900

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
SAVANNAH RIVER OPERATIONS OFFICE
P. O. BOX A
AIKEN, SOUTH CAROLINA 29801
(TEL & TEL NORTH AUGUSTA S C)

RDT STANDARDS TRANSMITTAL

ATT.	DISTRIBUTION	RETURN COMMENTS TO	DATE												
	List 1	NOT LATER THAN	March 13, 1975												
		COGNIZANT ENGINEER	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 50%;">TYPE SUBMISSION</th> <th style="width: 50%;">TYPE ACTION</th> </tr> <tr> <td>☒ 1. TENTATIVE</td> <td>☒ A. TRIAL USE</td> </tr> <tr> <td>☐ 2. DRAFT</td> <td>☐ B. INFORMATION</td> </tr> <tr> <td>☐ 3. AMENDMENT</td> <td>☐ C. COMMENTS</td> </tr> <tr> <td>☐ 4. REVISION</td> <td>☐ D.</td> </tr> <tr> <td>☐ 5.</td> <td></td> </tr> </table>	TYPE SUBMISSION	TYPE ACTION	☒ 1. TENTATIVE	☒ A. TRIAL USE	☐ 2. DRAFT	☐ B. INFORMATION	☐ 3. AMENDMENT	☐ C. COMMENTS	☐ 4. REVISION	☐ D.	☐ 5.	
TYPE SUBMISSION		TYPE ACTION													
☒ 1. TENTATIVE		☒ A. TRIAL USE													
☐ 2. DRAFT		☐ B. INFORMATION													
☐ 3. AMENDMENT	☐ C. COMMENTS														
☐ 4. REVISION	☐ D.														
☐ 5.															
	J. M. Proietti														
	PHONE FTS 803														
	642-2291														
	EXTENSION														
	NUMBER	DESCRIPTION	ACTION												
	RDT F 8-11T	Fuel Shipping Container Tiedown for Truck Transport, January 1975	A												
<p>MAILED</p> <div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> <p style="text-align: center; margin: 0;">NOTICE</p> <p style="font-size: small; margin: 0;">This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.</p> </div>															

SIGNATURE

J. M. Proietti for R.L.C.
R. L. Chandler, RDT Standards Writer

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

RDT Standard

FUEL SHIPPING CONTAINER
TIEDOWN FOR TRUCK
TRANSPORT

JANUARY 1975

Any further distribution by any holder of this document or of the data therein to third parties representing foreign interests, foreign governments, foreign companies, and foreign subsidiaries or foreign divisions of U. S. companies should be coordinated with the Director, Division of Reactor Research and Development, U. S. Energy Research and Development Administration.

U.S. Energy Research and Development Administration

Division of Reactor Research and Development

Send copy and distribution inquiries to:

RDT Standards Office
Oak Ridge National Laboratory
Building 1000, Room 118-C
P. O. Box X
Oak Ridge, TN 37830

RDT STANDARD

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

RDT	F 8-11T		
DATE	January 1975		
PAGE	i	OF	i

FUEL SHIPPING CONTAINER TIEDOWN FOR TRUCK TRANSPORT

TABLE OF CONTENTS

	<u>Page</u>
1. SCOPE	1
1.1 Applicability	1
2. APPLICABLE DOCUMENTS	1
2.1 RDT Standard	1
2.2 Code of Federal Regulations	1
2.3 American Society for Testing Materials (ASTM) Publications	2
2.4 Other Regulations and Documents	2
3. DEFINITIONS	2
3.1 Base	2
3.2 Bolt	2
3.3 Clip	2
3.4 Cradle	2
3.5 Inspector	2
3.6 Package Assembly	2
3.7 Skid	2
3.8 Tiedown Lug	2
4. GENERAL REQUIREMENTS	3
4.1 Pertinent Regulations	3
4.2 Strength	3
4.3 Attachment	5
4.4 Tiedown Hardware Characteristics	6
4.5 Load Distribution	8
4.6 Approval of Design	8
4.7 Approval of Each Shipment	8
APPENDIX A - METHODS OF TIEDOWN	9
APPENDIX B - SAMPLE CALCULATIONS FOR BOLTED TIEDOWN	17
APPENDIX C - SAMPLE CALCULATION FOR UNDERBEAM SIZE	20
APPENDIX D - SAMPLE CALCULATION FOR WIRE ROPE	23
APPENDIX E - VEHICLE SHOCKS	25

RDT STANDARD

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

RDT	F 8-11T		
DATE	January 1975		
PAGE	1	OF	25

FUEL SHIPPING CONTAINER TIEDOWN FOR TRUCK TRANSPORT

1. SCOPE

This standard describes general requirements, methods of tiedown to conventional trailers for package assemblies having a suitable base, and acceptable size and arrangement of tiedown members for package assemblies up to 25 tons and within certain dimensional limits. Methods of tiedown other than those described are permitted if they comply with the general requirements set forth in Section 4.

