UNIFORM STANDARD FOR WOOD PALLETS

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Wood pallets are manufactured, recycled, repaired or remanufactured for the sole purpose of storing and/or transporting material. Under no circumstances should a pallet be used for anything other than its intended purpose, such as a person standing, stepping, or leaning upon them or otherwise using them for support or as a structural construction component. The wood pallet user has the obligation and responsibility to inspect for damage prior to each pallet use and to determine that the pallet design is appropriate for that particular unit load application. All pallets should be removed from service if determined to be unsafe and dangerous to persons or goods.
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- LeRoi Cochran, IFCO Systems, N.A. Inc.
- Ian Carter, Crane Point Industrial, LLC
- John Conway, Conway & Robinson, LLC
- Jeffrey Goettel, Superior Pallets, Inc.
- Stan Joray, Ox Box
- Niels Jorgensen, Kiln-direct.com
- Daniel Konz, Konz Wood Products
- Michael Krisher, Midland Wood Products, Inc.
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- Mark Oletti, Mid Continent Steel and Wire, Inc.
- Greg Ramsey, Philpac Corp.
- Ralph Rupert, Millwood Incorporated
- Bill Schneider, Remmey - The Pallet Company
- Gary Sharon, Litco International, Inc.
- Kelso Sims, Southern Fastening Systems
- Danny Sparrow, Neal’s Pallet Company
- Ryan Stearns, Atlas Pallet Company
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- Brad Gething, PhD
1 PURPOSE
The purpose of this Uniform Standard for Wood Pallets (hereinafter referred to as the Standard) is to establish nationally recognized minimum quality requirements for the principal types of wood pallets, and to provide a basis for common understanding among manufacturers, recyclers, distributors, and users of wood pallets.

2 SCOPE
This Standard applies to all lumber-deck and panel-deck pallets, either new, repaired or remanufactured as well as their lumber, panels, wood-based composites and engineered wood components and fasteners. Criteria contained in this Standard are applicable only at the completion of manufacture.

This Standard is in three parts. Part I is the Prescriptive Standard which concerns the manufacture of the pallet. This includes pallet and pallet component descriptions, definitions, fastener descriptions, workmanship criteria, dimensional tolerances, markings, moisture content levels, and repair and remanufacture of pallets. Part II is the Performance Standard which concerns the functionality of the pallet. This contains references to the testing of physical models or prototypes, and computer software to assist manufacturers, recyclers, distributors, and users to determine the performance level of a specified pallet. Use of the Performance Standard is required for new, repaired and remanufactured pallet constructions, along with conformance to Part I of the Prescriptive Standard. Part III covers Phytosanitation of Wood Pallets.

This Standard does not describe other established special requirements for export pallets and does not address the safety problems, if any, associated with the use of wood pallets. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.

To assist the user of this Standard, other related standards are listed in ANNEX A.

In any dispute regarding dimensions of components or defects, the U.S. customary units are governing.
PART I  PRESCRIPTIVE STANDARD

3  TERMINOLOGY AND DEFINITION

block - rectangular, square, multisided, or cylindrical deck spacer, often identified by its location within the pallet as corner block, end block, edge block, inner block, or center or middle block.

block size - pallet member dimension, specified by width followed by height and length.

deckboard - element or component of pallet top and bottom, perpendicular to stringers or stringerboards.

deckboard size - specified by thickness followed by width and length.

delamination - a visible separation in the plane of a panel or panel component. This may occur in the panel manufacturing process, or in use due to rough handling. The latter may be caused by impacting panel edges with a tine tip, and may or may not result in material being removed from the panel component (see Figure 13).

MIBANT Angle - fastener bend angle providing indication of (fastener) toughness and bending resistance (see Table 3).

notch area - a region around stringer notches with special defect limitations (see Figure 5).

Pallet Design System© (PDS) - a reliability-based computer-aided design (CAD) software for wood stringer and block pallets (see Section 11.2).

pallet length - pallet dimension between the extreme pallet ends, parallel to the stringers or top stringerboards. For panel-deck block pallets without stringerboards, it is the top deck pallet dimension parallel to the face grain for plywood (strong panel axis).

pallet width - pallet dimension between the extreme pallet sides, parallel to and corresponding to the length of the top deckboards. For panel deck block pallets without stringerboards, it is the top deck panel dimension perpendicular to the face grain for plywood (strong panel axis).

pallet size - pallet dimension specified by stringer or stringerboard length, followed by top deckboard length and overall pallet height. For panel deck block pallets, it is the length, width, and overall pallet height.

panel - a wood based structural panel, either plywood or oriented strand board (OSB).

1 For a complete listing of pallet definitions, see "Part 1 Definitions and Terminology Covering Pallets and Related Structures," MH1 Pallets, Slip sheets, and Other Bases for Unit Loads, Material Handling Industry of America (MHIA), www.mhia.org

2 MIBANT angles are measured according to procedures contained in ASTM F680 Standard Test Methods for Nails, ASTM International, www.astm.org
recycled pallet – pallet made reusable by sorting, repairing or remanufacturing, using new or reclaimed components from damaged pallets.

recycled wood pallet part - a pallet part that has been removed from a wood pallet after it has been in service.

remanufactured pallet - a pallet assembled entirely or in part with recycled wood pallet parts and manufactured by complete reassembly of all parts with new fasteners.

remanufactured combination "combo" pallet - a pallet assembled, specifically, with both new and recycled wood parts. Combo pallets are typically assembled with recycled top and bottom deckboards and new wood stringers.

repaired pallet – a pallet with damaged components replaced with new or used components.

shiner - protruding fastener point.

stringer - continuous, longitudinal, solid, built up, or notched beam component of pallet, supporting and spacing deck components, often identified by its location as edge (side) or interior (center) stringer.

stringer size - specified by width followed by height and length.

stringerboard - continuous, solid member extending the full length of the pallet, perpendicular to deckboard members and placed between deckboards and blocks.

stringerboard size - pallet and member dimensions, specified by thickness followed by width and length.

unit load – assembly of goods or single item on pallet for handling, moving, storing, and stacking, as single entity

4 CLASSIFICATIONS

4.1 Classes
• Stringer Pallet (see Figure 1)
• Block Pallet (see Figure 2)

4.2 Use Categories
• Reusable pallet is intended for more than one unit load.
• Single-use pallet is intended to be loaded once for one unit trip.
Figure 1. Schematic diagram of a typical stringer pallet with principal parts labeled.

Figure 2. Schematic diagram of a typical block pallet with principal parts labeled.
4.3 **Entry Types**
- Two-way entry pallet with openings accepting handling equipment only in two pallet ends, i.e. unnotched stringer pallet.
- Partial four-way entry pallet with openings at both ends and sides with limiting accessibility of the openings to common handling equipment, i.e. notched stringer pallet and block pallet with overlapping bottom stringerboards and bottom deckboards, or panels.
- Full four-way entry pallet with openings at both ends and sides with accessibility of all openings not limited to standard handling equipment, i.e. block pallets with perimeter boards, unidirectional, without bottom deckboards, or panel bottom decks with cutouts.

4.4 **Styles**
- Single-face
- Double-face, nonreversible
- Double-face, reversible

4.5 **Top Deck Constructions**
- Deckboard
- Deckboard/stringerboard
- Panel
- Panel/stringerboard

4.6 **Bottom Deck Constructions**
- Unidirectional bottom deckboards oriented in the direction of the pallet length or width only.
- Overlapping bottom boards oriented in both directions of the length and width of the pallet containing both bottom deckboards and bottom stringerboards.
- Perimeter bottom deckboards oriented in both directions of the length and width of the pallet containing butted boards and end boards (see Figure 3).
- Cruciform bottom deckboards oriented in both directions of the length and width of the pallet containing butted boards, end boards, and connector boards (see Figure 3), or panels with cutouts (see Figure 4).

4.7 **Sizes**
Each of the classified pallets is available in many sizes and designs. Therefore, size and design details need to be specified.
Figure 3. Component names for perimeter and cruciform bottom deck construction.

Figure 4. Panel bottom deck showing cutouts.
5 MATERIALS

5.1 Lumber Components

5.1.1 Wood species
The species of woods used in pallet manufacture are numerous. As an aid to the pallet designer, ANNEX B contains a classification of many commercially available woods listed according to similarities in mechanical properties, regional availability, and commercial use in pallets³. When specifying wood pallets, the wood species permissible in the structure can be indicated by the wood species class numbers given in ANNEX B.

5.1.2 Quality
Lumber components shall meet or exceed the minimum quality indicated by the growth and manufacturing defect limitations contained in Table 1. Definitions and descriptions of growth-related defects can be found in ANNEX C.

*Step* - Otherwise called saw (arbor) mismatch: not to exceed 1/32 in. (0.8 mm) on exposed face of components.

*Bevel sawing* - Acceptable if no more damaging than allowable wane or allowable size tolerance for deckboards, stringerboards, stringers and blocks.

*Manufactured (unintentional) hole* - Same as unsound knot (see Table 1 and Section 6.1.2).

*Saw cuts* - Same as unsound knot (see Table 1 and Section 6.1.2).

5.1.3 Moisture content
The moisture content level of pallet components is not limited. For measuring the moisture content of wood, use the following methods:

- ASTM D4442 Standard test methods for direct moisture content measurement of wood and wood-base materials
- ASTM D7438 Standard practice for field calibration and application of hand-held moisture meters

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³ Details concerning the development of these wood-species classifications are found in McLeod, J.A. 1985, “Development of Flexural Values for Pallet Stock,” M.S. Thesis, Department of Wood Science and Forest Products, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061.
### Table 1. Minimum Lumber Component Quality

<table>
<thead>
<tr>
<th>DEFECT</th>
<th>DESCRIPTION</th>
<th>DEFECT LIMITATIONS</th>
<th>REUSABLE&lt;sup&gt;a&lt;/sup&gt;</th>
<th>SINGLE-USE&lt;sup&gt;b,c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound knot&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Maximum portion of the cross section affected</td>
<td></td>
<td>½</td>
<td>7/8</td>
</tr>
<tr>
<td>Frequency of knots</td>
<td>Number of maximum size knots per component</td>
<td>2 in 6 in. (152 mm) of length</td>
<td>1 in every ½ length of component</td>
<td></td>
</tr>
<tr>
<td>Unsound knots and holes&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Maximum portion of the cross section affected&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td>¼</td>
<td>2/3</td>
</tr>
<tr>
<td>Wane</td>
<td>Maximum portion of the actual deckboard or stringerboard width by thickness (full length)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>¼ x 2/3&lt;sup&gt;h&lt;/sup&gt;</td>
<td>3/8 x full thickness&lt;sup&gt;g,h&lt;/sup&gt; (exposed)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum portion of the actual stringer and block width and height (full length)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1/3 x 2/3&lt;sup&gt;h&lt;/sup&gt; (non-exposed)</td>
<td>½ x full thickness&lt;sup&gt;g,h&lt;/sup&gt; (non-exposed)</td>
<td></td>
</tr>
<tr>
<td>Decay</td>
<td>Maximum portion of the cross section affected&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td>¼</td>
<td>¼</td>
</tr>
<tr>
<td>Splits/shakes&lt;sup&gt;j&lt;/sup&gt;</td>
<td>Maximum portion of the actual deckboard, stringerboard, stringer and block length (L) or width (W)</td>
<td>Deckboards: 1/3 L</td>
<td>Full length</td>
<td>Less than full length</td>
</tr>
<tr>
<td></td>
<td>Stringerboards: 1/3 L</td>
<td></td>
<td></td>
<td>Less than 4 in. (102 mm) or (2 x W)</td>
</tr>
<tr>
<td></td>
<td>Stringers&lt;sup&gt;k&lt;/sup&gt;:</td>
<td></td>
<td></td>
<td>½ L</td>
</tr>
<tr>
<td></td>
<td>Horizontal - Less than 4 in. (102 mm) or (2 x W) Vertical - Same</td>
<td></td>
<td></td>
<td>½ L</td>
</tr>
<tr>
<td></td>
<td>Blocks: ½ L</td>
<td></td>
<td></td>
<td>½ L</td>
</tr>
<tr>
<td>Slope-of-grain</td>
<td>Maximum deviation along deckboards, stringerboards, stringers length</td>
<td>1 in. (25 mm) in 4 in. (102 mm) of length</td>
<td>1 in. (25 mm) in 4 in. (102 mm) of length</td>
<td></td>
</tr>
</tbody>
</table>

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<sup>a</sup> With the exception of the slope of grain criteria and wane restrictions, this minimum quality description corresponds to Standard PDS Component Grade (see Section 11.2).

