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

This standard is issued under the fixed designation D4675; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

INTRODUCTION

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

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 materials is best suited for the application. Contact your supplier for further information.

It is recognized that there are other materials (not covered) that may also offer acceptable solutions or may be used in conjunction with flat strapping. Also, examples of ancillary materials are shown in Fig. 1.

Strapping may be recyclable. Contact your supplier for further information.

1. Scope

1.1 This guide covers information on flat strapping materials (steel or nonmetallic) for the prospective user wanting initial guidance in selecting a strapping material and applied configuration for use in packaging (closing, reinforcing, baling, unitizing, or palletizing) and loading (load unitization and securement to transport vehicle) applications. 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 a type of strap, the minimum size or strength, or both, and type of joint or seal, or both, that must be used for certain 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 testing. The need for thorough user testing is to be emphasized as is a review of pertinent regulations that can influence the selection of sizes, types, and possibly, application methods.

1.4 The sections in this guide appear in the following order:

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[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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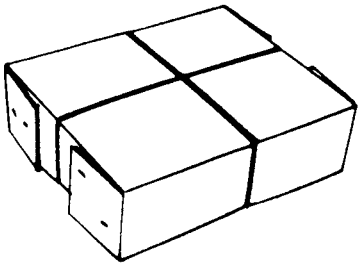
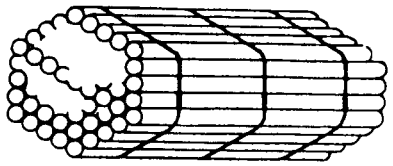
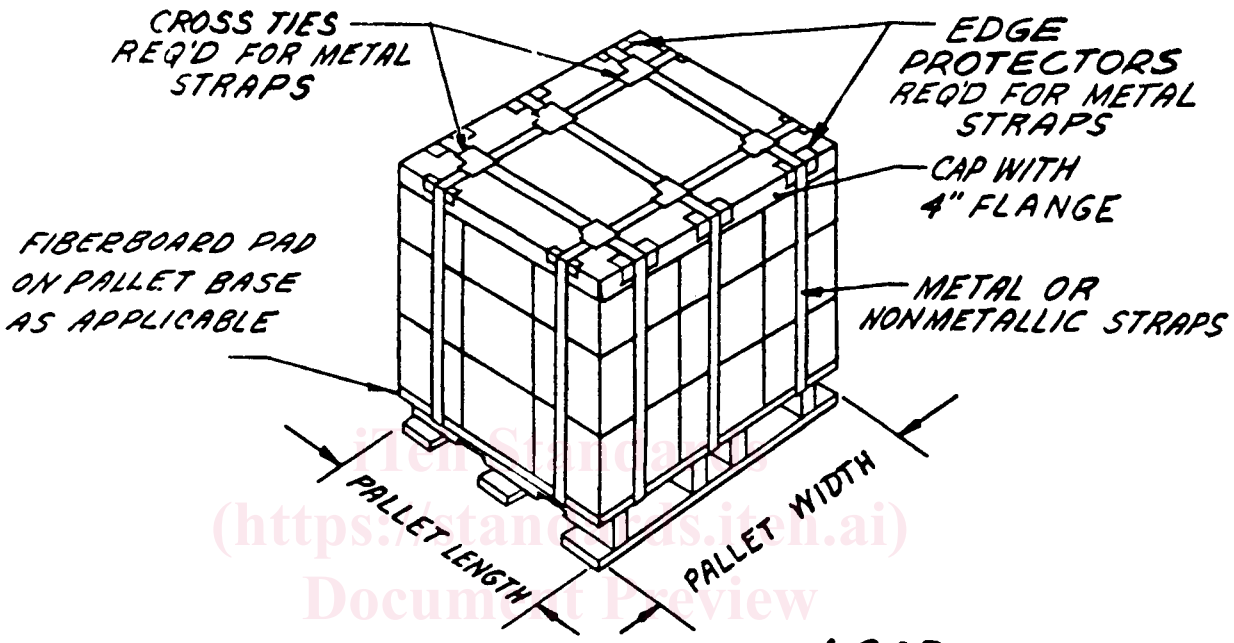


