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Table 4-1 Structural Load Requirements for Light Rail Vehicles (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|-------------|--------------------------|---|--|
| 7 | Corner post shear | Load of 133 kN (30,000 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stress in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 67 kN (15,000 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Load of 67 kN (15,000 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways. | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection. |

Table 4-1 Structural Load Requirements for Light Rail Vehicles (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|--------------------------|---|--|
| 7 | Corner post shear | Load of 133 kN (30,000 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stress in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 67 kN (15,000 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Load of 67 kN (15,000 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways. | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection. |

Table 4-1 Structural Load Requirements for Light Rail Vehicles (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|--------------------------|---|--|
| 7 | Corner post shear | Load of 133 kN (30,000 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stress in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 67 kN (15,000 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Load of 67 kN (15,000 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways. | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection. |

Table 4-2 Structural Load Requirements for Streetcars (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|-----------------------------|---|--|
| 7 | Corner post shear load | Load of 100 kN (22,500 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stresses in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 50 kN (11,250 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Longitudinal load of 50 kN (11,250 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall load at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall load at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection |

Table 4-2 Structural Load Requirements for Streetcars (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|-----------------------------|---|--|
| 7 | Corner post shear load | Load of 100 kN (22,500 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stresses in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 50 kN (11,250 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Longitudinal load of 50 kN (11,250 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall load at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall load at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection |

Table 4-2 Structural Load Requirements for Streetcars (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|-----------------------------|---|--|
| 7 | Corner post shear load | Load of 100 kN (22,500 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stresses in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 50 kN (11,250 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Longitudinal load of 50 kN (11,250 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall load at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall load at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection |

Table 4-2 Structural Load Requirements for Streetcars (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|-----------------------------|---|--|
| 7 | Corner post shear load | Load of 100 kN (22,500 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stresses in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 50 kN (11,250 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Longitudinal load of 50 kN (11,250 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall load at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall load at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection |

Table 4-2 Structural Load Requirements for Streetcars (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|-----------------------------|---|--|
| 7 | Corner post shear load | Load of 100 kN (22,500 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stresses in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 50 kN (11,250 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Longitudinal load of 50 kN (11,250 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall load at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall load at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection |

Table 4-2 Structural Load Requirements for Streetcars (Cont'd)

| Item | Type of Load | Specified Load | Acceptance Criteria |
|------|-----------------------------|---|--|
| 7 | Corner post shear load | Load of 100 kN (22,500 lb) applied to each corner post (or corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height measured from the top of end frame | Stresses in the carbody structure and corner post to be less than ultimate strength |
| 8 | Corner post elastic load | Load of 50 kN (11,250 lb) positioned at 380 mm (15 in.) above top of end sill applied to each corner post (corner structure) over a surface area of the corner post in separate longitudinal (inward) and transverse (inward) directions (a) load application direction variation permitted within 15 deg on either side of longitudinal (inward) or 15 deg on either side of transverse (inward) (b) the applied load area shall not exceed 250 mm (10 in.) in width nor 150 mm (6 in.) in height centered on the point of loading | No permanent deformation of any member, structural sheathing, or connection |
| 9 | Structural shelf | Longitudinal load of 50 kN (11,250 lb) applied at any point in the longitudinal (inward) direction (a) area of load application shall not exceed 250 mm × 150 mm (10 in. × 6 in.) (b) load direction variation permitted within 15 deg on either side of longitudinal (inward) | No permanent deformation of any member, structural sheathing, or connection |
| 10 | Side wall load at side sill | Load of 178 kN (40,000 lb) applied in transverse (inward) direction at the side sill, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No permanent deformation of any member, structural sheathing, or connection. Localized deformation of the side wall profile in the area of the application is permitted. |
| 11 | Side wall load at belt rail | Load of 44 kN (10,000 lb) applied in the transverse (inward) direction at the belt rail, and distributed along an area of 2.4 m × 150 mm (96 in. × 6 in.), not including the doorways | No more than 75 mm (3 in.) of permanent structural deformation into the vehicle interior. This load shall not result in edges or protrusions of vehicle structure within the vehicle interior. |
| 12 | Roof, concentrated load | Load of 1.330 kN (300 lb) spaced over area of 380 mm × 330 mm (15 in. × 13 in.) | No permanent deformation of any member, structural sheathing, or structural connection |

articulation system shall be equipped with strain-measuring devices in locations that will allow estimation of maximum stresses predicted by the stress analysis in areas of stress concentration as determined by the stress analysis. During testing, the following shall be measured:

- (a) the strain at critical points, including window and door corners, side sill, corner and collision posts, structural shelf, and other areas
- (b) deflection of carbody
- (c) diagonal dimensions at window and door openings
- (d) residual deflection of carbody
- (e) residual strain, if any

As agreed to between the customer and the manufacturer, the carbody shall be preloaded before the load tests to stabilize the overall structure, and the maximum force shall then be applied incrementally at least twice. The customer shall approve the results of the last test. These tests shall verify that there is no permanent deformation to the carbody or individual elements when subjected to the loads identified in [section 5](#) regarding permanent deformation.

