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Guide to the Pallet Design System (PDS©) Pallet Specification Sheet

The PDS **Pallet Specification Sheet** provides complete details on pallet design, dimensions of all components, and all materials used in construction.

Customer: identifies company for whom PDS design work was performed.

Pallet ID: identification of this particular pallet design, chosen by Customer or Preparer.

Classification: identifies size and general design and construction of pallet.
- **Pallet Size** is listed as Length x Width.
- **Pallet-class** can be either Stringer-class or Block-class.
- **Deck-style** can be Single-Face, Double-Face Non-reversible, or Double-Face Reversible.
- **Entry-style** can be 2-way, partial 4-way, or full 4-way.
- **Use class** can be Multiple-Use or Limited-Use. **Manufacture class** can be New, Remanufactured, or Remanufactured/Combo.

Pallet Treatments: identifies whether **Heat Treating** or **Fumigation** is performed for ISPM-15 Compliance, and whether **Conditioning** (Drying) of pallet is performed after manufacture and assembly.

Components: for each component group, the **style** and **type** and the **number** and actual **dimensions** of each component are listed. The fastening schedule is shown graphically on the pallet drawings.

Style: Deck Styles include **Deckboard** and **Panel**.

Type: Deckboards can be **New** Lumber, **Recycled** Lumber, or **Wood Composite** (Panel Strips).

Dimensions: number and actual (average) dimensions of components at time of manufacture. Due to sawing variation, exact dimensions will vary from component to component within acceptable tolerances defined by the **Uniform Standard for Wood Pallets** (www.palletcentral.com).

Special Manufacturing Features: forklift entry notches, strapping notches and slots, and chamfers are specified within the component group receiving these manufacturing features.

Spec Sheet Notes: provides a place for the Preparer to input any additional or custom information to be displayed at the bottom of the Pallet Specification.

PALLET DESIGN SYSTEM Version 4.1

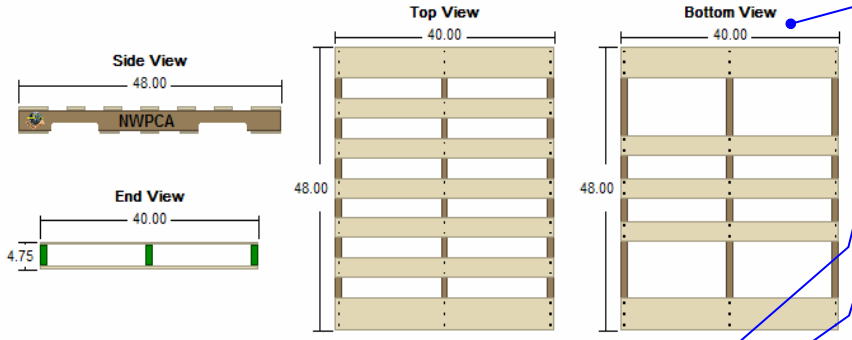
Pallet Specification Sheet

All dimensions in inches

Customer:
Company Name of Customer
Address of Customer

Prepared by:
Pallet Professional and NWPCA Member
Licensed to Perform PDS Design Work
PDS License: 50 Printed: December 01, 2008

Pallet ID: Stringer-Class Pallet Example
Classification: 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Multiple-Use, New Manufacture
Pallet Treatments: ISPM-15 Compliance: Heat Treatment (HT)



Components

Top Deck:
Style: Deckboard **Type:** New Lumber

Number	Thickness	Width	Length
5	0.625	3.500	40.00
2	0.625	5.500	40.00

Volume: 4.9 bd ft

Bottom Deck:
Style: Deckboard **Type:** New Lumber

Number	Thickness	Width	Length
3	0.625	3.500	40.00
2	0.625	5.500	40.00

Volume: 3.7 bd ft

Stringers:
Type: New Lumber

Number	Width	Height	Length
3	1.375	3.500	48.00

Volume: 4.8 bd ft
Partial 4-way Entry Notch:
Depth: 1.250 Length: 9.00 Location: 6.00 Radius: 0.75

Materials

Fasteners:

Fastener ID:	2-1/4 x 11-1/2 Ga. SS
Fastener Type:	Helically Threaded Nail
Fastener Length:	2.25
Thread Length:	1.25
Thread Diameter:	0.124
Wire Diameter:	0.112
Head Diameter:	0.280
Helixes:	7.5
Flutes:	4
Thread Angle:	60
MIBANT Angle:	36
FWI:	73
FSI:	67
Total Number:	84

New Lumber:
Lumber ID: Mixed Eastern Hardwoods

Species Class	Grade	Lumber Mix
High Density Eastern Hardwoods	Standard &BTR	50 %
Medium Density Eastern Hardwoods	Standard &BTR	25 %
Low Density Eastern Hardwoods	Standard &BTR	25 %

Moisture Content (at manufacture and assembly): Green

Total New Lumber Volume: 13.5 bd ft

Spec Sheet Notes:
Information specific to Customer here

PDS can use either U.S. Customary Units (inches, lbs) or S.I. Units (mm, kg)

Prepared by: identifies company licensed to use PDS and perform PDS design work. The **Preparer** understands the importance of correct pallet specification and construction and the effect on the pallet's ability to protect and safely support Customer's product during transport and storage.

Drawings: in addition to the small 2-D drawings on the Specification Sheet, PDS creates separate, fully-dimensioned 2-D and 3-D pallet drawings.

Materials: complete details are provided for all materials used in construction of the pallet, including **Fasteners**, **New Lumber**, **Recycled Lumber**, and **Composite Panels**.

Fasteners: Detailed Fastener Specifications are required in order to predict pallet performance. Pallet performance is highly dependent on the connections between components, which in turn are highly dependent on the fastener withdrawal resistance and fastener shear resistance in the connections.

New Lumber: New Lumber components are those produced from cants, rough-sawn lumber, or dimension lumber which has not previously been used.
- **Species Class:** Each PDS Species Class contains from one to several wood species. Species within each Class are either commonly used together without differentiation and/or they have similar mechanical properties.
- **Grade:** defines the Lumber Characteristic Restrictions permitted within the Pallet Component. Component Grades were developed to control structural and functional performance. PDS Component Grades include single grades (Select, Premium, Standard, Utility, and Economy), as well as mixed, or &BTR, grades (Premium &BTR, Standard &BTR, Utility &BTR, and Economy &BTR). For single grades, all the components are of the quality defined by that grade. For &BTR grades, the minimum grade component is identified, but components of all higher grades are also included.
- **Lumber Mix:** PDS allows up to 5 different Species Classes and/or Grades within a single New Lumber Specification. This is necessary when a mixture of Species Classes is used for components.
- **Moisture Content** of the lumber components at time of manufacture and pallet assembly must be specified in PDS.

Volume: based on actual specified component dimensions. This is NOT the total volume of lumber required to produce pallet components, which would include saw kerf, end trim, and culling of below-grade material.

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Guide to the Pallet Design System (PDS©) Pallet Structural Analysis

The PDS **Pallet Structural Analysis** uses a reliability-based engineering analysis to predict the performance of the pallet described on the **Pallet Specification Sheet** under the **Load** and **Support Conditions** specified by the Preparer.

Unit Load Type specifies the load model used in the Structural Analysis of the pallet. The **Safe Load Capacity** of the pallet is dependent on the Load Type. PDS contains several Unit Load Types which can be used to represent most common pallet loads.

Unit Load Weight Variability indicates how much the weight of the load on each pallet may vary. If the pallet is used to support the same load each and every time, the variability is Low. If the pallet is used to support loads ranging from cotton balls to cans of soup, the variability is High. Since PDS uses a reliability-based engineering analysis, load variability affects the predicted safe load capacity.

Service Environment: Most shipping and handling environments are classified as a **Dry** Service Environment, in which the pallet is NOT continuously exposed to liquid water or extremely high humidity, and the wood will reach an Equilibrium Moisture Content (EMC) of 19% or less. **Wet** Service Environments are those in which the pallet is frequently or continuously exposed to liquid water or extremely high humidity, and the wood will reach an Equilibrium Moisture Content (EMC) greater than 19%.

Racked Across Length indicates the pallet is supported only at its ends, either in a rack system or conveyor.

Racked Across Width indicates the pallet is supported only at its edges, either in a rack system or conveyor.

Span is the distance between the supports in a rack system or a conveyor.

Stacked Support assumes the floor supports the bottom pallet in a stack.