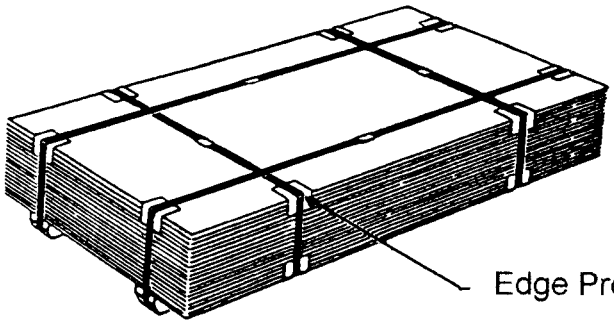
(a) Fiberboard Box Closure



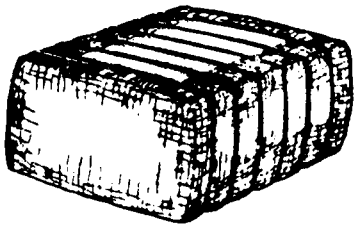
(b) Bundles of Tubing



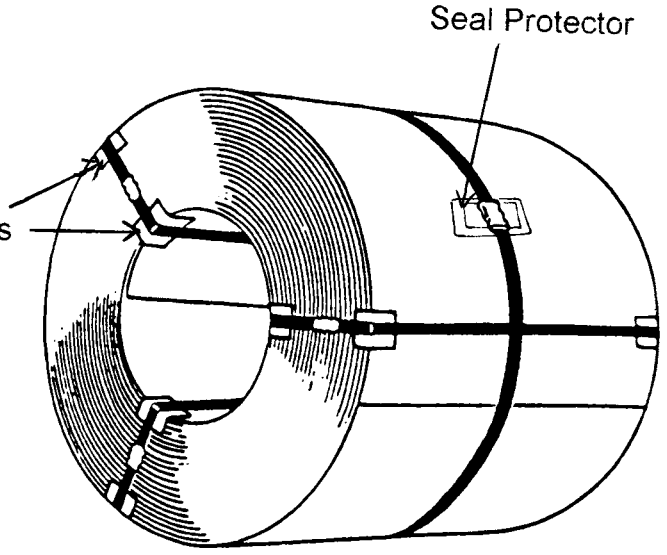
(c) Pallet



(d) Unitized Sheets



(e) Bales of Textile Fiber



(f) Coils

FIG. 1 Applications for Steel and Nonmetallic Strapping

1.5 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.

1.6 *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 statements are given in Section 5 and Note 13.1 and 15.3.

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:*

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 Procedures[5]

Association of American Railroads— Railing[6]

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 refer 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 are peculiar to nonmetallic only, or to steel only.

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

3.2.2 *corner break strength*, *n*—the reduced break strength due to the strap being bent around an edge. (See Specification D3953.)

3.2.3 *dead stretch (creep)*, *n*—permanent deformation, resulting from the application of tension over time.

3.2.4 *ductility in bending (resistance to "work hardening")*, *n*— ductility is the opposite of "brittleness". This quality is related to corner break strength and closely allied with strength and elongation in determining impact resistance. It is also important in tensioning applications requiring the strap to be bent double, and in loop joint applications. (Specification D3953 contains test procedures and specifications.)

3.2.5 *elongation at break*, *n*—the increase in strapping length due to tensile load at the time of break. (See Specifications D3950 and D3953.)

3.2.6 *energy to break*, *n*—the maximum force required to break a strap as measured by the area under the stress-strain curve.

3.2.7 *environmental resistant properties (see Table 1)*:

3.2.8 *atmospheric contamination*, *n*—the presence of chemicals in the atmosphere which degrades strap properties. (See Section 14.)

