Hazardous Materials Package Performance Regulations*

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INTRODUCTION

The hazardous materials (hazmat) packaging development and certification process is currently defined by two different regulatory philosophies, one based on "specification" packagings and the other based on "performance" standards. With specification packagings, a packaging is accepted for hazmat transport if it is constructed according to an agreed set of design specifications. In contrast, performance standards do not specify the packaging design; they specify performance standards that a packaging design must be able to pass before it can be certified for transport. In this case, the packaging can be designed according to individual needs as long as it meets these performance standards. Performance standards have been used nationally and internationally for about 40 years to certify radioactive materials (RAM) packagings. In the United States, two major packaging categories for RAM, Type A and Type B, must satisfy distinct performance standards listed in Title 10, Code of Federal Regulations part 71 (10CFR71) (USNRC 1991). Type A packagings are for transporting relatively small quantities of RAM as defined by curie level and hazard level, and Type B packagings are for transporting larger quantities. Thousands of these packages are shipped annually, yet, since the performance standards were instituted, there have been no documented releases above the regulatory limit from a Type B package during transportation and only limited releases from Type A packages (Cashwell and McClure, 1992). Thus, it is reasonable to state that for RAM transport, performance specifications have maintained transport safety.

A committee of United Nations' experts recommended the performance standard philosophy as the preferred regulation method for hazmat packaging (United Nations 1986). Performance standards for hazmat packagings smaller than 118 gallons have been adopted in 49CFR178 (USDOT 1991). Packagings for materials that are classified as toxic-by-inhalation must comply with the performance standards by October 1, 1993, and packagings for all other classes of hazardous materials covered in 49CFR178 must

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A main concern when setting performance standards is determining the appropriate standards necessary to assure adequate public protection without making the packagings prohibitively expensive for the shipping industry. For packages containing bulk (in excess of 118 gallons) quantities of materials that are extremely toxic by inhalation, there currently are no performance requirements. This paper discusses a Hazmat Packaging Performance Evaluation (HPPE) project being conducted at Sandia National Laboratories for the U.S. Department of Transportation Research & Special Programs Administration (DOT-RSPA) to look at the subset of bulk packagings that are larger than 2000 gallons. The objectives of this project are to evaluate current hazmat specification packagings and develop supporting documentation for determining performance requirements for packagings in excess of 2000 gallons that transport hazardous materials that have been classified as extremely toxic by inhalation (METBI).

HAZARDOUS MATERIALS PACKAGING PERFORMANCE EVALUATION METHODOLOGY

One major component of the HPPE project involves using atmospheric dispersion codes to estimate the effects of packaging leak rate of METBI on the distance from the release within which the airborne concentration of METBI is considered dangerous. This involves studying the toxicity data for the METBI materials to determine which toxicity parameters to use to determine what concentration limits to consider dangerous and how to apply these data to exposure durations that differ from the duration reported for the particular toxicity parameter. Another major component of the HPPE project involves estimating the performance of current bulk hazmat specification packagings. These estimates of packaging performance can be combined with the calculations of the effects to provide guidance for selecting packaging performance specifications.

The project has been divided into the following tasks: review existing regulations, review current specification packagings, describe accident environments, characterize the METBI materials, select appropriate toxicity parameters, develop computer modeling capabilities, and develop guidance for selecting packaging performance requirements.

The review of existing regulations showed that, although hazmat is required to be transported in its corresponding specification packaging or packagings, these specification packagings were developed primarily on a case by case basis and do not provide a consistent level of protection between specification packaging designs.

The review of specification packagings is currently under way. Bulk packaging provisions for METBI materials shipped in quantities in excess of 2000 gallons are specified in 49CFR178. The following representative specification packagings have been chosen for review: DOT51, MC331, MC105, MC112, MC113, MC114, IM101, and MC312. These particular specification packagings span both the truck and rail transportation modes and include cargo tanks, portable tanks, and pressurized and non-pressurized rail tank cars. The salient parameters for these specification packagings will be obtained from the appropriate sections in 49CFR and the ASME Boiler & Pressure Vessel Code (ASME 1992). These salient parameters will subsequently be used to estimate the predicted response of these specification packagings to thermal, impact, and crush loads such as those specified in the 49CFR and 10CFR performance specifications.