1.1 Applicability. When specified by the person in charge, this standard applies to shipment of radioactive material in packages having a gross weight in excess of one ton, while being transported over roads and highways. It is applicable basically to both rigid and flexible tiedown systems. However, if a flexible tiedown is to be used, this standard should be applied in conjunction with RDT Standard F 8-9. Attachment to trucks or trailers which are transported by rail or water, as in piggyback shipment, and tiedown systems for large packages (normally exceeding 50,000 pounds using specially designed vehicles) are not included. This standard will not normally apply to less than truckload (i.e., non-exclusive use) shipments.

2. APPLICABLE DOCUMENTS

The following documents are a part of this standard to the extent specified. The issue of a document in effect at the time of any tiedown, including any amendments or other published changes, shall apply. Where this standard appears to conflict with the requirements of a referenced document, such conflict shall be brought to the attention of the organization or authority responsible for the shipment.

2.1 RDT Standards.

RDT F 2-2	Quality Assurance Program Requirements
RDT F 8-9T	Design Basis for Fuel and Irradiations Experiment Resistance to Shock and Vibration in Truck Transport

2.2 Code of Federal Regulations.

10 CFR	Title 10, Atomic Energy
29 CFR 17	Labor
49 CFR	Title 49, Transportation

2.3 American Society for Testing Materials (ASTM) Publications.

ASTM A 307 Low-Carbon Steel Externally and Internally Threaded Standard Fasteners

ASTM A 391 Standard Specification for Alloy Steel Chain

2.4 Other Regulations and Documents.

AECM 0529 USAEC Manual Chapter 0529. Safety Standards for the Packaging of Fissile and Other Radioactive Materials

Rigger's Handbook, Broderick & Bascom Rope Company

3. DEFINITIONS

3.1 Base. A plate, platform or structure to which the package is attached during transport, which distributes the load over the bed of the vehicle.

3.2 Bolt. A rod with a head on one end and threads on the other, or a rod threaded to accommodate nuts on both ends.

3.3 Clip. A metal fastener used to fix one wire rope to another, or a wire rope to itself.

3.4 Cradle. A frame which is contoured to support the package body or package trunnions or both. For transport by conventional trailer, a cradle must include a base for attachment to the vehicle.

3.5 Inspector. An individual assigned to examine the tiedown of a package to determine if it is being assembled in accordance with drawings and specifications.

3.6 Package Assembly. A basic unit which provides containment and shielding together with any support structure, mounting fixtures, or other appurtenances which are attached to the package for transport.

3.7 Skid. A particular type of base designed to permit handling of the package assembly by a forklift or platform lift.

3.8 Tiedown Lug. A device usually made of steel bar fastened to the frame of a truck or trailer and to which tiedown wire ropes or chains are attached.

4. GENERAL REQUIREMENTS

4.1 Pertinent Regulations. Blocking and bracing shall be in accordance with 49 CFR 177.842(d). Tiedown devices which are structural parts of a package shall be in accordance with 10 CFR 71.31(d) and AECM 0529. Present regulations do not specify the strength of tiedown members which are not a structural part of the package.

4.2 Strength. All parts of the tiedown system, including attachment of the package to the cradle or base, and attachments to the vehicle, shall be so designed and fabricated that static stresses would not exceed 75% of the yield strength if the truck bed or trailer bed were subjected to a sustained acceleration of 2 g forward or backward, 1 g sidewise, 3 g vertically up or 2 g vertically down. Because of the gravity field, the net separating force between container and vehicle for downward acceleration is one times the container weight. For bolts, lashing rings, and tiedown lugs, the calculated stress under such conditions shall not exceed 75% of the yield strength. Required bolt torque shall be specified and shall correspond to an initial stress of no more than 75% of yield. For wire rope, chain, turn-buckles, and shackles, the load shall not exceed that given in Tables 1, 2, 3, and 4. Purchased or fabricated items shall be in accordance with RDT Standard F 2-2.

Table 1. Maximum Design Load for Improved Plow
Steel Wire Rope for Package Tiedown^a

Wire Rope Diameter (in.)	Max Design Load for Improved Plow Steel (lb)	Weight (lb/ft)	Approx Radius of Wire Rope Thimble (in.)
3/8	2,400	0.23	7/8
7/16	3,200	0.31	1
1/2	4,200	0.40	1-3/16
9/16	5,400	0.51	1-7/32
5/8	6,600	0.63	1-3/8
3/4	9,600	0.90	1-5/8
7/8	12,800	1.20	1-13/16
1	16,800	1.60	2

^aThe recommended maximum design load is based on data in CFR 29, Chapter XVII, Section 1926.251(c)(1), Table H-3 (7/1/73).

