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July 16, 2010

**TO: PARTIES INTERESTED IN EVALUATION REPORTS ON CONTINUOUS ROD TIE-DOWN RUNS AND CONTINUOUS ROD TIE-DOWN SYSTEMS USED TO RESIST WIND UPLIFT**

**SUBJECT: Revisions to the Acceptance Criteria for Continuous Rod Tie-down Runs and Continuous Rod Tie-down Systems Used to Resist Wind Uplift**

Dear Madam or Sir:

Enclosed is a copy of the subject revised acceptance criteria approved by the ICC-ES Evaluation Committee on June 16, 2010, effective July 1, 2010.

The approved revisions incorporate provisions that allow evaluations to be performed on either: (a) the independent "continuous rod tie-down run" (CRTR), which is a new term for the continuous rod tie-down assembly; or (b) the "continuous rod tie-down system" (CRTS), which includes both the continuous rod tie-down assembly and the wood framing through which loads are transferred to the rods. Allowable loads for the components comprising the CRTR must be derived through calculations in accordance with Section 3.2.1, with the exception that allowable loads for couplers and other proprietary components must be derived through testing and evaluation as outlined in Section 3.1.1. Allowable loads for a CRTS are expressed in units of force per unit length of wall line, and may be derived either through calculations in accordance with Section 3.2.2 or through testing in accordance with Sections 3.3, 3.4, 3.5 and 4.2.

Evaluation reports issued on or after the effective date noted above, and falling within the scope of this criteria, will be required to comply with the enclosed edition of the criteria. Evaluation reports issued prior to the effective date may be in compliance either with the enclosed acceptance criteria or with the previous edition. Evaluation reports based on a superseded version of an acceptance criteria must be brought into compliance with the most recent edition at the time the reports are reissued. Therefore, applicants should submit data verifying compliance at the time they apply for re-examination.

If you have any questions, please contact Jason Smart, Senior Evaluation Specialist, at (800) 423-6587, extension 5692. You may also reach us by e-mail at [es@icc-es.org](mailto:es@icc-es.org).

Yours very truly,

A handwritten signature in black ink that reads 'Gary G. Nichols'.

Gary G. Nichols, P.E., SECB  
Vice President

GGN/raf

Enclosure

cc: Evaluation Committee

# ACCEPTANCE CRITERIA FOR CONTINUOUS ROD TIE-DOWN RUNS AND CONTINUOUS ROD TIE-DOWN SYSTEMS USED TO RESIST WIND UPLIFT

**AC391**

**Approved June 2010**

**Effective July 1, 2010**

**Previously approved February 2010, June 2009**

## **PREFACE**

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code*® reads as follows:

The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

This acceptance criteria has been issued to provide all interested parties with guidelines for demonstrating compliance with performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and adopted following public hearings conducted by the ICC-ES Evaluation Committee, and is effective on the date shown above. All reports issued or reissued on or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from the previous edition, a solid vertical line (|) in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A deletion indicator (→) is provided in the margin where a paragraph has been deleted if the deletion involved a technical change. This criteria may be further revised as the need dictates.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

***Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports.***

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# ACCEPTANCE CRITERIA FOR CONTINUOUS ROD TIE-DOWN RUNS AND CONTINUOUS ROD TIE-DOWN SYSTEMS USED TO RESIST WIND UPLIFT (AC391)

## 1.0 INTRODUCTION

**1.1 Purpose:** The purpose of this acceptance criteria is to establish requirements for (a) continuous rod tie-down runs used to resist wind uplift forces, or (b) continuous rod tie-down systems used in wood light-framed construction to resist wind uplift, to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report under the 2009 *International Building Code*<sup>®</sup> (IBC), and the 2009 *International Residential Code*<sup>®</sup> (IRC). Bases of recognition are IBC Section 104.11 and IRC Section R104.11.

The reason for the development of this criteria is to establish guidelines for the evaluation of either (a) continuous rod tie-down runs (CRTRs) used to resist wind uplift, or (b) continuous rod tie-down systems (CRTSs) used to resist wind uplift, since the IBC, IRC, and associated referenced standards do not specify qualification, installation, design, and quality requirements for such assemblies.

### 1.2 Scope:

**1.2.1** This criteria provides methods to establish the Allowable Stress Design (ASD) loads for (a) continuous rod tie-down runs (CRTRs) used to resist vertical wind (uplift) forces, and (b) continuous rod tie-down systems (CRTSs) used to resist vertical wind (uplift) forces, based on tests and/or calculation. Except where otherwise stated in this criteria, the provisions of this criteria apply to evaluations performed on a CRTR, as well as to those performed on a CRTS.

**1.2.1.1** Evaluations performed on a CRTR or CRTS are limited in scope to the ability of the CRTR or CRTS to resist tension loads caused by vertical wind (uplift) restraint in light-framed structures. The CRTR or CRTS shall be evaluated independently from the lateral load-resisting system (e.g., shear wall). Uplift load-resisting system considerations, including framing, connections, and other elements within the wind uplift resisting load path are outside the scope of evaluations performed on the CRTR, and shall be considered and designed separately.

**1.2.1.2** Allowable Stress Design (ASD) loads for the steel components of the CRTR and CRTS shall be calculated in accordance with the IBC, as set forth in Section 3.2.1 of this criteria, with the exception that ASD loads for threaded rod coupler components shall be determined through testing per Section 4.1 of this criteria.

**1.2.1.3** Evaluations performed on a CRTS are limited in scope to the ability of the CRTS to resist vertical wind (uplift) loads in light-framed wood structures. For evaluations performed on a CRTS, ASD loads for the CRTS shall be calculated in accordance with the IBC and the additional requirements in Section 3.2.2 of this criteria, considering top plate design (bending capacity, deflection limitations, rotation control, and splices), bearing plate capacities, rod strength capacities, and rod elongation. The CRTS may be tested in accordance with Section 4.2 of this criteria, but individual CRTR component capacities

within the system shall not exceed the values determined in accordance with the IBC and Section 3.2 of this criteria.

The following components and anchorage devices are outside the scope of this criteria:

**1.2.1.4** Devices that are installed partially embedded into concrete or masonry construction, such as metal straps, die-stamped sill-plate connectors, or similar cold-formed or structural steel devices.

**1.2.1.5** Straight flat metal straps installed to collect and transfer tension forces from their point of origin to load-resisting elements.

**1.2.1.6** Anchorage to concrete or masonry.

**1.2.1.7** CRTRs using wire rope or cable as the tension component.

**1.2.1.8** Continuous rod tie-down assemblies used to resist wind or seismic shear wall overturning forces.

**1.2.2** Installations are limited to dry, interior locations protected from exposure to weather, except as permitted by Section 3.6.

### 1.3 Codes and Referenced Standards:

**1.3.1** 2009 *International Building Code*<sup>®</sup> (IBC), International Code Council.

**1.3.2** 2009 *International Residential Code*<sup>®</sup> (IRC), International Code Council.

**1.3.3** AF&PA NDS-2005, National Design Specification for Wood Construction (NDS), American Forest & Paper Association.

**1.3.4** AISC 360-05, Specification for Structural Steel Buildings, American Institute of Steel Construction.

**1.3.5** AISI S100-2007, North American Specification for the Design of Cold-Formed Steel Structural Members, American Iron and Steel Institute.

**1.3.6** ASTM A 36-05, Standard Specification for Carbon Structural Steel, ASTM International

**1.3.7** ASTM A 194-08, Standard Specification for Carbon and Alloy-Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both, ASTM International.

**1.3.8** ASTM A 307-04e01, Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength, ASTM International

**1.3.9** ASTM A 325-04b, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength, ASTM International.

**1.3.10** ASTM A 354-03a, Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners, ASTM International.

**1.3.11** ASTM A 370-09, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International.

**1.3.12** ASTM A 449-04, Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated,

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120/105/90 ksi Minimum Tensile Strength, General Use, ASTM International.

