WOOD I-JOIST MANUFACTURERS ASSOCIATION

ESTABLISHING FIRE EQUIVALENCY FOR FLOOR FRAMING MEMBERS TO UNPROTECTED 2X10 DIMENSION LUMBER OR EQUAL-SIZED STRUCTURAL COMPOSITE LUMBER

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1 Scope. This document provides the test methodology and procedures to demonstrate equivalent fire performance of floor framing members to unprotected 2x10 dimension lumber or equal-sized structural composite lumber floor joists. The basis and need for the equivalency is Exception 4 to Section R302.13 “Fire protection of floors.” in the 2015 or 2018 IRC, or Section R501.3 in the 2012 IRC.

1.1 General. These guidelines were developed by a WIJMA task group consisting of representatives of testing labs, manufacturers and certification/evaluation agencies (See Note). These guidelines are applicable to factory-applied or field-applied treatments or materials used to provide fire resistance to a floor joist, which includes fire-resistive paints, coatings or chemical treatments, or mechanically-attached fire protection materials. Certain details in this document focus primarily on prefabricated wood I-joists, but these guidelines are applicable to any residential floor joist product not specifically exempted in the IRC, including, but not limited to: open web joists and trusses with wood or metal web members, and light gauge metal joists, as well as prefabricated wood I-joists.

Note: ICC-ES Acceptance Criteria for Prefabricated Wood I-joists (AC14) Section 4.4 was relied upon for test methodology and technical content by permission.

1.2 Fire Performance: Section 2 describes the test method for establishing equivalent fire performance to 2x10 dimension lumber and equal-sized structural composite lumber floor joists. Section 3 describes the test specimen design for use in Section 2 testing.

1.3 Fire-Resistive Paints, Coatings and Chemical Treatments: Section 4 provides additional requirements for the evaluation of paints, coatings, or chemical treatments used as fire protection, including procedures for assessing corrosion and durability of paints, coatings or chemical treatments, and the potential effects on mechanical properties of the floor joist product. Provisions for prefabricated wood I-joists are included for both factory-applied products and field-applied products. Where fire-resistive paints, coatings, or chemical treatments are applied as protection for other types of floor joists, similar considerations apply, but specific details are not covered in this document.

1.4 Mechanically-Attached Fire Protection Materials: Section 5 provides requirements for the installation and inspection of mechanically-attached materials used to provide fire resistance to floor joists.

2 Test Method:

2.1 Furnace Exposure: The test specimen shall be subjected to an ASTM E119 time/temperature environment described in ASTM E119 Section 7.1 for the duration of the test, as noted in Section 2.4. Furnace temperatures shall be measured by thermocouples described in Section 7.2 of ASTM E119. Due to the combustibility and fuel load of the wood assembly, temperatures exceeding those described in the ASTM E119 procedure are allowed.

2.2 Load: Each floor joist member shall support a load corresponding to 50 percent of its full Allowable Stress Design (ASD) bending design load.

2.3 Deflection: Mid-span deflection of the center of the framing assembly shall be measured with a displacement transducer and reported. Where necessary, the transducer is permitted to be located up to 18 inches away from mid-span to accommodate loading apparatus. If the transducer is located away from mid-span, the deflection at mid-span shall be calculated by principles of mechanics. The minimum sampling rate shall be 1.0 Hz. If

displacement data noise reduction is necessary, the data may be smoothed using a centered moving average with a time window no greater than 10 seconds (±5 seconds from the center point). If noise reduction is used, the engineering judgement of a qualified lab representative shall be used to determine the time of individual member or assembly failure by examining the original and smoothed deflection data.

2.4 Test Duration: The test duration shall be defined as the time elapsed between the start of the test and when a floor joist can no longer support the applied load. For purposes of this test, a floor joist is no longer supporting the applied load if any of the following occurs:

a. An individual joist within an assembly fails, or

b. Multiple joists within an assembly fail, or

c. Center span deflection, as determined per Section 2.3, exceeds $^{1}/_{40}$ of the clear span, or

d. The deflection rate of change, as defined below, as an overall trend, decreases.

Deflection rate of change = dx/dt

where:

dx = difference in two adjacent deflection data points after noise reduction as applicable

dt = difference in two adjacent time data points.

Exception: Item "d" does not apply when evidence is submitted to show that the decrease in deflection rate of change was not due to a change in the load-carrying mechanism.

Graphs illustrating the deflection and the deflection rate of change, as a function of elapsed time, shall be submitted to demonstrate compliance with 2.4 (c) and 2.4 (d), respectively.