Table 2. Welded Link Chain Working Load Limit (pounds)^a

Nominal Size (in.)	Alloy Steel Chain ASTM Spec A 391	Yield Load of Load Link
1/4	3,250	-
3/8	6,600	7,300
1/2	11,250	12,500
5/8	16,500	18,200
3/4	23,000	25,300
7/8	28,750	31,700
1	38,750	42,700

^aThe working load limit is based on CFR 29, Chapter XVII, Section 1926.251(b)(4), Table H-1 (7/1/73).

Table 3. Working Load Limits for Turnbuckles^{a,b}

Wire Rope Size (in.)	Jaw or Eye Size (in.)	Load (lb) ^c
3/8	1/2	2,440
7/16	5/8	3,300
1/2	3/4	4,280
9/16	3/4	5,400
5/8	7/8	6,680
3/4	1	9,520
7/8	1-1/4	12,880
1	1-1/4	16,720
	1-1/2	21,000
	1-3/4	31,080
	2	36,800

^aDerived from Rigger's Handbook, Broderick & Bascom Rope Co. and information from Crosby-Laughlin Co.

^bWhere turnbuckles are used, a jumper shall be installed of equivalent rated load capacity between the points connected by the turnbuckle. The jumper (e.g., wire rope or chain) shall be of suitable size and configuration to assure the tiedown will assume the load in the event the turnbuckle fails and may be an integral part of the turnbuckle.

^cSafety factor = 5.

Table 4. Working Load Limits for Shackles^a

Shank (in.)	Load (lb)	Pin (in.)	Inside Width (in.)	Inside Length (in.)
1/2	2,800	5/8	1/2	1-7/8
5/8	4,400	3/4	5/8	2-5/16
3/4	6,400	7/8	3/4	2-5/8
7/8	8,600	1	7/8	3-3/16
1	11,200	1-1/8	1	3-1/2
1-1/8	13,400	1-1/4	1-1/8	3-15/16
1-1/4	16,400	1-3/8	1-1/4	4-5/8
1-3/8	20,000	1-1/2	1-3/8	4-15/16
1-1/2	23,800	1-5/8	1-1/2	5-1/2
1-3/4	32,400	2	1-3/4	6-5/8
2	42,400	2-1/4	2	7-3/4

^aThe working load limit is based on CFR 29, Chapter XVII, Section 1926.251(f)(1), Table H-19 (7/1/73).

Stress analysis may include frictional forces and shall take account of the relative stiffness or elasticity of tiedowns which can affect the load distribution among the members.

4.3 Attachment. The principal tiedown forces shall be transmitted to the vehicle frame and not to the wood or metal decking.

With chain or wire rope tiedown, the base shall be bolted or chocked to limit horizontal movement. If bolted, the bolts alone shall be adequate to carry the load. If chocked, the person in charge shall classify the contents as not fragile, or else all wire ropes or chains shall be tightened to about the same tension and such that the total vertical component of force exceeds the weight of the package.

On trailers equipped with built-in lashing rings made of steel rod at least 3/4 in. diameter and held in position with a 3/8 in. thick clip at least 2 in. long with 3/8 in. fillet welds or equivalent, the rings may be used for attaching chain or wire rope to package assemblies weighing six tons or less. For heavier packages, the manufacturer's data or a stress analysis shall verify that the lashing rings conform to the requirements of 4.2. Instead of lashing rings, tiedown lugs (see Fig. 1 and 2) bolted to the outside longitudinal channel and its related supports may be used.

Plastic or fiber rope shall not be used for tiedown.

The attachment to the vehicle shall comply with 49 CFR 393.102(d).

4.4 Tiedown Hardware Characteristics.

4.4.1 Bolts. Bolts used in bolted tiedowns and in fastening chocks shall be carbon steel or stainless steel. Shear stresses as well as tensile stresses shall be considered. Bolts shall be assumed to have strength corresponding to ASTM A 307, Grade A, (60,000 lb/in.² tensile strength minimum and 18% minimum elongation in 2 inches) unless marked to identify them as steel of higher strength.

4.4.2 Wire Rope. Wire rope shall be standard 6 × 19 classification made of improved plow steel with fibre core or equivalent and shall conform to the working limit noted in Table 1 for improved plow steel wire rope. The wire ropes shall have been prestressed to their maximum design load to overcome lengthening of the wire rope due to tightening of its cross section when initially loaded. At least four clips shall be used to secure loose ends of the wire ropes. Proper type of clip for the type and size of rope shall be used. When clips with U-bolts are used, the U-bolt shall be applied to the short end of the wire rope. The distance between clips shall be equal to six times the rope diameter. Any sharp corners with which a wire rope makes contact shall be padded or otherwise protected to prevent damage to the rope. Galvanized wire rope thimbles made of extra improved plow steel or equivalent (see Table 1) shall be used in each location where the wire rope is looped around a tiedown lug. Wire ropes shall be located so that they do not contact or rub each other. When such contact is unavoidable, means to prevent chafing or wear shall be provided. Use of turnbuckles with wire rope is recommended. Turnbuckles shall be prevented from loosening by using a lockwasher and a locknut at each end or by using No. 12, or heavier, gage wire. Turnbuckles shall not be locked by welding the turnbuckle to the threads.