**1.3.13** ASTM A 563-07a, Standard Specification for Carbon and Alloy Steel Nuts, ASTM International.

**1.3.14** ASTM D 2395-02, Standard Test Method for Specific Gravity of Wood and Wood-Based Materials, ASTM International.

**1.3.15** ASTM D 4442-92 (2003), Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials, ASTM International.

**1.3.16** ASTM D 4444-92 (1998), Standard Test Methods for Use and Calibration of Hand Held Moisture Meters, ASTM International.

**1.3.17** ASTM D 4761-05, Standard Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material, ASTM International.

**1.3.18** ASTM E 4-07, Standard Practices for Force Verification of Testing Machines, ASTM International.

**1.3.19** ASTM E 8-01, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International.

**1.3.20** ASTM F 1470-02, Standard Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection, ASTM International.

**1.3.21** ASTM F 1554-07a, Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength, ASTM International.

**1.3.22** ASTM F 1575-03, Standard Test Method for Determining Bending Yield Moment of Nails, ASTM International.

**1.3.23** ASTM F 1667-01A, Standard Specification for Driven Fasteners: Nails, Spikes, and Staples, ASTM International.

**1.4 Definitions and Material Requirements:**

**1.4.1 Continuous Rod Tie-down Run (CRTR):** A CRTR is made up of a particular series of any of the following components: (1) continuously or partially threaded steel rod; (2) steel nuts; (3) steel bearing plates; (4) hold-downs; (5) threaded rod couplers; and/or (6) shrinkage compensating devices, as needed to transfer tension loads from a structure into a supporting element such as a foundation. For the purposes of this criteria, the CRTR shall be limited to installations in light-framed walls and shall be used to resist tension loads caused by vertical wind (uplift) restraint only.

**1.4.2 Continuous Rod Tie-down System (CRTS):** A CRTS is a light-frame wood wall assembly containing multiple CRTRs, as defined in Section 1.4.1, having (1) a specified wall height and stud spacing, (2) specified wood framing member grades and dimensions, (3) specified sheathing (if included within the evaluated CRTS), and (4) specified framing-to-framing, framing-to-sheathing and framing-to-CRTR connections. For purposes of this criteria, the CRTS shall be limited to installations in light-frame wood walls, and shall only be used to resist tension loads caused by vertical wind (uplift) restraint.

**1.4.3 Continuously or Partially Threaded Steel Rod or Bolts:** Mild steel threaded rod and bolts shall

comply with ASTM A 36, ASTM A 307 or ASTM F 1554 Grade 36, respectively. High-strength threaded steel rod and bolts shall comply with one of the following standards: ASTM A 193, A 325, A 354 or A 449. Other specifications may be acceptable with prior concurrence of ICC-ES staff.

**1.4.4 Steel Nuts:** Steel nuts used with continuously or partially threaded steel rod as defined in Section 1.4.3 shall comply with ASTM A 563 or ASTM A 194. Nut dimensions shall comply with ANSI B18.2.2. The strength of the nuts shall comply with the proof load requirements of the applicable nut specification. High strength heavy hex nuts shall be used with high strength threaded rod.

**1.4.5 Threaded Rod Couplers:** Threaded rod couplers used with continuously or partially threaded steel rod shall satisfy the requirements cited for nuts in the rod specification. The minimum ASD strength, as established through testing in accordance with Section 4.1, shall equal or exceed the ASD strength of the connected threaded rod. Thread engagement length of couplers shall comply with ASTM A 563. High-strength couplers shall be used with high-strength threaded rod. The evaluation report applicant shall submit threaded rod coupler dimensions and material specifications to justify the coupler capacity, including cross-sectional area and thread engagement lengths to verify that these requirements are met. Complying couplers shall be supplied by the evaluation report applicant and shall be described in the quality documentation. Additionally, procedures shall be provided by the evaluation report applicant to ensure proper thread engagement of the couplers for in-field installations.

**1.4.6 Steel Bearing Plate:** Steel bearing plates used within a CRTR shall satisfy the flexural requirements of AISC 360 and the wood-bearing requirements of the 2005 NDS.

**1.4.7 Hold-down:** Hold-downs shall be evaluated in accordance with the ICC-ES Acceptance Criteria for Hold-downs (Tie-downs) Attached to Wood Members (AC155).

**1.4.8 Shrinkage Compensating Device:** Shrinkage Compensating Devices shall be evaluated in accordance with the ICC-ES Acceptance Criteria for Shrinkage Compensating Devices (AC316).

**1.4.9 Wood Framing:** Wood framing shall be solid-sawn lumber complying with IBC Section 2303.1.1, or structural composite lumber complying with IBC Section 2303.1.9. Structural composite lumber shall be evaluated in accordance with the ICC-ES Acceptance Criteria for Structural Wood-based Products (AC47) or the ICC-ES Acceptance Criteria for Wood-based Studs (AC202).

**1.4.10 Applicant's Published Specification:** A material specification, complying with the AISI S100 definition of "published specification," that is used in lieu of one of the standard material specifications referenced in Section 1.3 of this criteria. Regardless of whether the steel referenced in the *applicant's published specification* is cold-formed or hot-rolled, the steel shall comply with requirements set forth in Section A2.2, Section A2.3, Section A2.4, and Appendix A Section A2.2 of AISI S100. An applicant's published specification shall be published before the steel is ordered, and the mechanical properties of components ordered to the specification shall be

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confirmed under an ongoing quality control program in accordance with Section 5.3.1.

**2.0 BASIC INFORMATION**

**2.1 General:** The following information shall be submitted:

**2.1.1 Product Description:** Complete information pertaining to the CRTR or CRTS components, including material specifications, scaled production drawings showing all dimensions and tolerances, and information on protective coatings and the manufacturing process (including welds, if applicable) shall be submitted. Material specifications shall comply with applicable referenced standards noted in Section 1.3, or with the applicant's published specification. If a material used in the calculation method has higher strengths than specified in the referenced standards, verification of the higher strength, through certification, is required to be in the quality documentation in accordance with Section 5.3.1.

**2.1.2 Installation Instructions:** Installation details and drawings, noting installation requirements and/or limitations, shall be submitted. For evaluations performed on a CRTS, the installation instructions shall include framing details, including species, grade, dimensions, spacing, connections, hardware, etc. The installed CRTS, as described, shall be identical to the CRTS described within the submitted test report(s) in accordance with Section 2.3.2.

**2.1.3 System Calculations:** For CRTR evaluations, full system sample calculations shall be submitted, considering all of the design considerations given in Section 6.2.3. For CRTS evaluations, full system calculations shall be submitted in accordance with Section 3.2.2.

**2.1.4 Packaging and Identification:** Descriptions of field identification of the continuous rod tie-down components shall be submitted. For components that comply with the standards referenced in Section 1.3, identification provisions shall comply with the stated requirements. High-strength threaded rod identification shall also indicate the ASTM specification and grade, and heat batch number. Threaded rod couplers and other components manufactured in accordance with an applicant's published specification shall be clearly identified as to the manufacturer (a registered trademark or logo may serve as such an identity, provided a facsimile of the trademark or logo is included in the evaluation report), the model number, the ICC-ES evaluation report number (ICC-ES ESR-XXXX), and, as applicable, the inspection agency.

**2.2 Testing Laboratories:** Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

**2.3 Test Reports:** Test reports shall comply with AC85 and include the following information:

**2.3.1** For evaluations performed on a CRTR, the test report(s) on threaded rod couplers and other components that do not comply with a referenced standard or acceptance criteria, shall contain detailed descriptions of the tested CRTR components, including drawings detailing

all pertinent dimensions of the components. The test report shall also include the following information:

(a) The measured steel physical properties of the continuous rod tie-down components, including yield strength, tensile strength, elongation, base-metal thickness, and all other pertinent dimensions.

(b) Detailed drawings of the test setup, depicting location and direction of load application, location of displacement instrumentation and points of reference, and details of any deviations from the test requirements as outlined in Section 4.1. Additionally, photographs shall supplement the detailed drawings confirming the test setup, and failure modes during and after testing.