Note: It is expected that deflection will have a generally increasing rate of change throughout the test as the joist(s) degrade. If the deflection rate of change reaches an ultimate peak and then generally decreases, this is considered an indication that load is being transferred to other elements within the assembly and that the test joist(s) is no longer supporting the applied load. Figures A1 and A2 provide illustrative examples of curves created by hypothetical test data. Figure A1 illustrates an overall deflection versus time curve and is best used to evaluate condition 2.4 (c). Figure A2 illustrates the corresponding deflection rate (dx/dt vs. time) curve. The inflection points in Figure A1 correspond to the peaks (circled) in Figure A2. The raw data was smoothed using a moving average as described in 2.3. Figure A2 is best used to evaluate condition 2.4 (d). Note that there are decreasing rates of change after the 1st and 2nd peaks, but increasing rates generally resume afterward. However, the rate after the 3rd (ultimate) peak continues to decrease. The point of failure is taken to be point at which the deflection rate does not recover, indicating the activity of a load-carrying mechanism other than, or additional to, that provided by the degrading joists. Note further that the Figures A1 and A2 illustrate two non-failure deflection rate peaks. Individual tests may contain different numbers of such peaks, or no non-failure peaks.

2.5 Condition of Acceptance: For the purpose of determining equivalency, the test duration shall equal or exceed 15 minutes , 30 seconds, which is the required minimum duration calculated using the methodology specified in Chapter 16 of the National Design Specification (NDS), for Wood Construction assuming unprotected solid-sawn 2x10 dimension lumber or equal sized structural composite lumber floor joists, a 3-sided fire exposure, a nominal char rate of 1.5 inches/hr, a bending strength to ASD ratio of 2.85, and a load corresponding to 50 percent of the full ASD bending design load.

3 Test Specimen Design:

3.1 Framing Members: The use of single or multiple floor joists is allowed. Floor sheathing is permitted to be included for lateral support of the joists, but shall be detailed so as not to provide any vertical support. Where

sheathing is used to provide lateral support for the joists, the sheathing shall be square-edged and discontinuous across the joist(s) with a 1/8 in. minimum gap between adjacent panels. The sheathing shall be 23/32 in. or less in thickness and installed with the strength axis perpendicular to the joists, such that there are panel joints at maximum 4-foot intervals along the length of the joist(s). For wood joists, sheathing shall be attached using 8d common nails (0.131 in. x 2.5 in.) or smaller nails spaced approximately 24 in. o.c. at panel edges and in the field of the panel. No construction adhesive shall be used in the attachment of the sheathing to the joists.

3.1.1 All components utilized in the manufacture of the floor joist members (fasteners, plates, hardware, etc), including flange or chord splices if permitted, shall be included in the tested members. The use of strongback(s) to transfer load from joists to the boundaries of the assembly, or to the furnace walls shall not be permitted during the test.

3.1.2 Mechanically-attached components that provide some or all of the required fire-resistance to the floor joists shall be fully described, detailed and reviewed by the evaluation agency.

3.1.3 The floor joist members tested shall conservatively represent the range of member sizes and configurations for which equivalency is sought.

3.1.4 When evaluating prefabricated wood I-joists, the I-joists with the minimum desired flange depth and width, web thickness, and I-joist depth that will share equivalence shall be used.

3.1.5 Holes in floor joists shall be considered in the test plan and member design if web holes are allowed in application. One method used for the consideration of the effect of a web hole in a prefabricated wood I-joist is to cut a round hole in the test joist with a minimum diameter equal to 1/3 of the joist depth at one end of the member. The hole would be centered at mid-depth of the joist and located approximately 2 feet from the face of the support (as measured to the center of the hole), or closer.

3.2 Detail Drawings and Calculations: Protection is permitted to be added to assembly components not contributing to the load carrying capacity of the floor joist members. Dimensioned drawings and other documentation specifying all components and materials used within the tested assembly, support conditions, thermocouple placement, deflection transducer placement, boundary conditions, and all other relevant details shall be included within the test plan and the test report. Structural calculations shall also be included within the test plan and the test report, and shall be reviewed by the evaluation agency.

4 Fire Protection Provided by Fire-Resistive Paints, Coatings, or Chemical Treatments: Fire protection provided by fire-resistive paints, coatings or chemical treatments, whether applied directly to the joist or to other components that are attached to the joist shall meet the requirements and conditions of Sections 4.1 through 4.4. Factory-applied fire-resistive paints, coatings or chemical treatments shall be applied with oversight by an accredited inspection agency. Field-applied fire-resistive paints, coatings, or chemical treatments shall require special inspection. For field-applied fire-resistive paints, coatings or treatments, or field-attached components with factory-applied treatments, the evaluation in accordance with Section 4.3 is permitted to be waived if field application occurs after the exterior shell of the structure is complete to protect from moisture and the temperature is maintained within the range specified by the manufacturer of the fire protection material.

