked (secured with brake shoe app. 2 m behind interfering wheel)

Height differences of coupler center lines shall be measured after installation before testing.

The below listed measurement equipment should be mounted on the locomotive or on the Hybrid coupler:

- Longitudinal force on DAC shank
- Longitudinal DAC head displacement
- Accelerations inside the driver's cab in all three directions
- Pressure in brake pipe
- Environmental temperature
- Speed of the locomotive
- Coupling status of both DAC shall be documented after each coupling and uncoupling procedure

Each impact test according to table 6 must be carried out five times. During the impact tests the freight wagon is always the standing wagon. The standing wagon it is not braked.

Tests to validate the performance of non- regenerative energy absorbing devices shall be performed according to OEM specification. Such a test can be performed dynamically on component level. The aim is to measure the specified energy absorption and force values tested within the agreed tolerance levels.

Table 6 Overview Impact Tests in DAC mode

Infrastructure	Impact Speed
Straight Track	2 kph
	5 kph
	7 kph*
150 m Curve	2 kph
	4 kph
75 m Curve	2 kph

**Note: 7 kph is an exceptional impact case to test out max draft gear capacity. No operation speed.*

8.2.3 Driving tests in DAC mode

Driving tests according to Table 8 must be carried out three times. Depending on the tested locomotive, these driving tests must be carried out with a freight wagon that represents an unfavorable wagon combination in terms of the coupler deflection angle in the curve of the track. In these tests, longitudinal forces, strokes, coupler angles and driving speed are to be measured.

If tracks are not available for testing the DAC mode performance, a theoretical investigation shall be provided to ensure the locos are safely operating in specified track conditions.

Table 7 Overview Driving Tests in DAC mode

Infrastructure	Driving
150 m Curve	Pulled
	Pushed
150 m S-Curve with 6 m intermediate straight	Pulled
	Pushed
75 m Curve	Pulled
	Pushed
Ramp with 2°30' inclination	Pulled
	Pushed

8.3 Tests in UIC mode

8.3.1 Coupling tests in UIC mode

Manual coupling tests are to be carried out in straight track and in a 150 m curved track. To do this, the screw coupler of the hybrid coupler must be attached to the towing hook of a freight car. The buffer plates must be clamped so that they touch. The activities and body movements to be carried out, which are necessary when coupling, must be documented, and described in pictures.

8.3.2 Driving tests in UIC mode

Driving tests in UIC mode as listed in the table are to be carried out in curved tracks. The tensile forces in the screw coupler are to be measured.

Table 8 Overview Driving Tests in UIC mode

Infrastructure	Screw coupler	Driving
150 m Curve	Screw coupler in short position (buffers touch in straight track)	Pulled
		Pushed
150 m S-Curve with 6 m intermediate straight	Screw coupler in short position (buffers touch in straight track)	Pulled
		Pushed
75 m Curve	Screw coupler in long position	Pulled
		Pushed
Ramp with 2°30' inclination	Screw coupler in long position	Pulled
		Pushed

8.4 Change between "DAC" and "UIC" mode

In this experiment, switching from DAC mode to UIC mode and vice versa is tested.

All activities to be carried out to implement the change must be described and documented using images. The force and time required for manual operation must be determined.

It shall be ensured that the free working space is not infringed, or the infringement does not lead to dangerous operational procedures. This can be done by proofing if the real working space is infringed when a mockup of the defined working space is moved in. If 3D data are available a check in 3D is applicable as well.

9 Conclusions

This test specification is prepared to generally describe necessary tests along the Technical Specification of Wagon and Locomotive DAC up to level 5 (D5.2). The results of these tests are to be used to verify compliance with the type, functional and interoperability requirements for DAC and the hybrid coupler at component, vehicle and train level.

Within the framework of Quality Gate 1 and 2, initial results of some of the validation measures presented here, which are used to validate the requirements selected by the operators, will be presented for evaluation. Quality Gate 1 has already taken place, and Quality Gate 2 will begin in September 2025. As specified in the grant agreement "the operators will verify that the functional requirements meet the use case, specification and the set of the test procedures are sufficient for qualifying and certifying the equipment for train integration". Mercitalia Rail, Rail Cargo, SNCF, Trafikverket, VTG, Deutsche Bahn, UIP, GATX are the operators involved in Quality Gate 1 and 2. After Quality Gate 2 and the completion of further tests relating to communication and electrical power systems, the list of tests required for the qualification and certification of the component for safe integration into the train will be determined.

To achieve TRL 9 a series of test is to be performed giving evidence, that the products meet the specified requirements.

Test results from all 3 level tests shall be documented and evaluated against clear pass/fail criteria. The objective of the document is to provide a general guidance through type-, functional and interoperability tests to be performed and specified in detail for each specific test examination.

The methodology is to achieve different approval level, enabling the products being safely used for the next complexity level, means types tests qualify for wagon tests, qualify for train tests, qualify for demo trains on public track. In addition to supplier specific tests, the aim is to test out full functional interoperability between different suppliers interacting safely.

Some functional tests are depending on the availability of infrastructure and applicable rolling stock. Climate conditions shall be tested in parallel running demo trains in the specific countries but cannot be fully covered in a train lab or test bench.

This specification shall be updated based on lessons learned from real test performances and or based on changes on defining specification or standards. To ensure this, DAC suppliers accompany the tests in the train test lab and on the demo trains. Weekly meetings are held between DAC suppliers to discuss topics such as interoperability functions and unwanted test incidents.