10.3.1 Vertical Load

10.3.1.1 Test Description. The carbody, supported on trucks or a simulation thereof, shall be subjected to a vertical load test. Consideration should be given to the existing stress due to weight of the bare carbody structure itself.

A test load equal to the vertical load specified in Item 1 of [Table 4-1](#) or [Table 4-2](#) shall be applied in a minimum of four evenly spaced increments. The test load may be applied by means of weights or jacks but shall be distributed in proportion to the distribution of weight in the finished vehicle. The carbody shall be unloaded in the increments in which it was loaded, in reverse order. Strain gauge and deflection readings shall be taken at each load increment.

10.3.1.2 Test Criteria. The test results shall verify the following:

- (a) Stresses are in accordance with the requirements of [section 5](#).
- (b) Vertical deflection readings plotted against load do not vary by more than $\pm 7.5\%$ from a straight line, with one end point at the origin and the other at the point that represents the measured deflection for the specified [section 5](#) load.
- (c) Strain readings plotted against load do not vary by more than $\pm 7.5\%$ from a straight line (linear) deflection curve, with one end point at the origin (zero load) and the other at the point that represents the measured deflection for the specified [section 5](#) load.
- (d) Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses approved prior to starting the test program as part of the stress analysis.

- (e) Recorded residual vertical deflection between the carbody bolsters following removal of the specified [section 5](#) load does not exceed 1.0 mm (0.04 in.).

- (f) Recorded residual carbody transverse width and/or opening diagonal changes in dimensions following removal of the specified [section 5](#) load do not exceed 1.0 mm (0.04 in.).

- (g) Indicated residual strains at strain gauges on principal structural elements following removal of the applied loads should not exceed 5% of the yield strength divided by the elastic modulus of the material to which the strain gauge is attached. Higher residual strains may be permitted based upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

- (h) There are no visual permanent deformations, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.3.2 Carbody Compression Loads

10.3.2.1 Test Description. The carbody, supported on trucks or equivalent supports to allow longitudinal movement, shall be subjected to compression load tests. The carbody shall be ballasted or otherwise loaded with properly distributed weights such that its weight is equivalent to that of a fully assembled ready-to-run vehicle. The test loads shall be applied horizontally at the anticlimber on the carbody longitudinal centerline, or to the coupler anchorage as is appropriate for the test being performed. No allowance shall be made for the camber of the carbody. Cushioning by means of soft metal sheets shall be provided for uniform bearing of the applied load. The test load application equipment (e.g., hydraulic rams) shall be configured in such a manner such that the “humping” deformation behavior of the car-shell structure during the compression loading does not transfer any portion of the car-shell weight from the trucks or simulated supports to the load application equipment. It is recommended that measures be taken in the test setup to prevent binding of the loading rams in the test article as the compression load is applied. The test loads shall be applied incrementally and shall include at least one return to a load not greater than 9 kN (2,025 lb) after attaining not less than 80% of the required maximum load.

10.3.2.2 Test Criteria. The test results shall verify the following:

- (a) The maximum stresses calculated from the strain reading in any structural element do not exceed the corresponding allowable stresses as specified in [section 5](#).
- (b) Indicated residual strains at strain gauges on principal structural elements following removal of the applied loads do not exceed 5% of the yield strength divided by the elastic modulus of the material to which the strain gauge is attached. Higher residual strains may be permitted based

upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

(c) There are no visual permanent deformations, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.3.3 Collision Post (Collision Wall) and Corner Post Loads: Elastic Loads

10.3.3.1 Test Description. The ability of the collision posts (collision wall), corner posts, and associated supporting structures to resist the elastic loads specified in Table 4-1 or Table 4-2 (or worse case as agreed to by customer and manufacturer) shall be tested. The test loads may be applied to one end (cab) of a structurally complete carbody or, as an alternate, a separate end-frame section may be constructed and tested. If the alternate method is chosen, the test element shall simulate to the maximum extent possible the location, the degree of fixity, and the magnitude and direction of reactions of the supporting carbody. Cushioning by means of soft metal sheets shall be provided for uniform bearing of the applied load.