4.1 Corrosion Effects of Fire-Resistive Paints, Coatings or Chemical Treatments

4.1.1 The corrosion effects of fire-resistive paints, coatings, or chemical treatments, where used, shall be evaluated in accordance with AWPA E12 with the following modifications:

a. Instead of evaluating the corrosion effects of a treatment chemical, the corrosion effects of the fire protection

material shall be evaluated. Thus, the provisions relating to AWPA Use Categories do not apply. Those provisions relating to minimum retention levels do not apply unless the fire protection is in the form of a wood-penetrating treatment chemical.

b. The fire-protection material shall be applied to structural composite lumber, sawn lumber of any species or species combination identified in NDS Supplement 2.1, or wood structural panels meeting PS1 or PS2.

c. Benchmark materials shall consist of unprotected structural composite lumber, unprotected sawn lumber of any species or species combination identified in NDS Supplement 2.1, or unprotected wood structural panels meeting PS1 or PS2.

d. The benchmark and the protected materials shall be tested with SAE 1010 uncoated carbon steel coupons as specified in AWPA E12.

e. The benchmark and protected materials shall be tested under conditions of 90% relative humidity and 90 °F for a minimum of 720 hours.

4.1.2 For acceptance, the protected material shall be assessed to be equal to or less corrosive than the unprotected benchmark material using a one-tail t-test with a significance level of 0.05. Assessment shall be based on comparison of visible corrosion in accordance with AC257 or based on comparison of average corrosion rates calculated from weight-loss measurements in accordance with the following equation from AWPA E12:

$$R = \frac{CW}{ATD}$$

where:

R	=	corrosion rate (mils/year)
C	=	units conversion constant, 3.44×10^6 (hr-mil/yr-cm)
W	=	weight loss due to corrosion (g)
A	=	area of entire metal coupon including broad faces and edges (cm^2)
T	=	time of exposure (hr)
D	=	density of metal (g/cm^3)

4.2 Effect of Fire-Resistive Paints, Coatings or Chemical Treatments on Joist Mechanical Properties: Where fire-resistive paints, coatings or chemical treatments are used as fire protection materials, tests shall be performed to ensure that the joist mechanical properties are not adversely affected by the fire protection materials.

4.2.1 When evaluating I-joists, one of the following two test programs shall be followed:

a. Flange stiffness, flange tension, flange compression, and I-joist shear shall be evaluated per ASTM D5055.

b. I-joist stiffness, moment and shear shall be evaluated per ASTM D5055.

4.2.2 Evaluations shall be based on a comparison between a control group (unprotected) and a matched group (protected), with each group comprising not fewer than 20 specimens when flange materials are tested or not fewer than 10 specimens when I-joist specimens are tested. Each of the following three conditioning environments shall be evaluated separately for both control and matched groups:

a. Ambient: Test in as-received or as-manufactured condition. Specimens shall be dry but are not required to be conditioned to equilibrium in a specific environment prior to testing in accordance with ASTM D5055.

b. Elevated temperature: Both protected and control groups are conditioned in accordance with ASTM D5664 (temperature at 150 ± 4°F and relative humidity ≥ 50 percent for 108 ± 3 days), followed by a redry period to the original weight ± 2 percent prior to mechanical testing in accordance with ASTM D5055.

c. Moisture cycled: Both protected and control groups are conditioned by submersion in ambient temperature water for 24 hours in accordance with Section 6.3.3 of ASTM D1037, followed by a redry period to the original weight ± 2 percent prior to mechanical testing in accordance with ASTM D5055.

The average mechanical property of the matched group (protected) under each conditioning environment shall not be less than the 95 percent lower confidence bound on the average mechanical property of the control group (unprotected) under the same conditioning environment, calculated as follows:

$$M_m \geq M_c\left(1-\frac{t\,V}{\sqrt{N}}\right)$$

where:

M_m = average mechanical property (stiffness or strength) of matched group (protected) for a specific conditioning environment listed in this section

M_c = average mechanical property (stiffness or strength) of the control group (unprotected) for the same conditioning environment as M_m,

t = student t statistic with 95 percent confidence (see Table 1 of ASTM D2915); t = 2.093 for 20 specimens (19 degrees of freedom) or t = 2.262 for 10 specimens (9 degrees of freedom)

V = coefficient of variation for the mechanical property of the control group at the conditioning environment; V ≤ 0.2 (when V is greater than 0.2, use 0.2 in the calculation)

N = sample size for the control group; N ≥ 20 when flange materials are tested or N ≥ 10 when I-joist specimens are tested.