(c) Individual and average maximum test load values observed. There shall be a description of the nature, type and location of failure exhibited by each continuous rod tie-down component tested, and a description of the general behavior of the tested components during load application.

(d) A description of the test method and loading procedure used; rate of loading; and time to failure or maximum load in accordance with Section 4.1.5.

**2.3.2** For evaluations performed on a CRTS in which ASD system loads are determined through testing in accordance with Section 4.2, the test report(s) shall contain a detailed description of the tested CRTS and its components, including drawings detailing all pertinent dimensions of the system and components, and sufficient information to verify compliance with the material requirements of Section 3.3. The test report(s) shall also include the following information:

(a) Actual dimensions, species, grade, specific gravity, and moisture content for each wood specimen.

(b) A description of any modifications to wood members used in system testing.

(c) The measured steel physical properties of the continuous rod tie-down components, including yield strength, tensile strength, elongation, and base-metal thickness.

(d) Detailed drawings of the test setup, depicting the threaded rod attached to the steel bearing plate (or hold-down), threaded rod location and spacing, wood top plate splice location and detailing, location and direction of load application, load applicator (e.g., hurricane tie simulator), including fastener description, location of displacement instrumentation and points of reference, and details of any deviations from the test requirements per Section 4.0. Additionally, photographs shall supplement the detailed drawings confirming the test setup, and the failure modes during and at the conclusion of the test shall be noted.

(e) Individual and average maximum test load values observed. There shall be a description of the nature, type and location of failure exhibited by each CRTS tested, and a description of the general behavior of the test assembly during load application.

(f) A description of the test method and loading procedure used; rate of loading; and time to failure or maximum load in accordance with Sections 4.1.5 and 4.2.5.

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(g) The test sample size shall be reported, and shall be in compliance with Sections 4.1.3 and 4.2.4.

**2.4 Product Sampling:** Sampling shall comply with Section 3.1 of AC85 for welded components and components complying with an applicants' published specification. Sampling shall comply with either Section 3.1 or Section 3.2 of AC85 for components fabricated without welds. The testing laboratory shall check and report on the characteristics of the specimens to confirm compliance with the drawings and specifications referenced in Section 2.1.1 of this criteria.

**3.0 TEST AND PERFORMANCE REQUIREMENTS**

**3.1 General:**

**3.1.1 Component Capacities:** Allowable (ASD) loads and corresponding displacements of the threaded rods and bearing plates shall be determined by calculations in accordance with Section 3.2.1. Allowable (ASD) loads and corresponding displacements for threaded rod couplers and other proprietary components that do not comply with a referenced standard or an ICC-ES acceptance criteria shall be determined in accordance with Sections 3.4.1.1 and 3.4.1.2, respectively, based on testing in accordance with Section 4.1. Allowable (ASD) loads and corresponding displacements for hold-downs and shrinkage compensating devices shall be evaluated in accordance with AC155 and AC316, respectively. Displacements for shrinkage compensating devices shall include the device average travel and seating increment,  $\Delta_R$ , as defined in AC316, which is independent of load.

**3.1.2 System Capacities:** For evaluations performed on a CRTS, the ASD uniform uplift load,  $W_{all}$ , and the corresponding displacement of the CRTS assembly shall be determined by calculations in accordance with Section 3.2.2, or by testing of the CRTS in accordance with Sections 3.3 through 3.5, and Section 4.2. ASD system capacities derived through testing shall not exceed the component capacities determined in accordance with Section 3.1.1.

**3.2 Calculations:**

**3.2.1 Component Calculations:** ASD loads and corresponding displacements of the threaded rods and steel bearing plates shall be calculated in accordance with Sections 3.2.1.1 and 3.2.1.2, respectively, using the minimum specified yield and tensile strengths, as specified in the applicable standard specification or applicant's published specification.

**3.2.1.1 Threaded Rod:** The ASD steel tension load capacity and elongation shall be calculated in accordance with AISC 360. Threaded rod elongation shall be based on the net tensile area. Elongation,  $\Delta_{rod}$ , shall be limited to 0.18 inches (4.6mm) for total rod length at the allowable (ASD) load. Rod elongation,  $\Delta_{rod}$ , and net tensile area,  $A_n$ , shall be determined in accordance with Equation 1.

$$\Delta_{rod} = \frac{PL}{A_n E} \quad (\text{Eq. 1})$$

where:

$$A_n = 0.7854 \left( D - \frac{0.9743}{n} \right)^2$$

- $A_n$  = net tensile area, in<sup>2</sup> or mm<sup>2</sup>
- $E$  = steel modulus of elasticity = 29,000,000 psi (200,000 MPa)
- $L$  = total rod length, in. or mm
- $P$  = tension in rod, lbs or N
- $D$  = basic major diameter, in. or mm
- $n$  = number of threads per inch of rod length (Ref. ASME B1.1)

**3.2.1.2 Steel Bearing Plates:** For steel plate materials, ASD structural capacities shall be calculated in accordance with AISC 360. Steel bending capacity values shall be derived from cantilever bending action of the steel plate as shown in Figure 1 to determine the required plate thickness. ASD wood bearing shall be calculated in accordance with the AF&PA NDS and shall be derived from the perpendicular to grain bearing stress of the wood member and the effective contact area of the steel bearing plate on wood, including the bearing area factor,  $C_b$ , if applicable, and taking a reduction of the plate area for the tension rod hole area. Displacements of the CRTR resulting from bearing plate bending and wood compression shall be calculated assuming a wood bearing deformation of 0.040 inches (1.0 mm) at the adjusted compression design value perpendicular-to-grain, and a linear load-deformation relationship up to that point.

**3.2.2 System Calculations:** CRTS capacity shall be limited by the lowest of: (1) the individual steel component capacities determined in accordance with Section 3.1.1; and (2) wood member and connection limitations, considering both deflection and capacity limit states in accordance with Sections 3.2.2.1 through 3.2.2.5. System calculations shall also be in accordance with the AF&PA NDS for wood, and AISC 360 or AISI S100 for steel, and shall consider the applicable load combinations in accordance with IBC Section 1605.3.

**3.2.2.1 Wood Member Flexural Stress:** The flexural capacity of two wood top plates acting as a composite member to resist distributed uplift loading while spanning between adjacent CRTRs may be considered when: (a) detailing is justified through calculation such that sufficient shear transfer connections between plates exist to ensure composite bending action; and (b) connections are added at top plate splices and justified through calculation demonstrating that the spliced connection capacity meets or exceeds shear and flexural demands and axial loads, if applicable. When evaluated in this manner, details of the splices and shear transfer connections between plates shall be provided in the evaluation report. Alternatively, it is permitted to limit the capacity to that of a single top plate without regard to connection details.

**3.2.2.2 Calculated Deflection Limitations of the CRTS:** The maximum calculated deflection of the top plate(s) between CRTR locations shall be limited to  $L/240$ , where L is the span of the top plate(s) equal to the distance between CRTRs. Either one or two top plates shall be considered effective in accordance with the limits of Section 3.2.2.1. Additionally, the sum of the calculated change in length of the CRTR and the calculated deflection of the top plate(s) between CRTRs shall not exceed 0.25 inch (6.4 mm) at the allowable (ASD) load.

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**3.2.2.3 Top Plate Rotation Restraint:** A positive method to resist torsional rotation of the top plates due to offsets between the point of load application (e.g., hurricane ties at the sides of the top plates) and load resistance (e.g., rods at the center of the top plate) shall be provided where such conditions exist. Calculations in accordance with IBC Section 1604.4 shall be used to determine the demand on connections used to resist top plate torsion. Details of the connection shall be provided in the report.

**3.2.2.4 Wood Member Shear Stress:** Allowable ASD load values based on shear stress perpendicular to grain shall be in accordance with the AF&PA NDS. Calculated capacity shall be based on a single top plate unless top plate splices are specifically designed and detailed per Section 3.2.2.1 to transfer shear, and details are provided in the report.

