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Designation: ~~E935 – 00 (Reapproved 2006)~~ E935 – 13

Standard Test Methods for Performance of Permanent Metal Railing Systems and Rails for Buildings[1]

This standard is issued under the fixed designation E935; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

~~1. Scope~~

~~1.1 These test methods cover procedures to be followed in testing the performance of permanent metal railing systems (guard, stair, and ramp-rail systems) and rails (hand, wall, grab, and transfer rails) installed in and for agricultural, assembly, commercial, educational, industrial, institutional, recreational, and residential buildings.~~

~~1.2 These test methods are applicable to such railing systems and rails having major structural components made of metal, with their secondary components made of metal or other materials such as wood, plastic, and glass.~~

~~1.3 These test methods can be used to determine whether permanent metal railing systems and rails comply with anticipated performance requirements of the applicable specifications, codes, and standards, such as those described in Specification E985.~~

~~1.4 Specifically, these test methods cover procedures for determining the static strength of metal railing systems and rails as structural elements when installed and fastened to concrete, masonry, wood, and metal as well as related products.~~

~~1.5 No consideration is given in these test methods to any possible deterioration of metal railing systems, rails, and connections, resulting from adverse environmental conditions. The performance of special tests covering this aspect may be desirable.~~

~~1.6 These test methods are limited to the application of concentrated loads described herein. Whenever given uniformly distributed loads are to be resisted by a railing system or rail in accordance with governing specifications, codes, and standards, the effects of such uniformly distributed loads on the member stresses shall be determined by calculation and the corresponding concentrated loads shall be given consideration during testing and data evaluation.~~

~~1.7 Should computations make it possible to provide the needed information, testing can be employed for verification.~~

~~1.8 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.~~

~~1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific hazard statement, see Note 1.~~

~~2. Referenced Documents~~

~~2.1 *ASTM Standards:*[2]~~
~~E4 Practices for Force Verification of Testing Machines~~
~~E575 Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies~~
~~E631 Terminology of Building Constructions~~
~~E985 Specification for Permanent Metal Railing Systems and Rails for Buildings~~
~~E1481 Terminology of Railing Systems and Rails for Buildings~~

~~3. Terminology~~

~~3.1 *Definitions:*~~For definitions of terms used in these test methods, see Terminology ~~E631~~ and Terminology ~~E1481~~.
~~3.2 *Definitions of Terms Specific to This Standard:*~~

[1] These test methods are under the jurisdiction of ASTM Committee E06 on Performance of Buildings and are the direct responsibility of Subcommittee E06.56 on Performance of Railing Systems and Glass for Floors and Stairs.

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[2] "Field Testing Device for Railing Systems and Rails," *Journal of Testing and Evaluation*, Vol. 16, No. 6, ID JTE11274J, Online, Available: http://www.astm.org, 01 November 1988.

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3.2.1 *infill*—in the context of this standard, the balusters of a baluster railing system and the structural as well as decorative elements, including panels, mesh, and similar elements, of a panel railing system, located between top and bottom rails and posts; to serve the twofold purpose of *(1)* protecting bodies from penetrating and falling through the baluster and panel infill areas and *(2)* providing a specified resistance to horizontal thrusts as are potentially encountered within the infill area.

3.2.1.1 *Discussion*—

Infills shall be designed in such a way as to deter climbing of the railing system.

3.2.2 *infill area*—the field of baluster and panel railing systems, bordered by rails, including top, intermediate, and bottom rails, and posts, including end and intermediate posts.

4. Significance and Use

4.1 These test methods are intended to provide information from which applicable design data can be derived for the performance of metal railing systems and rails installed and fastened to structural elements of concrete, masonry, wood, and metal as well as related products. Typical floor-mounted railings are shown in Fig. 1.

5. Test Selection

5.1 The only tests that need to be performed are those that are considered necessary to provide information required by the requesting party, testing agency, and regulatory body involved.

6. Installation

6.1 Install the railing system or rail being investigated in accordance with the manufacturer's or designer's specifications.

7. Sampling

7.1 Test a minimum of three representative replicate specimens of each type of railing system or rail when performance testing in accordance with either Test Method A or B is required (see Section 5).

