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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.

Table of Contents

Section

Introduction
List of Figures
List of Tables
1. Scope
2. Referenced Documents
3. Terminology
4. Significance and Use
5. Safety Hazard Guidelines
6. General Considerations
7. General Uses
8. Strap Tension
9. Packaging Design
10. Load, Unit, and Package Securement Configuration
11. Strap Selection
12. Joining Methods and Properties
13. Coatings, Finishes, and Resistance to Deterioration of Physical Properties
14. Environmental Considerations
15. Lubrication
16. Equipment for Strapping Application
17. Strap Application
18. Testing and Evaluation

Table of Contents

Section

19. Evaluation of Strap Failure
20. Keywords
Supplementary Requirements
Disclaimer and Contact Information

List of Figures

Title	Figure No.
Various Strapping Applications	1
Strap Cutting Techniques	2
Correct and Incorrect Applied Strapping	3
Notch Joint with Seals	4
Crimp Joint with Seals	5
Sealless Interlocking Joints	6
Loop Joint Secured to Stake Pocket	7
Loop Joint Placement	8
Buckle Styles	9
Crimp Joint Seals	10
Overlap Sealless Joints	11
Feedwheel Hand Tool Tensioning Application	12
Snap-On (Open) and Semi-Open Seals	13
Windlass Type Hand Tool Application	14
Thread-On (Closed) and Push Type (Overlap) Seals	15
Push Type Hand Tool Application	16
Nested Stack (Magazine Feed) Seal	17
Combination Tension and Seal-Feed Hand Tool Application	18
Intersection or Cross Tie Seal	19
Various Strapping Take-Up and Tensioning Methods	20
Corrugated Fiberboard Box Strap Placement	S1.1
Cleated-Panel Box Strap Placement	S1.2
Nailed Wood Boxes Strap Placement	S1.3
Wire Bound Box Strap Placement	S1.4

List of Tables

Title	Table No.
Strapping Applications Commonly Used for Packaging, Unitization, and Load Securement	1
Examples of Different Package Types	2
Appropriate Strapping Use as a Function of Environmental Conditions	3
Potential Causes for Strap Failure	4
Suggested Minimum Sizes of Steel and Nonmetallic Strapping for Corrugated Fiberboard Boxes	S1.1
Suggested Minimum Sizes of Flat Steel Strapping for Cleated-Panel Boxes	S1.2
Suggested Minimum Sizes of Flat Steel Strapping for Nailed Wood Boxes	S1.3
Weight of Contents Versus Length of Top Cleat	S1.4

