USE OF RISK ASSESSMENT IN ONSITE RADIOACTIVE MATERIAL TRANSFERS

Kenneth W. Stephens
Westinghouse Savannah River Company
Aiken, South Carolina 29808, USA 803/952-8358

ABSTRACT

Although the regulations governing packaging and transportation are requirements-based, there is a solid case to be made for using a risk-based approach to demonstrate safety-equivalence. The degree of risk acceptance implicit in the regulations can be calculated, and the risk results for a given situation can be compared against that number. If the risk from hypothetical onsite accident situations is less than the degree of risk accepted by the Department of Transportation for offsite shipments, then the case for safety-equivalence has been made. The viability of such an approach is being demonstrated at the Savannah River Site.

INTRODUCTION

In everyday life, ordinary people talk about risks. A mother says to her child, “Don’t cross that busy street—it’s too risky.” A wife says to her husband, “Why do you want to go skydiving? It looks risky.” All of us have an intuitive feel for risk, but when it comes to use of risk concepts in regulation, everyone becomes squeamish. The field of packaging and transportation is no exception.

This paper explores how a risk-based approach can be used for packaging and transportation and how it can be a useful tool to supplement simple requirements-based regulation. This approach is being demonstrated in a pilot project at the Savannah River Site, a Department of Energy (DOE) facility of about 300 square miles.

REQUIREMENTS-BASED REGULATION

The transportation regulations in use within the United States are based on those of the International Atomic Energy Agency (IAEA). The Department of Transportation (DOT) and the Nuclear Regulatory Commission (NRC) have in essence adopted the IAEA approach for regulating packaging and transportation of radioactive materials. That approach is perceived to have served the general public very well.

For operations within its own sites, DOE has Order 460.1A (and 461.1 for defense facilities), which is based on ensuring that onsite packaging and transportation is safety-equivalent to what DOT requires offsite for protection of the general public. Most observers would agree that there are some significant differences between dealing with a truck traveling public roads, and a transfer of radioactive materials on a controlled site, using trained workers, close communications, and quick access to emergency services. Nevertheless, the application of safety-equivalence in practice has been problematic. The IAEA (and DOT/NRC) approach to packaging safety centers around the A values, which are based on the results of hypothetical accident calculations. The A_1 and A_2 values for particular radionuclides were chosen such that if, for example, a package containing an A_2 amount of material is in an accident, a member of the general public could receive no more than 0.05 Sv (5 rem).

Application of the required safety-equivalence within a DOE site has, in many cases, been interpreted as meaning that in hypothetical accidents, the maximum allowable dose would be 0.05 SV (5 rem). That is a very restrictive criterion for application on a government site and is inconsistent with the practices followed for doses from nuclear facilities on the same site. Within IAEA, there has been considerable discussion regarding whether the 0.05 Sv (5 rem) criterion is even appropriate for members of the general public. In Safety Standards Series ST-2, this value was "retained," but IAEA acknowledged that it is conservative. Persons who have been involved with commercial nuclear power plants will recall that the NRC has long used 0.25 Sv (25 rem) as an evaluation guide for unmitigated releases to the general public. Thus, application of the 0.05 Sv (5 rem) value to workers on a controlled government site is extremely conservative. In fact, the IAEA has stated that such a practice is inappropriate.

In a practical sense, application of this criterion on DOE sites has had some unusual impacts. The scenario is as follows. If an accident has a frequency of occurrence of one in a million years (10^{-6}/yr) or less, it is considered Below Highly Unlikely. In such cases, it is acceptable to discount such accidents, because they are "incredible." However, if the hypothetical accident has a frequency greater than 10^{-6}/yr, and the calculated dose is greater than 0.05 SV (5 rem), then the result has been perceived as not meeting the safety-equivalence criterion specified by DOE Order 460.1A. In such cases, the way out has been to take compensatory measures to ensure that the accident frequency is kept below the magic frequency of 10^{-6}/yr. That may entail restricting the number of material transfers that can be accomplished in a given year, using escorts to reduce the likelihood of a particular accident (such as collision with a gasoline tanker), allowing transfers only during particular time of day so as to avoid heavy traffic, etc. Although such measures will certainly reduce the likelihood of an accident, they cause operational restrictions that can be very expensive, without commensurate benefit. For example, if an accident calculation results in a dose of 0.06 Sv (6 rem), the operational restrictions would not be justified by the relatively small difference between that dose and the target of 0.5 Sv (5 rem). By using the 0.05 Sv (5 rem) criterion, no distinction is made between an accident with a frequency of 10^{-3}/yr and 10^{-5}/yr, even though one is 100 times more likely than the other. Most people would agree that a 0.06 Sv (6 rem) dose for an accident that occurs once in 100,000 years is more desirable than a dose of 0.05 Sv (5 rem) that occurs once in 1,000 years.