The task of describing transportation accident environments involved reviewing hazmat accident literature. Hazmat accident data indicate that 98% of light truck/van accidents have velocity changes during impact of less than 30 mph (UMTRI 1980). However, other than this study, there is little data specific to hazmat transportation. For hazmat that is transported by routine road and rail, it has been decided for this project that the accident severity studies for radioactive materials can be applied to hazmat transport.

To characterize the METBI materials, a literature review was performed to compile data on material properties and measures of toxicity for the METBI materials. Thermodynamic properties of the METBI materials are necessary because some of the dispersion modeling requires thermodynamic properties. Data on toxicity is necessary to help determine the level of dangerous of a release. In addition, the METBI materials have been studied to determine their relevant release characteristics. The relevant release characteristics include: determining if a particular METBI material disperses as a dense gas, buoyant gas, or remains liquid; determining if it contains aerosol which will be removed by gravitational settling from the airborne concentration as it disperses; and determining if it reacts with compounds prevalent in surrounding air (such as water vapor) to disperse as a reaction product rather than as the original METBI. This information is necessary to accurately model the dispersion of METBI in the event of an accidental release.

Selecting appropriate toxicity parameters involved studying the various measures of toxicity to determine which are most appropriate to this application. There are several different types of toxicity parameters reported in the literature for toxic materials, but there is a large degree of uncertainty associated with using the readily available toxicity parameters for calculating comparative risks for this project. Common toxicity parameters include: the ERPG-2, which is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action; the LC_{50}, which is defined as an inhalation exposure level that is lethal to half of an exposed population; the LD_{50}, which is defined as an ingestion exposure level that is lethal to half of an exposed population; the LClo, which is defined as the lowest observed lethal inhalation exposure level; the LDlo, which is defined as the lowest observed lethal ingestion exposure level; the TLV, which is defined as a safe level of occupational exposure (customarily a time-weighted average value for 40 hours of exposure); and the STEL, which is defined as the level of exposure permitted for brief periods of time, such as to permit life saving activities, etc.) (Landis and van der Schalie, 1990).

One of the main uncertainties in using these parameters stems from the fact that most toxicity data are measured on animals in a laboratory setting. Therefore, applying the toxicity data to humans introduces uncertainty. Additional uncertainty is introduced by the difference between the exposure time expected during an accidental release (i.e., either the time a population is exposed while the toxic cloud drifts by, or the time the population is exposed before they are either evacuated or isolated by the emergency responders) and the exposure time reported for the toxicity parameter. For example, if a material has a reported exposure limit that was measured for an 8-hour exposure and the toxic cloud is calculated to be gone within an hour, how does that one hour exposure compare to the limit reported for an 8-hour exposure? Depending on how the human body reacts to this particular toxic material, a one hour exposure to a concentration of 8 times the 8-hour limit is not necessarily the same as an 8 hour exposure to the 8-hour concentration limit (i.e., the integrated dose is not necessarily the controlling factor). A third but related uncertainty is caused by the inconsistency of exposure times reported for the various toxicity data. The exposure times are frequently inconsistent even for the same parameter. For example, for the METBI materials, the LClo is reported for exposure times ranging from 1 minute to 8 hours.

The method chosen for applying existing toxicity parameters to this project provides a general rule of thumb for using toxic parameters for exposure times that are different than that reported for the parameter. This method was chosen because it has been used in other DOT-RSPA supported research. For an exposure time that is on the order of the time period of the particular toxic parameter, the method recommends using the value of that parameter as an "average concentration" during the exposure, rather than a peak concentration never to be exceeded during the exposure time. When the predicted exposure time is less than ¼ the time period of the reported guideline, the method recommends scaling factors based on exposure time. However, it must be emphasized that these guidelines are general and do not necessarily accurately represent each individual chemical.

The atmospheric dispersion of METBI in the event of a release is being modeled to determine the effect of packaging leak rate on the distance at which the half-hour integrated airborne concentration exceeds the chosen exposure limits. The dispersion model selected depends on whether the METBI released is a buoyant or dense gas. Instantaneous releases of buoyant ideal gases have been modeled with Gaussian dispersion, which is a theoretical solution to the partial differential equations governing diffusion. This Gaussian dispersion model relies on characterizing the meteorological conditions according to atmospheric stability and wind speed. The continuous releases of buoyant gases and both the instantaneous and continuous releases of denser-than-air gases are being modeled with the SLAB code (Ermak 1988). The SLAB code solves modified forms of the mass/energy conservation equations.

