Computer Calculation of Wire-Rope Tiedown Designs for Radioactive Materials Packages

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INTRODUCTION AND SUMMARY

The Transportation Technologies Group within the Chemical Technology Division of Oak Ridge National Laboratory provides support to, among others, the Transportation Management Division within the Department of Energy's (DOE) Office of Environmental Management. One aspect of this support is the development of a series of topical Regulatory Compliance Guides (RCGs) on transportation issues impacting DOE and its contractors. RCGs provide DOE and its contractors with uniform and consistent guidance on the implementation of the regulations, standards, and guidelines supplied by multiple agencies with overlapping regulatory authority.

BACKGROUND

It is highly unlikely that packagings with proper tiedowns will come off their transport vehicle in the worst nonaccident events for truck transport. Even though most shippers take responsibility for specifying tiedown requirements, some shippers depend on the carrier for meeting tiedown requirements. Although reliance on the carrier's actions may be legal in most instances, the changing regulatory climate facing DOE indicates that mandating tiedown requirements with the carrier is a business practice that not only enhances package retention during transport, but also protects DOE from the actions of outside parties. In addition, as a shipper of exclusive-use vehicles for larger packages of radioactive materials, DOE or its subcontractor will be frequently required to provide the tiedown system to the transport vehicle.

This wire-rope tiedown RCG describes general requirements for wire-rope tiedowns securing radioactive materials packages to conventional trailers. These packages all have

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a suitable base plate (pallet or skid) or flat base, and appropriate size and arrangement of tiedown assemblies for packages that are within weight and dimensional limits of the equipment. Tiedown devices other than wire ropes are permitted if they comply with the general requirements set forth by the regulations, but are not considered in this RCG and are not generally recommended for packages greater than 5,000 pounds.

This tiedown methodology has provided a basis for the development of a standard under the auspices of the American National Standards Institute (ANSI). This standard, drafted by Subcommittee N14.31, provides an effective way to encourage and ensure uniform implementation of tiedown requirements, and provides general guidelines for securing packages weighing 500 pounds or greater onto legal-weight trucks, using wire rope.

REGULATORY CONSIDERATIONS

Tiedowns required for radioactive materials packages are generally stronger than those required by Federal regulations applicable to other types of loads and packages. The tiedown system is to keep a package on the transport vehicle for all nonaccident events. To this end, different agencies of the Federal Government have separately proposed or promulgated regulations applicable to tiedowns for radioactive materials packages. These agencies, along with other commercial, international, and standards organizations, have also developed guidance documents on the implementation of the regulations.

The RCG addresses regulatory requirements and standards from the U.S. Department of Transportation (49 CFR 393), the U.S. Nuclear Regulatory Commission (NRC) (10 CFR 71), the International Atomic Energy Agency (IAEA) (Safety Series No. 6), and DOE (DOE Order 1540.1A). Guidance for implementation of these regulations and standards from the Nuclear Regulatory Commission, the International Atomic Energy Agency, the Commercial Vehicle Safety Alliance, and ANSI Committee on Transportation of Fissile and Radioactive Materials are also included.

METHODOLOGY

Methods, tools (where applicable), and guidelines to follow in satisfying tiedown regulations are described in the wire-rope tiedown RCG. In truck transport, several points are common to all tiedown requirements. Some of the points considered in this RCG are the following:

1. inertial loads and stresses;
2. connections between the package and its base, if it has one;
3. packaging dimensions and weight;
4. vehicle selection;
5. placement on the vehicle;

6. attachment to the vehicle; and
7. design, installation, and inspection of the tiedown.

This RCG contains the requirements for wire-rope tiedowns of radioactive material shipping packages (loaded or empty) weighing 5,000 pounds or more, and shipped via legal weight truck transport. The tiedowns are used to secure the package to the transport vehicle for safe transport under the worst nonaccident event for truck transport or normal conditions of transport. The RCG may be used as a guide to make a responsible engineering judgment in the application of tiedowns.

With this RCG, personnel from the shipper's Quality Assurance or Inspection Groups examine each transport vehicle and each component of the packaging before its use to ensure they are in good condition. Following the loading and securing of the package, the personnel also examine the package and all components to ensure compliance with the regulations. Thus the shipper is responsible for deviations, quality assurance, and inspection.

TIEDOWN STRESS CALCULATION PROGRAM

A method for defining an appropriate tiedown system through the use of the Tiedown Stress Calculation Program (TSCP) is included in the RCG. A diskette containing a copy of the TSCP is included with the guide. The TSCP is a user-friendly, menu-driven database system written in FoxPro 2.5. The program has been compiled into an executable form, which simply means that no additional software (other than DOS) is needed in order to run the program. The TSCP calculates, based on user-specified inputs, the requirements for wire-rope tiedowns. The RCG also includes the User's Guide for system requirements, program installation, and program operation. This program will help ensure uniform implementation of applicable regulatory requirements, but the TSCP is provided for informational purposes only, and the shipper is responsible for ensuring adequacy for a particular purpose. The extent of the development and maintenance of the TSCP will depend upon feedback from the users and future funding levels.