3.2.9 *mechanism*, *n*—includes application, tool, tooling, tensioner, sealer, and power strap equipment.

3.2.10 *moisture sensitivity*, *n*—the degradation of properties caused by presence of moisture or moisture vapor.

3.2.11 *temperature sensitivity*, *n*—the deterioration of properties caused by high or low temperatures.

3.2.12 *ultraviolet light sensitivity*, *n*—the degradation of strapping caused by ultraviolet rays from sunlight or electric lamps.

[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 Plaze, 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.

[6] Available from Association of American Railroads—Railing, Association of American Railroads—Railing Highwoods Center, 7001 Weston Parkway, Suite 200, Cary, NC 27513.

TABLE 1 Strapping Preference as a Function of Handling Severity of Elements

Type	Specification D3953			Specification D3950				
	Regular-Duty Steel	Regular-Duty High Strength Steel	Heavy-Duty Steel	Bonded Rayon Cord	Bonded or Woven Polyester Cord	Polypropylene Plastic	Nylon Plastic	Polyester Plastic
Ultraviolet[A]	x	x	x	...	x	...	...	...
Moisture	x	x	x	...	x	x	...	x
Elevated temperatures	x	x	x	x	x	...	x	x
Low temperatures	x	x	x	x	x	...	x	x
Exposure to corrosives	...	...	...	x	x	x	x	x
Concern for damage to unit surface	...	...	...	x	x	x	x	x

[A] UV inhibitors are available for polypropylene, nylon, and polyester plastics.

3.2.13 *joint efficiencies*, *n*—joint strength divided by the minimum acceptable breaking strength of the strap, expressed as a percentage. (See Specifications D3950 and D3953 for minimum acceptable percentage values.)

3.2.14 *joint strength*, *n*—the highest longitudinal tensile force that must be applied to cause a strap joint to fail.

3.2.15 *notch sensitivity*, *n*—a measure of the ability of a strapping material to resist "nick or cut" propagation.

3.2.16 *settling tolerance*, *n*—the ability of a strap to remain taut when used to confine a settling unit load.

3.2.17 *shear plane*, *n*—a shear plane is the surface area between two contiguous items that will allow the items to slide relative to each other when a force is applied.

3.2.18 *tension transmission*, *n*—the ability of strapping to transmit tension around an edge.

3.2.19 *yield point*, *n*—when a strap is subjected to load beyond its elastic limit, the point at which a strap reaches permanent deformation or continues to deform without an increase in load.

4. Significance and Use

4.1 This guide assists the user in selecting a strapping material and configuration for initial handling, transit, and storage tests. It describes general unit (load) types, strapping properties, unit-strapping interaction, weight considerations, unit shear planes, component frictional characteristics, and unit geometry.

5. Safety Hazards

5.1 *Cutting Strap*—All working strapping is under tension when in use. Sudden 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 operator when strap tension is suddenly released. *Cutting tensioned strap is hazardous*. Use caution and follow approved safety procedures.

5.1.1 When cutting a tensioned strap, always stand to one side of the strap being cut, pressing the strap against the package above the cutter.

5.2 Excessive tensioning may cause strap breakage. Always position yourself to one side of strap being tensioned. Never stand directly over or in front of a strap being tensioned.

5.3 Never operate the tool in such a manner that a hand could slip resulting in a loss of balance.

5.4 *Reuse*—Since mechanical properties of strapping may be altered by tensioning or during physical distribution cycles, the reuse of strapping is discouraged.

5.5 *Altering or Improper Use of Tensioners*—Do not extend length of handle on manual tensioner, nor 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 tensioner with potential severe injury to the operator.

5.6 *Improper Use*—Strapping should be used only as intended.

5.6.1 *Punching or Nailing*—Never punch strapping with nails, staples, or other sharp objects. This may cause premature strap failure. Also, attempting to nail through steel strapping may present a hazard especially when power nailing or stapling. Type 2 steel strapping has pre-punched holes intended for nail-on applications.