A BETTER WAY

Given the above considerations, why does use of this extremely conservative dose-only criterion persist at DOE sites? The difficulty in quantifying safety-equivalence is the reason. How could it be better handled? We need only look to the experience of those who have applied risk assessment in a wide variety of industries over the past 30 or 40 years.

The concept of risk for this purpose is defined as:

$$\text{risk} = \text{frequency} \times \text{consequence}$$

Thus, if the frequency is, say, 10^{-5}/yr and the resulting dose is 0.04 Sv (4 rem), then the resulting risk is:

$$0.04 \times 10^{-5} \text{ Sv/yr} \quad \text{or } 4 \times 10^{-5} \text{ rem/yr}$$

Those of us working in the commercial nuclear industry in the early 1970's will recall how the NRC, in a period of rapidly increasing numbers of nuclear plants, wondered about the level of risk. They commissioned an investigation called the Reactor Safety Study (and in the vernacular, the Rasmussen report, named after Norm Rasmussen at MIT, who headed the study). That work was pioneering, because it accomplished two things:

First, it was unique in the size and comprehensiveness of such a study. Although the basic techniques had existed for a number of years, nobody had ever applied them in such a large effort.

Second, the project actually advanced the state of the art in probabilistic risk assessment.

The legacy of the Reactor Safety Study has been powerful. Its techniques have been applied in a wide range of applications, including not only the nuclear industry, but also the chemical industry.

APPLICATION OF RISK TECHNIQUES TO PACKAGING AND TRANSPORTATION

In view of the longstanding success of risk assessment techniques such as those described above, why then have they not been embraced for use with packaging and transportation onsite at DOE facilities? The major challenge has been development of a standard against which safety-equivalence can be judged. After all, the IAEA and DOT/NRC regulations have been requirement-based, rather than risk-based. How can the analyst handle this problem of "comparing apples and oranges"?

Even though the IAEA and DOT/NRC regulations are not overtly risk-based, they nevertheless represent a very definite, implicit degree of risk acceptance. For example, in DOT regulations, the presumption is that a Type A package will not necessarily withstand an accident. The A values are structured so that in such an accident, the maximum dose received by a member of the public is 0.05 Sv (5 rem). Accordingly, if one can calculate the frequency of such an accident, that frequency can be multiplied by the known dose consequence, and thereby the degree of risk acceptance associated with the DOT regulation can be ascertained. .

A number of studies have examined accident frequencies. One such study was performed by Argonne National Laboratory for the DOT Office of Hazardous Materials Technology. The study, entitled, "A National Risk Assessment for Selected Hazardous Materials Transportation," [1] was released in February of this year. The Argonne study is noteworthy because it recognizes that the identification and specification of such events can lead to substantial bias if not performed carefully. Accordingly, the authors reviewed previous studies to assess the current knowledge for specifying accident rates and release probabilities. After finding inconsistencies among several published studies, the investigators developed an alternative approach to the problem on the basis of an analysis of national commodity flow information and hazardous material release data. That approach largely eliminated the potential biases that have often resulted from combining different (and sometimes incompatible) data sources.

The Argonne study adopted accident rates ranging from 0.64/million truck miles (Interstate highways) to 9.1/million truck miles (urban areas). These equate to:

0.64×10^{-6}/mile to 9.1×10^{-6}/mile

If the truck travels only 10,000 miles per year, then the accident frequency range becomes:

0.64×10^{-2}/yr to 9.1×10^{-2}/yr

The Argonne study estimated that 0.082 of the hazardous material freight truck accidents were severe enough to result in a release. Thus, the frequency of accidents severe enough to result in a release ranges from:

0.52×10^{-3}/yr to 7.5×10^{-3}/yr

Given that the dose to a member of the public allowed by DOT in an accident involving Type A packages is 0.05 Sv (5 rem), the product of frequency and consequence becomes:

2.6×10^{-5} Sv/yr to 37.5×10^{-5} Sv/yr

Which is the same as:

2.6×10^{-3} rem/yr to 37.5×10^{-3} rem/yr

Thus, these numbers represent a conservative calculation of the degree of risk accepted by DOT for the transport of Type A radioactive materials. From the above derivation, one can reasonably conclude that DOT is accepting risks as great as:

37.5×10^{-5} Sv/yr (37.5×10^{-3} rem/yr)

APPLICATION IN ACTUAL CASES

In principle, one need only calculate the frequencies and consequences of accidents, do the multiplication to calculate the risk, and then compare the calculated risks against the above risk numbers associated with DOT compliance. If the calculated risks are below those numbers, then there is an *a priori* case for declaring safety-equivalence. If the calculated risks are above the DOT risk numbers, then other action will be required, e.g., do more refined calculations, add compensatory measures, etc.