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.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[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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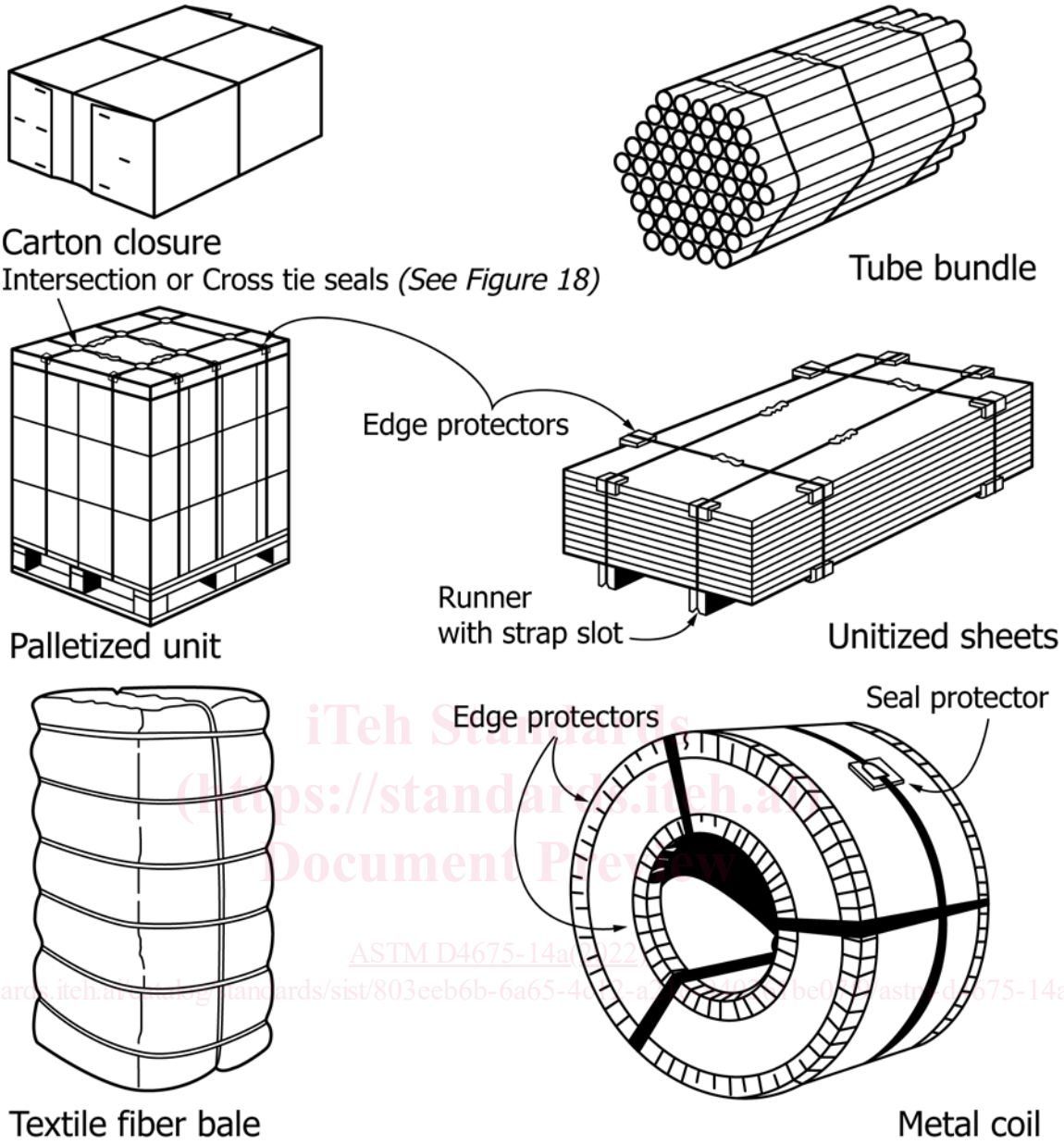

FIG. 1 Various Strapping Applications

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]

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

[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.

[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.

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.

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.

[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.