4.3 Durability of Fire-Resistive Paints, Coatings, or Chemical Treatments: The paints, coatings, or chemical treatments, where used, shall be evaluated to ensure that field exposures to the elements do not adversely affect their fire performance.

4.3.1 When evaluating prefabricated wood I-joists, specimens shall consist of the minimum thickness of proposed web stock, with dimensions of 4 feet by 4 feet (1.2 m by 1.2 m). The fire-resistive paint, coating or treatment shall be applied to each specimen in accordance with the manufacturer's quality documentation, except that it shall be applied only to one side (same side for all specimens). No coatings or sealants shall be applied to the opposite side (see Note 1). A minimum of three specimens shall be used as matched control specimens (painted, coated or treated, but not subjected to any exposure conditions). The remaining specimens shall be subjected to exposure conditions as described in Section 4.3.2. The exposed specimens and the control specimens shall be tested in accordance with Section 4.3.3.

(**Note 1**: If it is suspected that exposure of the uncoated side to moisture cycling is playing a role in the

results of the ICAL (intermediate scale calorimeter) tests, a control study may be performed by comparing the ICAL results of exposed uncoated web stock to those of unexposed uncoated web stock, to determine the magnitude of these effects.)

4.3.2 Exposure Conditions: Exposure conditions shall be as follows:

a. Evaluate three-cycle freeze-thaw effect, including 24-hour water soak: A minimum of three specimens shall be conditioned in accordance with Section 4.7 of ASTM D7032, followed by a redry period to the original weight ± 2 percent prior to testing.

b. Evaluate UV effect: A minimum of three specimens shall be conditioned by subjecting specimens to the water spray exposure described in ASTM D2898 Method B, except that each cycle shall consist of four hours of water exposure, followed by four hours of ultraviolet (UV) exposure on the protected face. Specimens shall be subjected to a total of six eight-hour cycles. The UV exposure shall be accomplished using UV lamps meeting the specifications, irradiance and placement requirements of ASTM D2898. Specimens shall be re-dried to the original weight ± 2 percent prior to testing.

4.3.3 Intermediate Scale Calorimeter (ICAL) Tests: Each specimen shall be exposed to a uniform heat flux on the protected face using the radiant panel configuration described in ASTM E3048 with an energy input of 50 kW/m^2. Three thermocouples shall be placed on the unexposed face, equally spaced along a diagonal line between opposite corners of the specimen. The test shall be continued until one of the following limiting conditions occurs:

a. Burn-through (i.e., the existence of flame on or over the unexposed surface of the specimen for periods of at least five seconds)

b. The average temperature measured by three thermocouples on the unexposed face of the specimen reaches 300 °C (572 °F)

c. An individual thermocouple on the unexposed face of the specimen measures a temperature of 400 °C (752 °F).

The time to reach the first of the limit states (a, b, or c, above) shall be recorded for each specimen as the official test duration. Due to possible equipment limitations, if the individual ICAL test goes beyond 45 minutes without reaching any of the limit states, the test shall be terminated and the time of test duration shall be assigned a value of 45 minutes for the purposes of obtaining an average. Due to potential artificial edge effects introduced by the sample holder, where surface flames may curl around the specimen edges or heat transfer from the return edges of the metal holder may be higher than in the field of the specimen, flaming within 5 inches of the edges of the unexposed specimen shall be allowed. These flames can be extinguished using a suitable means that will not affect the field of the unexposed specimen surface.

The average test duration (including for those that go beyond 45 minutes as described above) for the exposed specimens shall be at least 90 percent of the average test duration for the control group, for each durability exposure condition. If any of the exposure conditions results in an average test duration that is less than 90 percent of the average burn-through time for the control group, I-joist specimens may be subjected to the durability exposure condition and tested in accordance with Sections 2.1 through 2.4. The requirements of such a durability exposure condition are deemed to comply when the test result satisfies the requirements of Section 2.5.

4.4 Quality Control for Fire-Resistive Paints, Coatings, or Chemical Treatments: Requirements for the quality control of fire-resistive paints, coatings, or chemical treatments used as fire protection materials shall be based upon the production and testing of qualification material and shall include provisions regarding composition, verification of chemical formulation, product handling and storage, surface preparation, application rates, etc.