<sup>b</sup> This minimum quality description corresponds to Economy PDS Component Grade (see Section 11.2).

<sup>c</sup> This quality is limited to use for deckboards and stringerboards 5/8 in. (16 mm) thick or greater and stringer or blocks 1-1/4 in. (32 mm) wide or greater. Single-use pallets with deckboards and stringerboards less than 5/8 in. (16 mm) thick or stringer or blocks less than 1-1/4 in. (32 mm) in width shall meet or exceed the reusable quality level.

<sup>d</sup> Sound knots are limited in any portion of the notch area “B” (see Figure 5) to 1/3 of the net cross section above the notch and in any portion of notch area “A” to ½ the net cross section above the notch.

<sup>e</sup> Unsound knots (decay within knot) or holes are limited to ¼ of the net cross section above the notch in areas “A” and “B” (see Figure 5).

<sup>f</sup> Provided the average width of the wood is not less than ¾ of the actual width of the component.

<sup>g</sup> Full thickness of wane on non-exposed surfaces is permitted in no more than 2 pieces per pallet.

<sup>h</sup> Fasteners driven through maximum wane or decay shall be compensated (see Section 6.1.3).

<sup>i</sup> No decay (outside of unsound knot) is allowed over or within 2 in. (51 mm) of the ends of the stringer notches.

<sup>j</sup> See definition and description of splits in ANNEX C.

<sup>k</sup> Not allowed in the notch area (see Figure 5).

<sup>l</sup> In the notch area the wane shall be limited to 1/3 of the stringer width and 1/3 of the height above the notch. No wane shall be permitted in or below the notch fillets within the notch area (see Figure 5).
5.1.4 Preparation
Lumber component tolerances apply at any moisture content.

5.1.4.1 Dimensions
Lumber components shall have a target thickness and width uniform in dimension and 50% of components shall meet or exceed the target dimension at the time of component manufacture. Based on current Good Manufacturing Practices (GMP), the target thickness of deckboards and stringerboards may deviate ±1/32 in. (±0.8 mm). The target width and height of stringers and blocks may exceed the specified dimensions by a maximum of 1/8 in. (3 mm) and 1/4 in. (6 mm), respectively.

The following are acceptable manufacturing tolerances allowed on established target dimensions:

<table>
<thead>
<tr>
<th>Deckboards and Stringerboards</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thicknesses:</td>
<td>±1/16 in. (±1.6 mm) maximum deviation</td>
</tr>
<tr>
<td>(including target deviation of 1/32 in. [±0.8 mm])</td>
<td></td>
</tr>
<tr>
<td>Width:</td>
<td>+unlimited, -1/4 in. (-6 mm) maximum deviation</td>
</tr>
<tr>
<td>Length:</td>
<td>+1/8 in. (+3 mm), -1/4 in. (-6 mm) maximum deviation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stringers and Blocks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Width:</td>
<td>±1/16 in. (±1.6 mm) maximum deviation</td>
</tr>
<tr>
<td>Height:</td>
<td>±1/16 in. (±1.6 mm) maximum deviation</td>
</tr>
<tr>
<td>Length:</td>
<td>+1/8 in. (+3 mm), -1/4 in. (-6 mm) maximum deviation</td>
</tr>
</tbody>
</table>

Conformance to these manufacturing tolerances in components and pallets can be expressed using standard statistics reflecting variations equal to or less than those permitted in this Standard. Two standard deviations from target size shall be less than the tolerances specified.

5.1.4.2 Deckboard chamfer
The deckboard chamfers, if specified, shall be located on both outside faces of bottom end boards and all interior edges of bottom boards adjoining wheel openings. The chamfers shall be at least 12 in. (305 mm) long and at an angle between 35 to 45º, located 1/4 in. (6 mm), ±1/8 in. (±3 mm) from the bottom of the board. Chamfers shall not extend into connections.

5.1.4.3 Stringer notches
Notches in stringers, if required, shall be specified by location (distance from stringer end), depth, and length (see Figure 5). The recommended opening sizes to be provided by the notch and the bottom deck, if present, are 2 in. (51 mm) to the top of the notch and 9 in. (229 mm) in length with a minimum flat surface of 7 in. (177 mm) recommended for the notch top. Notches shall have rounded or filleted corners with a radius not less than 1/2 in. (13 mm), nor greater than 1-1/2 in. (38 mm). Square notches are not acceptable. Manufacturing tolerances shall be ±1/8 in. (±3 mm) of actual specified dimensions except for the notch location which shall be within ±3/8 in. (±9.5 mm) of target.
5.2 Wood Panel (Plywood or OSB) Components

5.2.1 Quality
Wood panels shall conform to the latest edition of one of the following standards:
- PS 1-07 Structural Plywood
- PS 2-04 Performance Standard for Wood-Based Structural-Use Panels
- PRP 108 Performance Standards and Policies for Structural-Use Panels
- ANSI/HPVA HP-1-2004 American National Standard for Hardwood and Decorative Plywood

Each panel deck piece shall be identified with the appropriate trademark of a recognized grading agency (see ANNEX D). The firm supplying the panels shall furnish certification that the original panels were trademarked.

All panels used for pallet components shall be bonded with exterior (fully waterproof) adhesive. Panels that exceed the delamination limits of the standards listed in this Section as a result of their manufacturing process are not permitted to be used for new, repaired or remanufactured pallets.

5.2.2 Grade
Unless specified otherwise by the purchaser, panels for panel decks shall be either: Rated Sheathing, Exposure 1; or Rated Sturd-I-Floor, Exposure 1. Exterior is an acceptable alternative to Exposure 1. Panels of any grade may be used to fabricate laminated pallet blocks.

5.2.3 Preparation

5.2.3.1 Dimensions
Panel decks for block class pallets shall consist of a single piece. Panel decks for stringer class pallets shall be oriented with the plywood face grain (strong panel axis) perpendicular to the stringers, and may consist of more than one piece, provided the minimum width (perpendicular to plywood face grain or strong panel axis) of any piece is 24 in. (610 mm) or greater, and the panel joints are perpendicular to the stringers.
Wood panel components shall have a target thickness and width uniform in dimension and 50% of components must meet or exceed the target dimension at the time of component manufacture. Based on current GMP, the target thickness of panel decks and plywood strip bottom deckboards may deviate ±1/32 in. (±0.8 mm).

Blocks may be laminated from panel components. The target width, length and height of finished panel component blocks may exceed the specified dimensions by a maximum of 1/8 in. (3 mm). Sides shall not deviate from being square to the block top or bottom by more than 1/8 in. (3 mm), and any deviation from square shall not be in addition to the target width and length.

The face grain of plywood strip bottom deckboards shall run in the direction of the deckboards' length. OSB strips are not permitted to be used as bottom deckboards.

The following are acceptable manufacturing tolerances allowed on established target dimensions.

**Panel Decks and Plywood Strip Bottom Deckboards**
Plywood strip bottom deckboards and panel areas around cutouts shall be not less than 6 in. (152 mm) wide

<table>
<thead>
<tr>
<th>Thicknesses:</th>
<th>±1/32 in. (±0.8 mm) maximum deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length and Width:</td>
<td>±1/8 in. (±3 mm)</td>
</tr>
</tbody>
</table>

**Laminated Blocks (including individual laminations)**

<table>
<thead>
<tr>
<th>Width:</th>
<th>±1/8 in. (±3 mm) maximum deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height:</td>
<td>±1/16 in. (±1.6 mm) maximum deviation</td>
</tr>
<tr>
<td>Length:</td>
<td>±1/8 in. (±3 mm) maximum deviation</td>
</tr>
</tbody>
</table>

Conformance to these manufacturing tolerances in components and pallets can be expressed using standard statistics reflecting variations equal to or less than those permitted in this Standard. Two standard deviations from target size shall be less than the tolerances specified.

**5.2.3.2 Panel Decks and Plywood Strip Bottom Deckboard Chamfer**
The deckboard chamfers if specified, shall be located on both outside faces of bottom end boards and all interior and exterior edges of panel bottom decks adjoining wheel openings. The chamfers shall extend the full width of the openings, and shall be at an angle of 35 to 45° located 1/4 in. (6 mm), ±1/8 in. (±3 mm) from bottom of deck or board.

**5.2.3.3 Laminated Pallet Blocks**
Pallet blocks may be laminated from panel components using either fasteners (see Section 6.2.6) or adhesives. A water resistant adhesive shall be used and applied according to manufacturers' recommendations.
5.3 **Wood-based Composites Components**

5.3.1 **Quality**

High-density moisture-resistant wood-based composite blocks shall meet or exceed the following criteria:

- **Density:** 36.9 – 42.1 lbs. ft\(^3\) (591 – 675 kg/m\(^3\))
- **Adhesive:** only approved glue and additives that can assure the stability of the blocks can be used as bonding agents.

Table 2 lists the minimum performance requirements of the blocks. Tests are described in ANNEX E.

<table>
<thead>
<tr>
<th>TEST</th>
<th>MINIMUM PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-hour block soak test</td>
<td></td>
</tr>
<tr>
<td>Weight change</td>
<td>(\leq 25%) increase</td>
</tr>
<tr>
<td>Length change</td>
<td>(\leq 2%) increase</td>
</tr>
<tr>
<td>Width change</td>
<td>(\leq 2%) increase</td>
</tr>
<tr>
<td>Height change</td>
<td>(\leq 6%) increase</td>
</tr>
<tr>
<td>Side tine compression test</td>
<td>(\geq 1,400) lbf. @ 9 in./min.</td>
</tr>
<tr>
<td>Nail insertion force test</td>
<td>(\leq 500) lbf. @ 1.5 in./min.</td>
</tr>
<tr>
<td>Nail withdrawal force test</td>
<td>(\geq 310) lbf. @ 1.5 in./min.</td>
</tr>
</tbody>
</table>

All wood-based composite used for block components shall be bonded with exterior (fully waterproof) adhesive. Wood-based composite blocks that exceed the limits of the tests listed in this Section as a result of their manufacturing process are not permitted to be used for new, repaired or remanufactured pallets.

5.3.2 **Preparation**

Wood-based composite blocks shall have target length, width and height uniform in dimension and 50% of blocks shall meet or exceed the target dimension at the time of component manufacture. Based on current GMP, the target length, width and height of blocks may exceed the specified dimensions by a maximum of 3/16 in. (4.8 mm), 1/8 in. (3 mm) and 1/16 in. (1.5 mm), respectively.

The following are acceptable manufacturing tolerances allowed on established target dimensions.

<table>
<thead>
<tr>
<th>Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length: +3/16 in. (+4.8 mm), -0 in. (-0 mm) maximum deviation</td>
</tr>
<tr>
<td>Width: +1/8 in. (3 mm), -1/16 in. (1.6 mm) maximum deviation</td>
</tr>
<tr>
<td>Height: (\pm 1/16) in. (\pm 1.6 mm) maximum deviation</td>
</tr>
</tbody>
</table>
Conformance to these manufacturing tolerances in components and pallets can be expressed using standard statistics reflecting variations equal to or less than those permitted in this Standard. Two standard deviations from target size shall be less than the tolerances specified.

5.4 Engineered Wood Components

5.4.1 Quality
High-density moisture-resistant engineered wood laminates shall meet or exceed the following standards:
- ASTM D3043 Standard test methods for structural panels in flexure
- ASTM D4761 Standard test methods for mechanical properties of lumber and wood-base structural material

All engineered wood components used for deckboards and stringers shall be bonded with exterior (fully waterproof) adhesive. Engineered wood that fail the test methods of the standards listed in this Section as a result of their manufacturing process are not permitted to be used for new, repaired or remanufactured pallets.

5.4.2 Preparation
Engineered wood components shall have target thickness and width uniform in dimension and 50% of components shall meet or exceed the target dimension at the time of component manufacture. Based on current GMP, the target length, width and height of deckboard or stringer may exceed the specified dimensions by a maximum of 3/16 in. (4.8 mm), 1/8 in. (3 mm) and 1/16 in. (1.6 mm), respectively.

The following are acceptable manufacturing tolerances allowed on established target dimensions:

**Deckboards and Stringerboards**
- Thicknesses: ±1/16 in. (±1.6 mm) maximum deviation
- Width: +unlimited, -1/4 in. (-6 mm) maximum deviation
- Length: +1/8 in. (+3 mm), -1/4 in. (-6 mm) maximum deviation

**Stringers**
- Width: ±1/16 in. (±1.6 mm) maximum deviation
- Height: ±1/16 in. (±1.6 mm) maximum deviation
- Length: +1/8 in. (+3 mm), -1/4 in. (-6 mm) maximum deviation

Conformance to these manufacturing tolerances in components and pallets can be expressed using standard statistics reflecting variations equal to or less than those permitted in this Standard. Two standard deviations from target size shall be less than the tolerances specified.
5.5 Fasteners

Fasteners are classified as driven nails and staples, bolts, wood screws, and lag screws. The types and properties of fasteners affect pallet performance.

