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Standard Guide for Selection and Use of Flat Strapping Materials[1]

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This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

This guide covers two common categories of flat strapping materials: steel and nonmetallic. Within each of these two broad categories there are distinct types that lend themselves in differing degrees to particular applications.

The goal of this guide is to help the user focus on the desired elements of performance or service, and the unique properties of each strapping material in order to judge which of these strapping products is best suited for the intended strapping application. For further information, consult with your strapping supplier, your carrier, and any packaging/loading regulations applicable to your products. It is of particular importance, for both safety and satisfactory performance, that the user informs the strapping supplier of all intended uses and usage conditions that may differ from industry custom and practice or from intended strapping applications. Likewise, the user needs to inform the strapping supplier of any practice of the user's carrier that the user believes may differ from any requirement or recommendation of the carrier's association or of any applicable ASTM or regulatory provisions. The user also should inform the strapping supplier of the following expected conditions: load, unit, or package characteristics (rigid, expanding, shrinking, or combination); severity of handling; nature of transport equipment; storage conditions (stacking height and weight); exposure to environmental conditions; extreme temperatures (particularly if prolonged outdoor exposure is anticipated); exposure to chemicals; exposure to abrasive surfaces; and exposure to sharp or pointed objects that can cause nicks, scratches, or holes in the strapping. There are other materials not covered by this guide, which may also offer acceptable solutions or may be used in conjunction with flat strapping to provide acceptable solutions for the user's intended application. Examples of accessories, such as, edge protectors, seal protectors, etc. are shown in Fig. 1.

Strapping may be recyclable but must never be reused. Contact your supplier for further information.

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1. Scope

1.1 This guide[1] covers information on flat strapping materials (steel and nonmetallic) for the prospective user wanting initial guidance in selecting a strapping material and information on suggested application methods for use in packaging (closing, reinforcing, baling, bundling, unitizing, or palletizing), and loading applications (load unitization and securement to transport vehicle). The use applies to handling, securement, storage, and distribution systems.

1.2 Carrier associations have established certain packaging and loading requirements that (in some cases) specify the type of strap, the minimum size or strength, the type of joint or seal, and the number of straps, seals, and joints that must be used for particular types of shipments or under certain conditions. Users should consult with their carriers initially to determine if there are applicable published requirements. Individual carriers may establish their own requirements. (See 2.2.)

1.3 *Limitations*—This guide is not intended to give specific information as to how strapping must be used in any particular packaging or loading situation. Rather, it is intended to be informational in nature and is offered as a starting point for the testing of strapping being considered by the user. Thorough user testing is essential, as is a review of pertinent regulations that can influence strap selection (size and type), and application methods.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

[1] This guide is under the jurisdiction of ASTM Committee D10 on Packaging and is the direct responsibility of Subcommittee D10.25 on Palletizing and Unitizing of Loads.

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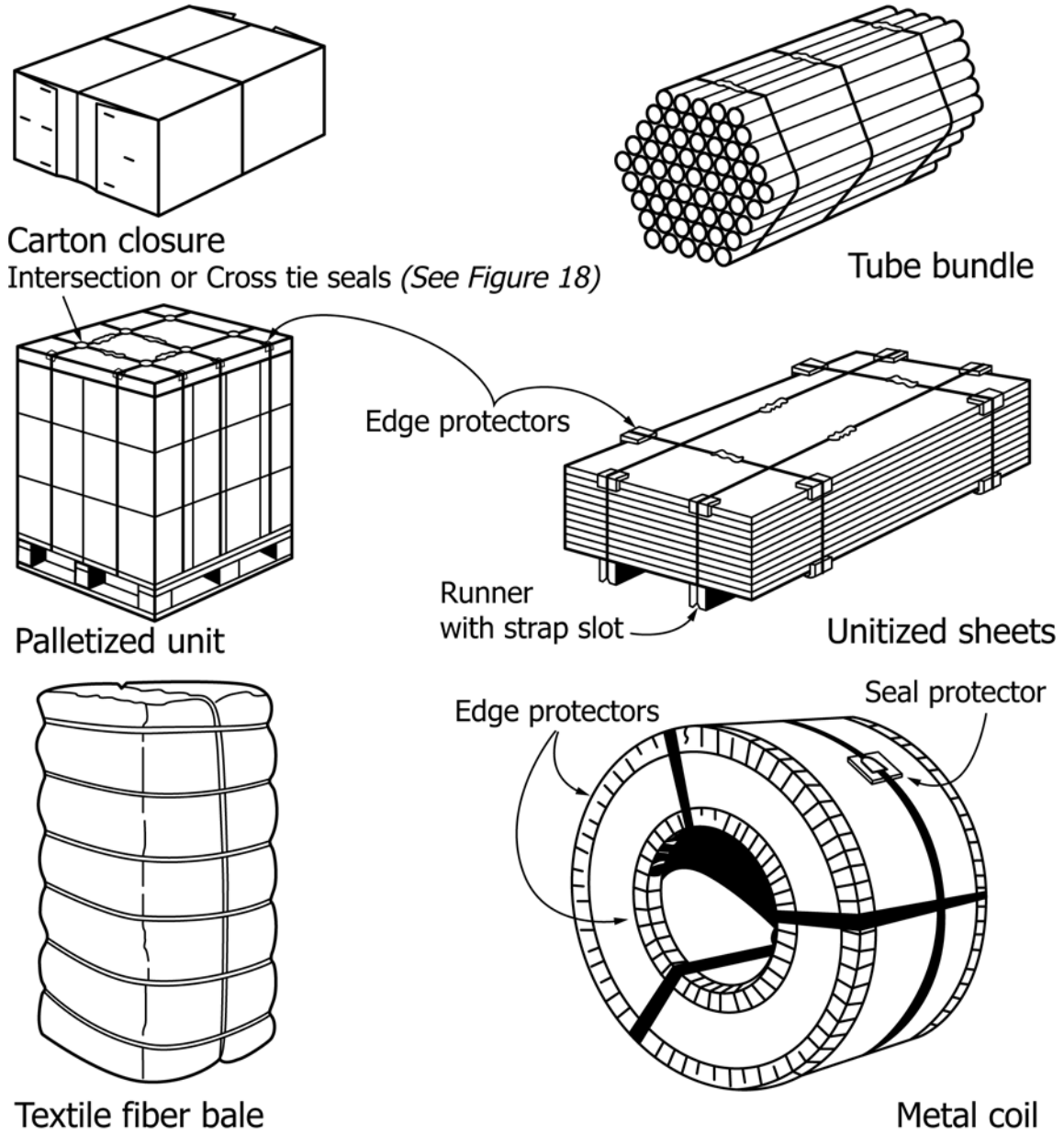

FIG. 1 Various Strapping Applications

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific safety hazard guidelines, however, are provided in Section 5.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D996 Terminology of Packaging and Distribution Environments
D3950 Specification for Strapping, Nonmetallic (and Joining Methods)
D3953 Specification for Strapping, Flat Steel and Seals
D4169 Practice for Performance Testing of Shipping Containers and Systems

2.2 *Other Standards (most current revisions):*
Uniform Freight Classification Code, Rule 41, Section 9[3]

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Railroad Freight Classification, available from Uniform Classification Committee, 222 South Riverside Plaza, Chicago, IL 60606.

National Motor Freight Classification 100-L, Item 222, Section 7[4]
ISTA, International Safe Transit Association, Pre-Shipment Test Procedure[5]
Association of American Railroads (AAR/TTCI)— Closed Car Loading Methods and Open Top Loading Rules[6]
IMO/ILO/UN ECE Guidelines for Packing or Cargo Transport Units (CTUs)[7]
Driver's Handbook on Cargo Securement[8]

3. Terminology

3.1 *Definitions*—For general definitions of packaging and distribution environments see Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:* The following refers to the characteristics and properties of strapping materials. These can be objectively measured to some extent and are used to rank the relative effectiveness of different strapping materials in different applications. The definitions given here are for the purposes of this guide only and do not necessarily reflect general usage or ASTM standard definitions. Some properties are common to both steel and nonmetallic strapping. Other properties pertain to just steel strapping or to nonmetallic strapping only.

3.2.1 *break strength, n*—the longitudinal tensile force that is applied to cause a strap to rupture. (See Specifications D3950 and D3953.)

3.2.2 *chemical contamination, n*—exposure to chemicals which may degrade the strap's physical properties. (See Section 13).

3.2.3 *corner break strength, n*—the reduced break strength due to the strapping being bent around a corner or edge. (See Specification D3953.)

3.2.4 *dead stretch (creep), n*—strain (elongation) resulting from constant tensional stresses over time.

3.2.5 *ductility in bending (resistance to "work hardening"), n*—refers to the ability of steel strapping to deform without rupture under the tensile stress resulting from bending, or its resistance to work hardening. It is the opposite of "brittleness." Ductility is related to corner break strength and closely associated to strength and elongation. (See Specification D3953.)

3.2.6 *elongation at break, n*—the increase in strapping length (strain) when the tensional loading (stress) gets high enough to cause strap failure. (See Specifications D3950 and D3953.)

3.2.7 *energy-to-break, n*—the energy/force (total area under the stress-strain curve), resulting from strength and elongation properties required to break a strap.

3.2.8 *environmental resistant properties, n*—the ability of steel or nonmetallic strapping to withstand degradation from (but not limited to) exposure to sunlight, low and high humidity, and caustic chemicals.

3.2.9 *initial applied tension (IAT), n*—highest amount of stress induced into the strap while the tensioning mechanism is still engaged.

3.2.10 *initial retained tension (IRT), n*—the stress that remains in the strap immediately after completion of the joint and removal of the tensioning equipment.

3.2.11 *joint efficiencies, n*—joint strength divided by the minimum breaking strength of the strap, expressed as a percentage (For minimum acceptable percentage values, see Section 12, and Specifications D3950 and D3953.)

3.2.12 *joint strength, n*—the highest longitudinal tension (strain) that must be applied to cause a strap joint to fail. A failure at the gripper marks (outside of the joint) made by the hand tool, strapping head, or tensile tester specimen holding grippers is not to be considered the strength of the joint.

3.2.13 *lubrication, n*—an intentionally applied substance on the strap surface that lowers the coefficient of friction.

3.2.14 *mechanism, n*—device used in application of strapping, such as tensioner and sealer, combination tool, or power strapping equipment.

3.2.15 *moisture sensitivity, n*—the degree to which mechanical properties degrade due to the presence of moisture or moisture vapor. (See Section 13.)

3.2.16 *notch sensitivity, n*—the measure of a strapping material's ability to resist tearing or breaking due to a nick or cut.

3.2.17 *settling tolerance, n*—the ability of a strap to remain taut when used to confine a dimensionally shrinking load, unit, or package.