Wire rope shall be examined before each use, and replaced if there is any broken, kinked, or badly worn wire; excessive corrosion; or evidence of heat damage.

4.4.3 Chain. Chains shall be alloy steel in accordance with ASTM A 391, or equivalent, and shall conform to the working load limit noted in Table 2 for alloy steel chain. The handles of any "breakover" load binders used to tighten chains shall be secured with two loops of wire (No. 12, or heavier, gage; annealed; soft; black steel) or with a loose end of the chain to prevent opening of the binder during transport. If ratchet type load binders are used, it will not be necessary to bind the handle.

Fig. 1. Tiedown Lug.

Fig. 2. Tiedown Lug Backup Plate.

To provide evidence of overloading, it is recommended that a load link as noted in Table 2 be installed in each chain. When a load link is found deformed, the chain will have been stressed beyond its load limit. The chain shall be carefully examined and replaced if defective. As an alternative, chain may be inspected and replaced or repaired when needed as outlined in CFR, Chapter XVII, Section 1918.64 (b), (d), and (e).

Chain shall be examined before each use and replaced if any link is bent severely, corroded or pitted, or if interlink wear or transverse nicks or gouges reduce the diameter of the chain link by more than 10%.

4.5 Load Distribution. The base of a package assembly shall be of such size that the load on the truck or trailer bed exceeds neither the rated unit loading nor the rated total capacity of the vehicle. In the absence of a unit load rating for a particular vehicle, 500 lb/ft² may be assumed.

Proper placement of the load on the vehicle to avoid exceeding allowable axle loadings is the responsibility of the carrier. The location of attachment points on the vehicle and certain dimensions of tiedown members shall be selected accordingly.

4.6 Approval of Design. The shipper shall approve the design of the tiedown system for a particular type of package, taking account of any requirements which may exist because of special features of the package.

4.7 Approval of Each Shipment. The shipper shall designate a "person in charge" for conformance of shipment(s) to this standard where applicable under Topic 1.1. The identity of and means of contact with the "person in charge" shall be clearly made known to the carrier and/or his designated representative. The person in charge shall act for the shipper and shall approve the type and condition of the decking; and shall verify that the assembly of the tiedown system, including bolt torque and wire rope tension, is in accordance with the requirements of this standard. Deviations shall be approved in writing by the person in charge only on the basis of facts, particular controls or analysis which, in the judgement of the person in charge, assure tiedown of equivalent effectiveness of the methods, equipment and requirements of this standard. A copy of the written deviation approval and a written summary of the basis for the approval shall be transmitted to the cognizant AEC Field Office Transportation (Traffic) Manager before the close of business of the next working day.

An inspection checklist shall be prepared for each package assembly tiedown and shall be reviewed and approved in writing by the person in charge before release for shipment. The checklists, approvals of deviations and the basis for the approval as transmitted by the person in charge shall be retained by the shipper in an available file for at least two years after the date of shipment.

APPENDIX A

METHODS OF TIEDOWN

A.1 SUMMARY

This appendix describes two acceptable but not mandatory types of tie-down, and presents tables and figures for ready reference so that field personnel can in many cases select a suitable system meeting requirements of Section 4 without performing a stress analysis. Other methods and configurations, for example the use of strap assemblies made of plastic webbing, are permitted if they meet the requirements of this standard.

The types of tiedown considered are applicable to packages equipped with bases of the required size and strength and are designated as the bolted tie-down, in which the base is bolted to the vehicle; and the wire rope or chain tiedown, in which the package assembly is secured by wire rope or chain to the frame of the vehicle and the base is restrained by chocking. A combination of the two may be used with certain restrictions described in 4.3.

Specific instructions and data for packages within certain ranges of weight and dimensions are provided in A.2 and A.3; Tables 1, 2, 5, and 6; and Fig. 3 and 4. Packages which because of size, weight, or location of attachment points do not fall within the scope of Tables 5 and 6 may be tied down in a similar manner provided a stress analysis which includes considerations such as illustrated in Appendices B and D demonstrates that applicable requirements are met.

A.2 BOLTED TIEDOWN

The following specifications are based on a trailer with two main longitudinal I-beams. Bolt locations are selected to miss these I-beams. If trailers of other design are used, load distribution shall conform to 4.5.