5.5.1 Driven Fasteners

Driven fasteners include nails and staples. As used in pallets, nails are classified as plain shank, helically threaded, annularly threaded, fluted, or twisted square wire. Staples have either round wire or approximately square wire legs, referring to the cross sectional shape of the wire. All driven fasteners shall be specified using either of three methods:

1. Direct measurement of the physical and mechanical characteristics (indicated in Table 3 and Figure 6); and
2. Specification of connection design properties, or
3. Both 1 and 2.

<table>
<thead>
<tr>
<th>NAILS</th>
<th>STAPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain shank</td>
<td>Helically threaded</td>
</tr>
<tr>
<td>Length</td>
<td>Length</td>
</tr>
<tr>
<td>Wire diameter</td>
<td>Wire diameter</td>
</tr>
<tr>
<td>Thread length</td>
<td>Thread length</td>
</tr>
<tr>
<td>Thread-crest diameter</td>
<td>Thread-crest diameter</td>
</tr>
<tr>
<td>Number of helixes</td>
<td>Number of rings</td>
</tr>
<tr>
<td>Number of flutes</td>
<td>Number of flutes</td>
</tr>
<tr>
<td>MIBANT angle$^a$ or bending yield strength$^b$</td>
<td>MIBANT angle or bending yield strength</td>
</tr>
</tbody>
</table>

Table 3. Physical and Mechanical Characteristics of Driven Fasteners Used in Pallets

a ASTM F680 Standard Test Methods for Nails
b Nail heads shall be flat or slightly countersunk in shape. Nails shall have no point or a blunt point, not to exceed 5/32 in. (4 mm) in length. In chisel point nails, the point width shall not exceed the wire diameter.
c When the MIBANT test is performed, not more than 8% of the fastener shall show partial or complete shank failure.
d ASTM F1575 Standard Test Method for Determining Bending Yield Moment of Nails
The fastener length shall be sufficient to provide a minimum penetration of 1-1/4 in. (32 mm) into the stringer or block for all deckboard thicknesses over 1/2 in. (13 mm) and a minimum penetration of 1 in. (25 mm) for deckboard thicknesses of 1/2 in. (13 mm) or less. Manufacturing tolerances shall conform to those specified in ASTM F1667 and bending yield strength shall not be less than 100,000 psi (690 MPa). The minimum acceptable quality of driven fasteners is specified in Table 4. Design for lateral resistance shall follow the National Design Specification (NDS)\(^4\) with applicable adjustments for shank deformation (\(C_z\)) and moisture as described in ANNEX F. Design for withdrawal resistance shall follow the NDS with inclusion of adjustments for strength level, shank characteristics (\(C_w\)), and moisture as described in ANNEX F.

### 5.5.2 Bolts

For bolted constructions, steel carriage bolts can be used. Unless otherwise specified, these bolts shall be furnished in the coarse thread series, Class 2A tolerance (ASME B1.1). When steel carriage bolts are employed, washers under the head of the bolt shall be used if specified. If bolts with underhead fins are specified, instead of carriage bolts, washers under the head shall not be used. Washers shall be located under the bolt nut.

---

Table 4. Minimum Characteristics of Driven Fasteners\(^a\) for Single-use (S) and Reusable (R) Pallets

<table>
<thead>
<tr>
<th>Application</th>
<th>Nails</th>
<th>Staples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum Penetration</td>
<td>Minimum $C_w$ (^b)</td>
</tr>
<tr>
<td></td>
<td>in. (mm)</td>
<td>R</td>
</tr>
<tr>
<td>Stringer or block pallets</td>
<td>New</td>
<td>1.25 $^{c, f}$ (32)</td>
</tr>
<tr>
<td></td>
<td>Repair</td>
<td>1.5</td>
</tr>
<tr>
<td>Clinched mat</td>
<td>All</td>
<td>Complete penetration and clinched</td>
</tr>
</tbody>
</table>

\(^a\) Or equivalent connection as determined by comparison of the $C_w$, $C_z$, and Fastener Head or Crown Pull-Through Resistance (HPR) multiplied by the minimum number of fasteners per connection in Section 6.2.4.1.

\(^b\) Fastener withdrawal characteristic. Calculation shown in ANNEX F.

\(^c\) Fastener shear characteristic (withdrawal basis). Calculation shown in ANNEX F.

\(^d\) Fastener bending yield strength as determined by ASTM F1575.

\(^e\) For deformed-shank fasteners, penetration includes only deformed portion embedded in the main member.

\(^f\) For pallets with deckboards that are $\leq \frac{1}{2}$ in. ($\leq$13 mm) thick, minimum penetration shall be 1 in. (25 mm).

The sizes of the holes drilled through deckboards and stringerboards into stringers or blocks shall be 1/32 in. (0.75 mm) larger in diameter than the bolt diameter for bolts less than 1/2 in. (13 mm) diameter. For 1/2 in. (13 mm) or larger diameter bolts, the hole shall be 1/16 in. (1.5 mm) larger. When two or more bolts are connecting green members, the over sizing of holes shall be twice that specified above.

The head and nut bearing surfaces shall be washer faced with a flat or lock washer as specified. If "Teenuts," or equivalent, are specified, washers below the head shall not be used.

### 5.5.3 Wood Screws and Lag Screws

Wood screws and lag screws, generally in compliance with ASME B18.2.1 and ASME B18.6.1, shall have cut or rolled, single or double threads along two-thirds of their shank lengths, shall be inserted into the pallet components to be assembled with a screwdriver or screw motion machine tool. Over driving and over tightening of the connection shall be avoided. Approximately two-thirds of the screw length and seven times the shank diameter shall be the minimum penetration length into the main member. Where pre-drilling is required, the maximum lead hold diameter shall be the fastener shank diameter, and the pilot hole diameter shall not be larger than the thread root diameter. Where lag screws are used, washers under the head of the screws shall be used.

Design for connections with screws and lag screws shall follow NDS for shear and withdrawal. Adjustment for strength design shall use the strength level adjustment factor ($K_F$) equal to 3.32.
6  MANUFACTURE OF PALLETS

6.1  Component Defects
For definitions and classifications, see ANNEX C.

6.1.1  Sound knots
Fasteners may be driven through sound knots.

6.1.2  Unsound knots and holes
Fasteners shall be compensated when associated with unsound knots or holes. Unsound knots or holes shall not be permitted in the outer edge of end boards, nor on the exposed ends of stringers or blocks.

6.1.3  Wane and decay
Wane and decay are permitted on any component; provided it is not located on the outer edge of endboards, or on the exposed sides of stringers or blocks. Decay is not permitted in the notch area (see Figure 5). Wane may appear on the surface or edge of other components; but in no case shall fasteners be driven into or through either defect. Not more than one third (33%) of the components in a pallet may contain wane. Any fastener associated with maximum wane shall be compensated.

6.1.4  Splits and shake
Splits and shakes running the full thickness of a component (not applicable to nail splits) shall be straddled with fasteners in the top and bottom end deckboards and butted side bottom deckboards.

6.1.5  Panel components
Knots, knotholes, splits in individual veneers and other voids do not affect the strength and stiffness of plywood panels having a minimum dimension of 24 in. (600 mm). For widths less than 24 in. (600 mm), the plywood face shall not have knots, plugs, or open defects (knotholes and splits) that aggregate more than one fourth the width of either face ply at any cross section of the piece.

6.2  Assembly

6.2.1  Wood component placement
The placement of wood components shall be as follows:
− All leading deckboards shall be within ±1/4 in. (±6 mm) of their specified location.
− Other wood components shall be within ±1/2 in. (±13 mm) of their specified location, except that bottom boards shall not extend into the stringer notch.

Maximum placement deviation shall be limited to one third of the components in any pallet. All similar components shall be placed parallel unless otherwise specified.
6.2.2 Pallet size deviation
The pallet size shall be limited to plus +1/4 in. (+6 mm) and -1/2 in. (-13 mm) of the target dimension, as measured at specific points along the pallet length and width. The pallets must be flat on their top and bottom surfaces to within 1/4 in. (6 mm) maximum deviation from the corner-to-corner straight line.

6.2.3 Squareness
Square or rectangular pallets shall be limited to 1.5% or 1 in. (25 mm) difference in the measured top deck diagonals, whichever is greater.

6.2.4 Fastening - driven fasteners

6.2.4.1 Fastener schedules

Nails and staples
The minimum number of driven fasteners per pallet component is specified in Table 5.

<table>
<thead>
<tr>
<th>DECKBOARD WIDTH</th>
<th>MINIMUM NUMBER* OF FASTENERS PER CONNECTION OF SINGLE-USE OR REUSABLE PALLETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 5-1/4 in. (133 mm)</td>
<td>2</td>
</tr>
<tr>
<td>5-1/4 up to 7 in. (133-179 mm)</td>
<td>3</td>
</tr>
<tr>
<td>7 to 8 in. (179-203 mm)</td>
<td>4</td>
</tr>
<tr>
<td>Corner block</td>
<td>3b</td>
</tr>
<tr>
<td>Interior block</td>
<td>2</td>
</tr>
</tbody>
</table>

a no less than one nail or staple per 8 sq. in (5,161 mm²) of block fastening surface
b corner blocks with less than 16 sq. in. (10,322 mm²) of block fastening surface shall be connected with at least two (2) fasteners

Bolts, wood screws, and lag screws
The end deckboards shall have at least two bolts, wood screws, or lag screws, per corner connection and at least one at all other connections. It is recommended that bolts be retightened at the time the connected components reach equilibrium moisture content (EMC) during the use of the pallet. Panel deck block pallets shall have at least one bolt per block. Bolted blocks that are not round shall have at least one additional pallet assembly fastener per block to prevent block rotation.
6.2.4.2  **Fastener placement**  
Fasteners shall be placed in such a way as to minimize splitting of the connected components. Staple crowns shall not be parallel to the grain of the deck components. A combination of the various fastener types in a single connection shall not be permitted if they do not interact effectively; that is, simultaneously contributes to the stiffness and strength, or both, of the connection. For example, bolts in oversize holes and driven fasteners represent a poor combination and cannot be expected to work in unison. They shall not be placed in the same connection or different connections of an assembly.

Panel deck stringer pallets shall have a minimum of three fasteners at the end of each stringer starting 1 in. (25 mm) in from the end and spaced 2 in. (51 mm) on center. Interior fasteners shall be spaced a maximum of 10 in. (254 mm) on center. When using laminated blocks, the fastener length requires a minimum of 1 in. (25 mm) overlap between the top and bottom deck fasteners (see Figure 7).

6.2.4.3  **Clinching points of driven fasteners**  
Clinched fasteners shall be at least ¼ in. (6 mm) longer than the sum of the thicknesses of the components being fastened and driven in such a manner as to prevent buckling of the fastener under the crown or head.

6.2.4.4  **Fastener caused splits**  
Open splits with visible fastener shanks or legs shall be limited. No more than one open split with a visible fastener shank or leg per connection shall be permitted and not more than 1/3 of the components per pallet shall contain open splits with visible fastener shanks or legs at the completion of manufacture.

6.2.4.5  **Protruding fasteners**  
Nail heads, staple crowns, bolt heads, nuts, and screw heads shall be flush or below deck surfaces. Countersinking fastener heads and protruding fastener points shall not significantly affect pallet performance. No protruding fastener points (shiners) shall be permitted on the exposed face of outside stringers or blocks or in lead deckboard areas. Two protruding fasteners on unexposed surfaces are permitted so long as they do not significantly affect pallet performance. Protruding fastener points are not permitted when using non clinched fasteners to attach deckboards to stringerboards in block class pallets. Fasteners not driven into stringers and blocks shall be compensated.

6.2.5  **Fastening - chemical adhesives or glues**  
Adhesives shall only be used in conjunction with driven fasteners conforming to Section 5.5.