3.2.18 *shear plane, n*—the contact surface area between two items at which they move relative to one another when parallel and opposing forces are applied to these areas. The parallel application of forces causes the items to slide against one another.

3.2.19 *system strength, n*—the strength of an applied strap (closed loop) including both the strap and joining method.

3.2.20 *temperature sensitivity, n*—the degree to which the mechanical properties degrade due to extreme low or high temperatures.

3.2.21 *tension transmission, n*—the ability of strapping to slide around a corner/edge during tensioning.

3.2.22 *ultraviolet (U.V.) light resistance, n*—the degree to which the mechanical properties degrade due to ultraviolet ray exposure. U.V. inhibitors are available for all types of nonmetallic strapping.

[4] Available from National Motor Freight Traffic Association (NMFTA), 1001 N. Fairfax St., Alexandria, VA 22314, http://www.nmfta.org.
[5] Available from International Safe Transit Association (ISTA), 1400 Abbot Road, Suite 160, East Lansing, MI 48823–1900, http://www.ista.org.
[6] Available from Association of American Railroads, Transportation Technology Center, Inc. (AAR/TTCI), 55500 Dot Road Pueblo, CO 81001, http://www.aar.com.
[7] Available from International Maritime Organization, Publishing Service, 4 Albert Embankment, London, SE1 7SR, United Kingdom, http://www.imo.org.
[8] Available from Driver's Handbook on Cargo Securement, 1200 New Jersey Avenue, SE, Suite W60-300, Washington, DC 20590, http://www.fmcsa.dot.gov/documents/cargo/cargosecurement-16-04.pdf.

3.2.23 *unit strap lifting method (USLM), n*—a specialized application for overhead lifting and transport of large and heavy loads, units, or packages primarily at port facilities. (See Table 1.)

3.2.24 *yield point, n*—the stress at which a material begins to deform physically. Prior to reaching the yield point, the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible.

4. Significance and Use

4.1 This guide is intended to assist the user in selecting strapping material(s) and application method(s) for evaluation when subjected to handling, transit, and storage tests. It describes general load, unit and package types, strapping properties, strapping performance, weight considerations, shear planes, component frictional characteristics, and geometry.

5. Safety Hazard Guidelines

5.1 Safety guidelines need to be followed to avoid personal injury or death. Examples of safety guidelines are presented below. Users should consider engaging an individual qualified by training to conduct a risk assessment on all strapping applications to determine best safety practices.

5.2 *Strap Cutting*—When straps are under tensional loading, the release of this tension will produce a hazard when the loose ends snap free after being intentionally or accidentally cut, frayed, or otherwise released. Contents under restraint or the strap itself, or both, may spring toward or fall upon the operator or a bystander when strap tension is suddenly released. *Cutting tensioned strap is hazardous.* Use caution and follow approved safety procedures. (See Fig. 2.)

5.2.1 *Strap Cutting Techniques:*

(1) Wear safety gloves and eye protection when working with steel or nonmetallic strapping.

(2) Keep a safe distance away from the danger zone. (See the Gray Area in Fig. 2.) When tensioned straps that secure a load, unit, or package are cut the contents could shift or fall. Bystanders need to be in an area where they will not be struck by flying or flailing strap ends when the strapping is being cut.

(3) Never stand under a strapped load, unit, or package. Never stand directly in front of a load, unit, or package secured by a strap being cut.

(4) Stand to one side of the strap being cut.

(5) Use one hand to hold the strap firmly against the load, unit, or package. Never place your hand on or near the seal while cutting the strap. (See Fig. 2.)

5.2.2 Always wear proper Personal Protective Equipment (PPE) such as gloves, eye protection, steel toe safety shoes, etc., when working with steel or nonmetallic strapping.

5.3 Excessive tensioning may cause strap breakage. Always position yourself to one side of strap being tensioned. Never stand directly in-line of a strap being tensioned.

5.4 *Strapping Tools*—Read and understand all instructions before operating any tool.

5.4.1 Never operate the tool in such a manner that could result in a loss of balance or loss of control of the tool, the load, unit, or package secured by the strap.

5.4.2 Never extend the length of the handle on a manual tensioner, or exceed the manufacturer's recommended maximum air pressure on pneumatic tensioners to gain increased strap tension. To do so could result in sudden strap failure or breakage of the tensioner. This could result in serious or fatal injury to the operator.

5.5 *Seals and Joints*—An improperly formed strap joint can result in premature failure and an unstable load, unit, or package. (See Section 12.)

5.6 *Strapping Alignment*—Apply strapping perpendicular to any edge (corner). A strap being applied and tensioned at an angle (edge loaded) may induce strap failure. Eventually the strap could shift to proper alignment position, resulting in a loose strap and product shift. (See 17.1.)

5.7 *Improper Use*—Use strapping only as intended by the supplier and consistent with all applicable regulations, standards, warnings, and instructions.

5.7.1 *Drilling, Punching, or Nailing*—Never drill holes in strapping. Never punch strapping with nails, staples, or other sharp objects. This may cause premature strap failure that could result in serious or fatal injury. Attempting to nail/staple through steel strapping may present a hazard, such as strap failure or richocheting of a nail/staple. For nail-on applications, use Type 2 steel strapping that has pre-punched holes.

5.7.2 *Pulling or Dragging*—Never use strapping as a means of pulling or dragging any load, unit, or package.

5.7.3 *Lifting*—Never use strapping as a means of lifting unless using the Unit Strap Lifting Method (USLM) system. (See 5.9 to 5.9.6.)

5.8 *Reuse*—Never reuse steel or nonmetallic strapping, since the mechanical properties of strapping may be altered by tensioning, during handling/shipping, or after having been applied in the first instance.

5.9 *Unit Strap Lifting Method (USLM)*—Before considering a USLM application, consult your USLM system vendor and transportation or Port Regulatory Authorities for application rules and specifications. The following warnings are in addition to the previously listed safety hazards. (See 5.2 through 5.8.)

5.9.1 *Compliance and Training*—Compliance with all safety aspects of USLM application is critical to protect personnel. Always train all users before using the USLM or handling USLM loads.

5.9.2 *Specified Strapping, Tools, and Seals*—Always use correctly marked USLM steel strapping and seals. (See Specification D3953.) Crimp type seals must be used and be applied with a crimp type sealer. The strapping must be applied so that the USLM markings are visible.

5.9.3 *Lifting Capacity*—Consult transport company or Port Authority Regulations, and your USLM system supplier to determine the lifting capacity of strapping. Never exceed the calculated lifting capacity.

5.9.4 *Damaged or Used Straps or Seals*—Never use damaged or used USLM strap or seals.

TABLE 1 Strapping Applications Commonly Used for Packaging, Unitization, and Load Securement

For guidance purposes only. The strapping types and sizes indicated for specific applications are typical. The table is not intended to recommend or specify.										
		Specification D3953 for Strapping Flat Steel and Seals			Specification D3950 for Strapping Nonmetallic (and Joining Methods)				
		Hand or Machine Applied			Hand Applied		Hand or Machine Applied		
Industry	Product	Type I Steel Regular Duty	Type I Steel Regular Duty High Strength	Type I Steel Heavy Duty	Type IA Bonded, Woven, or Composite Polyester Cord	Type I Bonded Rayon Cord	Type II Polypropylene	Type III Nylon	Type IV Polyester
		Moderate Tensile Strength Low Elongation High Retained Tension Well suited for rigid and moderate expanding units Not well suited for shrinking units.	High Tensile Strength Low Elongation High Retained Tension Well suited for rigid and moderate expanding units Not well suited for shrinking units.	High Tensile Strength Moderate Elongation High Retained Tension Well suited for rigid and moderate expanding units Not well suited for shrinking units.	Good Tensile Strength Moderate Elongation Good Retained Tension High Energy-to-Break Good Notch Sensitivity Well suited for shrinking, rigid, and expanding units.	Moderate Tensile Strength Moderate Elongation Good Notch Sensitivity Well suited for shrinking, rigid, and moderate expanding units.	Low Tensile Strength High Elongation Low Retained Tension Good Tension Recovery Well suited for shrinking and expanding units.	Moderate Tensile Strength Good Elongation Good Retained Tension Good Tension Recovery Well suited for shrinking, rigid, and expanding units.	Good Tensile Strength Moderate Elongation Good Retained Tension High Energy-to-Break Well suited for shrinking, rigid, and expanding units.
General	Appliances	3/8 " & 1/2 "					7/16 "	7/16 "	5/8 "
	Carton Closure					3/16 ", 1/4 " & 3/8 "	1/4 " & 3/8 "	3/8 "	
	Flat Glass		5/8 " & 3/4 "		5/8 " & 3/4 "				5/8 " & 3/4 "
	PVC Pipe	3/4 "	5/8 " & 3/4 "		1/2 ", 5/8 " & 3/4 "		7/16 "	7/16 "	1/2 ", 5/8 " & 3/4 "
Agriculture	Food Products in Wood Bins			3/4 "	5/8 " & 3/4 "				5/8 "
	Hay Bailing						1/2 "		1/2 "
	Cotton			3/4 "					3/4 "
	Tobacco			1/2 ", 5/8 " & 3/4 "			1/2 "		
	Fibers (Manmade & Natural)	5/8 " & 3/4 "	5/8 " & 3/4 "	1/2 ", 5/8 " & 3/4 "					5/8 " & 3/4 "
Bevarage	PET Bottles							3/8 "	3/8 "
	Cans							3/8 "	3/8 "
	Glass Bottles							7/16 " & 1/2 "	7/16 " & 1/2 "
Corrugated	KD Boxes	3/8 "					7/16 "		7/16 "
	Corrugated Sheet Bundles	3/8 ", 5/8 " & 3/4 "					7/16 "		7/16 "
Graphic Arts	Signature Logs						7/16 " & 1/2 "		7/16 " & 1/2 "
	Magazines						5 mm, 3/16 " & 1/4 "		
	Newspapers						5 mm, 3/16 " & 1/4 "		
	Palletized Printed Loads		1/2 " & 5/8 "		1/2 " & 5/8 "				7/16 ", 1/2 " & 5/8 "
Masonry	Brick		1/2 "	1/2 "					5/8 "
	Block/Pavers		1/2 " & 5/8 "	1/2 " & 5/8 "					5/8 " & 3/4 "
	Roof Tiles						7/16 "		
Forest Products	Lumber	5/8 " & 3/4 "	1/2 ", 5/8 " & 3/4 "	5/8 " & 3/4 "	5/8 ", 3/4 ", 1" & 1 1/4 "				5/8 " & 3/4 "
	Hardwoods	3/4 "		3/4 "	5/8 " & 3/4 "				3/4 " & 1"
	Hardboard Siding	5/8 " & 3/4 "		5/8 " & 3/4 "	5/8 " & 3/4 "				5/8 "
	Pressure Treated Lumber	5/8 " & 3/4 "	5/8 " & 3/4 "	5/8 " & 3/4 "	5/8 " & 3/4 "				5/8 "
	Landscape Timbers	3/4 "		3/4 "	5/8 ", 3/4 " & 1"				5/8 "
Panel Products	Flakeboard, MDF, OSB, Particleboard & Plywood		5/8 "	5/8 "	5/8 " & 3/4 "				5/8 " & 3/4 "
Engineered Wood Products	I-Joists, LVL, PSL & LSL			3/4 " & 1 1/4 "	5/8 ", 3/4 ", 1" & 1 1/4 "				5/8 " & 3/4 "