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.										
Industry	Product	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		
		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	⅜ " & ½ "					7⁄16 "	7⁄16 "	⅝ "
	Carton Closure					3⁄16 ", ¼ " & ⅜ "	¼ " & ⅜ "	⅜ "	
	Flat Glass		⅝ " & ¾ "		⅝ " & ¾ "				⅝ " & ¾ "
	PVC Pipe	¾ "	⅝ " & ¾ "		½ ", ⅝ " & ¾ "		7⁄16 "	7⁄16 "	½ ", ⅝ " & ¾ "
Agriculture	Food Products in Wood Bins			¾ "	⅝ " & ¾ "				⅝ "
	Hay Bailing						½ "		½ "
	Cotton			¾ "					¾ "
	Tobacco			½ ", ⅝ " & ¾ "			½ "		
	Fibers (Manmade & Natural)	⅝ " & ¾ "	⅝ " & ¾ "	½ ", ⅝ " & ¾ "					⅝ " & ¾ "
Bevarage	PET Bottles							⅜ "	⅜ "
	Cans							⅜ "	⅜ "
	Glass Bottles							7⁄16 " & ½ "	7⁄16 " & ½ "
Corrugated	KD Boxes	⅜ "					7⁄16 "		7⁄16 "
	Corrugated Sheet Bundles	⅜ ", ⅝ " & ¾ "					7⁄16 "		7⁄16 "
Graphic Arts	Signature Logs						7⁄16 " & ½ "		7⁄16 " & ½ "
	Magazines						5 mm, 3⁄16 " & ¼ "		
	Newspapers						5 mm, 3⁄16 " & ¼ "		
	Palletized Printed Loads		½ " & ⅝ "		½ " & ⅝ "				7⁄16 ", ½ " & ⅝ "
Masonry	Brick		½ "	½ "					⅝ "
	Block/Pavers		½ " & ⅝ "	½ " & ⅝ "					⅝ " & ¾ "
	Roof Tiles						7⁄16 "		
Forest Products	Lumber	⅝ " & ¾ "	½ ", ⅝ " & ¾ "	⅝ " & ¾ "	⅝ ", ¾ ", 1" & 1¼ "				⅝ " & ¾ "
	Hardwoods	¾ "		¾ "	⅝ " & ¾ "				¾ " & 1"
	Hardboard Siding	⅝ " & ¾ "		⅝ " & ¾ "	⅝ " & ¾ "				⅝ "
	Pressure Treated Lumber	⅝ " & ¾ "	⅝ " & ¾ "	⅝ " & ¾ "	⅝ " & ¾ "				⅝ "
	Landscape Timbers	¾ "		¾ "	⅝ ", ¾ " & 1"				⅝ "
Panel Products	Flakeboard, MDF, OSB, Particleboard & Plywood		⅝ "	⅝ "	⅝ " & ¾ "				⅝ " & ¾ "
Engineered Wood Products	I-Joists, LVL, PSL & LSL			¾ " & 1¼ "	⅝ ", ¾ ", 1" & 1¼ "				⅝ " & ¾ "

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)				
		Hand or Machine Applied			Hand Applied		Hand or Machine Applied		
		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.
Paper	Paper Rolls	3⁄8 " & 1⁄2 "							
	Copy Paper in Cartons					3⁄16 ", 1⁄4 " & 3⁄8 "	1⁄4 " & 3⁄8 "	3⁄8 "	
Metals	Aluminum Ingots			3⁄4 " & 1 1⁄4 "					5⁄8 ", 3⁄4 ", 1" & 1 1⁄4 "
	Aluminum Billets			3⁄4 "					3⁄4 ", 1" & 1 1⁄4 "
	Aluminum Extrusions			5⁄8 " & 3⁄4 "	1⁄2 ", 5⁄8 " & 3⁄4 "				5⁄8 "
	Scrap Aluminum			5⁄8 " & 3⁄4 "					5⁄8 " & 3⁄4 "
	Aluminum Rod			3⁄4 " & 1 1⁄4 "	5⁄8 ", 3⁄4 " & 1"				3⁄4 " & 1"
	Coiled Cooper Rod			1 1⁄4 "	3⁄4 ", 1" & 1 1⁄4 "				3⁄4 " & 1"
	Steel Wire			1 1⁄4 "	3⁄4 ", 1" & 1 1⁄4 "				5⁄8 " & 3⁄4 "
	Steel Structural Shapes			3⁄4 " & 1 1⁄4 "	5⁄8 ", 3⁄4 ", 1", & 1 1⁄4 "				3⁄4 " & 1"
	Cut-to-Length Flat Sheet Stock			5⁄8 ", 3⁄4 " & 1 1⁄4 "	5⁄8 ", 3⁄4 ", 1" & 1 1⁄4 "				5⁄8 ", 3⁄4 ", 1" & 1 1⁄4 "
	Steel Tubing			5⁄8 ", 3⁄4 " & 1 1⁄4 "	5⁄8 ", 3⁄4 ", 1" & 1 1⁄4 "				3⁄4 " & 1"
	Steel Coils	1⁄2 ", 5⁄8 " & 3⁄4 "		5⁄8 ", 3⁄4 " & 1 1⁄4 "	3⁄4 ", 1", & 1 1⁄4 "				5⁄8 ", 3⁄4 " & 1"
Load Securement	Truck & Railcar Unitization			3⁄4 " & 1 1⁄4 "	3⁄4 ", 1" & 1 1⁄4 "				
	Truck Tie Down			1 1⁄4 " & 2"					
	Railcar Doorway Protection			3⁄4 " & 1 1⁄4 "	1 1⁄4 " & 1 1⁄2 "				
	Open Top Railcar Tie Down			3⁄4 ", 1 1⁄4 " & 2"					
Unit Strap Lifting Method				1 1⁄4 " USLM					