5.6.2 *Pulling or Dragging*—Never use strapping as a means of pulling or dragging any packages or unit.

5.6.3 *Lifting*—Never use strapping as a means of lifting unless applied using the Unit Strap Lifting Method (USLM) system.

5.7 *Unit Strap Lifting Method (USLM) Hazards*—USLM is a specialized application of USLM steel strapping for overhead lifting and transport of large, heavy packages. Before considering a USLM application consult a USLM system vendor and transportation or port regulatory authorities for rules and considerations in application. Note the following warnings:

5.7.1 *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.

5.7.2 *Specified Strapping and Seals*—Always use correctly marked USLM steel strapping and seals (see Specification D3953). Strapping and seals must be applied so that markings are visible.

5.7.3 *Lifting Capacity*—Consult transport or port regulations and your USLM system supplier to determine the lifting capacity of strapping. Do not exceed the calculated lifting capacity.

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

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

5.7.6 *System Audit*—USLM systems require periodic performance audit. Consult your USLM system vendor.

GENERAL CONSIDERATIONS

6. General Properties of Strap Types (See Table 2, Table 3, and Table 4)

6.1 *Steel Strapping*—This product is described in Specification D3953 and is generally classified into regular-duty, regular-duty high strength and heavy-duty strapping. Of all the types of strapping, steel strapping has the highest tensile strength (break strength for a given cross-sectional area) and resistance to tension decay or creep. It is better suited to expanding or rigid units than it is to units that settle because it has a low settling tolerance. Regular-duty high strength strap is suggested for applications where high strength alone is the overriding consideration. Heavy-duty and USLM steel strapping are suggested for applications where both break strength and elongation are overriding considerations. Heavy-duty steel strapping is also suggested for high-temperature applications.

6.2 *Nonmetallic Strapping*:

6.2.1 *Corded Strapping (Type I and IA)*—These products are described in Specification D3950. Corded strapping consists of two basic types, rayon (Type I) and polyester (Type IA).

6.2.1.1 Of all types of strapping, polyester corded has high energy to break for a given cross section. Heavy-duty and extra-heavy-duty polyester corded strappings are suggested for

TABLE 2 Strapping Applications Commonly Used for Packaging, Unitization, and Load Securement

		ASTM D3953 Standard Specification for Strapping Flat Steel and Seals			ASTM D3950 Standard Specification for Strapping Nonmetallic (and Joining Methods)				
		Hand or Machine Applied			Hand Applied		Hand or Machine Applied		
Industry	Product	Type I Steel Regular Duty Moderate Tensile Strength Low Elongation High Retained Tension	Type I Steel Regular Duty High Strength High Tensile Strength Low Elongation High Retained Tension	Type I Steel Heavy Duty High Tensile Strength Moderate Elongation High Retained Tension	Type IA Bonded, Woven or Composite Polyester Cord Good Tensile Strength Moderate Elongation Good Retained Tension High Energy-to-Break Good Notch Sensitivity	Type I Bonded Rayon Cord Moderate Tensile Strength Moderate Elongation Good Notch Sensitivity	Type II Polypropylene (Plastic) Low Tensile Strength High Elongation Low Retained Tension Good Tension Recovery	Type III Nylon (Plastic) Moderate Tensile Strength Good Elongation Good Retained Tension Good Tension Recovery	Type IV Polyester (Plastic) Good Tensile Strength Moderate Elongation Good Retained Tension High Energy-to-Break
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" to 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 Baling						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"
Beverage	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 Load	3/8", 5/8" & 3/4"					7/16"		7/16"
Graphic Arts	Signature Logs						7/16" & 1/2"		7/16" & 1/2"
	Magazines						5mm, 3/16" & 1/4"		
	Newspapers						5mm, 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"
Paper	Paper Rolls	3/8" & 1/2"							7/16"
	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 Copper 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"		58", 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"					
	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					