TABLE 1 *Continued*

For guidance purposes only. The strapping types and sizes indicated for specific applications are typical. The table is not intended to recommend or specify.									
Industry	Product	Specification D3953 for Strapping Flat Steel and Seals			Specification D3950 for Strapping Nonmetallic (and Joining Methods)				
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Paper	Paper Rolls	⅜ " & ½ "							
	Copy Paper in Cartons					3/16 ", ¼ " & ⅜ "	¼ " & ⅜ "	⅜ "	
Metals	Aluminum Ingots			¾ " & 1¼ "					⅝ ", ¾ ", 1" & 1¼ "
	Aluminum Billets			¾ "					¾ ", 1" & 1¼ "
	Aluminum Extrusions			⅝ " & ¾ "	½ ", ⅝ " & ¾ "				⅝ "
	Scrap Aluminum			⅝ " & ¾ "					⅝ " & ¾ "
	Aluminum Rod			¾ " & 1¼ "	⅝ ", ¾ " & 1"				¾ " & 1"
	Coiled Cooper Rod			1¼ "	¾ ", 1" & 1¼ "				¾ " & 1"
	Steel Wire			1¼ "	¾ ", 1" & 1¼ "				⅝ " & ¾ "
	Steel Structural Shapes			¾ " & 1¼ "	⅝ ", ¾ ", 1", & 1¼ "				¾ " & 1"
	Cut-to-Length Flat Sheet Stock			⅝ ", ¾ " & 1¼ "	⅝ ", ¾ ", 1" & 1¼ "				⅝ ", ¾ ", 1" & 1¼ "
	Steel Tubing			⅝ ", ¾ " & 1¼ "	⅝ ", ¾ ", 1" & 1¼ "				¾ " & 1"
	Steel Coils	½ ", ⅝ " & ¾ "		⅝ ", ¾ " & 1¼ "	¾ ", 1", & 1¼ "				⅝ ", ¾ " & 1"
Load Securement	Truck & Railcar Unitization			¾ " & 1¼ "	¾ ", 1" & 1¼ "				
	Truck Tie Down			1¼ " & 2"					
	Railcar Doorway Protection			¾ " & 1¼ "	1¼ " & 1½ "				
	Open Top Railcar Tie Down			¾ ", 1¼ " & 2"					
Unit Strap Lifting Method				1¼ " USLM					

FIG. 2 Strap Cutting Techniques

5.9.5 *Stand Clear*—Before lifting, be sure all personnel are away from the load, unit, or package. Never stand underneath or near a load, unit, or package being lifted.

5.9.6 *System Audit*—USLM systems require periodic performance audits. Consult your USLM system vendor for guidance.

GENERAL CONSIDERATIONS

6. General Properties of Strap Types

6.1 *Steel Strapping*—Standard specifications for steel strapping are found in Specification D3953. There are two types of steel strapping — Type 1, Flat Strapping: Power Machine and Hand Application; classified into Regular-Duty, Regular-Duty High-Strength, Heavy-Duty, and USLM (Unit Strap Lifting Method) and Type 2: Nail-On. Of all the types of banding, steel strapping has the highest tensile strength (ksi) and break strength (lbf) for a given cross-sectional area, and is resistant to tension decay from creep. It is better suited for use with expanding and rigid loads, units, or packages because steel strap, which virtually does not stretch, cannot recover and stay tight on dimensionally shrinking loads, units, or packages.

6.1.1 Regular duty strapping is suggested for lighter duty, lower tension applications.

6.1.2 Regular duty high strength strapping is suggested for applications where high strength alone is the overriding consideration.

6.1.3 Heavy duty strapping is suggested for applications where both break strength and elongation are overriding considerations.

6.1.4 USLM strapping is suggested for overhead lifting and transport of large and heavy loads, units, or packages primarily at port facilities.

6.1.5 Nail-On strapping suggested applications are to reinforce products to avoid skewing, maintain position by connecting individual units or dunnage during shipping, reinforce the corners and joints of packaging, and for use in light duty hanging or suspension applications.

6.2 *Nonmetallic Strapping*—Standard specifications for nonmetallic strapping are found in Specification D3950. There are two broad classifications of nonmetallic strapping: Cord strapping and Extruded strapping. There are two types of Cord strapping (Type I and Type IA). There are three types of Extruded strap (Type II, III, and IV).

6.3 *Cord Strapping (Type I and IA)*—Cord strapping consists of two basic types: Rayon (Type I) and Polyester (Type IA).

6.3.1 Rayon cord strap (Type I) is a bonded non-woven cord strap. It is a soft strapping product that possesses good knot strength. Compared to polyester cord strapping, rayon cord strapping has a lower tensile strength (stress) and greater amount of elongation (strain). Rayon cord strapping does elongate at low tensile stress, thus possessing good elastic characteristics. Rayon strapping is not water resistant and loses strength when subjected to moisture. As such, it should be used primarily in environmentally controlled applications.

6.3.2 Polyester cord strapping (Type IA) is made from polyester multi-filament yarns that are either woven together (Woven), bonded with a plastic binder (Bonded), or encased in a polypropylene extrusion (Composite), and has high energy-to-break for a given cross section. Heavy duty and extra heavy duty polyester cord strappings are suggested for applications where break strength, elongation recovery, and high energy-to-break are overriding considerations. Polyester cord strapping is more resistant to weathering and moisture than rayon cord strapping. Use steel buckles where maximum joint efficiency is required. Cord strapping may also be joined with a hand tied knot for general bundling purposes and low tension applications. Knotting is not recommended for high tension applications.

6.4 *Extruded Strapping (Smooth and Embossed) (Type II, III, IV)*—Extruded nonmetallic strapping consists of three basic types: polypropylene (Type II), nylon (Type III), and polyester (Type IV). All three extruded nonmetallic strapping types can be either smooth (no texture) or embossed (textured).

6.4.1 *Polypropylene (Type II)*—Polypropylene strapping is made from either of two closely related materials: polypropylene homopolymer, or polypropylene copolymer. While these materials have excellent resistance to moisture, they are the least heat-resistant of all the common strapping materials and also have the greatest tension decay or creep of any of the common strapping materials. Of the nonmetallic strapping materials, they are the most easily heat sealed or friction welded. (See Fig. 11.) They tend to be more suitable for light to medium duty packaging and unitizing applications.

6.4.2 *Nylon (Type III)*—Nylon strapping has the highest elongation recovery of all nonmetallic strapping materials, and that, combined with a relatively low dead stretch (creep), gives it the highest amount of retained tension on shrinking loads, units, or packages. Where severe settling is the major consideration, nylon would be the preferred strapping material. In terms of tensile strength, it is between polypropylene and polyester strapping material. It has the best cold temperature

performance of all the nonmetallic strap types. Nylon strap is hygroscopic (sponge-like) and is the most susceptible to degradation from moisture fluctuations.

6.4.3 *Polyester (Type IV)*—Polyester strapping has the lowest elongation in the working range and the least amount of tension decay or creep of all the nonmetallic strappings. It is more suitable for rigid and expanding loads. Like steel strapping, polyester strapping has excellent elongation recovery characteristics, but does not stretch much during application. Because strapping cannot recover more than it stretched during application and while on the load, unit, or package, polyester strapping is not generally used when a considerable amount of dimensional shrinking occurs. Polyester strapping exhibits relatively good resistance to the effects of extreme temperatures and moisture.

7. General Uses

7.1 To expedite handling, strapping may be used to secure a handling base (skids, platforms, pallets, runners, spacers, etc.) on loads, units, or packages. For example, 2 × 4 runners strapped to a concrete or steel slab to allow forklift or crane/cable handling or to secure other packaging materials (battens, stiffeners, wrappings, etc.) in position. (See Fig. 1.)

7.2 Strapping may be used for load securement to or within a transport vehicle. When used for this purpose, strapping is applied under tension to restrain or control the movement of lading, and thus must accommodate in-transit shocks or irregular movements. National and international regulations provide guidelines or minimum requirements, or both. (See 2.2.)

7.3 Strapping may be used for lifting only if applied using the Unit Strap Lifting Method (USLM). Consult transportation or Port Regulatory Authorities and a USLM system supplier for application requirements. USLM is a system for lifting unitized loads with specialized lifting gear and USLM steel strapping and seals, applied with specialized tensioners and sealers. USLM is used on a variety of bulk cargos such as, wood pulp, logs, and aluminum billets.

7.4 Strapping also may be used to provide security against accidental loss or theft of the contents or to indicate pilferage.

7.5 Strapping functions best when all resultant forces act directly parallel to, and in-line with, the direction of the strap. (See Fig. 3.)

8. Strap Tension

8.1 Strapping primarily functions under tension. Strap tension basically:

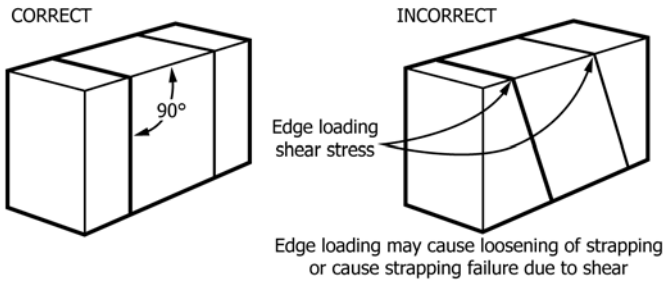


FIG. 3 Correct and Incorrect Applied Strapping

8.1.1 Imposes circumferential (peripheral) compressive forces to resist a change in configuration. For example, tubing secured in a hexagonal or round unit, scrap paper secured in bales, etc. (See Fig. 1.)

8.1.2 Increases the frictional forces between the adjacent surfaces within the load, unit, or package. For example, forces between cartons on a pallet. (See Fig. 1.)

8.1.3 Restricts or eliminates longitudinal, lateral, and vertical movement of products within loads, units, or packages (cargo).

PACKAGING DESIGN

9. Distribution

9.1 Identify receiver(s)/consignee(s), their location(s), and their shipping point(s)/consignor(s).

9.2 Determine the needs and requirements of the receiver(s). This will provide information on handling equipment and practices, storage practices/conditions, and possible specific requirements of individual users.

9.3 Determine applicable transportation modes: air, water, rail, or truck. This will further define the shipping conditions and applicable rules/regulations. (See 2.2.)