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.

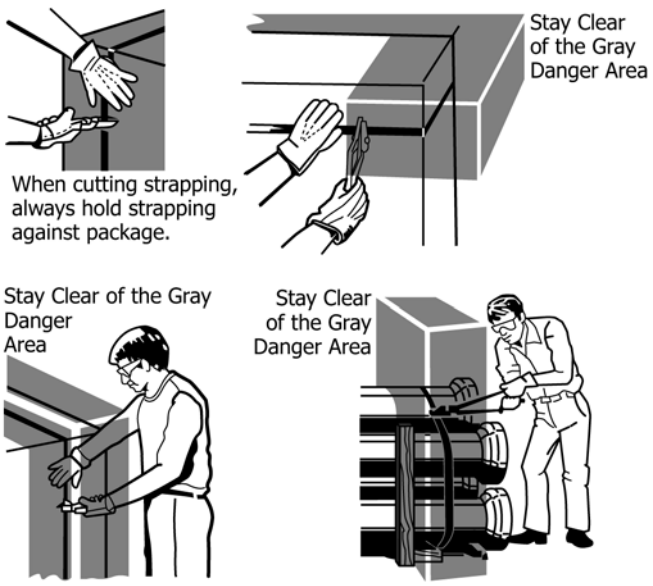

FIG. 2 Strap Cutting Techniques

(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.

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:

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.)

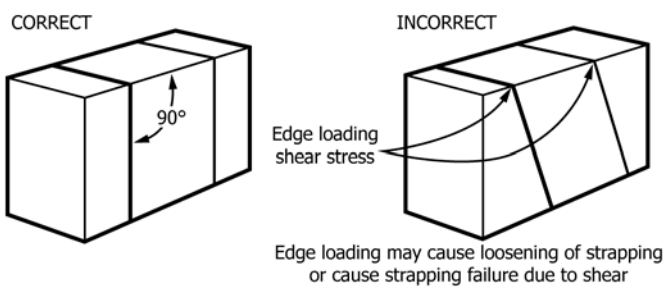

FIG. 3 Correct and Incorrect Applied Strapping

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,

(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,

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

(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 in. by 0.035 in. (32 mm 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 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.)

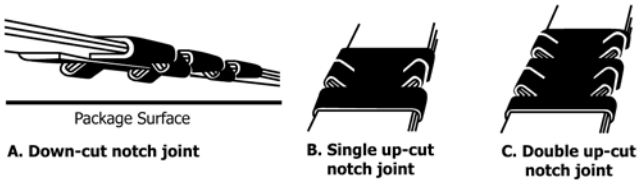

FIG. 4 Notch Joint with Seals

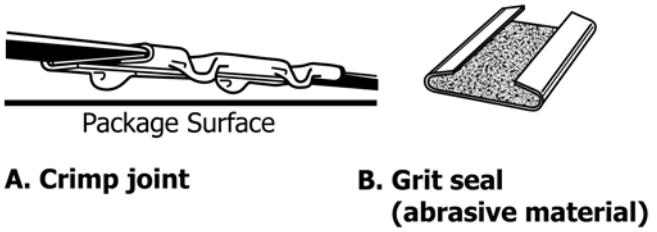

FIG. 5 Crimp Joint with Seals