**3.2.2.5 Wood Member Combined Axial and Flexural Stress:** Where the wood top plate(s) transfer combined axial and bending forces (i.e., the top plate acts as a drag strut/collector while also acting as a horizontal beam spanning between CRTRs), the calculated limit due to combined action shall be established. Consideration of one or two plates being effective in resisting combined behavior shall be made in accordance with Section 3.2.2.1, with additional consideration of axial forces in the splice connections.

### 3.3 Test Materials:

**3.3.1 Wood:** All wood materials used in CRTS testing shall be of structural quality, with structural design values substantiated by accepted procedures, such as those referenced in Section 2303 of the IBC, and shall comply with Sections 3.3.1.1 through 3.3.1.4.

**3.3.1.1 Specific Gravity of Wood:** The wood members used in CRTS testing shall have a tested specific gravity, determined in accordance with ASTM D 2395, within 10 percent of the code-specified value, and shall be reported on an oven-dry basis in accordance with ASTM D 2395. Specific gravity measurements taken at moisture contents other than oven-dry condition shall be adjusted to the oven-dry moisture content in accordance with Appendix X1 of ASTM D 2395.

**3.3.1.2 Moisture Content of Wood:** The moisture content of the wood members shall be determined in accordance with ASTM D 4442 or D 4444, and reported.

**3.3.1.3 Stiffness Testing of Wood Members:** Each of the wood members to be used within the top plates of tested CRTS assemblies shall be non-destructively tested to determine their actual flat-wise long-span modulus of elasticity in accordance with Sections 12 through 17 of ASTM D 4761, prior to construction of the assemblies in which the members will be used. The actual flat-wise long-span modulus of elasticity of each individual wood member to be used within the top plates of the tested CRTS assemblies shall not exceed 110 percent of the code-specified value for that lumber species and grade. The average of the flat-wise long-span modulus of elasticity values for all of the wood members comprising the top plate,  $E_{tested}$ , shall be calculated. These average  $E_{tested}$  values shall be

calculated separately for each respective CRTS test assembly.

**3.3.1.4 Dimensions of Wood Members:** Three thickness and width measurements shall be taken at the quarter points along the length of each of the wood members to be used within the top plate of each tested CRTS assembly. The measurements shall be taken to the nearest 0.01 inch (0.25 mm), and the average thickness,  $d$ , and width,  $b$ , of the wood members to be used in each respective top plate shall be calculated. These measurements shall be taken at the time of the stiffness testing performed in accordance with Section 3.3.1.3.

**3.3.2 Metal Components:** The physical properties of the tested continuous rod tie-down components, including yield stress, tensile strength, elongation dimensions, and uncoated base-metal steel thickness, shall be determined for each component, including hold-downs and shrinkage compensating devices. Standard tensile tests of the metal from which the continuous tie-down component was produced shall be conducted in accordance with ASTM E 8. Alternatively, the data are permitted to be obtained from the mill certificates of the metal from which the continuous tie-down components are manufactured. The uncoated base-metal thickness of the steel from which the tested continuous tie-down components is formed shall be measured or calculated. All other pertinent dimensions of each component shall also be measured and reported. If the measured cross-sectional dimensions or tensile strength obtained from testing or mill certificates exceed minimum specified values as established in accordance with Section 2.1 of this criteria, the ASD loads determined in accordance with Section 3.4 shall be proportionally reduced in accordance with Section 3.5.

**3.3.2.1 Anchor Bolts and Threaded Rod:** Anchor bolts and threaded rods used in CRTS testing shall comply with the requirements of Section 1.4.3.

**3.3.2.2 Nuts and Threaded Rod Couplers:** Nuts and threaded rod couplers used in testing shall comply with the requirements of Sections 1.4.4 and 1.4.5, respectively.

**3.3.2.3 Fasteners:** Nails shall comply with ASTM F 1667 or the ICC-ES Acceptance Criteria for Nails and Spikes (AC116). Nail bending yield strength,  $F_{yb}$ , shall be derived using the procedures of ASTM F 1575, or the ICC-ES Acceptance Criteria for Nails and Spikes (AC116), as applicable. Wood screws shall comply with either ASME Standard B18.6.1 or the ICC-ES Acceptance Criteria for Alternate Dowel-type Threaded Fasteners Less Than  $\frac{1}{4}$  Inch in Diameter (AC233). Bending yield strength of the screws shall be derived using the procedures of Section 4.4 of AC233. Predrilled holes shall be a field requirement when wood screws are installed into predrilled holes for testing. Fasteners from the same manufacturer's lot that are used in continuous tie-down system testing shall be sampled in accordance with ASTM F 1470.

**3.3.2.4 Hold-downs and Shrinkage Compensating Devices:** Hold-downs and shrinkage compensating devices used within tested CRTS assemblies shall be the subject of a current ICC-ES evaluation report in accordance with AC155 or AC316, respectively, and shall be labeled as such.

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**3.4 Derivation of Allowable (ASD) Tension Loads:**

**3.4.1 Derivation of ASD Loads for CRTR:** ASD tension loads for the CRTR shall be the lesser of the ASD loads determined in accordance with Section 3.1.1 for each of the individual components within the CRTR. ASD loads for threaded rod couplers and other proprietary components that do not comply with a referenced standard or acceptance criteria shall be derived in accordance with Section 3.4.1.1.

**3.4.1.1 Allowable (ASD) Loads for Threaded Rod Couplers:** Threaded rod couplers shall be tested for all rod sizes, including transition couplers, in which recognition is sought. For each size, a minimum of three threaded rod couplers shall be tested in accordance with Section 4.1, and the threaded rod coupler shall develop 100 percent of the intended rod tensile strength,  $F_u$  of the rod, and 125 percent of the specified yield strength,  $F_y$  of the intended rod.

**3.4.1.2 Allowable (ASD) Loads for Proprietary Components Not Complying with a Referenced Standard or Acceptance Criteria:** Where the sample size of tests performed on proprietary components tested in accordance with Section 4.1 is three to five, the ASD load is the lowest peak value from a single specimen divided by a factor of safety of 3.0. Where the test sample size is six or more, the ASD load is the mean peak value from all specimens divided by a factor of safety of 3.0. The ASD loads shall be adjusted in accordance with Section 3.5, as applicable.

**3.4.2 Derivation of Allowable (ASD) Loads for CRTS:** Allowable (ASD) uniform uplift load of a CRTS,  $W_{all}$ , may be derived through either (a) analysis and calculations in accordance with Section 3.2.2, or (b) testing in accordance with Section 4.2 of a minimum sample size as determined in accordance with Section 4.2.4. Regardless of the method of load derivation, the ASD component capacities determined in accordance with Section 3.1.1 shall not be exceeded. Where derived through testing in accordance with Section 4.2, the ASD uniform uplift load of a CRTS,  $W_{all}$ , in pounds per lineal foot (plf), shall be the lesser of  $W_{all, str}$ , calculated in accordance with Equation 2, and  $W_{all, defl}$ , calculated in accordance with Equation 3.

$$W_{all, str} = \frac{P_{ult}}{2.0 \times L} \quad (\text{Eq. 2})$$

$$W_{all, defl} = \frac{P_{defl}}{L} \quad (\text{Eq. 3})$$

where:

$P_{ult}$  = Average ultimate test load (uplift) of the tested CRTS assemblies, in pounds,

$P_{defl}$  = Average test load corresponding to the applicable deflection limit per Section 3.4.2.1, in pounds,

$L$  = Length of the tested CRTS wall assemblies, feet.

The ASD uniform uplift load of a CRTS,  $W_{all}$ , derived through testing in accordance with Section 4.2 corresponds to a ten-minute load duration, and shall not be further increased by any load duration factor,  $C_D$ , but

shall be adjusted in accordance with Section 3.5, as applicable.

