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# Pushback Couplers in Passenger Rail Equipment

Abstract: This *Recommended Practice* contains design and testing requirements for inclusion of pushback couplers on passenger rail equipment.

Keywords: passenger rail, pushback couplers

Summary: This document recommends minimum requirements for inclusion of pushback couplers on passenger rail equipment in order to improve the crashworthiness of passenger rail vehicles during collisions. All values in this document are provided in English units, which shall be used for calculations and testing. Metric equivalents are provided for reference only.

Scope and purpose: This document applies to pushback couplers and retrofit pushback couplers installed on locomotive-hauled equipment (cab cars, trailer cars), new retrofit, and multiple unit (MU) cars intended for use on the general railroad system of the United States. It does not apply to non-passenger-carrying locomotives and power cars. It is expected that carbody structures that meet the carbody strength requirements of APTA CS-S-034-99, Revision 2, can support pushback couplers designed to the requirements defined in this *Recommended Practice*.

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The American Public Transportation Association greatly appreciates the contributions of Karina Jacobsen, who provided the primary effort in the drafting of this *Recommended Practice*.

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## Introduction

(This introduction is not a part of APTA PR-CS-RP-019-11, *Recommended Practice for Pushback Couplers in Passenger Rail Equipment*.)

This Recommended Practice for Pushback Couplers in Passenger Rail Equipment represents a common viewpoint of those parties concerned with its provisions, namely, transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any standards, practices or guidelines contained herein is purely voluntary. In some cases, federal and/or state regulations govern portions of a rail transit system's operations. In those cases, the government regulations take precedence over these recommended practices. APTA recognizes that for certain applications, the standards or practices, as implemented by individual rail transit systems, may be either more or less restrictive than those given in this document.

This recommended practice describes the minimum requirements for inclusion of pushback couplers on passenger rail equipment in order to improve the crashworthiness of passenger rail vehicles during collisions.

# Pushback Couplers in Passenger Rail Equipment

## 1. Design requirements

### 1.1 General

The requirements of this *Recommended Practice* are intended to result in the inclusion of pushback, energy-absorbing couplers that bring the end frames together during a collision and minimize vertical and lateral motions between coupled cars and impacting cars. All existing requirements and functions for conventional couplers shall still be met unless otherwise specified.

The pushback coupler shall include a frangible structural element to trigger the pushback feature and energy-absorption structural elements.

### 1.2 Coupler design requirements

Couplers shall meet the requirements of 49 CFR 238, APTA PR-CS-S-034-99, Revision 2, as well as this *Recommended Practice*. The couplers shall be designed and manufactured to comply with all the requirements and guidelines of APTA PR-M-RP-003-98 or other related standard per coupler type, unless otherwise specified.

In addition, the coupling mechanism shall provide the following functions:

- Release at a compressive force level no greater than 800,000 lbf (3559 kN) and push back to permit anti-climbing mechanisms or end frames of colliding equipment to engage.
- Absorb energy in a controlled manner while pushing back. A controlled manner means that the deformation sequence experienced by the pushback coupler follows a prescribed sequence of deformations, i.e. progressive collapse from the front to the rear of the pushback coupler.
- Provide climb resistance compliant to APTA-PR-CS-S-034-99, Revision 2, for CEM equipment.
- Provide coupler buff strength greater than the release force level of the pushback function.
- Provide coupler draft strength greater than the maximum design draft loads of the specific application.
- The coupler shall be capable of supporting a minimum 150,000 lbf (667 kN) draft/tension load for any value of pushback including after exhaustion of the pushback function. This will enable limp-home capability for the equipment and prevent the train from experiencing undesired separation of cars during the event or when being towed back to a repair facility.
- Provide torsional resistance of ±150,000 ft · lbf (203 m · kN) torsion before pushback function. This load is intended to help keep cars upright and in-line for minor derailments. Rollover in more series incidents is addressed through the push back function and interlocking of car ends. There is a related requirement in APTA PR-CS-S-034-99 (Revision 2) Section 5.5.2.3 for Overturn Resistance that ties the torsional strength of the coupler and the strength of the coupler pocket. The coupler is intended to fail prior to damaging the carbody structure.
- Provide a centering function to maximize the probability of coupler engagement.
- The uncoupling mechanism should be designed to accommodate the complete pushback motion of the coupler without unintentional activation of the coupler lock mechanism causing car separation.




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There shall be no permanent deformation of the coupler support structure prior to exhausting the pushback stroke.

Indicators shall be provided that shall be visible from outside the car to indicate full or partial activation of the energy absorption unit and the need for its replacement. The activation of the energy absorption unit shall be readily apparent when performing periodic inspections.