9.4 Contact potential carriers within each transportation mode, and determine if there are any general or specific rules and regulations.

9.5 The carriers can, and should be asked to provide information as to the type of equipment that will best suit specific needs.

10. Load, Unit, and Package Securement Configuration (See 2.2)

10.1 Generally, the "ideal" configuration is one that:

10.1.1 Can be safely handled in all stages of the distribution system,

10.1.2 Protects the security of the contents,

10.1.3 Meets all the requirements of the receiver(s),

10.1.4 Secures easily onto transportation equipment,

10.1.5 Maximizes the use of space in warehouses and transportation equipment,

10.1.6 Meets all national, international packaging and shipping regulations (see 2.2), and

10.1.7 Can be easily assembled and disassembled.

10.2 The configuration of the load, unit, or package needs to be such that it maintains as low a center of gravity as practical for maximum stability during handling, transit, and storage.

11. Strap Selection

11.1 Strap size, type, placement, and the number of straps required are all a function of the work to be done. (See Table 1 and Table 2.) The work to be done is determined by a number of factors, including (but not limited to):

(1) The number and direction of the shear planes,

(2) Friction of contact surfaces between all shear planes,

(3) Size, shape, and weight of load, unit, or package,

(4) Susceptibility of load, unit, or package to be damaged by strapping,

TABLE 2 Examples of Different Package Types

Package Content Type	Examples
Expanding	Natural and synthetic fibers Compressed scrap paper Corrugated fiberboard sheets Pressure treated lumber bundles Concrete reinforcing mesh Compressed coils of metal rods
Settling	Powders in cartons, bags, or other soft containers Jars or cans packed with corrugated separator sheets Green or wet lumber bundles that will lose moisture Brick cube when handled or shipped
Rigid	Concrete or metal slabs at ambient temperature Exterior grade plywood Cold Rolled steel

(5) Stacking pattern, height, and weight,
(6) Warehouse stacking conditions,
(7) Expected severity of handling,
(8) Mode of transportation,
(9) Nature of transport equipment,
(10) Shipping routes,
(11) Intended method of unloading and handling by recipient(s),
(12) Removal and disposal of strapping including environmental, sustainability, and safety considerations,
(13) Exposure to extreme low and high temperatures,
(14) Exposure to environmental conditions, (particularly if prolonged outdoor exposure is anticipated)
(15) Exposure to chemicals,
(16) Exposure to abrasive surfaces, and
(17) Exposure to sharp or pointed objects that can cause nicks, scratches, or holes in strapping.

11.2 Contents of a strapped load, unit, or package have a tendency to react in one of three ways. They can expand, remain rigid, or settle (shrink). Contents may appear to be one type and later, with different conditions, exhibit the characteristic of another type. Strapping selection must accommodate all anticipated content reactions. (See Table 2.)

11.3 *Shear Planes*—The number of shear planes within a load, unit, or package should have some bearing on strap selection and placement. Generally, more restraint is required to maintain integrity when there are more shear planes within a load, unit, or package. Supplementary materials such as edge protectors and dado cut battens may be used to augment the strap's effectiveness. (See Fig. 1.)

11.3.1 *Examples of Flat Surface Shear Planes Are:*

11.3.1.1 Multiple horizontal only; for example, plywood sheeting,

11.3.1.2 Multiple horizontal and unidirectional vertical; for example, dimensional lumber, and

11.3.1.3 Multiple horizontal and bidirectional vertical; for example, brick cube.

11.3.2 *Curved Surface Shear Planes*—Cylindrical objects that are not stacked vertically have a complex (curved) shear plane that tends to restrict sliding in the horizontal direction only. If cylindrical objects are stacked vertically, the shear planes are multiple in all directions.

11.4 *Coefficient of Friction*—The coefficient of friction of the contact surfaces is also a major consideration. For example, a bundle of rough-cut 2 × 4's does not require as much restraint as an identical bundle of smoothly planed 2 × 4's. A similar example would be dry steel sheets versus heavily oiled steel sheets. A function of tensioned strapping is to maintain load, unit, or package integrity by limiting movement between contacting surfaces. Friction will also help reduce the loss of integrity caused by multiple shear planes. In cargo securement applications, the coefficient of friction also plays an important role.

12. Joining Methods and Properties

12.1 *Joints*—Joints are generally lower in strength than the parent strap. It is therefore very important that all elements contributing to form the joint be compatible. Some examples (but not limited to) are:

12.1.1 *Strap*—Size, type, coating/finish, and lubricity do affect the selection of the joining method.

12.1.2 *Joining Method*—Must be compatible with strap and sealing mechanism. Seals for steel strap and the different types of nonmetallic strap, although similar, are not interchangeable. Never use a seal designed for use with steel strapping on nonmetallic strapping or vice versa. Specific buckles for nonmetallic strapping are also only for use on specific types of strapping and are generally not interchangeable. Always ensure that the joint method selected is intended for the type of strapping being used.

12.1.3 *Joining Mechanism*—Must be compatible with type of strap and seal (if used) and needs to be in good mechanical condition. Joining mechanisms for steel and nonmetallic strapping, although similar, are not interchangeable.

12.1.4 *Tension Mechanism*—Must be compatible with the type of strap and joint.

12.1.5 *Operator Technique*—Combine above elements together to ensure that the joint is properly formed. Always follow manufacturer's instructions.

12.1.6 *Periodic Testing of Joints*—To ensure that all elements of the system are functioning properly, test sample joints as often as deemed necessary. Joints should be taken from the actual application. A joint may have all the appearances of a good seal, but could possess less than the required strength.

12.2 *Joint Types*—The four basic types of strap joints are overlap, buckle, intersection, and loop.

12.2.1 *Overlap Joint*—This is the most common type of joint and is made by joining two ends of strapping around a load, unit, or package for securement. (See Figs. 4, 5, 6, and 11.)

12.2.2 *Buckle Joint*—This type of joint is made by joining nonmetallic strapping around a load, unit, or package for securement by threading the two strap ends into a buckle. (See Fig. 9.)

12.2.3 *Intersection Joint*—The joining of two steel straps which cross at right angles for purposes of maintaining relative position. (See Fig. 19.)

12.2.4 *Loop Joint*—The joining of one end of strapping to the strapping itself, normally to encircle an anchor fixture. (See Fig. 7.)

12.3 Joint strength is expressed by joint efficiency (see 3.2.12). A strapping joint will usually be something less than 100 % of actual strap break strength. Joint efficiency of different types of joints on different types of strapping varies greatly. Specification D3953 specifies the minimum joint efficiency for Type I steel strapping to be 45 % (single notch), 75 % (double notch, crimp, and sealless), and 90 % (USLM crimp). Specification D3950 specifies the minimum joint efficiency for nonmetallic strapping to be 45 % for Type I and Type IA Grades 1 and 2, Type II, Type III, and Type IV, and 55 % for Type IA Grades 3, 4, 5, 6, and 7. All of the minimum joint efficiencies are based on joint strength as a percentage of the minimum break strength of the strap. Other standards or regulations may specify higher or lower minimum required joint efficiencies.

12.4 Steel and nonmetallic strapping are made from materials with fundamentally different characteristics. Therefore, different joining methods are used.

JOINTS FOR STEEL STRAPPING

12.5 *Overlap Notch Joints for Type 1 Steel Strapping:*

12.5.1 *Notch Joint and Seals for Strapping (see Fig. 4)*:

12.5.2 A notch joint is a mechanical interlocking of the overlapping strap ends that are within a seal. The interlocking consists of tabs that are formed in pairs on either side by shearing and bending partially through the seal and strap edges.

12.5.3 Sealing mechanisms may be designed to form either up-cut or down-cut tabs. Up-cut tabs minimize damage to product/package surface under the sealed joint.

12.5.4 Effectiveness of notch joints is a function of:

12.5.4.1 Joint strength and strap's specified minimum break strength,

12.5.4.2 Depth and the number of pairs of notches,

12.5.4.3 Mechanical properties of the seal, and

12.5.4.4 Design and condition of the sealing mechanism, and operator technique.

12.5.5 The notched steel strap joint will always be something less than 100 % of actual strap break strength because the effective strap cross section is reduced in the shearing action to form the tabs. A single pair of notches will produce a substantially lower joint efficiency than two pairs of notches. Strapping having a cross section greater than 1¼ by 0.035 in. (32 by 0.89 mm) may require additional seals or pairs of notches to obtain optimum joint efficiency, and the seals may need to be of a heavier gauge that approaches the thickness of the parent strapping.

12.5.6 When properly formed notch joints fail, they usually break at the notch when tensionally overloaded, causing sudden and total release of strap tension. However, if the notches are poorly formed as a result of the wrong seal being used, operator error, or the sealing mechanism being badly worn, the joint may fail by the straps pulling out at a lower tension.

12.6 *Overlap Crimp Joints for Type 1 Steel Strapping:*

12.6.1 *Crimp Joint and Seals*—For steel strapping, friction is developed in a crimp joint by pairs of deformations on the top edges of the seals and the overlapped strap ends. (See Fig. 5.) Since the strap is not cut, the maximum potential joint strength can approach the parent strap strength. The finish on the strap will affect its lubricity, and consequently, the number of crimp pairs or amount of deformation required. (See Fig. 5A.)

12.6.2 Some styles of crimp seals are available with a knurled, scored, or grit (abrasive material) on the internal surface of the seal that augments the friction to provide higher joint strengths on lubricated steel strapping. (See Fig. 5B for an example of a grit seal.)

12.6.3 Crimp joints tend to fail by slipping, but may allow some retention value to be maintained after slipping occurs. This is the "slip and hold" or "controlled slip" characteristic.

12.7 *Overlap Spot Welded Joints for Type I Steel Strapping:*

12.7.1 The minimum joint strength is 75 % of the minimum break strength of the strap.

12.8 *Overlap Interlocking Joint for Type I Steel Strapping:*

12.8.1 Sometimes referred to as sealless or keylock joint. Overlapping ends are aligned and simultaneously die-cut to form a mechanical interlock. Interlocking joints produce a required 75 % minimum joint efficiency—comparable to double notch seal joints. (See Fig. 6.)

12.9 *Loop Joint for Type I Steel Strapping:*

12.9.1 Loop joints are normally used in securing loads to transportation equipment. A loop joint is formed when a strap end is passed around an anchoring fixture on the vehicle (stake pocket, round bar, etc.) and then brought back and joined to the body of the strap. (See Figs. 7 and 8.)

12.9.2 **Warning—**Tying down and securing products to a railcar, truck, flatbed, or ocean shipping container is one of the most demanding strapping applications. Therefore, it is especially important that the user refer to all applicable industry reference documents and regulations. (See Section 2.) Consult your supplier for further information and best practices.