A Stacked 1 High Analysis will always be provided. PDS can analyze the pallet when 2 or more Unit Loads are in a Stack, either in the warehouse or in shipping.

PALLET DESIGN SYSTEM Version 4.1
Pallet Structural Analysis

Customer:
Company Name of Customer

Prepared by:
Pallet Professional and NWPCA Member
PDS License: 50 Printed: December 01, 2008

Pallet ID: Stringer-Class Pallet Example
Classification: 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Multiple-Use, New Manufacture
Unit Load Type: Uniformly Distributed - Full Pallet Coverage
Unit Load Weight Variability: Medium
Service Environment: Dry Environment (EMC <= 19%)

Support Condition	Safe Maximum Load	Deflection at Maximum Load	User Specified Deflection Limit	Maximum Load for Deflection Limit	Critical Member
Racked Across Length (NWPCA, Span = 44.00)	1710 lbs.	0.46 in.	0.40 in.	1234 lbs.	Center Stringer
Racked Across Width (Span = 36.00)	1595 lbs.	0.76 in.	0.50 in.	770 lbs.	Bottom Deckboard
Stacked 1 Unit Load High	4713 lbs.	0.19 in.	----	----	Top Deckboard
Stacked 4 Unit Loads High	1813 lbs. (each pallet)	0.19 in.	----	----	Top Deckboard

Lateral Collapse Resistance

Low | Medium | Good | Excellent

H/V = 1.91

Safe Maximum Load: PDS reports the safe load capacity based on pallet strength. This safe load capacity is NOT the load which would cause the pallet to fail. Rather it is the safe working load which includes safety levels calibrated to industry accepted practice based on successful pallet designs used throughout the world.

Deflection at Maximum Load: PDS reports the pallet deflection at the safe load. The deflection in a loaded pallet will increase over time. Most of this increase will occur within the first few days, after which the rate of increase in deflection will subside. PDS estimates the deflection after 30 days.

The **Critical Member** is identified in the Pallet Structural Analysis Results for each Support Condition. The Critical Member is the component that is most highly stressed (compared to its strength) and which therefore limits the Safe Load Capacity of the pallet. If the Pallet Designer wishes to increase the safe load capacity of the pallet, he/she can do so most efficiently by increasing the strength of the Critical Member or making some other design change which decreases the stress in the Critical Member.

Maximum Load for Deflection Limit: If a Deflection Limit is specified, PDS will report the safe load to maintain this deflection limit if less than the safe load limited by pallet strength.

User Specified Deflection Limit: If there is a known limit to how much pallet deflection can be tolerated in a handling system, either because of a fragile product on a pallet or deflection-sensitive handling equipment, this User-Specified Deflection Limit can be input.

Lateral Collapse Resistance: Lateral Collapse is a failure mode in stringer pallets characterized by lateral movement of the top vs. bottom deck, rotational failure of all stringer-deck connections, and collapse of stringers onto their sides. Handling equipment can no longer enter the pallet and product damage is likely. Lateral Collapse most frequently occurs during shipping when horizontal forces cause lateral movement and/or shifting of the load perpendicular to the stringers. Forces during handling of the pallet can also cause Lateral Collapse.

PDS estimates the **H/V Ratio**, the ratio of **H**orizontal to **V**ertical Force required to cause Lateral Collapse. The Vertical Force is equal to the weight on the pallet. The handling environment supplies the Horizontal Force, either due to motion of the load during transit or mishandling by forklift. The greater the H/V Ratio, the greater the Lateral Collapse Resistance.

The **Lateral Collapse Resistance** is indicated on a graphical scale, with Low, Medium, Good, and Excellent ranges. The Low range includes H/V Ratios <= .6. The Medium range includes H/V Ratios between .61 and .99. The Good range includes H/V Ratios between 1.0 and 2.5. The Excellent range includes H/V Ratios >= 2.51.

Multiple-Use pallets should have Good or Excellent Lateral Collapse Resistance. Limited-Use pallets may serve satisfactorily with Medium Lateral Collapse Resistance, but should be handled carefully. Pallets with Low Lateral Collapse Resistance are likely to have Lateral Collapse failures.