10.3.3.2 Test Criteria. The test results shall verify the following:

(a) The maximum stresses calculated from the strain reading in any structural element do not exceed the corresponding allowable stresses as specified in section 5.

(b) Indicated residual strains at strain gauges on the principal structural elements following removal of the applied loads do not exceed 5% of the yield strength divided by the elastic modulus of the material to which the strain gauge is attached. Higher residual strains may be permitted based upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

(c) There shall be no visual permanent deformation, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.4 Crash Energy Management Tests

10.4.1 Test Description. Tests to validate the CEM design, if prescribed, may include a series of dynamic tests of the individual elements, testing of subassemblies, or testing the global structure. While it is recommended at a minimum to test each crush element, the actual valida-

tion of the global crush behavior may also require assembly testing.

10.4.2 Test Criteria. These tests should demonstrate compliance with the CEM requirements in section 8.

10.5 Coupler Impact Tests

These tests shall demonstrate that the vehicle when normally operating with a deployed coupler complies with the following:

(a) The coupler can remain fully serviceable when subjected to coupling impacts up to the coupling speed requirements of Item 1 in Tables 4.6-1 and 4.6-2.

(b) The coupler system shall be tested dynamically to determine the structural design coupler releases loads. By analysis or test, the carbody will be shown to support collision loads through the coupler sufficiently past the point of release as required in Item 3 of Table 4-1 or Table 4-2.

11 REFERENCES

- APTA PR-CS-S-004-98, Rev. 1, Standard for Austenitic Stainless Steel for Railroad Passenger Equipment
- APTA PR-CS-S-015-99, Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction
- APTA PR-CS-S-034-99, Rev. 2, Standard for the Design and Construction of Passenger Railroad Rolling Stock
Publisher: American Public Transportation Association (APTA), 1666 K Street, NW, Washington, DC 20006 (www.apta.com)
- AWS D1.1/D1.1M (latest edition), Structural Welding Code — Steel
- AWS D1.2/D1.2M (latest edition), Structural Welding Code — Aluminum
- AWS D15.1 (latest edition), Railroad Welding Specification for Cars and Locomotives
Publisher: American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166 (www.aws.org)
- IEEE/ASTM SI 10-1997, Standard for Use of the International System of Units (SI): The Modern Metric System
Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854 (www.ieee.org)
- SAE Paper No. 1999-01-0071, NHTSA's Vehicle Compatibility Research Program
Publisher: Society of Automotive Engineers (SAE International), 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

(c) There are no visual permanent deformations, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.3.3 Collision Post (Collision Wall) and Corner Post Loads: Elastic Loads

10.3.3.1 Test Description. The ability of the collision posts (collision wall), corner posts, and associated supporting structures to resist the elastic loads specified in [Table 4-1](#) or [Table 4-2](#) (or worse case as agreed to by customer and manufacturer) shall be tested. The test loads may be applied to one end (cab) of a structurally complete carbody or, as an alternate, a separate end-frame section may be constructed and tested. If the alternate method is chosen, the test element shall simulate to the maximum extent possible the location, the degree of fixity, and the magnitude and direction of reactions of the supporting carbody. Cushioning by means of soft metal sheets shall be provided for uniform bearing of the applied load.

10.3.3.2 Test Criteria. The test results shall verify the following:

(a) The maximum stresses calculated from the strain reading in any structural element do not exceed the corresponding allowable stresses as specified in [section 5](#).

(b) Indicated residual strains at strain gauges on the principal structural elements following removal of the applied loads do not exceed 5% of the yield strength divided by the elastic modulus of the material to which the strain gauge is attached. Higher residual strains may be permitted based upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

(c) There shall be no visual permanent deformation, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.4 Crash Energy Management Tests

10.4.1 Test Description. Tests to validate the CEM design, if prescribed, may include a series of dynamic tests of the individual elements, testing of subassemblies, or testing the global structure. While it is recommended at a minimum to test each crush element, the actual valida-

tion of the global crush behavior may also require assembly testing.

10.4.2 Test Criteria. These tests should demonstrate compliance with the CEM requirements in [section 8](#).

10.5 Coupler Impact Tests

These tests shall demonstrate that the vehicle when normally operating with a deployed coupler complies with the following:

(a) The coupler can remain fully serviceable when subjected to coupling impacts up to the coupling speed requirements of Item 1 in [Tables 4.6-1](#) and [4.6-2](#).