The TSCP is designed primarily to calculate the stresses on wire rope tiedowns, based on static accelerations applied to the package. The program is able to evaluate a number of tiedown configurations (see Figure 1).

The methodology used to perform these calculations is given in the IAEA Safety Series No. 37 (IAEA 1990). This methodology is based on the fact that the analyst identifies the location of the tiedown points on the package and on the trailer. The TSCP program then calculates the angles that the wire rope makes between the package and the attachment points. The program applies three force vectors in the longitudinal, transverse, and vertical directions to the center of gravity of the package. These force vectors identify the load factors, and therefore the loads, that the wire ropes must resist without breaking.

Based on the calculated stresses, appropriate sizes of wire rope, the number of U-bolts needed, turnback lengths, U-bolt torques, shackle sizes, and turnbuckle sizes are specified as part of the output of the program. In addition, the TSCP has the capability of calculating tensile and shear stresses for some bolted tiedowns.

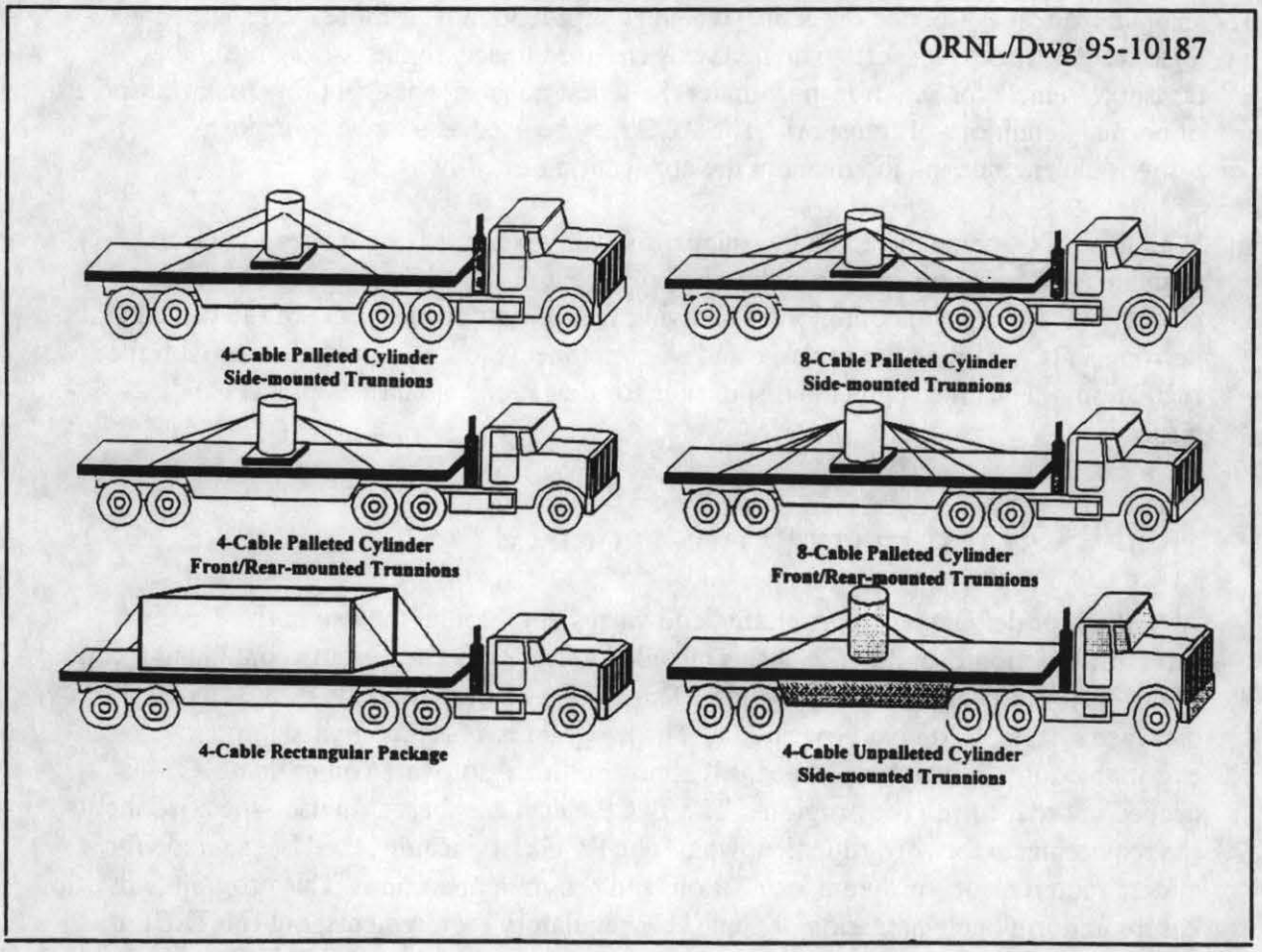

Figure 1. TSCP Cask Tiedown Configurations.