12.9.3 The contact surface between the strap and the anchor fixture (pocket) is critical to the strength of the final strap

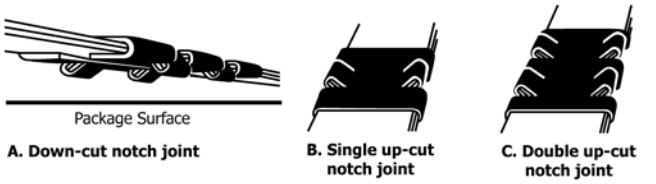


FIG. 4 Notch Joint with Seals

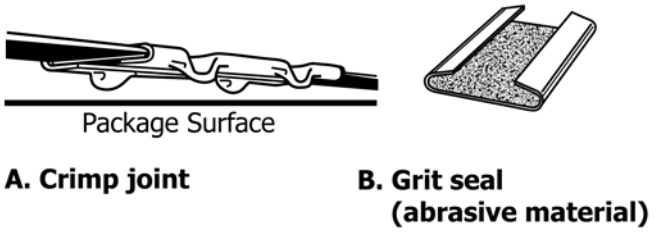


FIG. 5 Crimp Joint with Seals

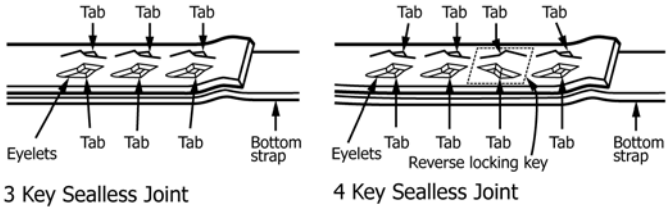


FIG. 6 Sealless Interlocking Joints

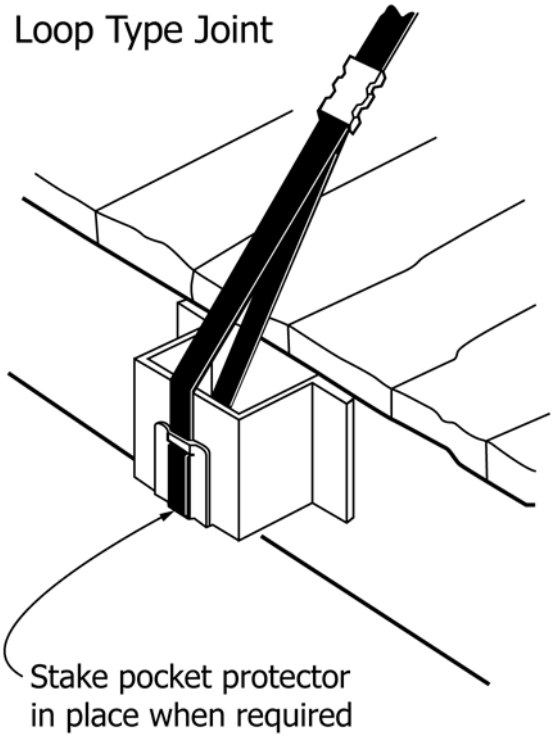


FIG. 7 Loop Joint Secured to Stake Pocket

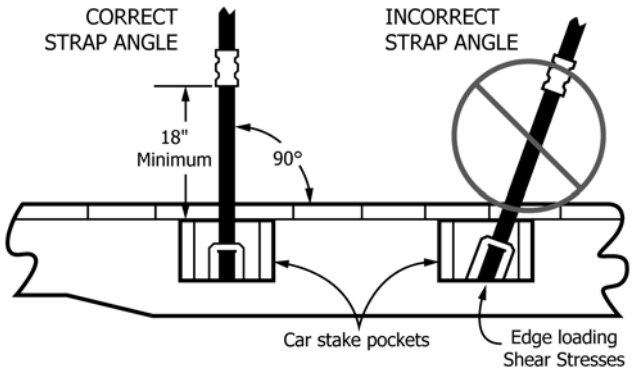


FIG. 8 Loop Joint Placement

system. A sharp bend at the bottom of the loop may cause the strap to fail when high impact forces are encountered. A securement surface (edge) having a large, smooth radius is recommended. Otherwise, strap protection needs to be used. The direction of strap pull should be perpendicular to the anchor device to avoid "edge loading" the strap loop. (See Figs. 7 and 8.)

JOINTS FOR NONMETALLIC STRAPPING

12.10 Polypropylene (Type II) and nylon (Type III) strapping can be joined with a buckle, crimp seal, or sealless joint. Polyester (Type IV) strapping can be joined with a crimp seal or sealless joint.

12.11 *Buckle Joints*—Buckles are available in various materials, finishes, designs, and sizes. Buckle style and width must be compatible with strap type and width. Steel wire and plastic buckles are typically used with polypropylene and nylon strapping. Heavy gauge steel wire and ladder buckles are suggested for cord strapping where higher tension and joint strengths are required. (See Fig. 9.)

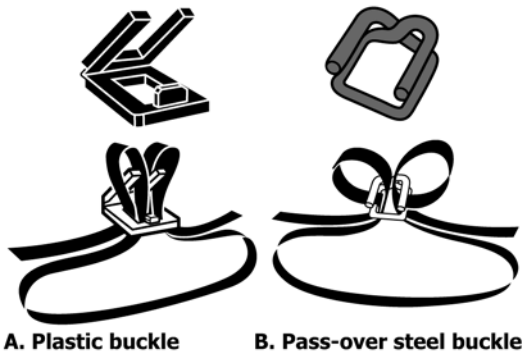
12.12 *Overlap Crimp Seal Joint:*

12.12.1 Polypropylene, nylon, and polyester strapping can be joined with crimp seals. For nonmetallic strapping, the full length of the metal seal is crimped to create friction. When using lubricated nonmetallic strapping, apply a crimp seal with serrated teeth, knurled, or grit (abrasive material) coating on the internal surface. (See Fig. 10.)

12.13 *Overlap Welded Joint:*

12.13.1 All types of nonmetallic strapping (except cord strapping) can be heat-sealed or friction-welded. Joint strengths vary with the type of flat strapping and application equipment. (See Fig. 11.)

12.14 *Seal Styles*—End-use applications will determine seal type. The use of a particular style depends on the application and the sealing mechanism. The length of the seals will vary, depending on the number of seals and crimps, according to the manufacturer's standards. Material thickness and hardness



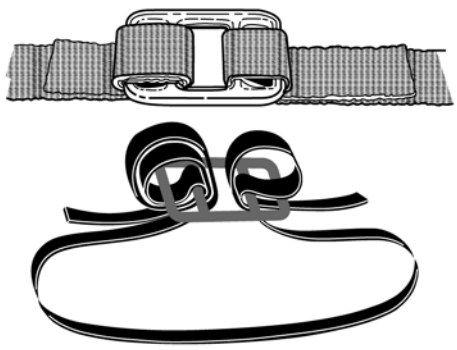


FIG. 9 Buckle Styles

FIG. 10 Crimp Joint Seals

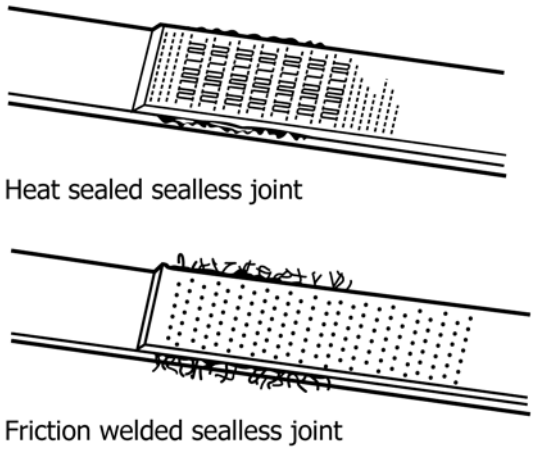


FIG. 11 Overlap Sealless Joints

contribute to performance. The seal must be able to be notched (steel strapping only) or crimped without tearing or cracking.

12.14.1 *Style I—Snap-On (Open or Semi-Open)*—Style I can be applied either during or after tensioning. (See Fig. 12.) This style seal (see Fig. 13) is used primarily with feedwheel (rotary dog) type tensioning tools on flat strapping surfaces, where the strap is usually fed directly from the coil.

12.14.2 *Style II—Thread-On or Closed*—Style II is normally used to help maintain strap alignment during tensioning. (See Fig. 14.) This style (see Fig. 15) can be used on flat surfaces with windlass type (slotted drum) tensioning tools. The strap must be pre-threaded through the seal before being looped around the load, unit, or package and loaded into the tensioning tool.

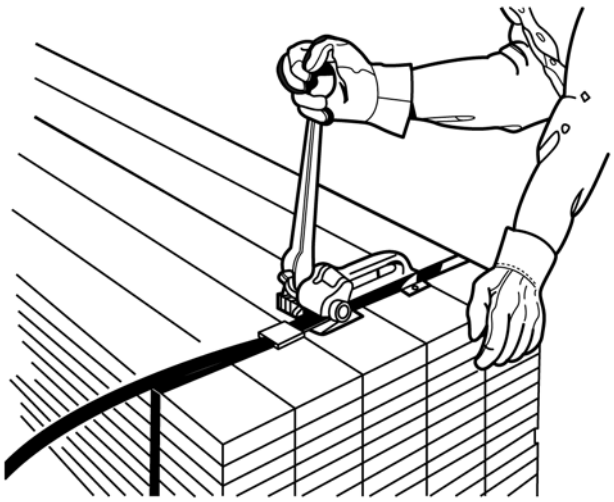


FIG. 12 Feedwheel Hand Tool Tensioning Application

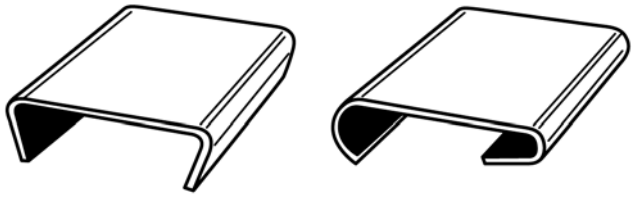


FIG. 13 A. Snap-On (Open), B. Semi-Open

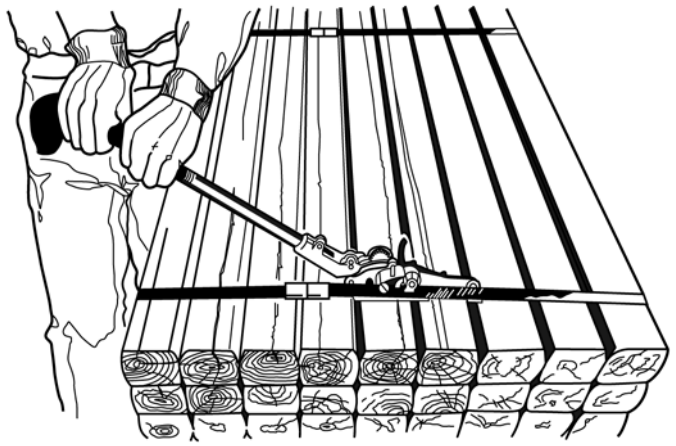


FIG. 14 Windlass Type Hand Tool Application

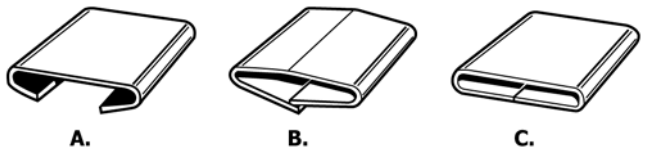


FIG. 15 A. Thread-On (Closed) Seal, B. and C. Push Type (Overlap) Seals

12.14.3 *Style III—Push Type (Overlap)*—Style III (see Figs. 15B and 15C) is used for applications involving round or irregularly-shaped loads, units, packages, or bundles, such as coils, pipe, coiled rod, and small surfaces when the use of a push type tensioning tool is required. Strapping is generally used directly from the coil, threaded through the seal, and formed into a "lasso" or slip loop around the load. The slack is removed until hand tight. The pusher bar nose of the tool pushes against the rear end of the seal as tension is applied; thus the name "push type." (See Fig. 16.)