4.4.1 Factory Application: Quality documentation for application of fire-resistive paints, coatings, or chemical treatments used as fire protection shall be submitted to the evaluation agency. A qualifying inspection by the evaluation agency or an accredited inspection agency shall be conducted at each fire protection material application facility prior to acceptance by the evaluation agency.

The application of fire-resistive paints, coatings, or chemical treatments used as fire protection shall be performed under a quality program with inspections by an accredited inspection agency.

4.4.2 Field Application: Instructions required by the manufacturer of the field-applied fire-resistive paints, coatings, or chemical treatments shall be followed, and special inspection shall be required to ensure compliance with the code evaluation report for the field-applied fire resistive paint, coating, or chemical treatment. Prior to application, surface preparation and temperature conditions shall be documented by the applicator and verified by the special inspection agency to comply with this document. Since field application may obscure joist markings, making subsequent identification difficult or impossible, full identification of the floor joists (brand, series, depth, manufacturing date/time, third party agency, evaluation report) shall be conducted and documented prior to application of the fire-resistive paint, coating, or chemical treatment. An identification floor layout plan shall be fully detailed and submitted to the authority having jurisdiction (AHJ).

When fire-resistive paints, coatings, or chemical treatments are field-applied to I-joists, whether or not joist markings are obscured by the application, the original certification of the I-joist may be void, unless supporting documentation showing compliance to this document is provided to and approved by the original third party agency. In addition, the application of fire-resistive paints, coatings, or chemical treatments might not be acceptable to the I-joist manufacturer and might affect product warranties. Consult with the I-joist manufacturer for guidance.

5 Mechanically-Attached Fire Protection Components: Mechanically-attached components that provide some or all of the required fire resistance to the floor joists shall be installed as described and detailed in the certification test report. Factory-installed proprietary protection shall be installed with oversight by an accredited inspection agency. Field-installed protection shall require special inspection. Exception: Field-applied, common building materials (gypsum wallboard, OSB, plywood, mineral wool insulation, etc.) used in a non-proprietary manner with typical connections to provide some or all of the fire resistance, shall not require special inspection.

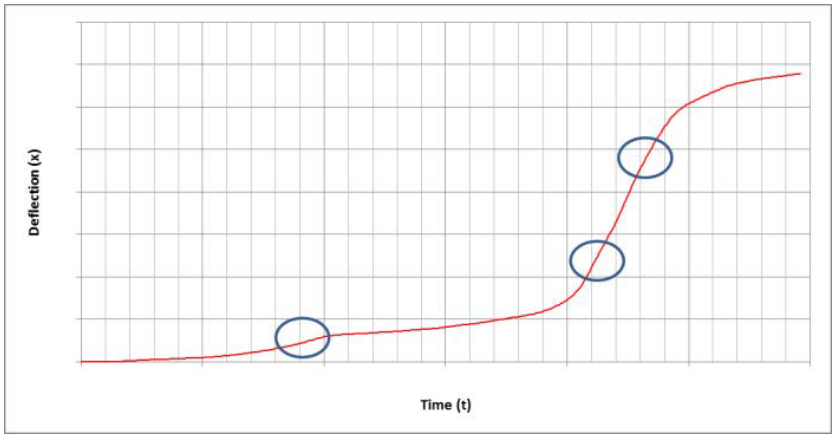

FIGURE A1--DEFLECTION VERSUS TIME CURVE

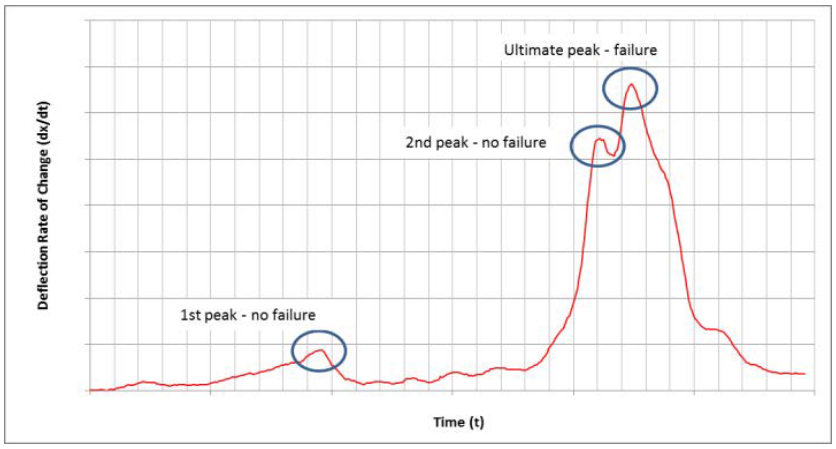

FIGURE A2--DEFLECTION RATE CURVE