EXAMPLE

Assume there is a need to transport radioactive material from a university in a Type B package. The package that is chosen is 24 in. in diameter, 36 in. tall, weighs 6,000 lb., and is attached to a pallet for shipment. (The program was written using English units.) The steel pallet is 5 ft. on a side and adds 6 in. to the height of the package when it is ready for shipment. The shipment will be by truck. The flatbed trailer on which the package will be placed is 96 in. wide, has a depressed bed, and has D-ring attachment points every 2 ft. along the length of the trailer located 3 in. in from the edge of the trailer. Assume the package has two lifting trunnions located 6 in. from the top closure end to which tiedown cables are attached during shipment. The pallet is chocked so that it cannot slide on the trailer bed.

In accordance with the IAEA requirements, the TSCP currently uses load factors of 2 *g* longitudinal, 1 *g* lateral, and 2 *g* vertical that are applied simultaneously to the center of gravity of the package. Under these conditions, the wire-rope tiedowns are to remain intact; they may, however, break if those forces generated by those load factors are exceeded.

The results of the calculation are given in Table 1.

As a result of this analysis, the proper size of the wire rope necessary to secure the package to the trailer is 9/16 in., assuming that the tiedown points are 48 in. from the center of the package once it is placed on the trailer. The output also tells the traffic manager what size clips and other hardware to use to be in compliance with standard tiedown practices.

SUMMARY

This RCG provides guidance on the use and selection of appropriate wire-rope-type package tiedowns. It provides an effective way to encourage and to ensure uniform implementation of regulatory requirements applicable to tiedowns. It provides general guidelines for securing packages weighing 5,000 pounds or greater that contain radioactive materials onto legal-weight trucks (exclusive of packagings having their own trailer with trunnion-type tiedown). This RCG includes a computerized Tiedown Stress Calculation Program (TSCP), which calculates the stresses in the wire-rope tiedowns and specifies appropriate sizes of wire rope and associated hardware parameters (such as turnback length, number of cable clips, etc.).

Table 1. Tiedown Force Calculation Results

Tiedown Assumptions

PACKAGE INFORMATION:	
Package configuration:	Palleted Package Side-mounted Trunnions 4 Cables with Chocks
Pallet size:	72.00 by 72.00 inches
Package name:	Example
Package weight:	6,000 lb
Certification number:	USA/1111/B( )
TRAILER INFORMATION:	
Trailer width:	96.00 in.
Width from tiedown to tiedown:	90.00 in.
Distance between D-ring with package wire rope connection:	48.00 in.
Length of wire rope:	65.51 in.
Angle(s) between tiedown and trailer bed:	27.2 degrees
Angle(s) between tiedown and plans vertical to trailer edge:	34.5 degrees
LONGITUDINAL (FORWARD) FORCES:	
Load assumed:	2.00 g
Force on wire rope:	8,400 lb
Force on chocks:	0 lb
LATERAL (SIDE) FORCES:	
Load assumed:	1.00 g
Force on wire rope:	7,180 lb
Force on chocks:	0 lb
VERTICAL FORCES:	
Load assumed (net):	2.00 g
Force on wire rope:	6,552 lb
SUMMARY:	
Total calculated wire rope force:	22,132 lb
Calculated force should not exceed 100% of wire rope breaking strength.	

Table 1. Tiedown Force Calculation Results (Continued)

TIEDOWN FORCE CALCULATION RESULTS

Rec. Wire Rope	Wire Rope Size (in.)	Nominal Breaking Strength (lb)	Wire Rope Clips Needed	Turnback Length (in.)	Clip Torque (ft-lb)	Shkle Size (in.)	Trnbuc Size (in.)
	7/16	15640	2	7	65	7/16	5/8
	1/2	20400	3	11-1/2	65	1/2	3/4
----->	9/16	25800	3	12	95	9/16	3/4
	5/8	31600	3	12	95	5/8	7/8
	3/4	45200	4	18	130	3/4	1

REFERENCES

International Atomic Energy Agency, *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material,* Third Edition (as Amended 1990), Safety Series No. 37, Vienna, 1990.