Drill holes in the bed of the vehicle positioned as noted in Table 5. The holes shall not be more than 1/2 in. larger in diameter than the specified bolts. Insert 1-in. diameter bolts or threaded fasteners as specified through the holes in the package assembly base and holes drilled in the floor. Cut two lengths of square tubing as given in Table 5, drill to receive the bolts and place beneath and at right angles to the two longitudinal I-beams. Put the bolts through the tubing and fasten each end of the bolts in place with a lockwasher, a nut, and a locknut. A cotter pin through the lower end of the bolt may be used in place of the locknut to gain additional clearance if needed. To prevent local deformation of the tubing adjacent to the nut, place a close fitting block of wood inside the tubing drilled to accept the bolt. The square tubing may be placed at right angles to the transverse supports of the trailer floor if interference is encountered when placing it beneath the longitudinal I-beams. In either arrangement the tubing shall be secured against at least two structural members of the trailer frame.

If desired, other structural steel sections (standard or fabricated) may be used as underbeams instead of the square tubing provided that the maximum tensile stress for design conditions does not exceed 75% of the yield strength of the metal. Account shall be taken of possible local deformation, as in the region of the square tubing adjacent to the nut.

Table 5. Bolted Tiedowns for Package Assemblies up to Ten Feet High
(See Fig. 3)

Weight of Package Assembly (tons)	No. of Bolts ^a	Torque (ft-lb)	Minimum Base Size (ft) ^b	Minimum Bolt Spacing in Base (ft)	Minimum Size of Sq Tubing (in.) ^{c,d}
1 to 2	4	100 to 140	2 × 4	3.5 apart lon- gitudinally (L) 1.5 apart trans- versely (T)	4 × 4 × 1/2
2 to 4	4	200 to 220	4 × 4	3.5 (L) 2.25 (T)	4 × 4 × 1/2
4 to 6	4	200 to 220	4 × 6	5.5 (L) 2.25 (T)	4 × 4 × 1/2
6 to 10	4	200 to 220	5 × 8	7.33 (L) 4.33 (T)	4 × 4 × 1/2
10 to 15	6	200 to 220	7 × 9	8.33 (L) 6.33 (T) with 3rd bolt located on CL at each end	5 × 5 × 1/2
15 to 20	6	200 to 220	7 × 12	11.33 (L) 6.33 (T) with 3rd bolt located on CL at each end	5 × 5 × 1/2
20 to 25	8	200 to 220	7 × 14	13.33 (L) 6.33 (T) with 3rd and 4th bolts equally spaced between outer bolts at each end	5 × 5 × 1/2

^a Steel bolts to be 1 in. - 8 of ASTM A 307, Grade A, or bolts of equal or higher strength.

^b Base size selected to give a maximum loading of approximately 500 lb/sq foot in the area under the base.

^c A structural steel section (standard or fabricated) may be used provided that the maximum tensile stress developed does not exceed 75% of the yield strength of the metal.

^d See sample calculation in Appendix C for size of underbeam.

Table 6. Wire Rope or Chain Tiedown
(See Fig. 4)

Assembly Weight (tons)	Minimum Width of Package (ft) ^a	Minimum Size of Wire Rope (in.) ^{b,c}	Minimum Size of Chain (in.) ^{c,d}	Method of Chocking ^e	Size of Turnbuckle Jaw if Used (in.)
1 to 2	2	3/8	3/8	A or B	1/2
2 to 4	2	1/2	3/8	A or B	3/4
4 to 6	3	1/2	3/8	B	3/4
6 to 10	3	3/4	1/2	B	1
10 to 15	4	3/4	1/2	B	1
15 to 20	4	1	5/8	B	1-1/4
20 to 25	4	1	5/8	C	1-1/4

^aTable is based on maximum height of 10 ft for package assembly.

^bImproved plow steel 6-19 wire rope, or equivalent (see A.3 for location of attachments and angles of wire rope).

^cBased on eight wire ropes or chains; i.e., two at each "corner" of the package; one wire rope or chain at each "corner" may be used if of equal or greater strength in accordance with Tables 1 and 2.

^dAlloy steel chain ASTM A 391, or equivalent.

^eA = 2 by 6 in. lumber and 10 d nails.

B = 3 in. by 3 in. by 1/4 in. angle iron with two 1 in. - 8 bolts in each piece. Install a 3 in. square by 1/4 in. thick flat washer beneath the deck, a lockwasher, and nut on each bolt and torque to 200 to 220 ft lb; install a jamnut and torque it to the same value.

C = Same as B except use three bolts in each angle iron across the ends.

Fig. 3. Bolted Tiedown Layout.
(For a package assembly of 4 to 6 tons.)