# 2. Validation of design

## 2.1 General

Pushback coupler design validation shall be provided through analysis and testing described in the following sections. The analyses are required to demonstrate the required features of the pushback coupler function, both in typical service operation and under collision conditions. Compliance shall be demonstrated by meeting acceptance criteria for the specified evaluation scenario.

Testing of the pushback coupler is required to validate the pushback coupler design. The tests as described demonstrate that the pushback coupler meets minimum energy absorption and the initiation load requirements. Existing test data for the proposed design may be submitted by the coupler supplier and considered by the purchaser to fulfill the testing requirements.

## 2.2 Analysis

The pushback coupler analyses for each car end shall include as a minimum the analyses included in **Table 1**. The analysis shall be provided for the respective passenger equipment based on the appropriate evaluation scenario provided in Section 2.2.1. The following shall be analyzed:

TABLE 1: Pushback Coupler Analyses Matrix

| Analysis | Type | Level | Input Parameter | Criterion |
|---|---|---|---|---|
| Service operation | Collision dynamics using 1-Dimensional lumped-mass model | Train | 5 mph (8 km/h) impact for evaluation scenario | No PBC initiation |
| PBC exhaustion | Collision dynamics using 1-Dimensional lumped-mass model | Train | 12 mph (19.3 km/h) impact for evaluation scenario | Maximum load does not exceed the carbody crippling load |
| Retention | Structural loads[1] | Car | 150,000 lbf (667 kN) draft for any value of pushback | Resist draft load without failure |
| Torsional resistance | Structural loads[1] | Car | 150,000 ft · lbf (203 m · kN) torque before push back | Resist torsional load without failure |

The general requirements and the analyses described above define the minimum level of analyses required to demonstrate the performance of the pushback coupler in typical operation and for an idealized collision scenario. Additionally, analyses need to show that the attachments and support structure are strong enough to sustain the peak load transmitted from the pushback coupler. The carbody crippling load is assumed to be 1.6 million lbf (7,117 kN) for all equipment that meets the 800,000 lbf (3559 kN) buff strength requirement, else

[1] Structural loads analyzed using either analytical or finite element analysis solution




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the crippling load will be provided by the car manufacturer through a large-deflection analysis of its design with a flat rigid-barrier analysis.

### 2.2.1 Evaluation scenario

The train-level pushback coupler evaluation scenario shall be an idealized in-line train-to-train collision as follows:

1. Equipment:
    a) An initially moving train consisting of:
        i) One leading cab car, four trailer cars and one conventional locomotive. Cab cars and trailer cars shall be assumed to be fitted with the pushback energy-absorbing coupling mechanisms required in Section 1;

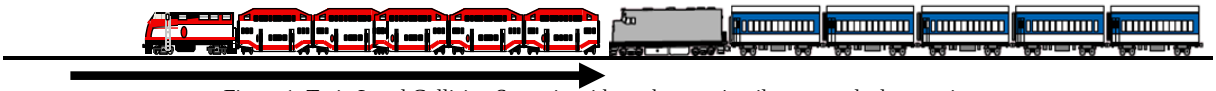

Figure 1: Train Level Collision Scenario with a cab car + 4 trailer cars and a locomotive

OR

        ii) Six MUs. The MUs shall be assumed to be fitted with the pushback energy-absorbing coupling mechanisms on both ends of each car as required in Section 1.

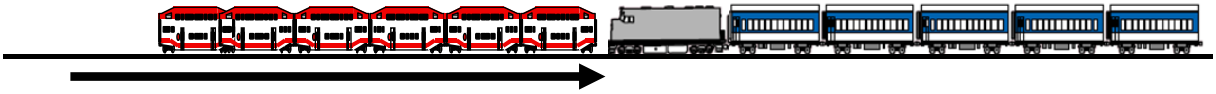

Figure 2: Train Level Collision scenario with a six MUs

    b) An initially standing train consisting of one leading conventional locomotive followed by a conventional train consist of equal mass to the initially moving train consist. The lead conventional locomotive shall be idealized as a rigid body with a draft gear.
    c) Weight definitions:
        i) For cab cars, trailer cars and MUs, use maximum ready-to-run AW0 car weights; and
        ii) Assume a conventional locomotive weight of 260,000 lbm.

2. Initial conditions:
    a) Level, tangent track.
    b) Impact closing speed of:
        i) 5 mph (8 km/h); and
        ii) 12 mph (19.3 km/h).
    c) Standing train brakes applied at full service.
    d) Moving train brakes applied at emergency.

3. Model and analysis:
    a) A 1-Dimensional, lumped parameter analysis is required where the non-linear spring characteristics represent the force-crush characteristics of the pushback coupler and the supporting carbody structure up to and including crippling of the carbody.