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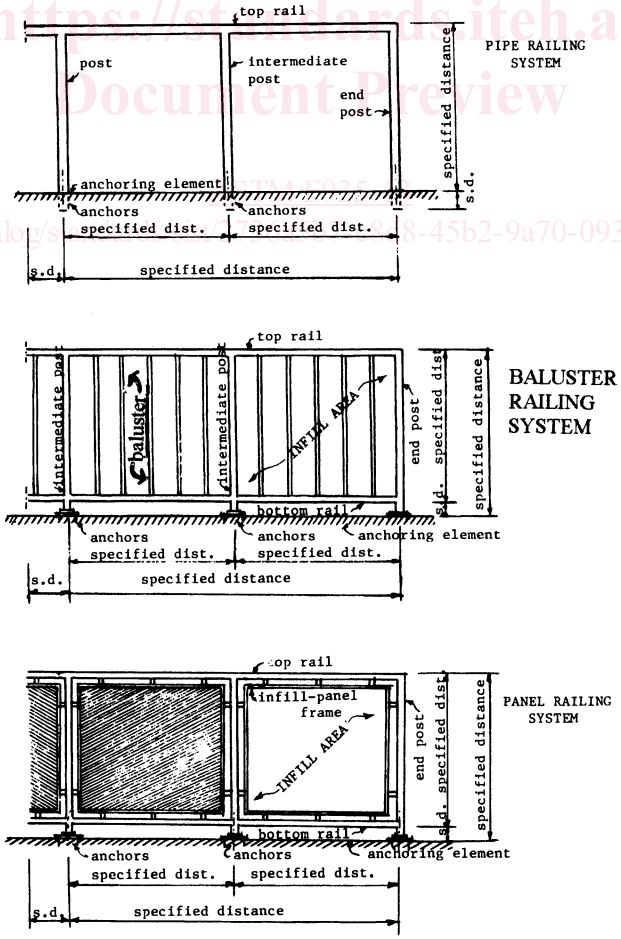

FIG. 1 Front Views of Sections of Three Typical Railing Systems

7.2 Test a minimum of three representative replicate specimens of each type of infill when performance testing in accordance with either Test Method C or D is required (see Section 5).

7.3 If sequential testing of the same specimen in accordance with Test Methods A, B, C, and D is permissible, Test Method B or D shall be followed by Test Method A or C.

8. Test Specimens

8.1 *Specimen Conditioning and Curing*—If aging, seasoning, or curing conditions affect the performance and capacity of the anchorage system of the railing system or rail, take appropriate measures, in accordance with the manufacturer's recommendations, to age, season, or cure the anchorage elements or components prior to testing. Report such conditions in detail. Observe their physical effects and fully describe them in the test report.

8.2 *Specimen Moisture Content and Temperature Conditions (applicable only to hygroscopic products)*—If the prevailing moisture content and temperature conditions can affect the performance of the elements and components of the anchorage system, hold these parameters constant for a given series of tests on the performance of railing systems and rails. The choice of the controlled conditions depends on the environments of the field conditions to be given consideration. Such field conditions shall be simulated. Testing shall begin only after the test specimens have reached approximately stable conditions with regard to temperature and moisture content.

8.3 *Specimen Description*—Examples of typical floor-mounted test specimens are shown in Fig. 1 in diagrammatic form. The specimen installation, including the post spacing, shall be the same as the actual field installation. The specimen shall have a minimum of three posts if this is in line with the actual field installation simulated.

9. Calculation

9.1 *Load-Deformation Data*—Determine the unadjusted, adjusted, and appropriate average load-deformation data for each loading point of each of the test series (see Section 15 and 19).

9.1.1 Calculate the unadjusted deformation (Δ) at a given load (or released load) for an individual test in the following manner:

$$\Delta = A_n - A_1 \quad (1)$$

where:

A_n = the instrument reading at a given load (or released load), and
A_1 = the initial instrument reading.

9.1.2 Obtain the adjusted deformation (or residual deformation) by plotting the unadjusted deformation versus the applied load (or released load) and extrapolating a smooth curve through the data points back to zero load (or deformation). The adjusted deformation at maximum load or any other test load is observed from the plot relative to the zero load.