Fig. 4. Wire Rope Tiedown Layout.
(For a package assembly of 15 to 20 tons)

Table 5 specifies size and spacing of tiedown members and required bolt torque to comply with 4.2 and 4.3 strength and load requirements for a package assembly not more than 10 ft high. The specifications are based on stress analysis illustrated in Appendix B. The number of bolts and the torque values are selected to provide adequate frictional force without overstressing the underbeams.

A.3 WIRE ROPE TIEDOWN

Attach wire rope to each of the four "corners" of the package assembly at points two-thirds or more of the height above the base. Fix the other end of the cables to lashing rings or tiedown lugs at the side of the vehicle frame. The wire ropes are to be drawn taut to remove slack and kinks. A 3/4 ton come-a-long is usually suitable for this purpose. The base shall be no smaller than shown in Table 5, and shall be chocked on all four sides as shown in Table 6 with timber or steel angle of at least three-fourths the length of each side. If possible, set the chocking tight so as to permit no more than 1/2 in. horizontal movement of the base. However, to allow some latitude in the location of principal chocking members, etc., wedges or shims of up to 3 in. thickness may be utilized if they are secured to prevent loosening. Attachment to the side of the vehicle shall be as described in 4.4.2.

When lumber is used for chocking, 1/8 in. diameter holes shall be pre-drilled in the lumber for the nails which fasten it to the deck of the vehicle. The nails shall be 10 d common, driven at right angles to the deck and staggered 4 in. apart. The specifications of Table 6 for chocking with lumber are based on wood decking of 1-1/2 in. thickness. The following species of wood are acceptable for chocking: red or white oak; white ash; yellow or sweet birch; beech; American or slippery elm; hickory; hard, sugar, or black maple; sweetgum; black cherry; and southern pine; western pine; and fir. All wood shall be straight-grained and free of decay and strength impairing knots.

When angle iron is used for chocking, each piece shall be anchored with at least two bolts, each having a 3 in. square by 1/4 in. thick steel washer, a lockwasher, a nut, and a jamnut under the vehicle bed; nuts shall be torqued as specified in footnote e of Table 6. The angle and bolt sizes shall be such that the horizontal forces developed under acceleration conditions described in 4.2, taking account of preload and friction, do not cause stress in the bolts or compressive stress in the bolt holes exceeding 75% of yield. When chain is used instead of wire rope, it shall be of the size and strength specified in Tables 2 and 6.

The size and number of wire ropes or chains, and the specifications of chocking members may be selected from Table 6 for package assemblies up to 10 ft high provided that the projection of the wire rope or chain is 15° to 25° from the fore-aft centerline of the carrier (see also 4.4.2).

The carrier shall inspect the tiedown wire ropes or chains periodically in transit and shall retighten them as necessary.

A.4 OTHER METHODS OF TIEDOWN

A package may be mounted on a base which has no provision for holddown bolts, or which has bolt holes not suitably spaced for the trailer. In such cases, two pieces of 4 in. or 5 in. (as required) square tubing may be placed over the base and the holddown bolts passed through them and the carrier deck at convenient spots to square tubing beneath the deck (see Fig. 5). The spacing and size of bolts shall be no less than that specified in Table 5. Chocking is required either as in Table 6, or bracing against the square tubing and bolts to prevent horizontal movement.

Other tiedown systems may be used if in compliance with strength and performance requirements of Section 4.

Fig. 5. Alternative Bolting Arrangement.

APPENDIX BSAMPLE CALCULATIONS FOR BOLTED TIEDOWN
(See Fig. 3)

B.1 BASIS

Weight of cask, $W = 4$ to 6 tons. Use 6 tons.

Base = $4 \text{ ft} \times 6 \text{ ft} = 24 \text{ ft}^2$ (500 lb/ft^2).

Cask size = 3 ft diameter by 10 ft high.

Bolts = Four $1 \text{ in.} - 8$ each torqued to $200\text{-}220 \text{ ft-lb}$ (ASTM A 307 Grade A; ultimate strength of $60,000 \text{ lb/in.}^2$).

Coefficient of friction of steel on wood, $\mu = 0.4$.

B.2 CALCULATIONS

B.2.1 Preload. Initial tensile load developed in a preloaded bolt is calculated by the approximation formula (Equation 1):

$$P = \frac{63T}{D} \quad (1)$$

where

P = bolt load, lb

D = nominal diameter, in.

T = torque applied to bolt, ft-lb.

When $T = 200 \text{ ft-lb}$, the preload of a $1 \text{ in.} - 8$ bolt is:

$$P_{200} = \frac{63 \times 200}{1} = 12,600 \text{ lb.}$$

And the stress is:

$$\frac{12,600}{0.551} = 22,800 \text{ lb/in.}^2$$

When $T = 220 \text{ ft-lb}$, the preload of the bolt is:

$$P_{220} = \frac{63 \times 220}{1} = 13,900 \text{ lb.}$$

And the stress is:

$$\frac{13,900}{0.551} = 25,200 \text{ lb/in.}^2$$

B.2.2 Longitudinal Acceleration of 2 g. The vehicle is assumed to be accelerating to the right, causing the cask to tend to rotate counterclockwise and produce a tensile force in the bolts at position F_1 (Fig. 3).