**3.4.2.1 Deflection Limits for Tested CRTS:** The vertical deflection of the top plate between CRTR locations on a tested CRTS assembly shall be limited to  $L/240$ , where  $L$  is either the distance between the CRTR attachment points, or the distance between the end of the top plate and the closest CRTR attachment point (for cantilevered ends). Additionally, the maximum vertical deflection of the top plate relative to the test bed (i.e., the sum of the change in length of the CRTR, top plate crushing under the bearing plates, and the deflection of the top plate between CRTRs) shall be limited to 0.25 inches at the ASD load.

**3.5 Adjustments to Test Results:** For CRTR evaluations, the ASD component loads for threaded rod couplers and other proprietary components tested in accordance with Sections 3.1.1, 3.4.1.1 and 4.1 shall be adjusted in accordance with Section 3.5.1, as applicable. For CRTS evaluations where an ASD uniform uplift load,  $W_{all}$ , is derived through testing in accordance with Section 4.2, the individual ultimate test values,  $P_{ult, i}$ , of the tested systems shall be adjusted in accordance with Sections 3.5.2 and 3.5.3, and the individual test values corresponding to the deflection limitations given in Section 3.4.2.1,  $P_{defl, i}$ , shall be adjusted in accordance with Section 3.5.4, as applicable. Additionally, the ultimate test value of each individual tested CRTS assembly,  $P_{ult, i}$ , divided by a factor of safety of 2.0 shall not exceed the sum of the lowest ASD component loads within each CRTR of the CRTS assembly, where ASD component loads for each component are adjusted in accordance with Section 3.5.1, as applicable.

**3.5.1 Adjustments for Metal Strength and Cross-sectional Area:** Where the actual tensile strength,  $F_{u- tested}$ , of the metal from which a tested component is formed exceeds the specified tensile strength,  $F_{u- spec}$ , and/or the actual controlling net cross-sectional area,  $A_{tested}$ , exceeds the specified net cross-sectional area,  $A_{spec}$ , of the component, the ASD load of the component,  $P_{component}$ , shall be multiplied by a reduction factor,  $R_s$ , calculated in accordance with Equations 4, 5 and 6, as follows:

$$R_s = \left( \frac{F_{u- spec}}{F_{u- tested}} \right) \times \left( \frac{A_{spec}}{A_{tested}} \right) \leq 1.0 \quad (\text{Eq. 4})$$

Additionally, if:

$$0.95 \leq \left( \frac{A_{spec}}{A_{tested}} \right) \leq 1.05 \quad (\text{Eq. 5})$$

then:

$$\left( \frac{A_{spec}}{A_{tested}} \right) = 1.0 \quad (\text{Eq. 6})$$

The actual tensile strength,  $F_{u- tested}$ , shall not exceed the **specified** tensile strength,  $F_{u- spec}$ , by more than 20 percent.

**3.5.2** Where any of the individual ultimate test values,  $P_{ult, i}$ , of the tested CRTS assemblies is controlled by failure of dowel-type fasteners in wood-to-wood or steel-to-wood connections, said test value(s) shall be

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multiplied by a reduction factor,  $R_{sg}$ , calculated in accordance with Section 3.3.3 of AC155.

**3.5.3** The individual ultimate test values,  $P_{ult,i}$ , of the tested CRTS assemblies shall be multiplied by a reduction factor,  $R_{Fb}$ , calculated based on the relationship between the adjusted NDS-specified bending design value,  $F_b'$ , and the NDS-specified modulus of elasticity,  $E_{spec}$ ; versus the actual average flat-wise long-span modulus of elasticity,  $E_{tested}$ , determined in accordance with Section 3.3.1.3. The NDS-specified bending design value shall be adjusted by the load duration factor,  $C_D$ , size factor,  $C_F$ , and flat use factor,  $C_{Fu}$ , as applicable. Examples of proper calculations of  $R_{Fb}$  for No.1 Douglas fir-larch, No.2 Douglas fir-larch, and No.1/No.2 spruce-pine-fir top plates are given in Equations 7, 8, and 9, respectively.

**Exception:** This reduction factor,  $R_{Fb}$ , is not applicable in cases where the CRTS is designed such that the top plate is not subjected to bending stresses during CRTS loading, or where it can be demonstrated that top plate bending and/or shear will never govern the ASD uniform uplift load,  $W_{all}$ .

For No. 1 Douglas fir-larch top plate:

$$R_{Fb} = \left( \frac{1000 \text{ psi } (1.6)(1.5)(1.1)}{(5.28 \times 10^{-3}) E_{tested} - 6336} \right) \leq 1.0 \quad (\text{Eq. 7})$$

For No.2 Douglas fir-larch top plate:

$$R_{Fb} = \left( \frac{900 \text{ psi } (1.6)(1.5)(1.1)}{(2.64 \times 10^{-3}) E_{tested} - 1848} \right) \leq 1.0 \quad (\text{Eq. 8})$$

For No.1/No.2 spruce-pine-fir top plate:

$$R_{Fb} = \left( \frac{875 \text{ psi } (1.6)(1.5)(1.1)}{(9.9 \times 10^{-3}) E_{tested} - 11550} \right) \leq 1.0 \quad (\text{Eq. 9})$$

**3.5.4** The individual CRTS test loads corresponding to the applicable deflection limit per Section 3.4.2.1,  $P_{defl,i}$ , shall be multiplied by a reduction factor,  $R_{EI}$ , calculated based on the NDS-specified moment of inertia,  $I_{yy-spec}$ , and the NDS-specified modulus of elasticity,  $E_{spec}$ , of the wood members used in the top plate; versus the calculated average moment of inertia,  $I_{tested}$ , and the average modulus of elasticity,  $E_{tested}$ , for all of the wood members comprising the top plate, in accordance with Equation 10. The average moment of inertia,  $I_{tested}$ , shall be calculated using the average thickness,  $d$ , and width,  $b$ , of the wood members measured in accordance with Section 3.3.1.4. These values shall be calculated separately for each respective CRTS test assembly.

$$R_{EI} = \left( \frac{E_{spec} I_{yy-spec}}{E_{tested} I_{tested}} \right) = \left( \frac{12 E_{spec} l_{yy-spec}}{E_{tested} b d^3} \right) \leq 1.0 \quad (\text{Eq. 10})$$

**3.6 Exterior Exposure or Damp Environments:** Where the CRTR or CRTS is intended for exterior exposure or damp environments, evidence of durability shall be submitted. The steel components shall be produced from corrosion-resistant stainless steel or the steel shall be zinc-coated. Evidence of compliance based on the requirements in the applicable code or referenced standard shall be submitted.

**4.0 TEST METHODS**

**4.1 Individual Component Testing:**

**4.1.1 Component Testing Machine:** Testing machines used for tests performed on threaded rod couplers and other proprietary components that do not comply with a referenced standard or acceptance criteria shall have a movable crosshead that is capable of operation at a constant rate of motion, and shall have a force-measuring device that is calibrated in accordance with ASTM E 4. A typical apparatus is illustrated in Figure 2.

**4.1.2 Displacement Measurements:** All displacements during individual component tests shall be measured by dial gages or linear variable displacement transformers (LVDTs) having a least reading increment of 0.001 inch (0.025 mm) or less. The displacement measurement device shall measure the relative movement between the component-to-component assembly or between the component and the test apparatus. Placement of the dial gages or LVDTs shall ensure accurate measurement of the relative movement.

**4.1.3 Minimum Sample Size:** A minimum of three continuous rod tie-down components for each type of threaded rod coupler or proprietary component (size, configuration, and material specifications) shall be tested on a test apparatus. If the maximum test load for an individual tested component varies by more than 15 percent from the average result, testing shall be conducted on three or more additional (six or more, total) continuous rod tie-down components.

**4.1.4 Test Setup:** Threaded rod couplers and other proprietary components shall be tested individually and independently in such a manner as to simulate the essential function of the continuous rod tie-down component. Test loads shall be applied with reference to the intended end-use application of the continuous rod tie-down component. The anchor bolt or rod shall be fastened to the test apparatus in such a manner that the connection to the test bed does not affect the test results. Additionally, the anchor bolt or rod shall be attached to the test apparatus with a nut and washer in accordance with the end-use application as set forth in the manufacturer's installation instructions.