12.14.4 *Style IV—Magazine Feed*—Style IV seals are loaded into the equipment's magazine and are mechanically fed into the sealing mechanism. Magazine seals are required for most combination tools and in fully powered strapping machines. Usage is primarily for high-volume applications. (See Figs. 17 and 18.)

12.15 *Style V-Intersection or Cross Tie Seals (Steel Strap Only)*—Style V is used in applications to maintain relative position of two crossing steel straps at right angles to each other. Proper application of one (1) or more intersection or cross tie seals will not reduce the steel strapping system strength. (See Fig. 1 and Fig. 19.)

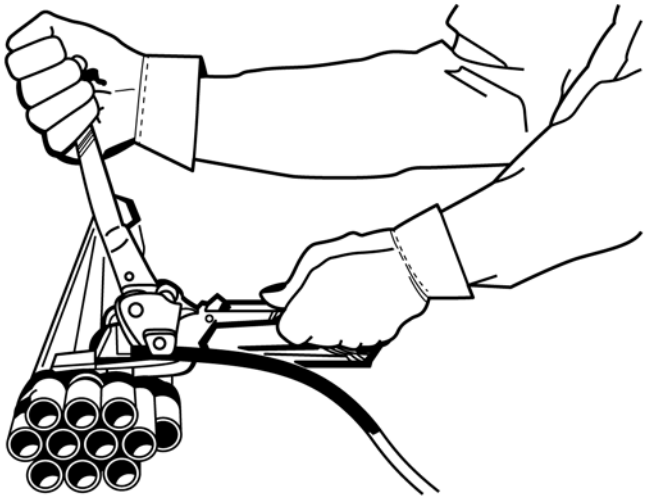


FIG. 16 Push Type Hand Tool Application

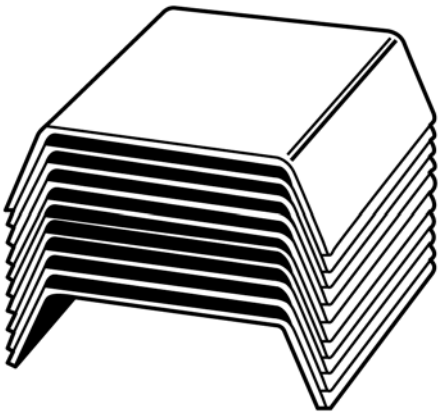


FIG. 17 Nested Stack (Magazine Feed) Seal

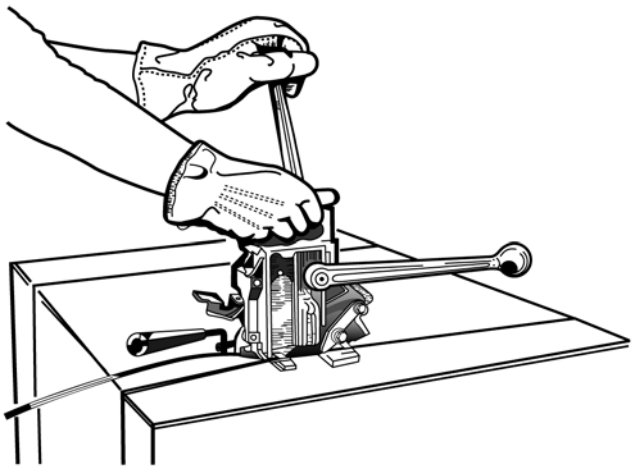


FIG. 18 Combination Tension and Seal-Feed Hand Tool Application

12.16 Seal Styles I, II, III, and IV are made specifically for steel strapping Type I and nonmetallic strapping Types II, III, and IV. Seal Type V is specifically for steel strapping.

12.16.1 Notch and crimp type seals may look similar but are generally not interchangeable. Never crimp a notch type seal and never notch a crimp type seal.

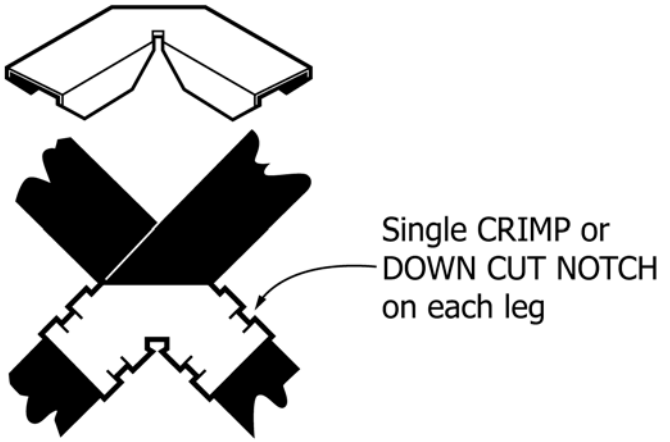


FIG. 19 Intersection or Cross Tie Seal

13. Coatings, Finishes, and Resistance to Deterioration of Physical Properties

For Initial Guidance Purposes Only—The following is for initial guidance only and not intended as recommendations or specifications. It is recommended that you contact your strapping supplier concerning the most suitable choice of strap coating and finish for your application.

The selection of strapping is application dependent and the required strap performance is affected by many variables. Strapping performance can be affected by exposure to various environmental conditions, such as: ultraviolet light, moisture or humidity, temperature, and corrosive substances. The environmental intensity and exposure time can also affect strapping performance. Consult knowledgeable parties or strapping suppliers, or both, to determine the proper strapping type and system for your application.

13.1 *Steel Strap Coatings and Their Purposes (See* Table 3*):*

13.1.1 Two factors that interact with each other to influence preferred strap finish or coating are Corrosion Resistance and Performance in Application Equipment.

13.1.2 *Coating Options*—Following are the coating options with varying degrees of protection. (See Specification D3953.)

13.1.2.1 *Organic (Finish A)*—Organic (paint) coating is the industry standard affording nominal resistance to corrosion for moderate time periods.

13.1.2.2 *Galvanized (Zinc Coated) (Finish B)*—This is a plated coating of metallic zinc that provides excellent corrosion resistance. (See Specification D3953 for galvanized types and grades of coating.)

13.1.2.3 *Metal-Filled Organic Paint Coatings (Finish C)*—Referred to as zinc epoxy or aluminum epoxy, these coatings improve corrosion resistance.

13.1.2.4 *Uncoated Strap (Finish D)*—Corrosion resistance is marginal.

13.1.3 *Performance in Application Equipment*—Lubricity is needed to ensure good tension transmission around sharp corners. Coating a thin layer of wax or wax-like substance on the strap surfaces is a customary commercial practice that will lubricate (reduce the coefficient of friction). Non-lubricated (dry) strap is preferred when used with crimp joints, unless grit seals are utilized.

TABLE 3 Appropriate Strapping Use as a Function of Environmental Conditions

	Specification D3953			Specification D3950				
Environmental Condition	Regular-Duty Steel	Regular-Duty High Strength Steel	Heavy-Duty Steel	Type IA Bonded, Woven, or Composite Polyester Cord	Type I Bonded Rayon Cord	Type II Polypropylene	Type III Nylon	Type IV Polyester
Ultraviolet	Yes	Yes	Yes	Yes	Yes	Yes[A] (if opaque) No[A] (if translucent)		
Moisture	Variable[B]	Variable[B]	Variable[B]	Variable[C]	No	Yes	No	Yes
High Temperatures	Variable – Extreme high temperatures can severely affect strapping performance. Consult your supplier for more information.							
Low Temperatures[D]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chemical Resistance	Variable – Corrosives can severely affect strapping performance. Consult your supplier for more information.							

[A] Strapping color other than translucent and some additives can serve as a U.V. inhibitor for nonmetallic extruded strapping by reflecting the sun's rays. (See 13.2.1.)
[B] Some steel strap coatings (zinc and galvanized) will improve resistance to deterioration due to rusting from moisture. (See 13.1.)
[C] The performance of Bonded and Woven Polyester Cord strapping, depending on the type of binder, may be reduced by moisture absorption. (See 13.2.3.)
[D] The effect of application-specific extreme temperatures on strapping performance varies greatly depending on duration of exposure, rate of temperature change, number of temperature change cycles, and the temperature in the application environment. (See 14.1.)

13.2 *Nonmetallic Strapping Resistance to Deterioration and Appropriate Use as a Function of Environmental Conditions (See* Table 3*):*

13.2.1 Strapping may be subjected to environmental conditions such as prolonged exposure to ultraviolet light, moisture, extreme low/high temperatures, and corrosive chemicals. Some color other than translucent and some additives can serve as a U.V. inhibitor for nonmetallic extruded strapping by reflecting the sun's rays.

13.2.2 Rayon cord strapping is not water resistant and loses strength when subjected to moisture. As such, it should be used primarily in environmentally controlled applications.

13.2.3 Bonded, woven, or composite polyester cord strapping is more resistant to weathering and moisture than rayon cord strapping. The performance of some cord strapping binder is reduced by moisture absorption.

13.2.4 Polypropylene strapping has excellent resistance to moisture but is the least heat-resistant of all the common strapping materials.

13.2.5 Nylon strapping has good cold-temperature performance. Nylon strap is hygroscopic (sponge-like) and is susceptible to degradation from moisture fluctuations. Break strength and elongation can be affected.

13.2.6 Polyester strapping exhibits relatively good resistance to the effects of extreme temperatures and moisture.

13.3 *Seals*—Various coatings are used on metal seals.