For a rigid base, rotation tends to be about the left edge of the base and moments may be calculated accordingly. However, the base will have some flexibility, and it appears normally conservative to assume that external forces on the cask system act at the bolts. Then taking moments about the center of gravity, external forces are calculated by Equations 2 and 3:

$$F_1 (2.75) + F_2 (2.75) = 2W(5). \quad (2)$$

$2W$ in this calculation is the force acting on the base of the cask due to acceleration of the vehicle bed.

$$F_1 + W = F_2. \quad (3)$$

For $W = 12,000$ lb, it is found that:

$$F_1 = 15,850 \text{ lb.}$$

The tensile force F_1 is divided between two bolts each having a cross sectional area of 0.551 in.^2 , resulting in a tensile stress in each bolt of $14,400 \text{ lb/in.}^2$.

The required horizontal force of $24,000$ lb is provided partly by friction and partly by bolt shear stress. There is normally enough "give" in the system, particularly with wood decking, that all four bolts will share the necessary load.

The net force between cask assembly and vehicle bed remains unchanged at the weight of the assembly plus the initial bolt tension. Thus the maximum friction force is calculated by Equation 4:

$$F_{mf} = \mu (4 \times P_{200} + W) \quad (4)$$

where

$$\begin{aligned} \mu &= 0.4 \\ P_{200} &= 12,600 \text{ lb} \\ W &= 12,000 \text{ lb} \end{aligned}$$

$$= 0.4 (4 \times 12,600 + 12,000)$$

$$= 24,960 \text{ lb.}$$

The shear load is:

$$24,000 - 24,960 = -960 \text{ lb.}$$

No shear load is developed in the bolts.

B.2.3 Lateral Acceleration of 1 g. Calculations similar to those for longitudinal acceleration give:

Tensile stress in bolts = 18,700 lb/in.²

Shear stress in bolts = negligible.

B.2.4 Vertical Acceleration of 1 g. The tensile stress in each tie-down bolt is calculated by Equation 5:

$$\frac{W}{4(\text{bolt cross sectional area})} = \frac{12,000}{4 \times 0.551} = 5,450 \text{ lb/in.}^2 \quad (5)$$

B.3 CONCLUSION

The maximum stress developed in the bolts is 25,200 lb/in.² when they are preloaded with a torque of 220 ft-lb. This is within their allowable limit.

APPENDIX C

SAMPLE CALCULATION FOR UNDERBEAM SIZE (See Fig. 6)

In the case of tiedown of a 20 ton cask, six 1 in. - 8 bolts are used and each is torqued to 200 to 220 ft-lb, which develops an initial load in each bolt of 13,900 lb.

Two pieces of 5 in. by 5 in. by 1/2 in. square tubing are positioned under the vehicle bed and under and at right angles to the two main longitudinal beams. Each is connected to the 20 ton cask by three 1 in. bolts.

Fig. 6. Underbeam Layout.
(For package assemblies of 15 to 20 tons)

Stresses at Section Z for maximum loading were calculated as follows (see Fig. 7).

Fig. 7. Underbeam Force Diagram.
(For package assemblies of 15 to 20 tons)

1. Shear stress by Equation 6:

$$S_{ZS} = \frac{S_Z}{A_Z} \quad (6)$$

where

S_{ZS} = shear stress, lb/in.²

S_Z = shear force, lb

A_Z = cross sectional area of the square tubing
= 8.14 in.²

$$S_Z = 20,850 - 13,900$$

$$= 6,950 \text{ lb}$$

$$S_{ZS} = \frac{6,950}{8.14}$$

$$= 855 \text{ lb/in.}^2$$

2. Maximum tensile stress in the outer fiber by Equation 7:

$$S_{ZT} = \frac{M_Z \times C_Z}{I} \quad (7)$$

where

S_{ZT} = tensile stress, lb/in.²

M_Z = moment, in.-lb

C_Z = distance from the center of the beam to the outer fiber, in.
= 2.5 in.