9.1.3 Obtain the appropriate average adjusted deformation at maximum load or any other test load for each of the test series as the arithmetic mean of the appropriate individual deformation determinations at a given load in a given series.

9.2 *Required Test-Load and Maximum-Load Data*—Determine the average required test load and maximum load for given assembly as the arithmetic mean of the appropriate test and maximum loads for each of the test series depending on the test requirements.

10. Report

10.1 Report the applicable information as listed in Practice E575 and specifically the following information:

10.1.1 Relevant physical-strength properties of the railing-system or rail materials used for the test specimens.

10.1.2 Description of the procedure used for the assembly and installation of the railing system or rail.

10.1.3 Description of the anchorage system.

10.1.4 Age, in days, at time of test of the railing or rail anchorage system, if this information is of any significance.

10.1.5 Age, in hours or days, since assembly and installation of the railing system or rail, if this information is of any significance.

10.1.6 Species, oven-dry specific gravity, and moisture content at time of test, in percent of the oven-dry weight and volume, of any wood members or components of the anchorage system.

10.1.7 Actual rate of loading between increments.

11. Precision and Bias

11.1 No statement is made on the precision or on the bias of these test methods since no data are available at this time that are based on the use of the test methods described.

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TEST METHOD A—APPLICATION OF HORIZONTAL STATIC LOAD TO TOP RAIL

12. Apparatus

12.1 *Testing Machine*—Any testing machine or loading device, capable of imposing forces accurate to within ±1 % when calibrated in accordance with Practices E4, is suitable and may be used provided the requirements of specified rate of loading and unloading are met. The testing device shall be of sufficient capacity to prevent yielding of its various components and shall insure that the applied load remains essentially parallel to the relevant axis of the assembly during testing.

12.2 *Test System*—A diagrammatic test set-up for applying horizontal tension forces to the assembly is shown in Fig. 2. The bearing plates, normally 150-mm (6-in.) long, shall be of sufficient size to prevent local failure of the surrounding structural members or components. The loading device shall be attached to the assembly by means of pins or a swivel connector to prevent the direct transfer of any flexural forces through the connection.

12.3 *Deflection Measurements*—Dial gages, having a smallest division of not more than 0.25 mm (0.01 in.), or any suitable measurement devices or calibrated sensors of at least comparable accuracy and sensitivity shall be used to measure the horizontal displacements of the top of the railing system or rail relative to its original location at each loading point prior to load application. These devices shall have sufficient measurement capability to indicate the displacement throughout the test range.

13. Test Specimen

13.1 *Specimens*—Load one specimen at the top of the rail at an end post. A second specimen shall have two equal loads applied at the top of the rail midway between posts. The third specimen shall be a repeat of the weaker of the first two specimens.

14. Procedure

14.1 *Positioning of Railing System or Rail*—Position the railing system or rail in the support system in such a way that the load is applied, as shown in Fig. 2, to the structural member perpendicular to the plane of the railing system or rail without causing any local failure at the point of load application.

14.2 *Mounting of Instruments*—Mount the three dial gages, measurement devices, or sensors at each loading point as is shown in Fig. 2. Place the sensing elements of the instruments in contact with and normal to the surface or an extension of the surface of the structural element or component being tested in such a way as to measure displacement in the direction of the applied load.

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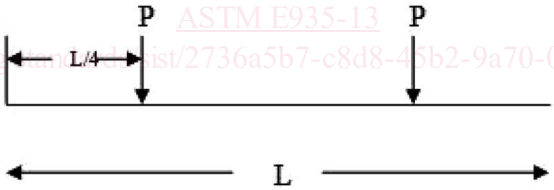

FIG. 2 Diagrammatic Test Set Up for Applying Horizontal Tensile Force at Any of Three Locations to Top Rail Perpendicular to Railing System, in Order to Determine Flexural Strength

Calculating the Equivalent Bending Moment Generated in a Uniform Load Scenario (see Eq 1 of Railing System)

NOTE 1—Any shear forces applied to the top rail shall be transmitted by any existing connections between top rail and railing post. A continuous top rail of uniform cross section along its span should not fail in shear, but in flexure, since the top rail usually acts like a long beam where existing shear stresses, as compared to existing flexural stresses, are relatively small. Should a top rail be designed with a least section modulus next to the post, a special and unusual case, then the design of the top rail shall be tested for such stresses as may exist in the light of the design limitations.