(b) The coupler system shall be tested dynamically to determine the structural design coupler releases loads. By analysis or test, the carbody will be shown to support collision loads through the coupler sufficiently past the point of release as required in Item 3 of [Table 4-1](#) or [Table 4-2](#).

11 REFERENCES

- APTA PR-CS-S-004-98, Rev. 1, Standard for Austenitic Stainless Steel for Railroad Passenger Equipment
- APTA PR-CS-S-015-99, Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction
- APTA PR-CS-S-034-99, Rev. 2, Standard for the Design and Construction of Passenger Railroad Rolling Stock
Publisher: American Public Transportation Association (APTA), 1666 K Street, NW, Washington, DC 20006 (www.apta.com)
- AWS D1.1/D1.1M (latest edition), Structural Welding Code — Steel
- AWS D1.2/D1.2M (latest edition), Structural Welding Code — Aluminum
- AWS D15.1 (latest edition), Railroad Welding Specification for Cars and Locomotives
Publisher: American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166 (www.aws.org)
- IEEE/ASTM SI 10-1997, Standard for Use of the International System of Units (SI): The Modern Metric System
Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854 (www.ieee.org)
- SAE Paper No. 1999-01-0071, NHTSA's Vehicle Compatibility Research Program
Publisher: Society of Automotive Engineers (SAE International), 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

(c) There are no visual permanent deformations, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.3.3 Collision Post (Collision Wall) and Corner Post Loads: Elastic Loads

10.3.3.1 Test Description. The ability of the collision posts (collision wall), corner posts, and associated supporting structures to resist the elastic loads specified in Table 4-1 or Table 4-2 (or worse case as agreed to by customer and manufacturer) shall be tested. The test loads may be applied to one end (cab) of a structurally complete carbody or, as an alternate, a separate end-frame section may be constructed and tested. If the alternate method is chosen, the test element shall simulate to the maximum extent possible the location, the degree of fixity, and the magnitude and direction of reactions of the supporting carbody. Cushioning by means of soft metal sheets shall be provided for uniform bearing of the applied load.

10.3.3.2 Test Criteria. The test results shall verify the following:

(a) The maximum stresses calculated from the strain reading in any structural element do not exceed the corresponding allowable stresses as specified in section 5.

(b) Indicated residual strains at strain gauges on the principal structural elements following removal of the applied loads do not exceed 5% of the yield strength divided by the elastic modulus of the material to which the strain gauge is attached. Higher residual strains may be permitted based upon further investigation (e.g., consideration of instrumentation error and boundary condition variations).

(c) There shall be no visual permanent deformation, fractures, cracks, or separations in the carbody. Any broken weld shall be analyzed to determine if the failure is the result of either inadequate weld quality or overstress before repair or redesign of the area, followed by retesting.

10.4 Crash Energy Management Tests

10.4.1 Test Description. Tests to validate the CEM design, if prescribed, may include a series of dynamic tests of the individual elements, testing of subassemblies, or testing the global structure. While it is recommended at a minimum to test each crush element, the actual valida-

tion of the global crush behavior may also require assembly testing.

10.4.2 Test Criteria. These tests should demonstrate compliance with the CEM requirements in section 8.

10.5 Coupler Impact Tests

These tests shall demonstrate that the vehicle when normally operating with a deployed coupler complies with the following:

(a) The coupler can remain fully serviceable when subjected to coupling impacts up to the coupling speed requirements of Item 1 in Tables 4.6-1 and 4.6-2.

(b) The coupler system shall be tested dynamically to determine the structural design coupler releases loads. By analysis or test, the carbody will be shown to support collision loads through the coupler sufficiently past the point of release as required in Item 3 of Table 4-1 or Table 4-2.

11 REFERENCES

- APTA PR-CS-S-004-98, Rev. 1, Standard for Austenitic Stainless Steel for Railroad Passenger Equipment
- APTA PR-CS-S-015-99, Standard for Aluminum and Aluminum Alloys for Passenger Equipment Car Body Construction
- APTA PR-CS-S-034-99, Rev. 2, Standard for the Design and Construction of Passenger Railroad Rolling Stock
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- AWS D1.2/D1.2M (latest edition), Structural Welding Code — Aluminum
- AWS D15.1 (latest edition), Railroad Welding Specification for Cars and Locomotives
Publisher: American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166 (www.aws.org)
- IEEE/ASTM SI 10-1997, Standard for Use of the International System of Units (SI): The Modern Metric System
Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854 (www.ieee.org)
- SAE Paper No. 1999-01-0071, NHTSA's Vehicle Compatibility Research Program
Publisher: Society of Automotive Engineers (SAE International), 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)