I = moment of inertia of the square tubing, in.⁴
= 25.7 in.⁴

$$\begin{aligned} M_Z &= 19 \times 13,900 \\ &= 264,000 \text{ in.-lb} \end{aligned}$$

$$\begin{aligned} S_{ZT} &= \frac{264,000 \times 2.5}{25.7} \\ &= 25,700 \text{ lb/in.}^2 \end{aligned}$$

3. Maximum combined shear stress by Equation 8:

$$S_{ZC} = \sqrt{\left(\frac{S_{ZT}}{2}\right)^2 + (S_{ZS})^2} \quad (8)$$

where

S_{ZC} = maximum combined shear stress, lb/in.²

$$S_{ZC} = \sqrt{\left(\frac{25,700}{2}\right)^2 + (855)^2} = 12,880 \text{ lb/in.}^2$$

APPENDIX DSAMPLE CALCULATION FOR WIRE ROPE
(See Fig. 4)

D.1 BASIS

Weight of cask, $W = 15$ to 20 tons. Use 20 tons.
 Base = $7 \text{ ft} \times 12 \text{ ft} = 84 \text{ ft}^2$ (480 lb/ft^2)
 Cask size = 4 ft diameter by 10 ft high
 Wire rope angles = as shown in Fig. 4
 Coefficient of friction of steel on wood, $\mu = 0.4$

D.2 CALCULATIONS

D.2.1 Longitudinal Acceleration of 2 g. The vehicle is assumed to be accelerating to the right, requiring a total forward force component F_1 in the right-hand wire ropes. The package tends to rotate counterclockwise about the left edge of the base; however, the assumption of a completely rigid base is somewhat unrealistic and would result in an underestimate of the actual wire rope tension. It is normally conservative to assume for purpose of calculating the overturning moment that the center of rotation is the edge of the package. Taking moments about the assumed center of rotation which is the edge of the package, Z , the force per corner $\left(\frac{F}{2}\right)$ is calculated by Equation 9:

$$2W + 3.5F_2 + 6.75F_1 = 2W \times 5 \quad (9)$$

where

$$\begin{aligned} W &= 40,000 \text{ lb} \\ \mu &= 0.4 \\ F_1 &= F \cos 46^\circ \cos 25^\circ \\ F_2 &= F \sin 46^\circ \end{aligned}$$

$$\frac{F}{2} = 23,600 \text{ lb.}$$

The chocking force, H , against the package base is calculated by Equation 10:

$$H + \mu W + \mu F_2 + F_1 = 2W. \quad (10)$$

Considering the longitudinal forces,

$$H = 20,800 \text{ lb.}$$

D.2.2 Lateral Acceleration of 1 g. By calculations similar to those for longitudinal acceleration, and taking account of the angles of the cables for this direction, it is found that:

$$F = 36,800 \text{ lb}$$

$$\frac{F}{2} = \text{force per corner} = 18,400 \text{ lb}$$

$$H = 8,100 \text{ lb.}$$

D.2.3 Vertical Acceleration of 1 g. Noting that F_2 represents the total force component for two corners:

$$2F_2 = 40,000$$

$$F = \frac{40,000}{2 \sin 46^\circ} = 27,800 \text{ lb}$$

$$\frac{F}{2} = \text{force per corner} = 13,900 \text{ lb.}$$

D.3 CONCLUSION

The maximum cable tension per corner is 23,600 lb, for which two 1 in. improved plow steel wire ropes are adequate.

Chocking bolts must withstand a total shear force of 20,800 lb longitudinally and 8,100 lb laterally.

APPENDIX E

VEHICLE SHOCKS

Reports published by the Shock and Vibration Information Center of the Naval Research Laboratory and by Battelle Memorial Institute - Columbus, and information acquired by a general survey of the literature and from direct observation of several shipments of package assemblies weighing 10 to 50 tons, lead to the conclusion that the maximum expected accelerations of the bed of a vehicle in normal transport with moderate or heavy loads for shocks of greater than 5 millisecond duration (i.e., frequency less than 100 Hz) are as given below. Going over chuck holes, rough roads and rail-road tracks and backing into platforms are included. The values are for spring-mounted vehicles; values for air-suspension vehicles are somewhat lower. Recommended design values are also shown.

	Acceleration (g)	
	Maximum Expected	Recommended Design
Longitudinal	1.0	2
Lateral	0.3	1
Vertical up	3	4
Vertical down	2	1

The upward vertical acceleration of the vehicle bed when added to the downward effect of the weight of the package results in a total equivalent load of 4 g with respect to the vehicle. This tends to force the package against the bed. Dependent upon the design of the package base, high stresses could be developed in the base. The downward vertical acceleration of the bed tends to separate the package from the vehicle. However, due to the weight of the package, the loading in the tiedown is the result of a net separating force of 1 g.

It is conservative to apply methods of static analysis to shocks of short duration. Additional conservatism is provided by the use of some design accelerations greater than observed accelerations. If the observed peaks of 1.0, 0.3, and 2 g were to occur simultaneously, the vector sum would be 2.25 g. However, the conservatism described above is considered adequate to justify stress analysis on the basis of independent occurrence of the shocks in the three principal directions. The design values also allow for minor accidents for which damage to the package assembly or tiedown would not be expected.