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Guide to the Pallet Design System (PDS©)
Pallet Durability Analysis

The PDS **Pallet Durability Analysis** uses a computer simulation coupled with an engineering analysis to predict the **Service Life**, in terms of **Handling Cycles**, for the pallet described on the **Pallet Specification Sheet** under the **Service Environment Conditions** defined on this Pallet Durability Analysis sheet.

PALLET DESIGN SYSTEM Version 4.1
Pallet Durability Analysis

Customer:
Company Name of Customer

Prepared by:
Pallet Professional and NWPCA Member
PDS License: 50 Printed: December 01, 2008

Pallet ID: Stringer-Class Pallet Example
Classification: 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Multiple-Use, New Manufacture

Pallet Service Life Analysis

The **Pallet Service Life Analysis** simulates a series of forces and impacts applied to the pallet during each handling cycle. The frequency and severity of these impacts are estimates based on laboratory measurements, warehouse observations, and the Virginia Tech FasTrack Handling Cycle. The resistance to damage and the damage level requiring component repair or replacement are based on laboratory testing and the NWPCA Uniform Standard for Wood Pallets.

Service Environment Conditions:
Average Handling and Treatment, Medium-Duty Loads, Dry Environment (EMC <= 19%)

Predicted Service Life: 9 Cycles **Predicted Cycles until First Repair:** 3

Results from Handling Cycle Simulation

Pallet Components		Cycles To First Repair	Cycles To First Replacement	Number of Times Replaced	Limits Pallet Service Life	Relative Component Damage during Simulation
Top Leadboards	(2)	3	5	1	Yes	
Top InteriorBoards	(5)					
Bottom Leadboards	(2)	3	5	1	Yes	
Bottom InteriorBoards	(3)					
Exterior Stringers	(2)	4	9			
Interior Stringers	(1)					

Each **Handling Cycle** assumes an average of 15 pallet handlings, with a handling defined as a single lifting, movement, and set-down of a pallet.

For **Multiple-Use** pallets, the Handling Cycle Simulation proceeds until a specific component requires replacement but has already been replaced the allowed number of times. The **Predicted Service Life** is that number of **Cycles**.

For **Limited-Use** pallets, which are not intended to be repaired or re-used, the Handling Cycle Simulation proceeds until a component requires repair or replacement. The **Predicted Service Life** is that number of **Cycles**.

Service Environment Conditions:

Handling Environment Severity reflects the general handling and treatment of pallets in their service environment.

- **Rough Handling and Treatment** occurs in service environments using untrained or unskilled material handling personnel, cluttered or crowded handling areas, rapid and non-careful pallet handling, frequent manual handling and dropping of pallets, and non-fragile and relatively low-value loads.
- **Average Handling and Treatment** is the typical service environment using moderately skilled material handling personnel, reasonably well organized handling areas, moderately careful pallet handling, minimal manual handling and dropping of pallets, and somewhat damage-sensitive or relatively valuable loads.
- **Good Handling and Treatment** occurs in service environments using trained or skilled material handling personnel, automated handling systems, well organized handling areas, careful pallet handling at moderate speed, infrequent or careful manual handling, and fragile and relatively high-value loads.

Intended **Service-Duty** reflects the approximate unit load weight and determines the weight to be used in the handling cycle simulation.

- **Light-Duty Loads** uses 1000 lbs.
- **Medium-Duty Loads** uses 2000 lbs.
- **Heavy-Duty Loads** uses 3000 lbs.

The following assumptions regarding **component repairs** and **replacements** are used in the simulation and Pallet Service Life Analysis:

- **Connections** in boards can be repaired once without having to replace the board. A repaired connection is restored to 65% of its original damage resistance. In boards, only repairs to connections are allowed.
- A **replaced board** is restored to 100% of its original damage resistance, but its connections lose 10% with each replacement.
- The **number of times a board can be replaced** depends on the stringer width: boards can be replaced twice for stringer widths of 1.5 to 2 inches, once if stringer width is less than 1.5 inches, and three times if stringer width is greater than 2 inches. The same rule applies to block widths for block pallets.
- **Stringers** can be **repaired twice** without having to be replaced. They are restored to 65% of their original damage resistance when repaired, 100% when replaced. Stringers can be replaced one time.
- In the **Handling Cycle Simulation**, forces and impacts are distributed equally among the number of specific components (e.g. the two Top Leadboards, or four Corner Blocks), and so the **Damage Level** for all the components of that specific type will remain equal. Therefore, when a repair or replacement is required, all these specific components (eg. both the Top Leadboards or all four Corner Blocks) must be repaired or replaced.