**4.1.5 Test Procedure:** Threaded rod couplers and other proprietary components shall be tested in tension, in accordance with ASTM A 370. Where pretensioning of the threaded rod occurs during installation, an initial load, or preload, shall be applied for tension (uplift) load testing of continuous rod tie-down components or assemblies, as follows: (1) The nut securing the bearing plate shall be tightened as defined in the manufacturer's installation instructions. (2) The testing machine load shall be recorded at this point (identified as preload). (3) Displacement measuring devices shall then be zeroed. The test load shall be applied at a uniform crosshead rate between 0.03 and 0.20 inch (0.8 to 5.1 mm) per minute until failure or maximum load. Loads shall be recorded to a precision of 1 percent during application of test loads. The displacements shall be recorded to the nearest 0.001 inch (0.025 mm), and a sufficient number of readings shall be taken until failure or maximum load is achieved.

At a minimum, each threaded rod coupler or proprietary component shall develop the greater of 100 percent of the specified tensile strength,  $f_u$ , times the net area of the

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threaded rod, or 125 percent of the specified yield strength,  $f_y$ , times the net area of the threaded rod.

**4.2 CRTS Testing:** Where the ASD uniform uplift load of a CRTS,  $W_{all}$ , is to be derived through testing, the CRTS wall assemblies shall be tested in accordance with Section 4.2.1 through 4.2.5.

**4.2.1 CRTS Testing Machine:** CRTS wall assemblies shall be tested on a machine that attaches to the top of the wall assembly at 24 inches on center with independent uplift load actuators that apply an equal uplift force at each point of load application, and force measuring devices that are calibrated in accordance with ASTM E 4. A typical set up for testing the CRTS is shown in Figure 3.

**4.2.2 Displacement Measurements:** All displacements during tests shall be measured by dial gages or linear variable displacement transformers (LVDTs) having a least reading increment of 0.001 inch (0.025 mm) or less. Placement of the dial gages or LVDTs shall be as specified in Figure 3 to ensure accurate measurement of the maximum deflection of the wood top plate.

**4.2.3 CRTS Test Assembly:** Each CRTS test assembly shall be tested in such a manner as to simulate the essential function of the system. Test loads shall be applied with reference to the intended end use of the CRTS. The load transfer plate (hurricane tie simulator) shall be attached to the side of the top plates of the wall assembly to simulate actual load transfer from truss/rafter to wall assembly. The wall assembly length must be sufficient to allow a minimum of four equally spaced CRTRs at the required spacing, and at least one hurricane tie simulator uplift fixture that is outside the CRTR at each end. The wood wall assembly construction shall be, at a minimum, built in accordance with the code. A splice in the upper-most top plate is required in the center of the wall assembly and the fastening schedule at the top plate splice shall be reported. Each CRTS test assembly shall have a minimum wall height of 8 feet (2.44 m). A typical CRTS test assembly is shown in Figure 3.

**4.2.4 Minimum Sample Size:** A minimum of two CRTS assemblies shall be tested for each selected combination of variables affecting the CRTS performance (e.g., selecting different lumber types or grades or different splice detailing would require new sets of system tests). If the individual ultimate test values,  $P_{ult,i}$ , for either test assembly varies by more than 10 percent from the average ultimate test load,  $P_{ult}$ , then an additional CRTS test must be completed.

**4.2.5 CRTS Test Procedure:** A direct uplift load shall be applied to the CRTS assembly as described in Sections 4.2.1 and 4.2.3. The CRTS assembly shall be loaded to failure over a time period of no less than one minute and not to exceed ten minutes. The displacements shall be recorded to the nearest 0.001 inch (0.025 mm), and a sufficient number of readings shall be taken until failure or maximum load is achieved. No initial load or preloading is permitted.

**5.0 QUALITY CONTROL**

**5.1 Quality Documentation:** Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted.

**5.2 Manufacturing Facility Inspections:** If any of the CRTR or CRTS components incorporate structural welds or are manufactured using materials complying with an applicant's published specification, inspections by an inspection agency accredited by the International Accreditation Service, or otherwise acceptable to ICC-ES, shall be provided. Third-party follow-up inspections are not required for CRTRs or CRTSs that do not contain welded components or components that are manufactured using materials complying with a referenced specification.

**5.3 Material Traceability:** The evaluation report applicant shall demonstrate within the quality documentation continuous material traceability of all continuous rod tie-down components and other system components supplied by the applicant. This requirement includes documenting the batch or heat lot number on high-strength or heat-treated threaded rods, high-strength couplers, and components manufactured to an applicant's published specification, as defined in Section 1.4.10.

**5.3.1 Mechanical Properties Testing Requirements:** If components of the CRTR or CRTS assemblies consist of high-strength material, as defined in Section 1.4.3, or are manufactured to an applicant's published specification, as defined in Section 1.4.10, the quality documentation shall specify the minimum requirements, as given in the applicant's published specification, and shall include provisions requiring verification that these minimum requirements are met for each batch or heat lot procured. Verification shall be performed through inspection of mill certificates and tensile test reports generated through testing in accordance with either Section 5.3.1.1 or Section 5.3.1.2.

**5.3.1.1** The report applicant shall obtain continual mechanical property test reports from the manufacturer of the high-strength threaded rods or other components, in lieu of independent testing by an accredited test facility.

**5.3.1.2** The report applicant shall obtain reports of continual independent testing of the high-strength threaded rods or other components, from an accredited testing laboratory, for each batch or heat lot procured.

**5.3.2** High-strength threaded rod shall comply with requirements described in Section 1.4.3.

**5.3.3** Couplers and nuts used with high-strength threaded rod shall comply with Sections 1.4.4 and 1.4.5.

**5.3.4 Identification of High-strength, Applicant-specified, and Proprietary Components:** High-strength threaded rod, threaded rod couplers, and other components manufactured to an applicant's published specification shall be clearly identified in accordance with Section 2.1.4.

**6.0 EVALUATION REPORT RECOGNITION**

**6.1 General:** The evaluation report shall include basic information in accordance with Section 2.1. For evaluations of CRTRs alone, the evaluation report shall exclude any information regarding the surrounding framing members, or any information regarding system dimensions, CRTR spacings, or components or members that are not part of the evaluated CRTR. For evaluations of CRTSs, the evaluation report shall include a comprehensive description of the system dimensions, CRTR spacing, framing members (including species, grade, cross-sectional dimensions, etc.), sheathing (if

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included within the evaluated CRTS), connections between the framing members, and stud spacing. The CRTS description(s) given within the evaluation report shall be representative of the evaluated CRTS(s).

**6.2 Evaluation Reports Recognizing CRTR Alone:**

For evaluations of CRTRs alone, the evaluation report shall include information and statements as described in Sections 6.2.1 through 6.2.4.

**6.2.1 Evaluation Report Tables (CRTRs Alone):**

The evaluation report shall include tables providing information in accordance with Sections 6.2.1.1 through 6.2.1.3:

**6.2.1.1** Continuous rod tie-down component dimensions, as set forth in Section 2.1.1, shall be included within the tables.

**6.2.1.2** The tables shall provide the ASD tension loads and corresponding elongations of the evaluated CRTRs, as derived in accordance with Section 3.1.1. At the option of the evaluation report applicant, the table may also provide the ASD loads for each individual component making up the CRTR.

**6.2.1.3** The tables shall include the following footnoted information:

(a) When the evaluated CRTR includes hold-downs and/or shrinkage compensating devices, a statement referencing the ICC-ES evaluation reports in which the specified hold-downs and/or wood shrinkage compensating devices are covered; and also indicating that the hold-downs and/or wood shrinkage compensating devices shall be installed in accordance with the referenced evaluation reports and the manufacturer's published installation instructions.

(b) A statement indicating that the contribution of wood shrinkage, wood deformation under load, and fastener slip, to the overall deflection of the wall in which the CRTR is installed, shall be analyzed by the registered design professional.