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4. Results:
   a) 5 mph (8 km/h) service analysis: Deformation of each car end is limited to the elastic response of the draft gear.
   b) 12 mph (19.3 km/h) PBC exhaustion analysis: Each carbody's crippling load in the trainset shall not be exceeded.

## 2.3 Testing

### 2.3.1 General

The coupler supplier may submit existing measurements from previously conducted tests of the specific pushback coupler design being proposed, for review and approval by the purchaser to fulfill of the following testing requirements.

In lieu of existing test data, tests shall be conducted to validate the pushback coupler design. This shall include one dynamic or quasi-static test as appropriate of each type of coupler and structural absorber to validate the design of each of the absorbers. The principal objective of these tests shall be to measure the force/crush characteristics of the coupler and structural energy absorbing elements, including the initiation load and the energy absorption capability of the pushback coupler design. Full-sized elements shall be tested.

### 2.3.2 Pushback coupler tests

The pushback coupler tests shall include, as a minimum, the tests included in **Table 2**. If the criterion can be effectively demonstrated, then a single test may be conducted for the energy absorption and initiation load requirements.

TABLE 2: Pushback Coupler Test Matrix

| Test | Type | Input Parameter | Criterion |
|---|---|---|---|
| Energy absorbed | Dynamic or quasi-static | Energy absorption | Minimum target value |
| Initiation load | Dynamic or quasi-static | Initiation load | Does not exceed 800,000 lbf (3559 kN) |

The purchaser shall decide on the energy absorption minimum target value before the conduct of the test.

For each element to be tested, the test plan shall include a description of the element to be tested, a description of required test fixtures, the conditions under which the test will be conducted and the data to be measured.

### 2.3.3 Pushback coupler test procedure

The test procedure shall be prepared for each test in step-by-step detail and shall include details of the test fixtures, instrumentation, data acquisition system and pass-fail criteria. For each test, approval by the purchaser of the pushback coupler test plan and the specific procedure is required prior to starting the test.

### 2.3.4 Pushback coupler tests

Perform each test in accordance with the procedure as noted in 2.3.3. The result shall be a force-displacement plot. Sufficient data shall be gathered to determine peak and average force measurements. Photograph each test article before and after testing, as well as at intermediate steps to ensure deformations occur in a controlled manner. Sufficient additional data and measurements shall be taken to evaluate modes of crush, strains and accelerations (sub-assembly acceleration). Each dynamic test shall be documented with high-speed

 

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cameras. The record of the test shall be provided digitally on optical media, CD-ROM or DVD or as determined by the purchaser.

### 2.3.5 Evaluation of results

Compare the force/crush characteristic from test with analytical predictions. Average force, peak force and force and displacement histories shall be compared. Modes of crush, strains and accelerations shall also be compared. The criterion as defined in **Table 2** shall be the requirements for demonstrating compliance of the design based upon test results.

## 3. References

This document shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

49 CFR, Part 229, Body structure, MU locomotives

49 CFR, Part 238, Passenger Equipment Safety Standards, Subpart C, Specific Requirement for Tier I Passenger Equipment.

American Public Transportation Association:

*Rail Standard*, APTA SS-C&S-034-99, "Design and Construction of Passenger Railroad Rolling Stock"
*Recommended Practice*, APTA PR-M-RP-003, "Purchase and Acceptance of Type H Tightlock Couplers"
*Recommended Practice*, APTA PR-M-RP-004-98, "Secondhand and Reconditioned Type H Tightlock Couplers"
*Recommended Practice*, APTA PR-M-RP-001-97, "Air Connections, Location and Configuration of, for Passenger Cars Equipped with AAR Long Shank Tight Lock or Similar Long Shank Type Couplers"

## 4. Definitions

crippling load: The ultimate strength of the occupant volume.

multiple unit (MU) car: A diesel multiple unit (DMU) or an electric multiple unit (EMU), with or without traction motors.

1D lumped-mass model: A collision dynamics model for which each railcar is represented by a spring-mass system and is constrained to move longitudinally along the tracks.

pushback coupler (PBC): A coupler that meets all requirements and functions of traditional couplers during operation and service, but additionally includes a retractable feature that activates at a given load and absorbs energy during pushback.

**flat rigid-barrier analysis:** For conduct of carbody crippling analysis a simplified boundary condition may be assumed where the carbody is squeezed between two platens up to the maximum load the car can sustain.

 

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## 5. Abbreviations and acronyms

| | |
|---|---|
| CEM | crash energy management |
| APTA | American Public Transportation Association |
| CFR | Code of Federal Regulations |
| EMU | electric multiple unit |
| DMU | diesel multiple unit |
| Km/h | kilometers per hour |
| kN | kilonewton |
| lbf | pound-force |
| lbm | pound-mass |
| mph | miles per hour |
| MU | multiple unit |
| PBC | pushback coupler |




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