6.2.6  **Laminated block fastening schedule**  
Laminated blocks shall be assembled with a minimum of two fasteners driven through either face conforming to the quality requirements of Table 3, but equal to the block height [1/2 in. (13 mm) if countersunk 1/4 in. (6 mm)] (see Figure 7).
Figure 7. Schematic diagrams of block lamination and fastening.
7 - REPAIR OF PALLETS

Properly repairing and recycling wood pallets is an environmentally conscientious practice, which also increases unit load material handling efficiency and reduces the cost of product storage and distribution. All pallets should be removed from service and be repaired, recycled or properly disposed of, if determined to be unsafe to persons or goods.

7.1 Damages

Damages which should be repaired in pallets with lumber, panel, wood-based composite, or engineered wood components:

7.1.1 Missing deckboards, stringers, blocks, or stringerboards.

7.1.2 Broken deckboards, stringers, the stringer foot, blocks or stringerboards (see Figure 8).

7.1.3 Splits in deckboards or stringerboards of more than half the length or width, which cannot be securely fastened (see Figure 9).

7.1.4 Splits in stringers or blocks of more than half the height or width and more than half the length (see Figure 9).

7.1.5 Full width splits of any length in stringer notches (see Figure 8).

7.1.6 Missing wood on more than two connections of the same component, which exposes one or more shanks (see Figure 10).

7.1.7 Missing wood of more than a fourth of the board width and half of the board length or equivalent (see Figure 10).

7.1.8 Missing wood at anyone connection, which exposes two or more fastener shanks, except at 4 in. (102 mm) wide deckboard and butted joints in perimeter base block style pallets, which require repair if one or more fasteners are exposed (see Figure 10 and Figure 11).

7.1.9 Missing wood on structural panel decks and panel strip bottom deckboards less than 24 in. (610 mm) wide (see Figure 12).

Any one area of rectangular shape up to 1 in. (25 mm) deep and 10 in. (254 mm) long in one edge of any component, or up to 1-1/2 in. (38 mm) deep and 20 in. (508 mm) long in aggregate on opposite edges.

7.1.10 Missing wood on structural panel decks and panel strip bottom deckboards between 24 and 36 in. (610 and 914 mm) wide (see Figure 12).

Any one area of rectangular shape up to 1-1/2 in. (38 mm) deep and 10 in. (254 mm) long in one edge of any component, or up to 2 in. (51 mm) deep and 20 in. (508 mm) long in aggregate on opposite edges.
Figure 8. Schematic diagrams of broken deckboard, stringer and stringer foot.
Figure 9. Schematic diagrams of splits in deckboards and stringer.
Figure 10. Schematic diagrams of missing wood.
Figure 11. Schematic diagrams of a block class pallet showing the butted connection in the bottom deck of a perimeter base design.

Figure 12. Schematic diagrams showing the allowable locations and extent of missing wood in a block pallet.
7.1.11 **Missing wood** on panel decks and panel strip bottom deckboards over 36 in. (914 mm) wide (see Figure 12).

Any one area of rectangular shape up to 2 in. (51 mm) deep and 10 in. (254 mm) long in one edge of any component, or up to 3 in. (76 mm) deep and 20 in. (508 mm) long in aggregate on opposite edges.

7.1.12 **Missing wood** in areas around cutouts in panel decks (see Figure 12).

In areas around cutouts where the strong panel axis does not span the opening between stringer or blocks, the total damage cannot exceed 1 in. (25 mm) deep and 10 in. (254 mm) long on either or both opposite sides. Otherwise, missing wood is limited as in Sections 7.1.9 through 7.1.11.

7.1.13 **Delamination** of panel decks and panel bottom deckboards less than 24 in. (610 mm) wide (see Figure 13).

Missing wood due to delamination is limited to a maximum of one-third of the panel’s total thickness for any width panel section and shall not occur in connections. Delamination is limited to a maximum of 3 in. (76 mm) deep and half the length of the affected edge or up to 4 in. (104 mm) and two-thirds the length in aggregate on opposite edges.

7.1.14 **Delamination** of panel decks and panel bottom deckboards between 24 and 36 in. (610 and 914 mm) wide (see Figure 13).

Delamination is limited to a maximum of 8 in. (203 mm) deep and half the total length of the affected edge or up to 10 in. (254 mm) and two-thirds the length in aggregate on opposite edges.

7.1.15 **Delamination** of panel decks and panel bottom deckboards over 36 in. wide (see Figure 13). Delamination is limited to a maximum of 12 in. (305 mm) deep and half the total length of the affected edge or up to 15 in. (381 mm) and two-thirds the length in aggregate on opposite edges.

7.1.16 **Delamination** around cutouts in panel decks (see Figure 13). In areas around cutouts where the strong panel axis does not span the openings between the stringers or blocks, the total delamination cannot exceed 3 in. (76 mm) and one-third the total length on either or both opposite edges. Otherwise, delamination is limited as in Sections 7.1.13 through 7.1.15.

7.1.17 **Block twist**, which overhangs pallet sides or ends.
Figure 13. Schematic diagrams of panel delamination.
7.2 Recommended General Repair Procedures

7.2.1 Pallets of known specification

The repair shall be in accordance with the respective requirements.

7.2.2 Pallets of unknown specification

7.2.2.1 Deckboard/stringerboard/block components
Pallet components with unacceptable damage should be removed and replaced with new or used components of similar material and dimensions where material quality and tolerances are given in Section 7.3.

7.2.2.2 Panel Deck Repair
A minimum width of 3-½ in. (89 mm) shall be removed from the entire length or width of a damaged edge of a panel deck that is to be repaired. The removed section must be replaced by a butted leading edge lumber deckboard of the same dimensions. For block class pallets, the blocks that the replacement deckboard is fastened to must be twice as long as the width of the replacement deckboard or 7 in. (178 mm) minimum, and oriented with this dimension perpendicular to the replacement deckboard.

An occasional wider or narrower component may be used so long as the gaps between deckboards are not excessive and that these components are properly fastened.

7.2.2.3 Fastener heads, crowns or points on exposed exterior pallet surfaces shall be driven flush or below the component surface.

7.2.2.4 Free standing fasteners should be driven into the block, stringer, or stringerboard and the joints shall be compensated with additional fasteners.

7.2.2.5 Loose components should be removed or securely fastened.

7.2.2.6 Twisted blocks overhanging pallet sides or ends shall be squared and refastened with at least two fasteners.

7.2.2.7 Stringers with horizontal or diagonal splits shall be repaired with metal connector plates (see Figure 14). The only permissible repair of a completely separated part, is the reattachment of a stringer end foot. Splits at large knows, 1 in. (25 mm) in diameter, or greater, shall not be repaired. Repair of cross-grain breaks are not permitted.
Figure 14. Schematic diagrams of two of the common styles of metal connector plates.
Metal connector plates specifications

Size: Plates shall be a minimum of 2-3/4 in. (70 mm) in length and width and 11 sq. in. (7097 mm$^2$) in area as determined by external plate dimensions.

Material: Minimum basse-metal thickness: 20 gauge (0.034 in.) (0.9 mm) minimum thickness of uncoated commercial grade sheet steel.

Teeth: At least 4 teeth per sq. in. (645 mm$^2$) of plate area as determined by external dimensions. The length of teeth shall be at least 0.325 in. (8.3 mm) excluding plate thickness.

Metal plate application

Apply plates with mechanical, hydraulic, or pneumatic power, using machinery designed and manufactured for this purpose.

The split shall be closed with a mechanically, hydraulically, or pneumatically operated press prior to plate application. A minimum of two plates shall be used per repair. The plates shall be applied opposite one another on each stringer side and pressed mechanically, hydraulically, or pneumatically flush with the wood surface at locations (see Figure 15). Plates shall be aligned in such a way that they do not overhang the stringer ends or edges. The plate edges or ends shall be approximately parallel to the ends or edges of the stringers. All teeth of each plate shall be pressed into the wood. The longest dimension of the plate shall be in the direction of the split. Each plate applied shall cover the split. Splits longer than 8 in. (200 mm) shall be repaired with four plates. Two opposite plates at each end of the split shall be used (see Figure 15).

Figure 15. Schematic diagrams showing proper placement of metal plates over splits.
7.2.2.8 Companion stringers — full length, half, notched, block, C-block, or plugs (see Figure 16)
Companion stringers shall be similar in width (see Table 6) and shall be no more than 1/4 in. (6 mm) “lower” in height than the component being repaired. Companion components shall be fastened to all supported top and bottom deck components using the fastener schedule in Section 6.2.4.1.

Figure 16. Schematic diagrams of companion stringer components used to repair wood pallets.

Full length companion stringer
This is the strongest companion repair practice and is recommended when both interior notched fillets are cracked or severe cracks are evident between notches. The companion stringer is similar in length to the repaired stringer and contains notches if used to repair a partial 4-way pallet (see Figure 17 and Table 6).

Half Stringers
This may be used when only one notch or stringer "foot" has failed. It is of a similar size and half the length of the original stringer and when necessary, contains a notch of similar size to that being repaired (see Figure 18).

C-block
This may be used when a stringer end foot or above notch area requires repair. The repair component consists of a complete stringer end foot and most of the above notch area. Typically the C Blocks are approximately 14 to 15 in. long (356 to 381 mm) (see Figure 19).
Figure 17. Schematic diagram of a full-length companion stringer repair.
* Deckboards are shortened for illustrative purposes.

Figure 18. Schematic diagram of half-companion stringer repair.
* Deckboards are shortened for illustrative purposes.
Figure 19. Schematic diagram of C-block and notched block stringer repairs.
* Deckboards are shortened for illustrative purposes.

**Notched block**
This companion component contains a notch of similar size to the notch being repaired and has two "feet" at least 4 in. (102 mm) long on either side of the notch (see Figure 19).

**Plugs**
These are short unnotched blocks, typically between 4 and 18 in. (102 and 457 mm) long that may be used to repair a split stringer foot and between notches in notched stringers (see Figure 20).

### 7.3 Repair Component Quality

#### 7.3.1 Fasteners
The fasteners used to repair connections or attach replaced components or companion components shall meet or exceed the quality described in Section 5.5.

#### 7.3.2 Wood components

##### 7.3.2.1 Component grade
New or used components may be used. The component grade shall be equivalent or better than the reusable pallet described in Section 5.1 and Table 1.
7.3.2.2 *Species replacement or companion components*
Medium to high density hardwood and softwood species may be used to repair or replace any component. These are Wood Species Classes 1, 2, 3, 4, 6, 11, 12, 21, 22, and 29 in ANNEX B. Lower density hardwoods and softwood species classes should be used for interior top and bottom deckboard replacement and repair only. These are Wood Species Classes 7, 13, and 14 in ANNEX B.

7.3.2.3 *Replacement panels or panel strips*
Shall be of similar grade, performance rating, and dimension, as those components being replaced and shall be in conformance with Section 5.2 and 5.4.

7.3.2.4 *Replacement components of similar dimension*
Table 6 defines "similar dimensions" and contains the maximum allowed deviation of replacement components from the component replaced.

Table 6. Maximum allowable deviation of replacement or companion components from component being replaced, repaired, i.e. components of similar dimensions. The tolerances are based on the component dimensions of the original pallet being repaired.

<table>
<thead>
<tr>
<th></th>
<th>LENGTH (in.)</th>
<th>THICKNESS OR HEIGHT (in.)</th>
<th>WIDTH (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deckboard and stringerboard</td>
<td>± 1/4 (+6 mm)</td>
<td>± 1/8 (+3 mm)</td>
<td>- 3/8 (-9 mm)</td>
</tr>
<tr>
<td>Stringer</td>
<td>± 1/4 (+6 mm)</td>
<td>± 1/8 (+3 mm)</td>
<td>- 1/8 (-3 mm)</td>
</tr>
<tr>
<td>Block</td>
<td>± 1/4 (+6 mm)</td>
<td>± 1/8 (+3 mm)</td>
<td>- 1/4 (-6 mm)</td>
</tr>
</tbody>
</table>
7.4 Repair Workmanship

7.4.1 Flatness
Pallets must be flat and the deckboard thickness within a pallet shall not vary by more than 3/16 in. (5 mm).

7.4.2 Squareness
The difference in diagonal length shall not exceed 1/2 in. (12 mm).

7.4.3 Deckboard spacing
The spacing shall not exceed 4 in. (102 mm) between top deckboards in pallets of unknown specification.

7.4.4 Overall pallet length and width
The tolerances on pallet length and width for Repaired Pallet Class 1 shall be ± 1/4 in. (± 6 mm), and for Repaired Class 2 or 3 the tolerance ± 1/2 in. (12 mm).

7.4.5 Fastening schedule and placement
In conformance with Sections 6.2.4.1. and 6.2.4.2.

7.4.6 Overall appearance
Sound construction, no deckboards in the notches, components are parallel and perpendicular and components are flush with the pallet perimeter unless otherwise specified.