NOTE 2—It is not considered good design practice and often not permissible to locate a top-rail connection of a continuous top rail above the railing post. Thus, the top-rail connection at the railing post should exist only if the post is continuous, that is, if the post reaches from below the top rail to above the top rail. In such an instance as well as when the continuous top rail is fastened to the post, the test load, that is to be applied to the top rail, has to be resisted by the connection or connections.

NOTE 3—If the top rail has to be attached to the railing post at the point of load application (Loading Point 1) because of continuity of the post from below to above the top rail, (*1*) in the case of an end post, the test load shall be applied to the top rail at a location where the center of the bearing plate (12.2) is four times the top-rail thickness from the continuous post; (*2*) in the case of an intermediate post, one half of the test load shall be applied to the top rail of each of those two locations where the centers of the bearing plates are four times the top-rail thickness from each side of the continuous post.

FIG. 3 Diagrammatic Test Set Up for Applying Vertical Compressive Force at Any of Three Locations to Top Rail Parallel with Plane of Railing System, in Order to Determine Resistance of Railing System to Vertical Forces

NOTE 1—Penetration Cone: Smoothly surfaced steel cylinder with integral 25-mm (1-in.) diameter truncated front end. Cylinder diameter shall be 25 pct larger than maximum permissible spacing between balusters and other infill elements, with cylinder length approximately twice the cylinder diameter. To reduce friction between penetration cone and support base, surface it with teflon plate.

FIG. 4 Diagrammatic Test Set-Up for Applying a Horizontal Force to a Penetration Cone Infill Area of Baluster and Panel Railing Systems

15. Load Application

15.1 If the rail is not supported by posts, apply the load in the same manner as described in 13; that is, at the rail end, at the rail middle, and, for the third specimen, at the rail end or rail middle, whichever resulted in the weakest of the two previously tested specimens.

15.2 *Initial Loading*—Apply the initial load corresponding to 50 % of the required test load in order to bring all members in full bearing. After release of the preload to 50 % of the preload, apply the required test load or the maximum load depending on the test requirements by initiating the step testing.

15.3 *Initial Deflection Reading*—Observe the initial deflections immediately after application of the initial test load and its release.

15.4 *Final Load Application*—In the required step loading during constant-level increment loading up to the required test load or maximum load, each increment of load shall amount to not more than 15 % of the estimated maximum load and shall be maintained as constant as is practical for a 2-min period. Instead of such continuous step loading with 2-min constant-load intervals, the step loading may be interrupted by releasing each step load to the initial test load and observing the residual deflection at the initial test load in order to make it possible to determine the total residual deflection for any loading condition. Plot the initial and 2-min readings of the force and deflection gages at each load point in the form of load-deformation curves. Maintain complete load-deformation time records throughout the test. If application of a given load is required for a certain period, such as 24 h, take deformation readings at the beginning, at intervals during this period, and at the end of this period, to allow satisfactory plotting of a time-deformation curve for the complete period.

15.5 *Rate of Loading*—The rate of loading between increments shall be uniform throughout the test and such that the load is applied at a constant rate of deformation of 5.0 ± 2.5 mm (0.20 ± 0.10 in.) per min. If this rate of loading cannot be achieved because of the type of testing machine used or the equipment available, the rate of loading shall be as near to that required in this section.

NOTE 1—**Precaution:** Possible injury to personnel and damage to the test equipment and instrumentation prior to, during, and after load application by any unexpected release of potential strain energy accumulated during testing can occur and must be given consideration.

NOTE 2—**Caution:** If tests are conducted in a structure and not in a testing laboratory, exercise caution against unwanted damage to the building, its components, and its finish.

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TEST METHOD B—APPLICATION OF VERTICAL STATIC LOAD TO TOP RAIL

16. Apparatus

16.1 *Testing Machine*—In accordance with 12.1.