14. Environmental Considerations

The following is for initial guidance only and not intended as recommendations or specifications. Exposure of strapping to environmental conditions may have an adverse effect on strapping that could present a safety hazard or may affect the securement properties of the strapping. It is recommended that you contact your strapping supplier concerning the effects of environmental conditions on strapping.

14.1 Exposure to environmental conditions such as ultraviolet light, moisture, extreme low and high temperatures, and corrosive chemicals will adversely affect the physical properties and performance of an applied strap.

14.2 *Corrosion Resistance*—For a given application, corrosion resistance may override other considerations. Special coatings or finishes will protect applied strap. (See Section 13.)

LUBRICATION

15. Lubrication (Steel and Nonmetallic Strapping)

15.1 *Lubricated Steel Strapping*—Unless otherwise specified, Type I steel strapping should have a coating of wax or wax-like lubricant applied to the surfaces of the strap that will render the strapping suitable for applications with tension tools and heads of the feedwheel (rotary dog) type.

15.2 Non-lubricated (dry) steel strapping is preferred when used with crimp joints, unless grit seals are utilized.

15.3 *Lubricated Nonmetallic Strapping*—Types II, III, and IV nonmetallic strapping will have either an internal lubricant or wax/wax-like lubricant applied to the surfaces of the strap to lower the coefficient of friction. Lubrication will facilitate good tension transmission around load, unit, or package corners and is used almost exclusively in nonmetallic strap hand tools and machines that are of the friction weld type joint.

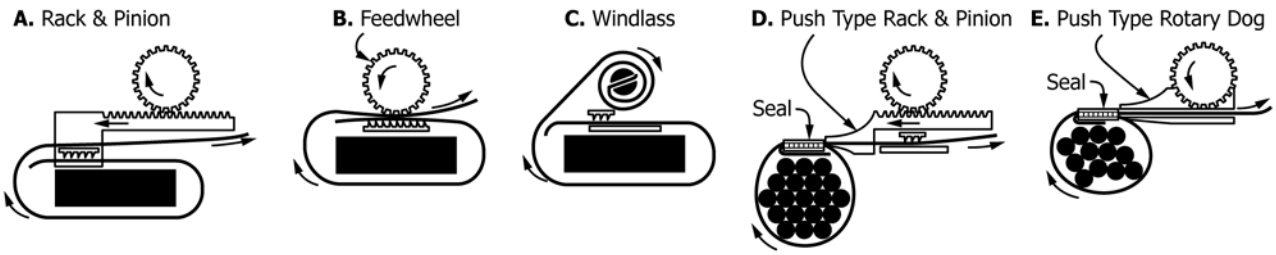
15.4 Non-lubricated (dry) non-metallic strapping is preferred when used with crimp joints, unless grit seals are utilized. A dry nonmetallic strap is almost exclusively used when the joints are hot knife welded.

16. Equipment for Strapping Application (See Fig. 20)

16.1 Following are mechanical functions that are generally needed to apply a strap:

16.1.1 Dispensing and feeding,
16.1.2 Take-up and tensioning,
16.1.3 Joining, and
16.1.4 Cutting.

16.2 Variations and options are available, ranging from two-piece manually actuated hand tools to manual and power-operated combination strapping tools (one tool that will tension, seal, and cut-off the strap) to fully automatic power operated machines.



NOTE 1—A. *Flat—Non-Compressible Load, Unit, or Package*—Take-up is limited to the length of the rack.
B. *Flat—Compressible Load, Unit, or Package*—Continuously takes-up a lengthy amount of strapping.
C. *Flat—Non-Compressible Load, Unit, or Package*—The windlass type can apply the most tension. Its ability to apply high tension is independent of the strap finish.
D. *Irregular—Non-Compressible Load, Unit, or Package*—Take-up is limited to the length of the rack.
E. *Irregular—Compressible Load, Unit, or Package*—Continuously takes-up a lengthy amount of strapping.

FIG. 20 Various Strapping Take-Up and Tensioning Methods

16.3 There are three broad mechanical principles for obtaining strap tensions:

(1) Rack and pinion,

(2) Feedwheel (rotary dog) type, and

(3) Windlass type (slotted drum).

Warning—Tools for steel and nonmetallic strap, although similar, are not interchangeable. Safety hazard statements are provided in Section 5.

17. Strap Application

17.1 *Alignment*—Strapping is best applied when it is positioned perpendicular to any edge (corner). Strapping being applied and tensioned at an angle (edge loading) may induce strap failure. After application, the skewed strap could slide on the edge to proper alignment. This would loosen the strap, which could cause product shift and resultant damage. (An example of correct and wrong strap angles are illustrated in Fig. 3.)

17.2 *Twisting*—Do not twist flat strapping. Limited twisting of Type IA cord strapping will not compromise its mechanical properties.

17.3 *Strap Tension:*

17.3.1 *Initial Applied Tension (IAT)*—Tensioning strap just as tight as the application will permit, should yield the highest amount of initial retained tension possible.

17.3.2 *Retained Tension*—The amount of tension decay over time will have a direct bearing on load integrity. The initial retained tension (IRT) measurement for nonmetallic strapping should be taken immediately after strap application, before there is any significant tension decay because of creep.

17.4 *Sealing*—If possible, vertical and horizontal straps should be applied centered on a side halfway between opposite edges (corners). This will ensure uniform tension transmission and minimize the loss of tension when the tool is removed and the strap snaps to the load, unit, or package.

17.5 *Strap Protection*—Straps must be protected from unusual physical stresses that could cause premature failure.

17.5.1 *Snagging Hazards*—Exposed strapping can be susceptible to rupture by snagging from the following causes:

17.5.1.1 *Material Handling*—For example, forklift truck tines may snag a vertical strap applied transverse to the direction of fork tine entry.

17.5.1.2 Sliding contact by adjacent loads, units, or packages can subject exposed vertical straps to snagging. Likewise, loads, units, or packages sliding on or within a transport vehicle may subject the straps to snagging.

17.5.1.3 Twisting of strap on the load, unit, or package may increase the risk of snagging.

17.5.2 *Edge Hazards*—Exposed strapping can be susceptible to rupture by exposure to sharp edges, such as:

17.5.2.1 Sharp corners on the load, unit, or package such as, plate steel. When this condition exists, use edge protection.

17.5.2.2 Sharp edges on the handling equipment, such as hooks or forks. To avoid damaging strapping, use handling equipment that is proper, approved, and in good operating condition.

TESTING AND EVALUATION

18. Testing and Developing Final Load, Unit, or Package Design

Strapping users should use a design protocol, such as Practice D4169 or latest ISTA Test procedures to determine and verify proper strapping and joint selection and proper strapping placement.

18.1 *Prototype Load, Unit, or Package*—A prototype needs to be constructed, tested, and evaluated under simulated conditions to determine the number, type, size, and location of straps required. When a prototype is developed that will safely and successfully survive the simulated conditions and provide appropriate protection, it needs to be tested through the complete handling and distribution system.

18.2 *Production of Final Load, Unit, or Package*—All the care used to develop the final load, unit, or package must be maintained in daily production. Techniques and mechanism conditions should be frequently monitored. Shippers may use mechanisms and techniques that could result in improved integrity or reduced costs, or both.

19. Evaluation of Strap Failure

19.1 Strap failure must be evaluated through examination of the break, including when and where the load, unit, or package was in the distribution process.

19.2 *Strap Breakage*—Potential causes for strap failures are listed in Table 4.

TABLE 4 Potential Causes for Strap Failure

Occurrence	Cause	Insufficient Strap Tension Examples
Before Application	Strap damaged due to improper storage Strap damaged due to improper handling Mechanical properties out of specification	
During Application	Excessive strap tension Improper alignment of strap in mechanism used for application Sharp edges of the package (See Fig. 1) (Use of edge protectors is recommended) Improper mechanism, joint, or strap selection Improper use of mechanism	
After Application	Improper mechanism, joint, or strap selection Excessive strap tension Improper alignment (induced) Sharp edges of the package (See Fig. 1) (Use of edge protectors is recommended) Over-stressed or transit fatigue Strap damaged from improper handling Environmentally induced deterioration	
	Insufficient strap tension	Improper strap type Improper strap size Insufficient applied tension Insufficient retained tension Improper mechanism or improper condition of mechanism Low air pressure to mechanism Inadequate hydraulic pressure to mechanism Incorrect strap lubricity Shrinkage of the load, unit, or package Excessive external stress Trapped slack in strap during application Unequal tension on multiple applied straps

20. Keywords

20.1 banding; buckles; bundling; mechanism; nonmetallic; packaging; seals; securement; steel; strapping; strapping joints; unitizing; USLM

SUPPLEMENTARY REQUIREMENTS

SUPPLEMENTARY GUIDANCE

The following information is for general guidance only. It is provided only as a possible starting point.

S1. Scope

S1.1 These supplementary requirements describe the suggested guidelines for the strapping of corrugated, fiberboard, cleated-panel, and wood boxes. General varieties of boxes covered in these supplementary requirements are:

S1.1.1 Corrugated fiberboard boxes,

S1.1.2 Cleated-panel boxes (fiberboard, paper over-laid veneer plywood, or plywood),

S1.1.3 Nailed wood boxes, and

S1.1.4 Wire bound boxes.

S1.2 *Corrugated Fiberboard Boxes*—Suggested guidelines for location of strapping are shown in Fig. S1.1. Suggested minimum sizes for straps are shown in Table S1.1. When a single strap is applied and crosses the top and bottom of the box, the strap is placed horizontally perpendicular to the line of the flap-closures.

S1.3 *Cleated-Panel Boxes*—Suggested guidelines for location of strapping are shown in Fig. S1.2. Suggested minimum sizes for straps are shown in Table S1.2.

S1.4 *Nailed Wood Boxes*—Suggested guidelines for location of strapping are shown in Fig. S1.3. Suggested minimum sizes for straps are shown in Table S1.3.

S1.5 *Wire Bound Boxes*—Suggested guidelines for strapping are shown in Fig. S1.4.