TABLE 3 Strapping Preference as a Function of Unit Type

Strapping Type	Unit Type				
	Severely[A] Settling	Moderately[B] Settling	Rigid	Moderately Expanding	Severely Expanding
Specification D3953:					
Steel Strapping Regular Duty, Regular-Duty High Strength or Heavy Duty	...	...	C	C	D
Specification D3950:					
Type I Cord Strapping (Rayon) (Regular Duty)	E	C	C	C	...
Type IA Cord Strapping (Polyester)	E	C	C	C	C
Polypropylene Plastic Strapping	E	C	C	...	...
Nylon Plastic Strapping	E	C	C	...	...
Polyester Plastic Strapping	E	C	C	C	C

[A] *Severe*—A perimeter change of 2 % or more.
[B] *Moderate*—A perimeter change of less than 2 %.
[C] Generally recommended.
[D] Best choice, other factor being equal.
[E] With buckles, can be retensioned.

applications where break strength and energy to break are overriding considerations. Polyester corded strapping is more resistant to weathering and moisture than rayon corded strapping. Use wire buckles where maximum joint efficiency is required. Corded strapping may also be joined using plastic buckles, seals, or hand-tied knots.

6.2.2 *Polypropylene (Type II)*—Polypropylene strapping is described in Specification D3950. Polypropylene strapping is used to describe strapping made from two closely related materials, polypropylene homopolyer and 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 materials. Of the nonmetallic strapping materials, they are the most easily heat sealed or fusion joined. They tend to be more suitable for light to medium duty applications.

6.2.3 *Nylon (Type III)*—Nylon strapping is described in Specification D3950. Nylon strapping has the highest elongation recovery of any strapping material, that, combined with a relatively low dead stretch, gives it the highest settling tolerance. With loads where severe settling is the major consideration, nylon would be the preferred strapping material. In terms of break strength, it is comparable to that of the polypropylene and polyester strapping material. It has the best cold-temperature performance of the nonmetallic group, but is most susceptible to moisture degradation.

6.2.4 *Polyester (Type IV)*—Polyester strapping is described in Specification D3950. Polyester has the lowest elongation in the working range and the least tension decay or "creep" of all the nonmetallic strappings. This makes it somewhat more suitable for rigid and expanding loads. Polyester strapping generally exhibits good resistance to the effects of temperature and moisture.

7. General Uses

7.1 Strap may be used to secure a handling base (skids, platforms, pallets, runners, spacers, etc.) to a unit to expedite handling, for example, 2 by 4-in. (5.08 by 10.16 mm) runners strapped to a concrete or steel slab to allow a fork lift or crane and cable handling or to secure other packaging materials (battens, stiffeners, wrappings, etc.), or both, in position. (See Fig. 1.)

7.2 Strap may be used for load securement to or within the transport vehicle. It is then applied under tension to restrain or control the movement of lading, and thus must accommodate in-transit shocks or irregular movements. Carrier regulations provide guidelines or minimum requirements, or both.

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, for example, wood pulp, logs, and metal billets.

7.4 Strap also may provide security against accidental loss or theft of the contents or indicate a loss or theft.

7.5 Strap functions best when all resultant forces act directly parallel, in line, with the direction of the strap.

8. Strap Tension

8.1 Strap primarily functions under tension. This tension basically:

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

8.1.2 Increases the frictional forces between the adjacent surfaces within the unit, for example, between cartons on a pallet and between the cartons and the pallet.

PACKAGING DESIGN

9. Distribution

9.1 Identify receivers (consignees) and their locations relative to shipping point(s) (consignors).

9.2 Determine receiver's needs and requirements. This will provide information on handling equipment and practices, storage practices and 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 and regulations. See 2.2.

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

9.5 The carriers can provide information as to the type of equipment that will best suit specific needs.

10. Package Configuration

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

10.1.1 Can be safely handled in the distribution system,

10.1.2 Protects the security of the contents,

10.1.3 Meets the receiver's requirements,

10.1.4 Secures easily on or to transportation equipment,