(c) The following statement: "The tabulated allowable (ASD) loads are obtained from calculations and tests on the individual components making up the CRTR. Other variables that may further limit capacities, such as anchorage strength in tension or shear, and stresses within the wood or steel members of the wall in which the CRTR is installed, shall be analyzed by the registered design professional."

(d) The following statement: "When using the basic load combinations in accordance with IBC Section 1605.3.1, the tabulated allowable (ASD) loads for the CRTR shall not be increased for wind or earthquake loading. When using the alternate basic load combinations in IBC Section 1605.3.2 that include wind or earthquake loads, the tabulated ASD loads for the CRTR shall not be increased by 33<sup>1</sup>/<sub>3</sub> percent, nor shall the alternative basic load combinations be reduced by a factor of 0.75."

(e) When the evaluated CRTR includes high-strength threaded rod and/or components manufactured to an applicant's published specification, a statement that the report applicant shall have available, upon request by the code official, current mill certificates and mechanical property test reports to demonstrate compliance with the applicable specification for each batch or heat lot to be

used in the field. The statement shall also indicate that the high-strength threaded rod and/or components manufactured to an applicant's published specification must be identified with the information required in Section 2.1.4 of this criteria.

(f) A statement indicating that the tabulated ASD CRTR tension loads and corresponding elongations are not intended to represent the capacity or deflection of the framing systems, or any other portion of the wall in which the CRTR is installed.

(g) The following statement: "Design of the framing systems is the responsibility of the design professional and must be performed in accordance with the applicable code, taking into account all of the design considerations given in Section X of this report", where "Section X" is the section of the evaluation report containing the design information required under Section 6.2.3 of this criteria.

**6.2.2 CRTR Diagrams:** The evaluation report shall include diagrams that clearly illustrate the evaluated CRTRs. Diagrams shall show building tie-off points, and clearly depict intended load path to supporting foundation or anchorage point via the wood or cold-formed steel members. Special anchorage conditions, such as a steel beam or wood beam connection, may optionally be included. Each diagram shall include a statement indicating that the design of the framing systems is the responsibility of the design professional, and shall be performed in accordance with the applicable code, considering all of the design considerations given in Section 6.2.3 of this criteria.

**6.2.3 Design (CRTRs Alone):** The evaluation report shall include a section entitled "Design," which shall include the following:

(a) A statement indicating that the design of framing and other elements within the wind uplift resisting load path is the responsibility of the design professional, and shall be performed in accordance with the applicable code, considering loads, displacements, shrinkage, etc.

(b) A statement indicating that the design of wall top plates receiving uplift load and distributing it to points of restraint (tie-downs) shall consider both deflection and strength limit states, including combined axial and flexural stress for cases where the wood top plate(s) also acts as a drag strut or collector, and shall also consider geometric compatibility.

(c) A statement indicating that a positive method to resist torsional rotation and cross-grain flexure of the top plates due to offsets between the point of load application (e.g., hurricane ties at the sides of the top plates) and load resistance (e.g., rods at the center of the top plate) shall be provided where such conditions exist; and that calculations in accordance with principles of mechanics shall be used to determine the demand on connections used to resist top plate torsion.

**6.2.4 Conditions of Use (CRTRs Alone):** The evaluation report shall include Conditions of Use as described in Sections 6.2.4.1 through 6.2.4.5:

**6.2.4.1 Preservative- or Fire-retardant-treated Wood:** The use of the CRTR(s) in contact with chemically treated wood is subject to the approval of the code official, since the effects of corrosion of metal in contact with

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chemically treated wood, on the structural performance of the components, are outside the scope of this report.

**6.2.4.2 Exposure:** Installation of the CRTR(s) shall be limited to dry interior locations. As an option, however, installations may be allowed in exterior exposures or damp environments when evidence of compliance with Section 3.6 is provided.

**6.2.4.3 Duration of Load Increase:** No further increase in duration of load for wind loading shall be allowed for the evaluated CRTR(s).

**6.2.4.4 Drawings and Design Details:** Drawings and design details verifying compliance with this report shall be submitted to the code official for approval. Drawings and calculations shall be prepared by a registered design professional when required by the statutes of the jurisdiction in which the project is to be constructed.

**6.2.4.5 Anchorage and Framing Members:** The following statement shall be included as a condition of use: "Design of the anchorage and framing systems is the responsibility of the design professional, and must be performed in accordance with the applicable code, considering all of the design considerations given in Section X of this report", where "Section X" is the section of the evaluation report containing the design information required under Section 6.2.3 of this criteria.

**6.3 Evaluation Reports Recognizing CRTS Wall Assemblies:** For evaluations of CRTS wall assemblies, the evaluation report shall include information and statements as described in Sections 6.3.1 through 6.3.4.

**6.3.1 Evaluation Report Tables (CRTS):** The evaluation report shall include tables providing information in accordance with Sections 6.3.1.1 through 6.3.1.3:

**6.3.1.1** Continuous rod tie-down component dimensions, as set forth in Section 2.1.1, shall be included within the tables. The tables shall also include a general description of each CRTS assembly, and reference the applicable section(s) of the evaluation report in which the detailed CRTS description(s) are given,

**6.3.1.2** The tables shall provide the ASD uniform uplift load,  $W_{all}$ , and corresponding vertical displacements of the evaluated CRTS(s), as derived in accordance with Section 3.1.2.

**6.3.1.3** The table(s) shall include the following footnoted information:

(a) When the evaluated CRTS includes hold-downs and/or shrinkage compensating devices, a statement referencing the ICC-ES evaluation report(s) in which the specified hold-downs and/or wood shrinkage compensating devices are covered; and also indicating that the hold-downs and/or wood shrinkage compensating devices shall be installed in accordance with the referenced evaluation report(s) and the manufacturer's published installation instructions.

(b) A statement indicating that the contribution of wood shrinkage to the overall deflection of the CRTS, shall be analyzed by the registered design professional.

(c) The following statement: "Anchorage of the CRTS is outside the scope of this evaluation report, and shall be designed by the registered design professional."

(d) The following statement: "When using the basic load combinations in accordance with IBC Section 1605.3.1, the tabulated allowable (ASD) uniform uplift load,  $W_{all}$ , for the CRTS shall not be increased for wind or earthquake loading. When using the alternate basic load combinations in IBC Section 1605.3.2 that include wind or earthquake loads, the tabulated ASD uniform uplift load,  $W_{all}$ , for the CRTS shall not be increased by 33<sup>1</sup>/<sub>3</sub> percent, nor shall the alternative basic load combinations be reduced by a factor of 0.75."

(e) When the evaluated CRTS includes high-strength threaded rod and/or components manufactured to an applicant's published specification, a statement that the report applicant shall have available, upon request by the code official, current mill certificates and mechanical property test reports to demonstrate compliance with the applicable specification for each batch or heat lot to be used in the field. The statement shall also indicate that the high-strength threaded rod and/or components manufactured to an applicant's published specification must be identified with the information required in Section 2.1.4 of this criteria.

**6.3.2 CRTS Diagrams:** The evaluation report shall include detailed diagrams that clearly illustrate each of the evaluated CRTS(s). Diagrams shall show all pertinent details of the CRTS, including but not limited to: (a) wall dimensions; (b) CRTR spacing; (c) CRTR component descriptions (including model numbers, where applicable); (d) framing members (including species, grade, cross-sectional dimensions, etc.); (e) sheathing (if included within the evaluated CRTS); (f) connections between the framing members, sheathing, etc.; (g) stud spacing; and (h) load application and anchorage points of the CRTS wall assembly.

**6.3.3 Conditions of Use (CRTS):** The evaluation report shall include Conditions of Use as described in Sections 6.3.3.1 through 6.3.3.5:

**6.3.3.1 Preservative- or Fire-retardant-treated Wood:** The use of continuous rod tie-down assemblies in contact with chemically treated wood is subject to the approval of the code official, since the effects of corrosion of metal in contact with chemically treated wood, on the structural performance of the components, are outside the scope of this report.