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Guide to the Pallet Design System (PDS©) Pallet Physical Property Analysis

The PDS **Pallet Physical Property Analysis** estimates the average **Pallet Weight** and the **Dimensional Changes** due to Wood Drying for the pallet described on the **Pallet Specification Sheet**.

PALLET DESIGN SYSTEM Version 4.1
Pallet Physical Property Analysis

Customer:
Company Name of Customer

Prepared by:
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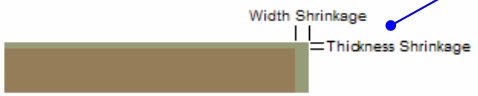
Pallet ID: Stringer-Class Pallet Example
Classification: 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Multiple-Use, New Manufacture

	At Manufacture	At 25% MC	At 19% MC	At 15% MC	At 12% MC
Average Pallet Weight	59 lbs.	41 lbs.	39 lbs.	38 lbs.	37 lbs.

Average Pallet Weight At Manufacture is based on estimated component weights at specified moisture content. Pallet weights will decrease if lumber components lose moisture to reach equilibrium with the environment. Estimated Pallet Weights at 25%, 19%, 15%, and 12% MC are provided for reference (if less than MC at manufacture.)



As wood dries below Fiber Saturation Point (about 28% MC), the wood fibers essentially pack tighter together. This results in a noticeable decrease in dimension across the grain, but only a tiny decrease along the grain. For lumber pallet components, the width and thickness dimensions will decrease slightly, but their length remains essentially the same.

While component dimensions may slightly decrease with drying, component strength and stiffness increases!

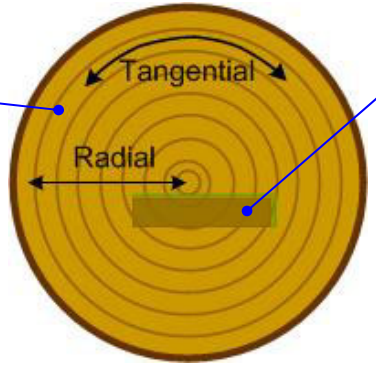
A general rule of thumb is a 1% decrease in width or thickness with a 5% decrease in MC (below Fiber Saturation Point).

Dimensional Change due to Wood Drying

Component	Original Dimension	Shrinkage from Manufacture to 19% MC	Shrinkage from Manufacture to 15% MC
Top Deckboards	0.625 in. Thickness 3.500 in. Width 5.500 in. Width	0.014 in. (+/- 0.004 in.) 0.078 in. (+/- 0.023 in.) 0.123 in. (+/- 0.036 in.)	0.020 in. (+/- 0.006 in.) 0.113 in. (+/- 0.033 in.) 0.178 in. (+/- 0.052 in.)
Stringers	3.500 in. Height 1.375 in. Width	0.078 in. (+/- 0.023 in.) 0.031 in. (+/- 0.009 in.)	0.113 in. (+/- 0.033 in.) 0.044 in. (+/- 0.013 in.)
Bottom Deckboards	0.625 in. Thickness 3.500 in. Width 5.500 in. Width	0.014 in. (+/- 0.004 in.) 0.078 in. (+/- 0.023 in.) 0.123 in. (+/- 0.036 in.)	0.020 in. (+/- 0.006 in.) 0.113 in. (+/- 0.033 in.) 0.178 in. (+/- 0.052 in.)

If lumber components lose moisture to reach equilibrium with the environment, they also decrease slightly in cross section. The estimated **dimensional change** is reported as **Shrinkage** and is provided for Manufacture to 19% MC and Manufacture to 15% MC (if less than MC at manufacture.)

The cellular structure of wood shrinks differently in two directions, based on the anatomy of the tree. Wood shrinks about twice as much **tangentially** as **radially**.



The orientation of the cells across the width and thickness of lumber components are usually a combination of the tangential and radial direction.

PDS provides shrinkage measurements based on the **average** of tangential and radial shrinkage, with a **(+/-)** value based on the range possible for pure tangential or pure radial shrinkage.