S1.5.1 *Length Straps*—One length strap should be applied over the corner of the top, bottom, and ends of the box, or over the intermediate batten closest to the center, and the closing side under the following conditions:

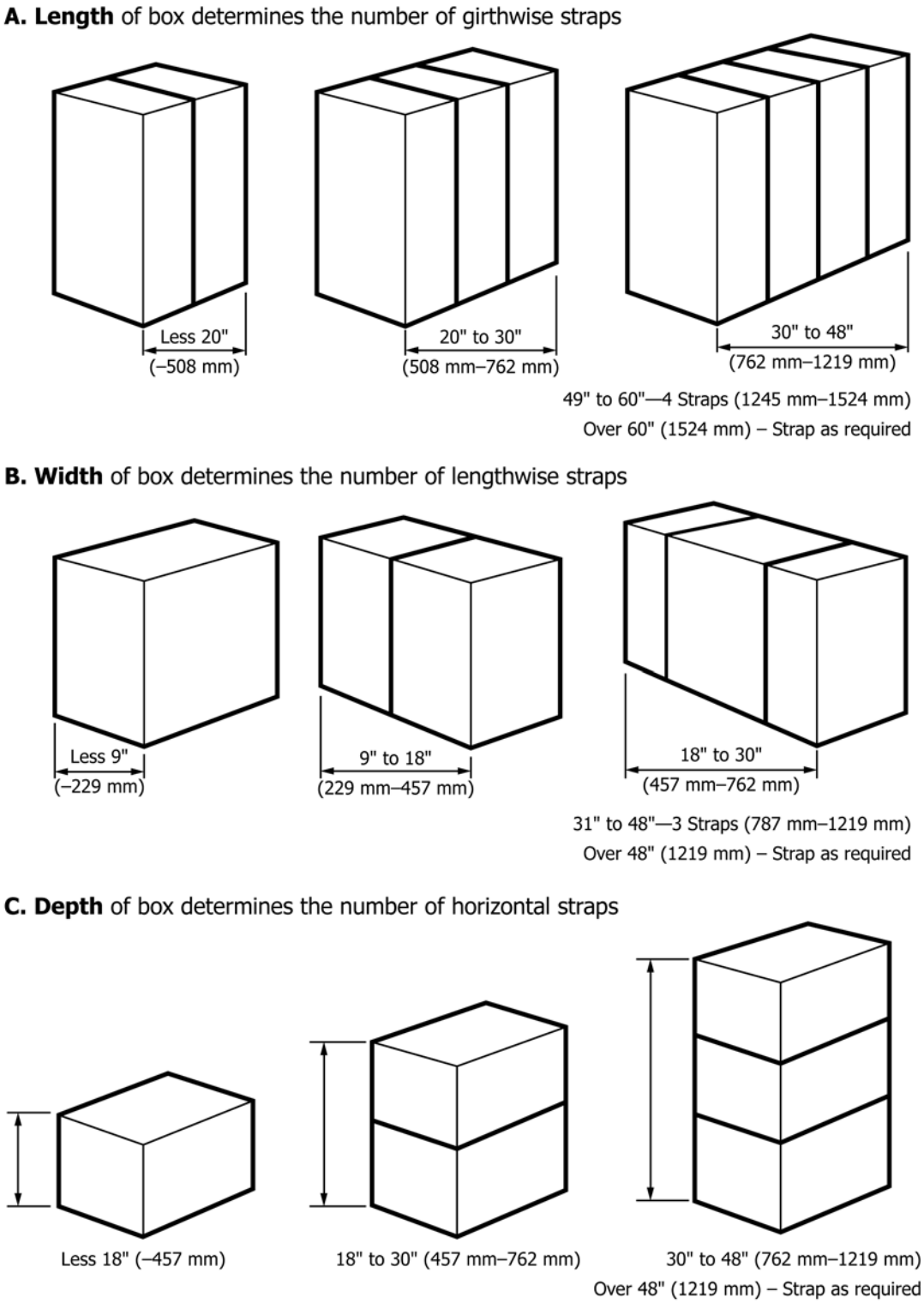


FIG. S1.1 Corrugated Fiberboard Box Strap Placement

S1.5.1.1 If the weight of the contents exceeds 250 lb (113.4 kg).

S1.5.1.2 If the top cleat exceeds the length indicated in Table S1.4 for the weight stated.

S1.5.2 *Girth Straps*—One girth strap should be placed not more than 3 in. from each end and over each intermediate cleat on boxes with a weight of contents over 250 lbs (113.4 kg).

S1.5.3 Boxes should be strapped before making wire closures.

S1.5.4 *Suggested Minimum Size Flat Metal Straps*—⅝ × 0.020 in. (15.87 × 0.51 mm) in accordance with Specification D3953, Type 1.

TABLE S1.1 Suggested Minimum Sizes of Steel and Nonmetallic Strapping for Corrugated Fiberboard Boxes

Gross weight of container and contents (lbs)	Steel Strapping Specification D3953	Nonmetallic Strapping Specification D3950 *(Other type and sizes may be applicable)*	
	Type I (in.)	Type II (in.)	Type IV (in.)
0 to 35	⅜ × 0.015	¼ × 0.025 ⅜ × 0.015	7⁄16 × 0.017 ½ × 0.015
35 to 70 incl.	⅜ × 0.015	¼ × 0.025 ⅜ × 0.015 7⁄16 × 0.025	7⁄16 × 0.017 ½ × 0.015
70 to 110 incl.	⅜ × 0.020 ½ × 0.015	⅜ × 0.020 7⁄16 × 0.025 ½ × 0.020	7⁄16 × 0.017 ½ × 0.015
Over 110 to 225 incl.	½ × 0.020 ⅝ × 0.015	7⁄16 × 0.025 ½ × 0.020 ⅝ × 0.015	7⁄16 × 0.023 ½ × 0.020

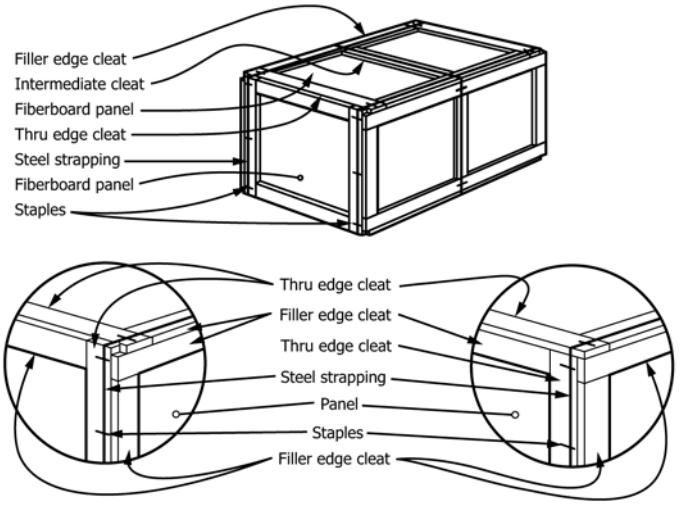
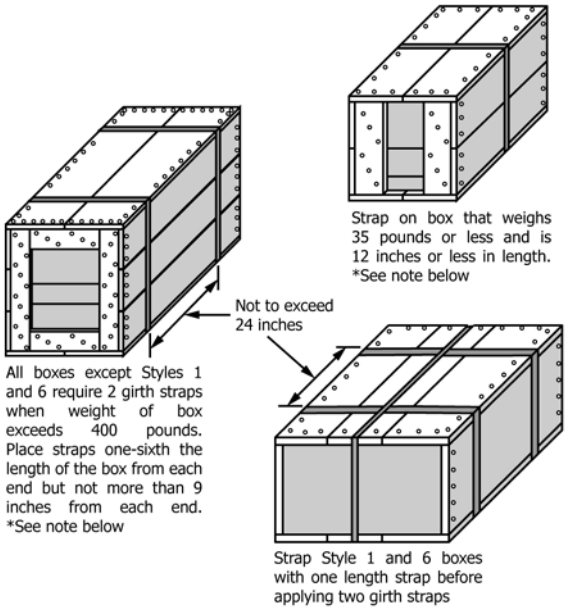


FIG. S1.2 Cleated-Panel Box Strap Placement

TABLE S1.2 Suggested Minimum Sizes of Flat Steel Strapping for Cleated-Panel Boxes

Weight of contents (lbs)	Size of Flat Steel Strapping When Different Numbers of Bands are Used (in.)[A]	
	2 Straps	3 or More Straps
up to 70, incl.	⅜ × 0.020	⅜ × 0.020
71 to 125, incl.	⅜ × 0.020	⅜ × 0.020
126 to 175, incl.	½ × 0.020	½ × 0.020
176 to 250, incl.	⅝ × 0.020	⅝ × 0.020
251 to 400, incl.	. . .	¾ × 0.020
401 to 1000, incl.	. . .	¾ × 0.023

[A] Specification D3953, Type 1.



***Note:** *Strap Class 1 boxes weighing less than 100 pounds only when specified.*

FIG. S1.3 Nailed Wood Boxes Strap Placement

TABLE S1.3 Suggested Minimum Sizes of Flat Steel Strapping for Nailed Wood Boxes

Net Weight of Contents, (lbs)	Specification D3953 Size, Type I (in.)[A]
0 to 70	⅜ × 0.015
70 to 125	⅜ × 0.020
125 to 175	½ × 0.020
175 to 250	⅝ × 0.020
250 to 400	¾ × 0.020
400 to 1000	¾ × 0.023[B]

[A] The minimum size of the flat steel straps is based on two straps per box.
[B] Three or more straps are generally used when the weight exceeds 400 lb.

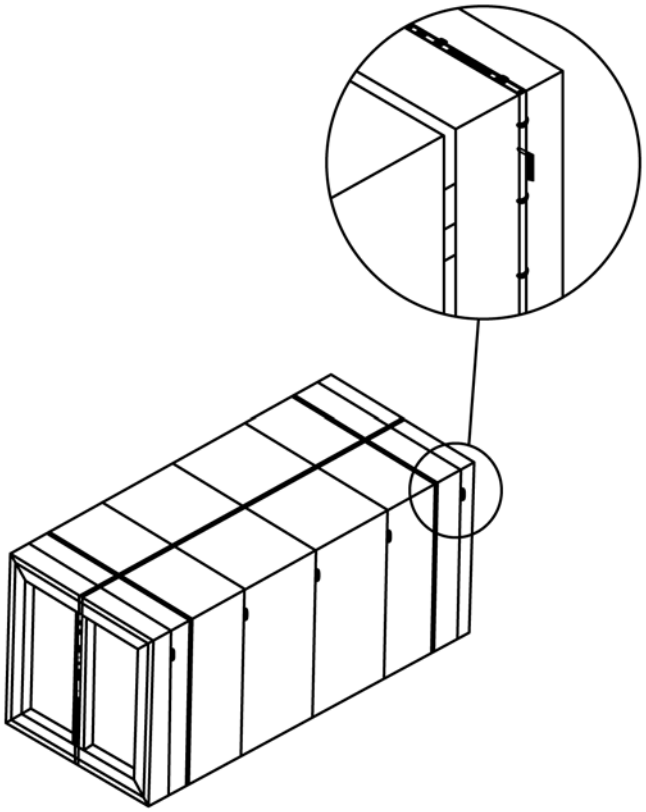


FIG. S1.4 Wire Bound Box Strap Placement

TABLE S1.4 Weight of Contents Versus Length of Top Cleat

Weight of Contents lbs (kg)	Length of Top Cleat in. (mm)
0 to 125 (0 to 56.7)	40 (101.6)
125 to 200 (56.7 to 90.7)	25 (63.5)
200 to 250 (90.7 to 113.4)	20 (50.8)