7.5 Classes of Repaired 48x40 Notched Three Stringer Pallets
Class 1 - Repaired pallets, shall be permitted to contain metal plates, but no companion stringer repairs.

Class 2 - Repaired pallets with one or two stringers repaired using plugs and/or notched blocks or longer companion stringers.

Class 3 - Repaired pallets otherwise not meeting Class 1 and 2 criteria.

7.6 Additional Descriptions for Class of Repaired Pallets
To better balance pallet economy and performance, the above classes may include additional descriptions such as described below:

GMA Deck Coverage - This implies seven top deckboards and five bottom deckboards. More top and bottom deckboards better protect product. The pallets are stronger, more functional, and more durable than pallets with fewer deckboards.

Four- or Six-Inch Wide Endboard - Pallets with nominal 6 in. (152 mm) wide, properly fastened end deckboards are more functional and durable. Two properly fastened nominal 4 in. (102 mm) wide endboards, butted together, are equivalent in performance to a single nominal 6 in. (152 mm) properly fastened board.
Hardwoods and Softwoods - Repaired pallets of the same design fabricated predominantly with dense hardwoods will be more durable and stronger than pallets of a similar design fabricated predominantly with softwood species.

Stringers Repaired with Metal Connector Plates - Notched stringers repaired using metal connector plates, in accordance with procedures described in this Standard, have been shown to restore the stringer to its original strength.

7.7 Marking
The recommended marking should include:
– Class of repair
– Repairer’s identification
– Date of repair
– Owner identification (if applicable, and for pallets of known specification)

Space permitting, the mark shall be a minimum of 2 in. (51 mm) high, with letters 1 in. (25 mm) high.

8 REMANUFACTURE OF PALLETS
The remanufacture of a pallet using recycled pallet parts is an environmentally conscientious practice, which also increases unit load efficiency, and reduces the cost of product storage and distribution. All pallets should be removed from service and be remanufactured, recycled or properly disposed of, if determined to be unsafe to persons or goods.

8.1 Quality of Parts

8.1.2 Fasteners
The fasteners used for the assembly of remanufactured pallets shall meet or exceed the quality criteria described in Section 5.5. Combo pallets containing new stringers or blocks shall be assembled using fasteners, which meet or exceed the criteria for "Manufacture of Pallets.” Pallets assembled with recycled stringers or blocks shall be assembled using fasteners meeting or exceeding the criteria for "Repair of Pallets."

8.1.2 New wood parts
The quality of new wood parts for use in remanufactured pallets shall conform to Sections 5.1, 5.2, 5.3 and 5.4.

8.1.3 Quality of recycled pallet parts

8.1.3.1 Recycled component grades
Recycled components shall conform to the quality criteria in Sections 5.1, 5.2, 5.3 and 5.4.
8.2.3.2 Wood species
The wood species used in remanufactured pallets is not limited. However, suggested groupings of wood species of practical value during sortation are listed Table 7. The wood species in each wood species class can be found in ANNEX B.

<table>
<thead>
<tr>
<th>WOOD GROUP</th>
<th>WOOD SPECIES CLASSES CONTAINED IN GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium/High density woods</td>
<td>All species listed in Species Classes 1, 2, 3, 4, 11, 21, 22</td>
</tr>
<tr>
<td>Low density woods</td>
<td>All species listed in Species Classes 6, 7, 12, 13, 14, 29</td>
</tr>
<tr>
<td>Hardwoods</td>
<td>All species listed in Species Classes 1, 2, 3, 4, 6, 7, 21, 29</td>
</tr>
<tr>
<td>Softwoods</td>
<td>All species listed in Species Classes 11, 12, 13, 14, 22</td>
</tr>
<tr>
<td>Mixed woods</td>
<td>All species listed for other wood groups</td>
</tr>
</tbody>
</table>

8.2 Quality of Assembly
Quality of assembly of remanufactured pallets shall be according to Section 6, with the following exceptions and additions.

8.2.1 Driving fasteners
Driving fasteners through existing fastener holes in recycled pallet components shall be avoided.

8.2.2 Pre-existing fastener holes
Pre-existing fastener holes shall be positioned during assembly so as to limit their impact on pallet performance. This includes positioning such holes near but not within connections.

8.2.3 Fastener cause splits
Not more than one half of the components in a reassembled pallet shall contain open splits with visible fastener shanks or legs.

8.2.4 Recycled component dimensional variation
Recycled component dimensional variation within each remanufactured pallet, relative to the target dimension (see Table 8).

<table>
<thead>
<tr>
<th>COMPONENT DIMENSION</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board Thickness</td>
<td>-0 +1/8” (-0 +3 mm)</td>
</tr>
<tr>
<td>Board Width</td>
<td>unlimited – ¼” (-6 mm)*</td>
</tr>
<tr>
<td>Board Length</td>
<td>±¼” (+6 mm)</td>
</tr>
<tr>
<td>Stringer Height</td>
<td>-0 +1/8” (-0 +3 mm)</td>
</tr>
<tr>
<td>Stringer Width</td>
<td>-0 +¼” (-0 +6 mm)</td>
</tr>
<tr>
<td>Stringer Length</td>
<td>±¼” (+6 mm)</td>
</tr>
<tr>
<td>Block Height</td>
<td>-0 +1/8” (-0 +3 mm)</td>
</tr>
<tr>
<td>Block Width</td>
<td>-0 +¼” (-0 +6 mm)</td>
</tr>
<tr>
<td>Block Length</td>
<td>±¼” (+6 mm)</td>
</tr>
</tbody>
</table>
*for each nominal deckboard width
PART II PERFORMANCE STANDARD

9 CONDITIONS OF PALLET USE

The use conditions which pallets shall sustain during unit load material handling vary. Therefore, the conditions of use shall be specified, including performance levels. Where conditions of use vary, the condition which results in the highest stress levels shall be used as a basis for determining performance.

9.1 Load Condition

Provide the description of the packages, containers or units to be placed on the pallet (i.e. bags, boxes, barrels, bulk containers, blocks and machinery including the use of load stabilizers).

Provide measurements and location of bearing areas for the packages, containers or units to be placed on the pallet and the pallet top and bottom decks, stringers or blocks.

Provide maximum and average load levels and load level variations.

9.2 Support Conditions

Indicate maximum unsupported free span along the pallet length and width.

Indicate maximum number of unit loads in a stack.

Indicate measurements and locations of bearing areas between the pallet stringers or stringerboards and top and bottom decks and their supports.

10 MEASURES OF PALLET PERFORMANCE

Pallet performance shall be specified in terms of strength, stiffness and durability. Pallet performance is directly correlated to the type and quality of fastener, grade, species, and moisture content of lumber components and the material handling environment.

Strength - determine design or safe working loads for each condition of use. When reusable pallet conditions exist, the pallet and pallet component performance shall be based on the minimum design or safe working load.

Stiffness - determine maximum deflection or pallets and pallet components for each condition of use.

Durability - Single-use or Reusable categories (see Section 4.2).

Single-use pallets are intended for use with a single unit load. This category of pallets requires sufficient damage resistance to survive at least one trip without requiring repair.

Reusable pallets are intended for repeated uses for more than one unit load. This category of pallets requires sufficient damage resistance to survive multiple trips without requiring repair.
The criteria for the classification of pallets are given in the documentation of the test procedures provided in Section 11.

11 TEST PROCEDURES

11.1 Testing for Physical Models or Prototypes
When possible, actual loads and supports shall be used in the test. However, load and support analogs, based on sound engineering principles, are acceptable. The following test methods and their design criteria are recognized:

ISO 8611 series. Pallets for materials handling – Flat pallets
International Standards Organization (ISO)
www.iso.org

ASTM International
www.astm.org

11.2 Testing of Computer Models
The computer software for predicting pallet performance is the Pallet Design System© (PDS)5.

5 The Pallet Design System (PDS) can be used for designing, selecting and predicting the performance of wood pallets. PDS is available through: NWPCA, www.palletcentral.com
PART III    PHYTOSANITATION STANDARD

12    PHYTOSANITATION OF WOOD PALLETS

Treatment and marking of wood pallets must conform to the International Standards for Phytosanitary Measures Publication No. 15 (ISPM 15) Regulations of wood packaging material in international trade. ISPM 15 has been adopted by the United States and its trading partners as their import requirements for wood pallets.

Treatment or quality mark (Figure 21) should include the following:
− IPPC logo
− Two-letter U.S. abbreviation
− Unique number assigned by an inspection agency to the facility
− HT or MB abbreviation

![Figure 21. HT and MB treatment marks.](image)

Wood pallets can be ISPM 15-compliant by adhering to any of the following:

12.1 Debarked
Wood pallets must be made of debarked wood. Any number of visually separate and clearly distinct small pieces of bark may remain if they are:
− Less than 3 cm (1\(\frac{3}{16}\) in.) in width (regardless of length), or
− Greater than 3 cm (1\(\frac{3}{16}\) in.) in width, with the total surface area of an individual piece of bark less than 50 cm\(^2\)

12.2 Heat treated (HT) Wood Pallets
Heat treatment and marking of wood pallets shall conform to the enforcement regulations and policy of the American Lumber Standards Committee (ALSC) Wood Packaging Material (WPM) Program.

12.3 Methyl bromide (MB) Fumigated Pallets
MB fumigation and marking of wood pallets shall conform to the enforcement regulations and policy of the Export WPM Fumigation Program.

12.4 New Pallets
New pallets that will be used for export shipment must be ISPM 15-compliant.
12.5 Recycled Pallets

Reusing ISPM 15-compliant wood pallets do not require retreatment and remarking. However, repaired, remanufactured and combo pallets must be retreated and remarked in order to be ISPM 15-compliant. Old marks must be obliterated.
ANNEX A
STANDARDS CONCERNING WOOD PALLETS AND CONTAINERS

National Wooden Pallet and Container Association (NWPCA)
www.palletcentral.com
– NWPCA Uniform Standard for Wood Pallets
– NWPCA Uniform Standard for Wood Containers

Material Handling Industry of America (MHIA)
www.mhia.org
– MH1 Pallets, Slip Sheets, and Other Bases For Unit Loads (2005 edition)
  • Part 1 Definitions and Terminology Covering Pallets and Related Structures
  • Part 2 Sizes of Wood Pallets
  • Part 3 Wood Pallets
  • Part 4 Export Pallets
  • Part 5 Driven Fasteners for Assembly of Pallets and Related Structures
  • Part 6 Protocol for Measuring Quality of Pallet Nails and Staples
  • Part 7 Testing Procedures for Pallets and Related Structures
  • Part 8 Slip Sheets
  • Part 9 Wood Pallets for Military Use
  • Part 10 Performance Specification for Pallets to be Used in Automated Unit-Load Material Handling Equipment

ASTM International
www.astm.org
D10 Packaging
– ASTM D1185 Standard Test Methods for Pallets and Related Structures Employed in Material Handling and Shipping
– ASTM D4169 Standard Practice for Performance Testing of Shipping Containers and Systems
– ASTM D6055 Standard Test Methods for Mechanical Handling of Unitized Loads and Large Shipping Cases and Crates
– ASTM D6179 Standard Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates
– ASTM D6198 Standard Guide for Transport Packaging Design
– ASTM D6199 Standard Practice for Quality of Wood Members of Containers and Pallets
– ASTM D6253 Standard Practice for Treatment and/or Marking of Wood Packaging Materials

F16 Fasteners
– ASTM F1575 Standard Test Method for Determining Bending Yield Moment of Nails
D07 Wood
- ASTM D1761 Standard test methods for mechanical fasteners in wood
- ASTM D3043 Standard test methods for structural panels in flexure
- ASTM D4442 Standard test methods for direct moisture content measurement of wood and wood-base materials
- ASTM D4761 Standard test methods for mechanical properties of lumber and wood-base structural material
- ASTM D5456 Standard specification for structural composite lumber
- ASTM D5457 Standard specification for computing reference resistance of wood-based materials and structural connections for load and resistance design
- ASTM D7438 Standard practice for field calibration and application of hand-held moisture meters