**6.3.3.2 Exposure:** Installation of the CRTS wall assemblies shall be limited to dry interior locations. As an option, however, installations may be allowed in exterior exposures or damp environments when evidence of compliance with Section 3.6 is provided.

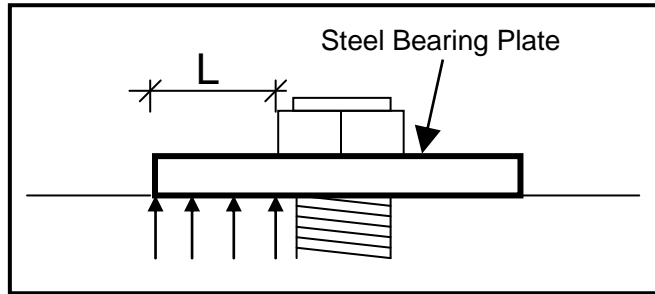
**6.3.3.3 Duration of Load Increase:** The ASD uniform uplift load of a CRTS,  $W_{all}$ , corresponds to a ten-minute load duration, and shall not be further increased by any load duration factor,  $C_D$ .

**6.3.3.4 Drawings and Design Details:** Drawings and design details verifying compliance with this report shall be submitted to the code official for approval. Drawings and calculations shall be prepared by a registered design professional when required by the statutes of the jurisdiction in which the project is to be constructed.

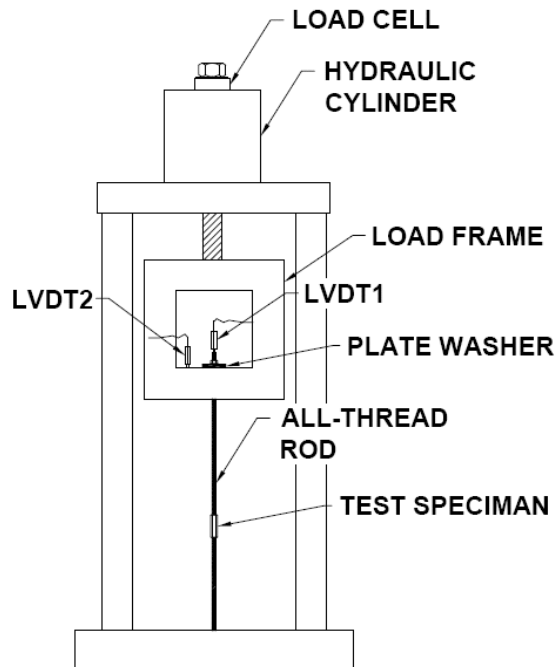
**6.3.3.5 Anchorage:** The following statement shall be included as a condition of use: "Design of the

**ACCEPTANCE CRITERIA FOR CONTINUOUS ROD TIE-DOWN RUNS AND CONTINUOUS ROD TIE-DOWN SYSTEMS USED TO RESIST WIND UPLIFT (AC391)**

anchorage of the CRTS wall assembly is the responsibility of the design professional, and must be performed in accordance with the applicable code." ■

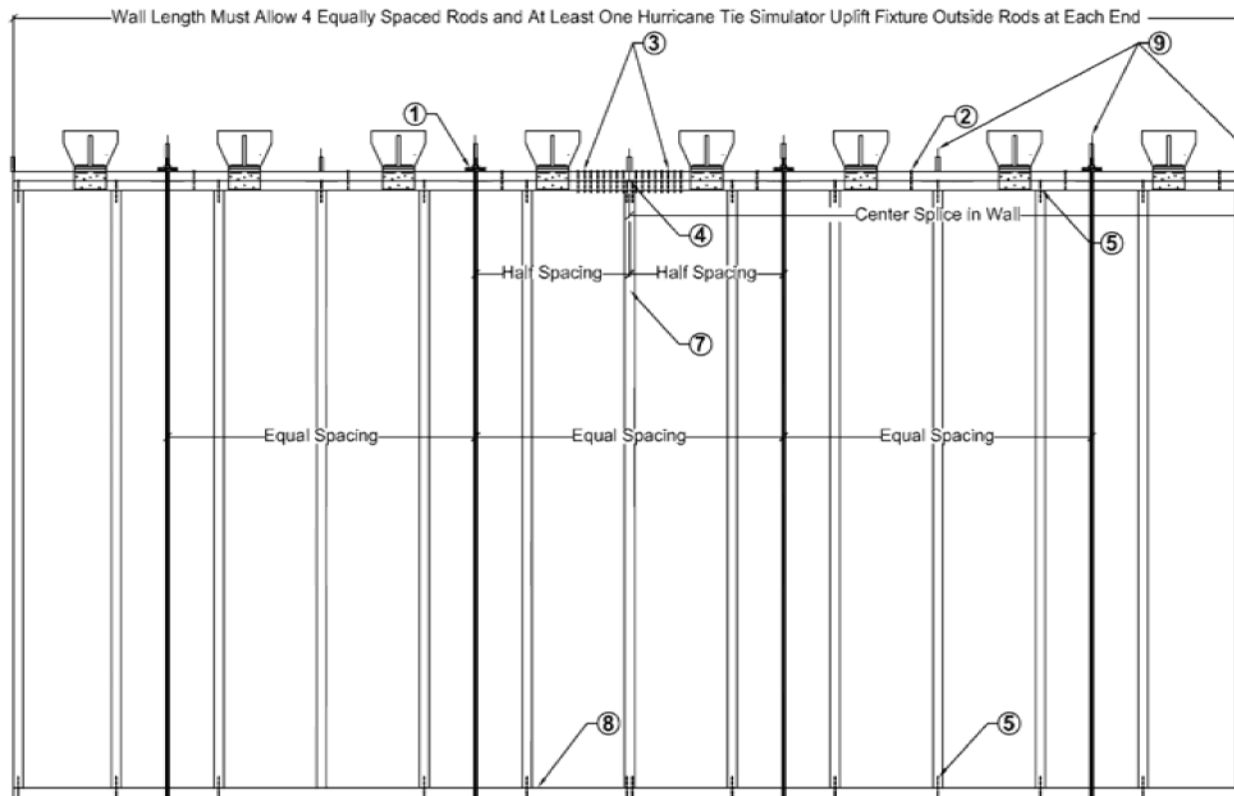


**FIGURE 1—STEEL BEARING PLATE CANTILEVER LENGTH**



**FIGURE 2—SAMPLE TEST APPARATUS FOR INDIVIDUAL COMPONENT TESTS**

**ACCEPTANCE CRITERIA FOR CONTINUOUS ROD TIE-DOWN RUNS AND CONTINUOUS ROD TIE-DOWN SYSTEMS USED TO RESIST WIND UPLIFT (AC391)**



- ① Steel Rod w/ Steel Bearing Plate
- ② System Mfr. shall specify fastener size and spacing used along double top plates
- ③ Fasten double top plates together at splice per IBC 2308.9.2.1 min. System Mfr. to specify splice connection used in testing
- ④ Splice in Top-Most Top-Plate
- ⑤ (2) 16d end nails plate to stud, Typ. At top plate only System Mfr. may add top plate to stud connectors. System mfr. shall specify what type of connector is used and spacing of connectors.
- ⑥ Attach Roof Framing Hurricane Tie Simulator to the Side of the Top-Plate at 24"o.c. using nails, size and spacing to emulate that expected in field.
- ⑦ 2x Studs at 16" o.c. (studs shall be Stud Grade of top plate wood species used)
- ⑧ 2x Sill Plate attached to test bed with ½" dia. A.B. w/ 2"x2"x<sup>3</sup>/<sub>16</sub>" min. plate washers at 32"oc max (No A.B. required where rods exist)
- ⑨ Placement of the dial gages or LVDTs shall be at the mid spans of the top plates between CRTR, at the top of the CRTR, and at the ends of the walls

NOTE: Framing Shall be Minimum of 8' Nominal Plate Height, Locate Splice in Center of Upper Top-Plate and Base Spacing of Rods from Center of Wall.

**FIGURE 3—CTRS TEST SETUP**