A generic atmospheric dispersion graph for hypothetical METBI Material X is shown in Figure 1. In Figure 1, the packaging leak rate which produces a maximum 30-minute average downwind airborne concentration equal to a selected exposure limit is graphed as a function of downwind distance from the release. The critical leak rate for each METBI is analogous to the A2/week leak rate used in RAM transport.

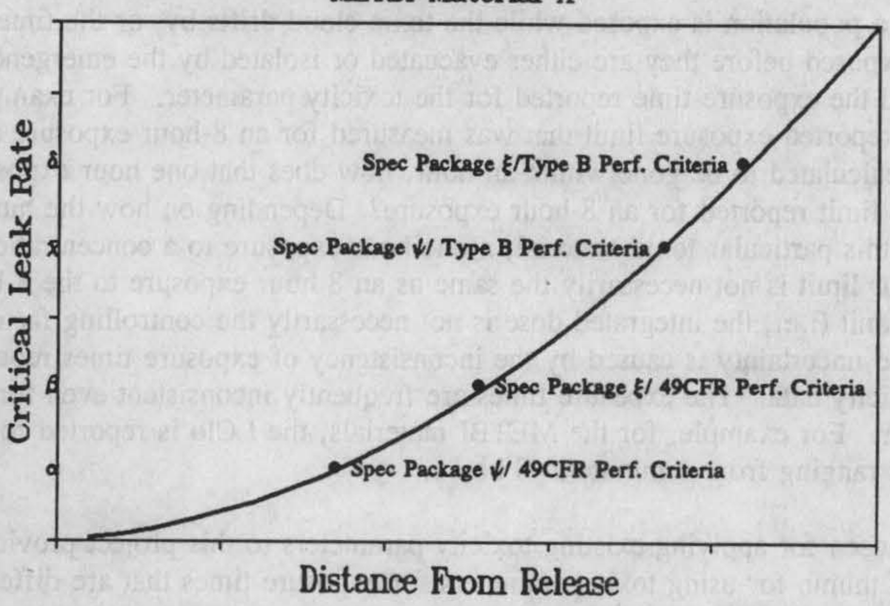

Figure 1. Critical Packaging Release Rate versus Distance At Which 30-minute Exposure Limit Occurs for METBI Material X

For this project, the exposure limits have been chosen such that harmful effects are not expected to occur from a 30-minute exposure. This is based on the assumption that the emergency responders can intervene within this time. Figure 1 provides quantitative evaluation of the effect of leak rate on the distance away from the release (which, if population density is known, relates to number of people) exposed to levels in excess of the exposure limit.

The estimated leak rates for the existing specification packagings can also be plotted as shown in Figure 1. For example, Specification Packaging Design ψ may be expected to experience a particular leak rate when exposed to 49CFR performance tests. The same specification packaging may be expected to experience a different leak rate if exposed to Type B performance tests. In addition, Specification Packaging Design ξ may be expected to experience different leak rates than Specification Packaging Design ψ when exposed to the same loading conditions. When plotted as shown in Figure 1, this provides a relative comparison of the level of safety provided by the different specification packagings.

A performance-based packaging standard can be defined for the hypothetical METBI material X such that the packaging must be able to sustain the 49CFR without leaking more than α and Type B loading conditions without leaking more than β, as shown in Figure 1. Since α and β represent the leak rates expected from the current specification packaging ψ, this type of performance standard would provide approximately the current level of safety associated with specification packaging ψ while changing the regulations from specification-based to performance-based. Furthermore, accident probability data can be used to estimate the probability of occurrence of the performance test conditions used to estimate the leak rates shown in Figure 1. This, in turn, can be used to estimate the probability of people being exposed to these levels. If it is desired to decrease the risks associated with hazardous material transportation, the methodology presented in this paper can be used to quantify the risk reduction provided by a given increase in the performance standards. The performance standards can be increased either by specifying a lower allowed leak rate or by specifying more strenuous (and, therefore, less probable) loading conditions for packaging certification.

CONCLUSION

In conclusion, two of the results of this hazardous material packaging performance evaluation project are the evaluation of the current specification packagings and the development of a methodology for selecting performance based packaging standards. The methodology being used gives a quantifiable measure for assessing the gains associated with increased performance standards. This methodology is especially useful for balancing the need to provide safe transport of hazardous materials without setting regulations so strict that the shipping industries can not afford to comply.

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