10 References

- D 2.1 Operational procedures
- D 5.2 Technical Specification of Wagon and Locomotive DAC up to level 5
- CEN EN_DAC 2023 (WI 00256A0K)
- UIC530-1:1982 Constructional conditions for wagons to be observed with a view of fitting the automatic coupler of the member railways of the UIC and OSJD respectively
- EN 50125-1:2014-11 Railway applications - Environmental conditions for equipment - Part 1: Rolling stock and on-board equipment
- EN 50125-2:2003-07 Railway applications - Environmental conditions for equipment - Part 2: Fixed electrical installations
- EN 50125-3:2003-10 Railway applications - Environmental conditions for equipment - Part 3: Equipment for signalling and telecommunications
- prEN 18171:2025 Railway applications - Railway rolling stock - Digital freight automatic coupler - Performance requirements specific interface geometry and test method
- EN ISO 9227:2022 Corrosion tests in artificial atmospheres - Salt spray tests
- EN 45545-2:2016 Fire protection on railway vehicles –
Part 2: Requirements for fire behavior of materials and components
- EN 16019:2014 Railway applications - Automatic coupler - Performance requirements, specific interface geometry and test method
- EN 14601:2024 Railway applications - Straight and angled end cocks for brake pipe and main reservoir pipe
- EN 60512-2-1: 2002 (identical to IEC 60512-2-1:2002) Connectors for electronic equipment - Tests and measurements - Part 2-1: Electrical continuity and contact resistance tests; Test 2a: Contact resistance; Millivolt level method
- EN 60529:2014 (identical to IEC 60529:1989 + A1:1999 + A2:2013) Degrees of protection provided by enclosures (IP Code)
- EN 12663-2:2010 Railway applications – Structural requirements of railway vehicle bodies – Part 2: Freight wagons
- EN 12663-1:2010 Railway applications – Structural requirements of railway vehicle bodies – Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons
- EN15566:2022 Railway applications – Railway Rolling stock – Draw gear and screw coupling

- EN 10228-1:2016 Non-destructive testing of steel forgings - Part 1: Magnetic particle inspection
- EN 10228-2:2016 Non-destructive testing of steel forgings - Part 2: Penetrant testing
- UIC 524:1978 Wagons - Technical specifications governing spring devices for wagons fitted with automatic couplers belonging to the UIC and OSJD member railways
- EN15551:2022 Railway applications – Railway rolling stock –Buffer
- EN 61373:2010 ((identical to IEC 61373:2010) Railway applications - Rolling stock equipment - Shock and vibration tests
- EN 50121-3-2:2016 Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock – Apparatus
- SS-INSTA 851:2023 Railway applications - Environmental conditions - Design guidance for rolling stock for severe winter conditions
- EN 15839:2012+A1:2015 Railway applications – Testing for the acceptance of running characteristics of railway vehicles – Freight wagons – Testing of running safety under longitudinal compressive forces
- UIC 530-2: 2008 Wagons – running safety
- IEEE 802.3 ETHERNET WORKING GROUP
- EN 15227:2020 + +A1:2024 Railway applications - Crashworthiness requirements for rail vehicles

Listed standards are to be considered as valid version applicable on the date testing is performed.

11 Appendices

The appendix will be used to collect open topics, which cannot be defined in this document due to not finalized requirements of the specification.

Table 9 List of open topics

No	Topic	Input from	Status
1	Reliability test of products need more input. Figures can be tested by operating the Demo trains or pre-deployment trains	WP 4/WP2	See Chapter 1
6.2.2.1	System air pressure leakage test on train level is not specified in current version. Based on EN 15355	WP 14	rejected. Lab test shall be appropriate to validate new component of DAC
6.2.2.2	Check venting time requirement based on picture 11-01		Detailed in D 5.2. Here only referenced
6.2.3.2	Contact performance test i.e. resistance, voltage drop, durability.....shall be added.	WP 9	added
6.2.4.4	Demonstration of safe brake pipe valve function shall be defined	WP 4/WP 6	Not applicable in 6.2.4.4. Now open pipe
6.2.7.2.2	Communication and power lines tests to be specified. Go/no go criteria to be defined.	WP 9	In D 5.4
6.2.5.2	New values based on derailment safety >500 kN	WP6	Figures checked. Detailed chapter in 7.2 (train level)
6.2.7.2.2	Go/NoGo electrical value shall be specified (e.g. max Rc value)	WP9	See 6.2.3.2
7.5	Uncoupling tests: More test cases needed? More details needed?	WP2	Test demand for D 5.3 is complete
7.7	Test requirements for train lab test to be added based on WP9 definition.	WP9	Covered in D 5.4
8.1.3	Load cycles for screw coupler test to be reviewed	WP6	Done, cycles are correct
8	Noise: To be discussed with experts/operators - kept open in appendix.	WP8	No action planned
8.4	Berne rectangle definition and testing for Hybrid coupler open	WP8	Added + new wording

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★ 3.2 - In a service brake application the reduction in pressure down to the required level must be effected smoothly and gradually. During a full service brake application the drop in pressure must be achieved in such a way that pressure in a 25 litre reservoir taking the place of the main brake pipe falls by 1.5 bars in 6-10 seconds (see verification diagram in Appendix 2).

During a full service brake application the air releasing capacity of the driver's brake valve must be such that the pressure contained in a 400 litre reservoir, connected instead of the main brake pipe, falls by 1.2 bars within a maximum of 10 s.

★ 3.3 - In the service brake application range the compensatory air flow must maintain a constant pressure in the main brake pipe at each braking step when an outlet with 4 mm aperture is opened in the same way as for the running position (see point 2.2.2).

★ 3.4 - During an emergency brake application, air must be released into the atmosphere from the main brake pipe by some form of direct mechanical action which opens up large outlets. The air releasing capacity of the driver's brake valve must be such that the pressure contained in a 400 litre reservoir, replacing the main brake pipe falls by 1.5 bars in a maximum of 2.5 s (see verification diagram in Appendix 2).

Figure 15: Topics for (emergency) brake application