16.2 *Test System*—A diagrammatic test set up for applying vertical forces to the assembly is shown in Fig. 3 or as in 12.2

16.3 *Deflection Measurements*—One dial gauge, having a smallest division of not more than 0.25 mm (0.01 in.), or any suitable measurement device or calibrated sensor of at least comparable accuracy and sensitivity shall be used to measure the vertical displacements of the top of the railing or rail relative to the original location at the loading point after release of the preload.

17. Test Specimen

17.1 *Specimens*—The three test specimens shall have two equal loads applied at the top of the rail midway between the posts.

18. Procedure

18.1 *Positioning of Railing System or Rail*—Position the railing system or rail in the support system in such a way that the load is applied, as is shown in Fig. 3, to the structural member parallel to the plane of the railing system or rail and normal to it without causing any local failure at the point of load application.

18.2 *Mounting of Instruments*—Mount the dial gage, measurement device or sensor at the loading point as is shown in Fig. 3. Place the sensing element of the instrument in contact with the surface or an extension of the surface of the structural element or component being tested in such a way as to measure displacement in the direction of the applied load.

19. Load Application

19.1 As under Section 15, except that the constant rate of deformation shall be 0.50 mm ± 0.25 mm (0.020 in. ± 0.010 in.)/min.

20. Failure Analysis

20.1 *Deformation at Failure*—Determine the required test load and maximum test load and the corresponding deformation for each assembly tested, depending on the test requirements.

20.2 *Failure Modes*—Determine the type of failure as follows:

20.2.1 Failure of the total railing system or rail.

20.2.2 Failure of elements or components of the railing system or rail.
20.2.3 Failure of the connections of the elements or components of the railing system or rail.
20.2.4 Failure of the anchorage.

TEST METHOD C—APPLICATION OF HORIZONTAL STATIC LOAD TO INFILL AREAS OF BALUSTER AND PANEL RAILING SYSTEMS

21. Installation

21.1 When determining the thrust resistance of the infill area of permanent metal railing systems for buildings, the balusters and other infill elements shall be tested in such a way as to simulate actual installation in the building in accordance with the manufacturer's or designer's specifications.

22. Sampling

22.1 A minimum of three replicate specimens of each type of balusters and other infill elements shall be tested, if the performance of this test is required.

22.2 The tests shall be performed either on the units or on the installed units. In the latter instance, sequential testing is permissible after testing in accordance with Methods A and B, provided the balusters and other infill elements had not been damaged during previous testing.

23. Apparatus

23.1 *Testing Machine*—In accordance with 12.1.

23.2 *Test System*—In accordance with 12.2; however, the horizontal force shall be applied to the balusters and other infill elements at the most critical location with a round or square bearing plate of 1 ft^2 in area.

24. Test Specimens

24.1 In accordance with Section 8.

25. Procedure

25.1 *Positioning of Bearing Plate*—Position the bearing plate with respect to the balusters and other infill elements in the support system in such a way that the load is applied horizontally at the most critical location without causing any local failure at the point of load application.

25.2 *Mounting of Instruments*—Mount the dial gage, measurement device, or sensor in such a way as to permit measurement of the maximum displacement which can be anticipated normal to the surface of the test specimen.

25.3 *Failure Analysis*—In accordance with Section 20.

26. Load Application

26.1 In accordance with Section 15.

27. Calculation

27.1 In accordance with Section 9.

28. Report

28.1 In accordance with Section 10.

TEST METHOD D—APPLICATION OF HORIZONTAL STATIC LOAD TO DETERMINE RESISTANCE TO CONE PENETRATION BY INFILL AREA OF BALUSTER AND PANEL RAILING SYSTEMS

29. Installation

29.1 When determining the infill-area cone-penetration resistance of permanent metal railing systems for buildings, the balusters and other infill elements shall be tested in such a way as to simulate actual installation in the building in accordance with the manufacturer's or designer's specifications.

30. Sampling

30.1 A minimum of three replicate specimens of each type of baluster and other infill elements shall be tested, if the performance of this test is required.

30.2 The test shall be performed on the installed units. Sequential testing is permissible after testing in accordance with Methods A, B, and C, provided the balusters and other infill elements had not been damaged during previous testing.

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