International Organization for Standardization (ISO)

www.iso.org

55 Packaging and distribution of goods
55.180 Freight distribution of goods
55.180.20 General purpose pallets
- ISO 445 Pallets for materials handling – Vocabulary
- ISO 6780 Pallets for intercontinental materials handling - Principal Dimensions and Tolerances
- ISO 8611-1 Pallets for materials handling - Flat Pallets - Part 1: Test methods
- ISO/TS 8611-2 Pallets for materials handling - Flat Pallets - Part 2: Performance requirements and selection of tests
- ISO/TS 8611-3 Pallets for material handling - Flat Pallets - Part 3: Maximum working loads
- ISO/TR 11444 Quality of sawn wood used for the construction of pallets
- ISO 12776 Pallets - Slip sheets
- ISO 12777-1 Methods of test for pallet joints - Part 1: Determination of bending resistance of pallet nails, other dowel-type fasteners and staples
- ISO 12777-2 Methods of test for pallet joints - Part 2: Determination of withdrawal and head pull-through resistance of pallet nails and staples
- ISO 12777-3 Methods of test for pallet joints - Part 3: Determination of strength of pallet joints
- ISO 13194 Box pallets – Principal requirements and test methods
- ISO 15629 Pallets for materials handling - Quality of fasteners for assembly of new and repair of used, flat, wooden pallets
- ISO 18333 Pallets for materials handling - Quality of new wooden components for pallets
- ISO 18334 Pallets for materials handling - Quality of assembly of new, wooden, flat pallets
- ISO 18613 Repair of flat wooden pallets
International Plant Protection Convention (IPPC)
www.ippc.int
- International Standard for Phytosanitary Measures (ISPM) Publication No. 15 Regulation for wood packaging material in international trade

American Society of Mechanical Engineers (ASME)
www.asme.org
- ASME B1.1 Unified inch screw threads (UN and UNR thread form)
- ASME B18.2.1 Square, hex, heavy hex and askew head bolts and hex, heavy hex, hex flange, lobed head and lag screws (inch series)
- ASME B18.6.1 Wood screws, inch series

National Institute of Standards and Technology (NIST)
www.nist.gov
- PS 1-07 Structural Plywood
- PS 2-04 Performance Standard for Wood-Based Structural-Use Panels
- PS 20-05 American Softwood Lumber Standard

APA – The Engineered Wood Association
www.apawood.org
- PRP 108 Performance Standards and Policies for Structural-Use Panels

Hardwood Plywood and Veneer Association (HPVA)
www.hpva.org
- ANSI/HPVA HP-1-2004 American National Standard for Hardwood and Decorative Plywood

National Hardwood Lumber Association (NHLA)
www.natlhardwood.org
- Rules for the measurement and inspection of hardwood and cypress
SPECIFICATIONS CONCERNING WOOD PALLETS AND CONTAINERS

North America

American Society of Agricultural and Biological Engineers (ASABE)
www.asabe.org
- Agricultural pallet bins (ASAE S337.1)

APA - The Engineered Wood Association
www.apawood.org
- Softwood plywood pallets PP 61-80
- Collapsible big bin
- Collapsible slim bin

ASTM International
www.astm.org
D10 Packaging
- ASTM D6254/D6254M Standard Specification for Wirebound Pallet-Type Wood Boxes
- ASTM D6573/D6573M Standard Specification for General Purpose Wirebound Shipping Boxes
- ASTM D6880 Standard Specification for Wood Boxes

Canadian Pallet Council (CPC)
www.cpcpallet.com
- 48x40 in. stringer pallet

Committee for Graphics Arts Technology Standards (CGATS)
- Graphic technology - Pallet loading for printed materials (1995)

The Electronic Industry Pallet Specification (EIPS) Task Group
www.hp.com/packaging/EIPS/
- Electronic Industry Pallet Specification, 2003

Grocery Manufacturers Association of America (GMA)
www.gmabrands.com
- Recommendations on the Grocery Industry Pallet System (1992)
Department of Defense
www.assist.daps.dla.mil/quicksearch
- A-A-52586 Pallet, material handling, wood stringer construction, 4-way partial, 48 x 40 inches
- MIL-C-3774B Crates, Wood: Open 12,000 and 16,000-Pound Capacity
- MIL-DTL-2427H Box, Ammunition Packing: Wood, nailed
- MIL-C-3774B Crates, Wood: Open 12,000- and 16,000-pound capacity
- MIL-C-21215A(1) NOT 1 Crates, Pallets, Ammunition
- MIL-P-15011J Pallet, Material Handling, Wood Post Construction, 4-Way Entry
- MIL-P-15943D(5) Pallet, material handling, wood, ship cargo, stevedoring, 48 inches long by 72 inches wide, 2-way entry
- MIL-P-45449B Pallets, units, wood, for shipment of projectile metal parts, and projectile ammunition
- MIL-P-87089 Pallets, material handling, molded wood particles 40 x 48 inch, 4-way
- MIL-STD-147 Palletized Unit Loads
- MIL-STD-299 Visual inspection standards for nailed wood boxes and wirebound wood boxes used in small arms ammunition
- QSTAG-880 ED.1 Military pallets, packages and containers
- STANAG-2828 ED.6 Military pallet, packages and containers

European Union

Association of Plastic Manufacturers in Europe (APME)
www.apme.org
Chemical Industry (CP) Pallets
- CP1 1000x1200 mm
- CP2 800x1200 mm
- CP3 1140x1140 mm
- CP4 1100x1300 mm
- CP5 760x1140 mm
- CP6 1200x1000 mm
- CP7 1300x1100 mm
- CP8 1140x1140 mm
- CP9 1140x1140 mm

Pallet Return System (PRS) Pallets
- PRS 4 1100x1300 mm
- PRS 7 1300x1100 mm
- PRS 8 1140x1140 mm
- PRS 9 1140x1140 mm
European Pallet Association (EPAL)  
www.epal.eu  
– 800 x 1200 mm EUR  
– 1200 x 1000 mm EUR 2  
– 1000 x 1200mm EUR 3  
– 800 x 600 mm EUR 6  
– Box pallets  
– Pallet collars

Asia  
– 1100 x 1100mm (T11)
# ANNEX B

## WOOD SPECIES CLASSES*

*These wood species classes correspond to those used in the Pallet Design System (PDS).*

<table>
<thead>
<tr>
<th>CLASS NUMBER</th>
<th>CLASS NAME</th>
<th>SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High density Eastern hardwoods</td>
<td>American beech, Ash (green, white), Birch (sweet, yellow), Black cherry, Black locust, Dogwood, Elm (rock, slippery), Hickory, Maple (black, red, sugar), Persimmon, Tan oak</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Bigleaf maple, Oregon ash</td>
</tr>
<tr>
<td>3</td>
<td>Medium density Eastern hardwoods</td>
<td>Ash (black, pumpkin), Hackberry, Maple (silver, striped), Magnolia, Paper birch, Sweetgum, Sycamore, Tupelo</td>
</tr>
<tr>
<td>4</td>
<td>Western hardwoods</td>
<td>California black oak, Cascara, Chinquapin, Madrone, Myrtle, Oregon white oak</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Red alder</td>
</tr>
<tr>
<td>7</td>
<td>Low density Eastern hardwoods</td>
<td>American basswood, Aspen (bigtooth, quaking), Buckeye, Butternut, Catalpa, Cottonwood (balsam,black), Eastern poplar</td>
</tr>
<tr>
<td>21</td>
<td>Eastern oaks</td>
<td>Red oak, White oak</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>Yellow poplar</td>
</tr>
<tr>
<td>CLASS NUMBER</td>
<td>CLASS NAME</td>
<td>SPECIES</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>North American Softwoods</strong></td>
</tr>
<tr>
<td>11</td>
<td>Douglas-fir</td>
<td>Douglas fir (coast, Interior West, Interior North, Interior South)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Western larch</td>
</tr>
<tr>
<td>12</td>
<td>Hem-Fir</td>
<td>Fir (California red, grand, noble, Pacific silver, white)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hemlock (Western, Mountain)</td>
</tr>
<tr>
<td>13</td>
<td>SPF</td>
<td>Baldcypress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eastern hemlock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fir (balsan, subalpine)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pine (Eastern white, jack, lodgepole, Monterey, Norway, Ponderosa,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sugar, Western white)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Redwood</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Southern pine (pitch, pond)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spruce (black, Engelmann, red, sitka, Virginia, white)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Western red cedar</td>
</tr>
<tr>
<td>14</td>
<td>Low density softwoods</td>
<td>Cedar (Alaska, Atlantic white, Eastern red, incense, Northern white,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Port Orford</td>
</tr>
<tr>
<td>22</td>
<td>SYP</td>
<td>Southern yellow pine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(loblolly, longleaf, shortleaf, slash)</td>
</tr>
<tr>
<td>CLASS NUMBER</td>
<td>CLASS NAME</td>
<td>SPECIES</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>European Species</strong></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Imported Hardwoods</td>
<td>Kapur</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Keruing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mengkulang</td>
</tr>
<tr>
<td>32</td>
<td>Dense European Hardwoods</td>
<td>Ash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beech</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oak</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plane</td>
</tr>
<tr>
<td>33</td>
<td>Dense European Softwoods</td>
<td>Douglas fir</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Larch (European, Japanese)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pine (jack, maritime, Scots)</td>
</tr>
<tr>
<td>34</td>
<td>Medium Dense Woods</td>
<td>Dutch elm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyrbrid larch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pine (Corsican, lodgepole)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poplar (black Italian, grey)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Redwood</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silver fir</td>
</tr>
<tr>
<td>35</td>
<td>Whitewood</td>
<td>English elm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sitka spruce (Canada)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Whitewood</td>
</tr>
<tr>
<td>36</td>
<td>Common European softwoods</td>
<td>Radiate pine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spruce (black, Norway, white, Sitka)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White willow</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td>Hybrid poplar</td>
</tr>
<tr>
<td></td>
<td><strong>South American and Other Species</strong></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td></td>
<td>Radiate pine (Chile)</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>Gmelina arborea (Costa Rica)</td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>Pinus caribaea (Venezuela)</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>Pinus elliottii</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>Pinus taeda</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>Eucalyptus grandis (Uruguay)</td>
</tr>
</tbody>
</table>
### ANNEX C
**DEFINITION AND CLASSIFICATION OF DEFECTS**

#### DEFINITIONS

- **Decay** – a disintegration of the wood substance due to actions of wood-destroying fungi, also known as dote, rot and unsound wood.

- **Sound knot** – a knot that is tight, solid, without voids and at least as hard as the surrounding wood in at least one face, exhibiting structural strength.

- **Split or shake** – separation within a wood member not confined to the wood surface, usually intersecting two surfaces. For the purposes of this Standard, a split intersecting only one face of the pallet component will be treated as a split only when it exceeds ½ the depth, width or thickness of the component.

- **Unsound knot** – a knot that is loose and/or, due to decay, has no structural strength.

- **Wane** – bark or lack of wood from any cause, except eased edges, on the edges of the pallet component.

#### DEFECT CLASSIFICATION

<table>
<thead>
<tr>
<th>Critical Defects</th>
<th>Other Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken components</td>
<td>Checks</td>
</tr>
<tr>
<td>Protruding nails on edge or end stringers, stringerboards, blocks, or deckboards</td>
<td>Component placing</td>
</tr>
<tr>
<td>Nonconforming pallets due to size, flatness or squareness</td>
<td>Compression wood</td>
</tr>
<tr>
<td>Missing wood exceeding allowable limits</td>
<td>Crook</td>
</tr>
<tr>
<td>Notch area defect (splits, decay, excess knot)</td>
<td>Decay</td>
</tr>
<tr>
<td>Fastener in decay</td>
<td>Decayed knot</td>
</tr>
<tr>
<td>Fastener in maximum wane</td>
<td></td>
</tr>
<tr>
<td>Holes</td>
<td>Pitch</td>
</tr>
<tr>
<td>Honeycomb</td>
<td>Saw cut</td>
</tr>
<tr>
<td>Inside shiner</td>
<td>Shake</td>
</tr>
<tr>
<td>Knots</td>
<td>Slope of grain</td>
</tr>
<tr>
<td>Missing nail</td>
<td>Splits</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Step</td>
</tr>
<tr>
<td>Overhang</td>
<td>Underhang</td>
</tr>
<tr>
<td>Pitch</td>
<td>Wane</td>
</tr>
<tr>
<td>Holes</td>
<td>Wane above notch</td>
</tr>
<tr>
<td>Honeycomb</td>
<td>Wane on edge of leading deckboard or exposed stringer</td>
</tr>
<tr>
<td>Inside shiner</td>
<td></td>
</tr>
</tbody>
</table>
ANNEX D
GRADING AGENCIES FOR STRUCTURAL PANELS

APA - The Engineered Wood Association
www.apawaod.org

Professional Service Industries/Pittsburgh Testing Laboratories
www.psiusa.com/services/wood.aspx?