On a pure risk basis, a single criterion for risk acceptance can be applied across the board for he entire spectrum of frequencies and consequences. However, people's perceptions of risk are distinctly non-linear. Accordingly, it may be necessary to modify the risk criterion for practical or "political" reasons. For example, a 5×10^{-5} Sv/yr (5×10^{-3} rem/yr) risk result may be perfectly acceptable if the dose consequence is 0.05 Sv (5 rem) and the frequency is 10^{-3}/yr. However, a dose of 5 Sv (500 rem) might not be perceived as acceptable, even at a frequency of 1×10^{-5}/yr. The risk is the same in either case. Of course, the only way someone would get that high a dose consequence would be to have a criticality. Clearly, having credible criticalities is not acceptable. This sort of philosophy is inherent in the philosophy for Type B casks. That is, the potential doses are so high, that additional protection (in the form of a more robust package) is needed.

PILOT APPLICATION OF RISK-BASED ANALYSIS

Here is an example of a situation in which risk-based analysis can be used to justify a departure from the traditional onsite analysis. In this case, the material being transferred is transuranic waste (TRU). Because the TRU typically contains radionuclides that are greater than one A_2, offsite shipment would require a Type B package such as the Trupact II. That is the package the Savannah River Site is using for shipments to the Waste Isolation Pilot Plant (WIPP). Much of the TRU at the Savannah River Site is stored in DOT 7A, Type A drums. The original plan was to transfer those drums onsite by using the Trupact I container (which is a large, rectangular truck-mounted box) designed for transporting Type B quantities. However, such transfers are relatively expensive, because there are rigorous requirements for leak testing before each transfer, high labor costs, etc. Because much of the volume of TRU at SRS really does not require remote handling and is considered low risk, the question was raised: "Is it acceptable to transfer such material onsite in Type A containers and still meet the criterion of overall safety-equivalence?" Once the risk-based approach to safety equivalence was developed, the use of Type A containers for transferring low-risk TRU became an excellent candidate for demonstrating the advantages of this approach.

The bounding accident consequences were developed using the following sequence: 1) the truck crashes, 2) the drums break completely open, 3) the drums and the contents of the drums burn in a fire, 4) the fire is extinguished, and 5) the drum contents are cleaned up within 24 hours. This scenario assumes an accident severe enough to overcome TRU waste drum containment.

The bounding accident frequency was calculated using the statistics for accident rates per mile, frequency of having an accident severe enough to breach the Type A containers, etc. The approach is basically the same as was outlined above. Given such information, the probability of a release from a Type A container under these conditions was found to be approximately 10^{-7} per year. Because that low frequency is Below Highly Unlikely (incredible), there might have been a case for declaring success. However, the analysts looked at the number and timing of the range of anticipated transfers. Given even a very generous projection of the transfers, it soon became obvious that the dose consequences would not be restrictive at all. Thus, the calculation was arbitrarily based on limiting the dose to 0.05 Sv (5 rem) and then calculating the maximum allowable number of drums per shipment and the allowable number of shipments. Those allowable numbers of drums and shipments are not at all restrictive compared to the needs at the Savannah River Site.

The irony of this pilot demonstration is that it would not have been considered at all if the risk-based approach had not been developed. Yet, the end result was shown to meet even the old, highly conservative 0.05 Sv (5 rem) criterion. The risk of these transfers is at least four orders of magnitude less than what was derived earlier as an acceptable degree of risk, vis a vis the level of risk implicitly accepted by DOT for offsite shipments.

SUMMARY

A risk-based approach can be used to demonstrate safety-equivalence in the context of the DOE Order governing onsite transportation. The degree of risk acceptance implicit in the DOT regulations can be calculated, and the risk results for a given situation can be compared against that number. If the calculated risk is less than or equivalent to that accepted by DOT, then the case for safety-equivalence has been made. The viability of such an approach is being demonstrated at the Savannah River Site and is suitable for use at other sites as well.

REFERENCES

[1] D.F. Brown, W.E. Dunn, and A. J. Policastro, “A National Risk Assessment for Selected Hazardous Materials Transportation,” Argonne National Laboratory, ANL/DIS-01-1, December 2000.