Timber Engineering Company (TECO)
www.tecotested.com
ANNEX E
WOOD-BASED COMPOSITE TESTS

E1. 24-hour Composite Block Soak Test

E1.1 Samples
• Ten (10) blocks (minimum) are required.
• Condition each block at ambient laboratory conditions for at least 48 hrs. prior to testing.

E1.2 Test equipment
• An appropriately sized open-top flat-bottom water tight tank capable of being filled to a depth of at least 12 inches. If required, more than one tank can be used.
• A suitable “hold down” fixture(s) to prevent the blocks from floating and to maintain a constant water hydraulic pressure of 0.2 psi at the top surface of the block.
  – The hold-down fixture may be suspended from above or placed into the tank.
  – The fixture should be designed to allow water free access to all block surfaces.
  – The fixture should be designed so that when submerged, the bottom of the block is at least 1” above the bottom of the tank and 5.5 inches (+/- .25) below the surface level of the water (providing a hydraulic pressure of .20 psi).

E1.3 Procedures
• Measure and record each block’s weight, length, width and height.
• Dimensional measurements are to be made using a surface plate and digital height gage capable of measuring to an accuracy of +/- .001 in.
• Each dimension should be measured at three different locations on the block, with the location of the measurement marked for future reference.
• Place the blocks into the tank such that:
  – blocks are oriented bottom (smooth) side up.
  – water temperature should be maintained between 65 and 75°F.
  – blocks are separated by at least 1 in. (25 mm)
• Blocks should be submerged for a minimum of 24 hours
• Remove blocks and allow to drain on an open grate.
• Final measurements should be made within 5 min. of removal from the tank.

E1.4 Measurements
• Measure the after-soak weight, length, width and height of each block.
• Measure dimensions at the same points as measured before.
• Calculate and report results as follows:
  – % change = (wet - dry) / dry x 100.
  – Average % and standard deviation of water-weight gain.
  – Average % and standard deviation for each dimensional change.
E2. Pallet Block Side Tine Compression Test

E2.1 Samples
- Ten (10) blocks (minimum) are required.
- Condition each block @ ambient laboratory conditions for at least 48 hr. prior to testing.

E2.2 Test equipment
Compression testing machine must have the following:
- a peak-load capacity of at least 5,000 lbf.
- adjustable platen set at 10 in./min.
- a fixture designed to simulate a fork truck fork tine (Figure E1).

![Figure E1. Fork tine fixture.](image)

E2.3 Procedures
- Measure and record the block’s weight, length, width and height.
- The test block should be oriented so that the fixture force is directed toward the center of one of the ends of the block (Figure E2).
Figure E2. Tine test block orientation.

**E2.3 Measurement**
- Measure the peak load at failure.

**E3. Nail Insertion Force Test**

While a specific nail insertion force standard method is not included in ASTM D1761, insertion force can be of significance. Typical nail guns may have more difficulty with insertion if driving force required is too high.

**E3.1 Samples**
- Ten (10) blocks (minimum) are required.
- 3 nails per block, nails should be clean and free of oil and any surface irregularities.
- Condition each block at ambient laboratory conditions for at least 48 hr. prior to testing.

**E3.2 Test Equipment**

Compression testing machine must have the following:
- A peak-load capacity of at least 5,000 lbf.
- Adjustable platen set at 1.5 in./min.
- A fixture capable of holding the nail upright and perpendicular to the block surface.

**E3.3 Procedures**
- Measure and record the block’s weight, length, width and height.
- Position the nailing force fixture on the center of the top side of the block.
- Insert first nail into fixture hole.
- Drive nail until nail tip is 2.1 in. into block surface using a platen speed of 1.5 in./min.
- Repeat with second and third nails.
E3.4 Measurement
• Measure maximum force required to insert each nail.

E4. Nail Withdrawal Force Test

E4.1 Samples
• Ten (10) blocks (minimum) are required.
• 3 nails per block, nails should be clean and free of oil and any surface irregularities.
• Condition each block at ambient laboratory conditions for at least 48 hr. prior to testing.

E4.2 Test Equipment
Compression testing machine must have the following:
• a peak-load capacity of at least 2,500 lbf.
• adjustable platen set at 1.5 in./min.
• a stationary fixture designed to secure the block to one platen.
• a gripping fixture shaped to fit the head of the nail and designed to provide true axial loading (Figure D3).

E4.3 Procedure
• Measure and record the block’s weight, length, width and height.
• Position the nailing force fixture on the center of the top side of the block.
• Insert first nail into fixture hole.
• Drive nail until nail tip is 2.1 in. into block surface using a platen speed of 1.5 in./min.
• Withdraw nail.
• Repeat with second and third nails.

E4.4 Measurements
• Measure maximum force required to remove each nail.
ANNEX F
CONNECTION DESIGN

F.1 Withdrawal Resistance

The strength-level withdrawal resistance is calculated as:

\[ W = 1380G^{2.5}D_sL_pC_wC_mC_K_F \quad \text{[U.S.]} \]
\[ W = 9.58G^{2.5}D_sL_pC_wC_mC_K_F \quad \text{[SI]} \]

where

- \( W \) - Withdrawal resistance (lbf [N])
- \( G \) - Specific gravity (oven-dry weight and volume basis or equivalent specific gravity)
- \( D_s \) - Diameter of nominal shank (in. [mm])
- \( L_p \) - Length of penetration into main member (in. [mm])
- \( C_w \) - Fastener withdrawal adjustment (calculated or empirical)
- \( C_m \) - Moisture adjustment factor
- \( K_F \) - Strength level conversion factor (3.32)

Withdrawal calculation is for fasteners driven into the side grain of sawn wood or the wood material. Pallet constructions where fasteners are loaded in withdrawal from end-grain of solid wood shall be avoided. For wood-based composites, the specific gravity is an equivalent specific gravity as determined following ASTM D5456.

The fastener withdrawal adjustment (\( C_w \)) quantifies the effect of shank deformation on the fastener withdrawal resistance and is calculated based on fastener geometry, or alternatively may be determined from empirical test data. For a smooth-shank fastener, \( C_w=1.0 \). The adjustments for moisture (\( C_m \)) are shown in F.1.2. The strength level conversion factor adjusts from an allowable value to average strength-level withdrawal resistance following AF&PA and ASTM D5457.

For staples, \( W \) is per leg, so the calculated \( W \) value is multiplied by 2. For rectangular wire staples, substitute wire thickness for \( D_s \).

An allowable withdrawal resistance (\( W_{all} \)) is calculated with \( K_F=1.0 \).
F.1.1 Fastener withdrawal adjustment

The fastener withdrawal adjustment (C<sub>w</sub>) was developed based on the original calculations of Fastener Withdrawal Index (FWI)<sup>6</sup> as documented by Osborn (1985)<sup>7</sup> as part of a larger function for pallet nail withdrawal. It is the expected effect of the shank deformations on the withdrawal resistance of the fastener. It is calculated based on fastener geometry specifications or measurements as,

\[ C_w = 1 + K(D_t-D_s)(H/L_t) \]

where

- C<sub>w</sub> - Fastener withdrawal adjustment
- K - Constant (helically threaded = 22, annularly threaded = 60)
- D<sub>t</sub> - Diameter of the thread crest (in. [mm])
- D<sub>s</sub> - Diameter of the nominal shank (in. [mm])
- H - Number of helixes
- L<sub>t</sub> - Thread length (in. [mm])

For screw-shank fasteners, the H-value is,

\[ H = (L_t*F)/(\pi*D_t*tan(A_t)) \]

where

- F - Number of flutes
- A<sub>t</sub> - Thread angle measured from normal to shank (deg)

For annularly threaded fasteners, H is calculated by substituting the number of rings per inch divided by 3, e.g., H=(rings/inch)/3 [U.S.], or H=(rings/mm)/0.118 [SI]. For smooth-shank fasteners, C<sub>w</sub>=1.0.

F.1.2 Empirical Determination

The fastener withdrawal adjustment for deformed-shank fasteners may be determined empirically by comparing withdrawal resistance test data for the deformed-shank fastener to the calculated withdrawal resistance per unit of penetration for a smooth shank fastener with the same nominal shank diameter. The test follows D 1761. The calculation is based on the allowable withdrawal capacity for nails that is converted to the reference strength level by using the conversion factor (KF) as given NDS (2005), Appendix N. The fastener withdrawal adjustment is the ratio:

---

<sup>6</sup> Fastener Withdrawal Index (FWI) is a measure of estimated withdrawal resistance of a given fastener relative to that for a high quality "base" nail.

\[ C_w = \frac{P_w}{W_r} \]

Where,
\( C_w \) = Fastener withdrawal adjustment
\( P_w \) = Mean maximum withdrawal resistance per unit length of penetration (lbf/in. [N/mm])
\( W_r = 1380G^{2.5}D_sC_mK_F \) [US], or 9.58G^{2.5}D_sC_mK_F [SI]

### F.1.3 Moisture adjustment for withdrawal resistance

Moisture adjustment factors (\( C_m \)) for withdrawal resistance in Table C1 are from the NDS, Table 10.3.3.

Table F1. Adjustment to withdrawal for expected moisture service.

<table>
<thead>
<tr>
<th>FASTENER TYPE</th>
<th>MOISTURE CONTENT</th>
<th>( C_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth-shank Nails and Staples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \leq 19% )</td>
<td>( \leq 19% )</td>
<td>1.0</td>
</tr>
<tr>
<td>( &gt; 19% )</td>
<td>( \leq 19% )</td>
<td>0.25</td>
</tr>
<tr>
<td>( \leq 19% )</td>
<td>( &gt; 19% )</td>
<td>0.25</td>
</tr>
<tr>
<td>( &gt; 19% )</td>
<td>( &gt; 19% )</td>
<td>1.0</td>
</tr>
<tr>
<td>Threaded Nails</td>
<td>Any</td>
<td>Any</td>
</tr>
</tbody>
</table>

### F.2 Lateral Resistance

Lateral resistance is calculated using the yield limit equations of NDS, Section 11. The solution with the least value is the reference design value and represents the expected yield mode. The reference design value is adjusted by the fastener shear adjustment (\( C_z \)) and for moisture condition (\( C_m \)),

\[ Z = Z_r C_z C_m K_F \]

where
\( Z \) = Strength-level lateral resistance (lbf [N])
\( Z_r \) = Reference design value (lbf [N])
\( C_z \) = Fastener shear adjustment
\( C_m \) = Moisture adjustment factor
\( K_F \) = Strength-level adjustment (3.32)
For staples, $Z_{nd}$ is per leg and is doubled. For rectangular wire staples, substitute wire thickness for fastener shank diameter in the yield equations. It is assumed that a connection with more than one fastener has the capacity of the product of the number of fasteners and the single fastener connection capacity. An LRFD allowable shear resistance is calculated by multiplying the $Z$ by the strength level adjustment factor of 3.32.

### F.2.1 MIBANT to bending yield strength

When MIBANT angle is supplied instead of $F_{yb}$, then conversion from MIBANT to $F_{yb}$ follows ISO 12777-1

\[
M_y = 1219.1 \times \text{MIBANT}^{-0.9653} \quad \text{(lbf·in.) [U.S.]}
\]

\[
M_y = 138.72 \times \text{MIBANT}^{-0.9653} \quad \text{(N·m) [SI]}
\]

where

- $M_y$ - fastener bending yield moment (lbf·in)
- MIBANT - MIBANT angle (degrees) measured by using F680
- $D_s$ - Nominal diameter of shank (in.)

Then, bending yield strength is calculated following F1575

\[
F_{yb} = \frac{M_y}{(D_s^3/6)}
\]

The calculated $F_{yb}$ (psi) is the average 5% offset bending-yield strength of the fastener that is used in the NDS yield mode equations.

### F.2.2 Fastener shear adjustment

The fastener shear adjustment ($C_z$) quantifies the effect on lateral resistance of the nail head and deformed shank as a “rope” effect (DIN EN 2008\(^8\)). The fastener shear adjustment ($C_z$) is calculated based on specifications and $C_z = 1.0$ for yield modes controlled by wood bearing failure (Modes IS and IM).

The fastener shear adjustment may be calculated from specifications as,

\[
C_z = 1 + \frac{(W/4)}{Z_t}
\]

---

where

\[ C_z \quad \text{- Fastener shear adjustment} \]
\[ Z_r \quad \text{- Reference design value for lateral resistance (lbf)}^9 \]
\[ W \quad \text{- Strength-level withdrawal resistance as calculated in C.1 (lbf)} \]

For smooth-shank nails and staples, \( C_z \) is limited to a value not greater than 1.15; for deformed-shank nails, \( C_z \) is limited to not greater than 1.50.

**F.2.3 Moisture adjustment for lateral resistance**

Moisture adjustment factors (\( C_m \)) for lateral resistance given in Table F2 are from the NDS, Table 10.3.3.

**Table F2. Adjustment to shear values for expected moisture service.**

<table>
<thead>
<tr>
<th>FASTENER TYPE</th>
<th>MOISTURE CONTENT</th>
<th>( C_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At time of fabrication</td>
<td>In-Service</td>
</tr>
<tr>
<td>Nails and Staples</td>
<td>( \leq 19% )</td>
<td>( \leq 19% )</td>
</tr>
<tr>
<td></td>
<td>&gt; 19%</td>
<td>( \leq 19% )</td>
</tr>
<tr>
<td></td>
<td>Any</td>
<td>&gt; 19%</td>
</tr>
</tbody>
</table>

**F.3 Fastener Head Pull-through**

Methods of estimating fastener head pull-through resistance (HPT) of nails and staples are presented by Osborn (1985). Head pull-through resistance is the estimated average resistance for the head of a nail (or crown of a staple) being pulled through the deckboard. If HPR is less than \( W \) (shank withdrawal resistance), then HPR governs design. HPT is calculated by

**Nails**

\[
\text{HPT} = 1,662,500 \, TG^{2.25} \frac{(D_h^2 - D_s^2)}{(MC - 3)} \quad [\text{U.S.}]
\]

\[
\text{HPT} = 454.3 \, TG^{2.25} \frac{(D_h^2 - D_s^2)}{(MC - 3)} \quad [\text{SI}]
\]

**Staples**

\[
\text{HPT} = [1,250,000 \, TG^{2.25} \frac{(4 / \pi) \, (L_c) \, (D_s)}{(MC - 3)}] \quad [\text{U.S.}]
\]

\[
\text{HPT} = [341.7 \, TG^{2.25} \frac{(4 / \pi) \, (L_c) \, (D_s)}{(MC - 3)}] \quad [\text{SI}]
\]

---

9 Yield limit can be determined using the Connection Calculator, www.awc.org/calculators/connections/ccstyle.asp
where

HPT - Head pull-through resistance (lbf [N])
T - Deckboard thickness (in. [mm])
G - Specific gravity of deckboard based on o.d. weight and volume
L_c - Crown length (in. [mm])
D_h - Head diameter (in. [mm])
D_s - Nominal shank diameter (in. [mm])
MC - Moisture content (%) at time of assembly (max = 28%, min = 12%)

F.4 Notations

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_t</td>
<td>Thread angle</td>
</tr>
<tr>
<td>C_m</td>
<td>Moisture content adjustment factor</td>
</tr>
<tr>
<td>C_w</td>
<td>Withdrawal adjustment factor</td>
</tr>
<tr>
<td>C_z</td>
<td>Shear adjustment factor</td>
</tr>
<tr>
<td>D_h</td>
<td>Diameter of head</td>
</tr>
<tr>
<td>D_s</td>
<td>Diameter of smooth shank or wire</td>
</tr>
<tr>
<td>D_t</td>
<td>Diameter of thread crest</td>
</tr>
<tr>
<td>F</td>
<td>Flutes</td>
</tr>
<tr>
<td>F_yb</td>
<td>Bending yield strength</td>
</tr>
<tr>
<td>G</td>
<td>Specific gravity or equivalent specific gravity</td>
</tr>
<tr>
<td>H</td>
<td>Helixes</td>
</tr>
<tr>
<td>HPT</td>
<td>Head pull-through</td>
</tr>
<tr>
<td>K_f</td>
<td>Strength level adjustment</td>
</tr>
<tr>
<td>L_c</td>
<td>Crown length</td>
</tr>
<tr>
<td>L_p</td>
<td>Penetration length into main member</td>
</tr>
<tr>
<td>L_t</td>
<td>Thread Length</td>
</tr>
<tr>
<td>M_y</td>
<td>Bending yield moment</td>
</tr>
<tr>
<td>MC</td>
<td>Moisture content</td>
</tr>
<tr>
<td>MIBANT</td>
<td>MIBANT angle</td>
</tr>
<tr>
<td>T</td>
<td>Thickness of deckboard</td>
</tr>
<tr>
<td>W</td>
<td>Withdrawal resistance</td>
</tr>
<tr>
<td>W_all</td>
<td>Allowable withdrawal for strength level design</td>
</tr>
<tr>
<td>W_r</td>
<td>Reference withdrawal resistance</td>
</tr>
<tr>
<td>Z</td>
<td>Shear resistance</td>
</tr>
<tr>
<td>Z_a</td>
<td>Allowable shear for strength level design</td>
</tr>
<tr>
<td>Z_r</td>
<td>Reference shear resistance</td>
</tr>
</tbody>
</table>
ANNEX G
PHYSICAL DESCRIPTION OF TYPICAL FASTENERS
MEETING CRITERIA IN SECTION 5.5.1, TABLE 3

Table G1. Examples of fasteners and fastening schedules which meet the minimum performance requirements provided in Section 5.5.1, Table 3 for reusable (new pallets) and for repaired Classes 1, 2 and 3 (repaired pallets)\(^a\) with minimum FWI=65 and FSI\(^b\)=55\(^a\).

<table>
<thead>
<tr>
<th>FASTENER TYPE/ SIZE</th>
<th>FASTENER PHYSICAL CHARACTERISTICS(^c)</th>
<th>MINIMUM FASTENER SCHEDULE (SECTION 6.2.4.1)</th>
<th>ONE ADDITIONAL FASTENER/ CONNECTION(^d)</th>
<th>DOUBLE THE MINIMUM FASTENER SCHEDULE(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>helically threaded nail 12 ½-gauge</td>
<td>wire diameter (in.)</td>
<td>0.105</td>
<td>0.099</td>
<td>0.105</td>
</tr>
<tr>
<td></td>
<td>thread diameter (in.)</td>
<td>0.118</td>
<td>0.104</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>68</td>
<td>70</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>41</td>
<td>55</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>68</td>
<td>51</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>55</td>
<td>40</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Flutes=5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>helically threaded nail 12-gauge</td>
<td>wire diameter (in.)</td>
<td>0.105</td>
<td>0.112(^e)</td>
<td>0.112(^e)</td>
</tr>
<tr>
<td></td>
<td>thread diameter (in.)</td>
<td>0.122</td>
<td>0.122</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>68</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>41</td>
<td>57</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>68</td>
<td>51</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>55</td>
<td>42.5</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Flutes=4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>helically threaded nail 11 ½-gauge</td>
<td>wire diameter (in.)</td>
<td>0.112(^e)</td>
<td>0.122 (^e)</td>
<td>0.112 (^e)</td>
</tr>
<tr>
<td></td>
<td>thread diameter (in.)</td>
<td>0.127</td>
<td>0.122 (^e)</td>
<td>0.122 (^e)</td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>68</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>46</td>
<td>53</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>66</td>
<td>53</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Flutes=4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>helically threaded nail 11-gauge</td>
<td>wire diameter (in.)</td>
<td>0.120</td>
<td>0.134</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>thread diameter (in.)</td>
<td>0.134</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>68</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>65.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flutes=4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>annularly threaded nail 11-gauge</td>
<td>wire diameter (in.)</td>
<td>0.120</td>
<td>0.130</td>
<td>0.130</td>
</tr>
<tr>
<td></td>
<td>thread diameter (in.)</td>
<td>0.130</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>72.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) When repairing connections to repaired Classes 1, 2 and 3, it is assumed the original fasteners in the connections which are still effective meet the minimum requirements in Section 5.5.1, Table 3 of this Standard for reusable new pallets.

\(^b\) Fastener Shear Index (FSI) - measure of estimated shear performance of a given fastener relative to that for a high quality “base” nail.

\(^c\) Fastener length and the ratio of head to wire diameter shall conform to the criteria in Section 5.5, Table 3. These examples include both the four- and five-flute fasteners.

\(^d\) Repairing connections, using an excessive number of fasteners which would degrade overall connection integrity, shall be avoided.

\(^e\) Or the same fastener with a 68° thread angle and 9% greater length.
Table G2. Examples of fasteners and fastening schedules which meet the minimum performance requirements provided in Section 5.5.1, Table 3 for single-use (new pallets) and for repaired Classes 1, 2 and 3 (repaired pallets)\(^a\) with minimum FWI=50 and FSI=40.

<table>
<thead>
<tr>
<th>FASTENER TYPE/SIZE</th>
<th>FASTENER PHYSICAL CHARACTERISTICS(^b)</th>
<th>MINIMUM FASTENER SCHEDULE (SECTION 6.2.4.1)</th>
<th>ONE ADDITIONAL FASTENER/CONNECTION(^c)</th>
<th>DOUBLE THE MINIMUM FASTENER SCHEDULE(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>helically threaded nail</td>
<td>wire diameter (in.)</td>
<td>0.099</td>
<td>0.099</td>
<td>0.099</td>
</tr>
<tr>
<td>12 ½-gauge</td>
<td>thread diameter (in.)</td>
<td>0.108</td>
<td>0.106</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>70</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>55</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>51</td>
<td>58</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>40</td>
<td>40</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Flutes=5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>helically threaded nail</td>
<td>wire diameter (in.)</td>
<td>0.105</td>
<td>0.105</td>
<td>0.105</td>
</tr>
<tr>
<td>12-gauge</td>
<td>thread diameter (in.)</td>
<td>0.115</td>
<td>0.112</td>
<td>0.110</td>
</tr>
<tr>
<td></td>
<td>thread angle (deg)</td>
<td>70</td>
<td>62</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>59</td>
<td>59</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>FWI per nail</td>
<td>49</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>FSI per nail</td>
<td>41</td>
<td>41</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Flutes=4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adhesive coated staple</td>
<td>wire width (in.)</td>
<td>0.080</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-gauge</td>
<td>wire thickness (in.)</td>
<td>0.075</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FWI per staple</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSI per staple</td>
<td>61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adhesive coated staple</td>
<td>wire width (in.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-gauge</td>
<td>wire thickness (in.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FWI per staple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSI per staple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adhesive coated staple</td>
<td>wire width (in.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-gauge</td>
<td>wire thickness (in.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FWI per staple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSI per staple</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) When repairing connections to the repaired Classes 2 and 3, it is assumed the original fasteners in the connections which are still effective meet the minimum requirements in Section 5.5.1, Table 3 of this Standard for single-use new pallets.

\(^b\) Fastener length and the ratio of head to wire diameter shall conform to the criteria in Section 5.5.1, Table 3. These examples include both the four- and five-flute fasteners.

\(^c\) Repairing connections, using an excessive number of fasteners which would degrade overall connection integrity, shall be avoided.
Table G3. Examples of fasteners and fastening schedules which meet the minimum performance requirements provided in Section 5.5.1, Table 3 for clinched mat fasteners\(^a\)

<table>
<thead>
<tr>
<th>PALLET CATEGORY</th>
<th>FASTENER TYPE/SIZE</th>
<th>FASTENER PHYSICAL CHARACTERISTICS(^b)</th>
<th>MINIMUM FASTENER SCHEDULE (SECTION 6.2.4.1)</th>
<th>ONE ADDITIONAL FASTENER/ CONNECTION(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repaired Class 1</td>
<td>staple 16-gauge</td>
<td>wire width (in.)</td>
<td>0.073</td>
<td>0.062</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wire thickness (in.)</td>
<td></td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td>130</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FWI per staple</td>
<td></td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FSI per staple</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>staple 16-gauge</td>
<td>wire width (in.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>wire thickness (in.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FWI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FSI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>plain nail 16-gauge</td>
<td>wire diameter (in.)</td>
<td>0.105</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FWI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FSI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaired Class 2 and 3</td>
<td>staple 16-gauge</td>
<td>wire width (in.)</td>
<td>0.062</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>wire thickness (in.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FWI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FSI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>plain nail 16-gauge</td>
<td>wire diameter (in.)</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIBANT angle (deg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FWI per staple</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FSI per staple</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) When repairing connections to any of the categories, it is assumed the original fasteners in the connections which are still effective meet the minimum requirements in Section 5.5.1, Table 3 of this Standard for single-use and reusable new pallets.

\(^b\) Fastener length and the ratio of head to wire diameter shall conform to the criteria in Section 5.5.1, Table 3. These examples include both the four- and five-flute fasteners.

\(^c\) Repairing connections, using an excessive number of fasteners which would degrade overall connection integrity, shall be avoided.