Hazardous Materials and the Fire Community: A Need for Better Understanding of State of the Art Software

John F. Moskal
Marian H. Long
Georges A. Melhem

Arthur D. Little, Inc.
Cambridge, Massachusetts, U.S.A.

NFPA Fall Meeting
November 16 - 18, 1992

Introduction

In 1990, the U.S. fire service responded to over 200,000 hazardous materials incidents. During the 1980's, many fire departments began developing hazardous materials response capabilities. Although hazardous materials incidents account for only 1 to 2 percent of total responses, they are rarely simple or straightforward operations and a significant amount of planning, training and equipment are involved in developing and maintaining a hazardous materials team. A recent example of this was the train derailment that took place near Duluth, Minnesota in June, 1992. An estimated 50,000 people fled their homes as a result of the event. The derailment led to a toxic cloud estimated at 20 miles long that affected the city of Duluth and was one of the nation's largest hazmat evacuations. Although no lives were lost, some have said that some of the emergency responders' equipment perhaps was inadequate and the response could may well have been an overreaction.[7]

Defining the Need

In order to avoid being caught off guard for a hazmat incident (either over-reacting or under-reacting), the parties involved with the response need to be adequately prepared. Preparation involves identification and assessment of potential hazards in a community, education and training, budgeting, selection of proper personal protective equipment and myriad other topics. Lately, however, preparation for hazardous materials incidents and emergency response has involved the use of computers.

With the growth of the personal computer industry in the 1980's, many different kinds of software having applications to spill response were developed.[2] The products ranged from chemical databases to mathematically complex consequence models. Hazard analysis or consequence models, which are the topic of this paper, are not as easy to use or understand as databases. There has been a well documented history over the last several years of the use of computers on-site during emergency response operations. Many computerized systems are offered as on-site tools. The concept is that the first responder (usually the fire department) would be able to get critical information on the chemical(s) involved in the incident and/or predict how far to evacuate, if necessary.[2]

Some computer software packages include site specific data such as information on the quantity and location of hazardous materials at a specific facility (the same type of information provided on Tier Two reporting forms required under SARA Title III in the United States).[1] Many of these applications are interesting and useful.

However, decisions at hazardous materials incidents need to be made quickly, and as a result, may preclude the use of computers at the incident. First responders, usually fire departments, typically arrive on scene soon after an incident and must make decisions on evacuations quickly. As consequence models become more complex, the number of variables needed for input to a scenario and the amount of time the computer needs to make the necessary calculations make the use of computers at an incident impractical. That is not to say, however, that they should not be used at all. The fact that the models have become more complex and require more in the way of input means that the results and predictions are also more accurate. The trick is to take advantage of what the computer and modelling software have to offer without compromising the quality of response to an incident or the health and safety of those involved. Given the current state of the art in source term, dispersion, fire and explosion modelling, their use is best utilized in the emergency response planning stages.[1] The models can also be a tremendous asset in developing contingency plans required under SARA Title III.

Industry is also increasingly using computer models to get a more realistic estimate of potential consequences. Local Emergency Planning Committees or LEPCs (bodies created under SARA to work with industry and the community concerning planning for hazmat incidents), fire departments and industry can use these models to work together to develop detailed, site specific estimates of potential consequences resulting from hazardous materials incidents. Fire departments and LEPCs can also work with industry to check each others assumptions to make sure that the estimates are accurate (e.g. weather conditions, release temperature and pressure, release amounts, etc). Not all communities have LEPCs or paid fire departments and as a result, it may be left up to industry to work with the community and volunteer fire departments to plan for these types of incidents.

Just as fire departments must analyze their need for a hazardous materials team,[4] the fire department and/or LEPC must also analyze their need for computer support before committing the financial resources necessary to obtain the hardware and software adequate to fully take advantage of the available models. There are several types of spill models on the market that offer varying degrees of complexity and range in price from free to the $20,000 range. In tough economic times, money is in short supply. However, intelligent selection and proper use of a modelling package may allow financially strapped organizations to save money elsewhere (e.g. selection of personal protective equipment) and prevent over-reaction to hazmat incidents as was described earlier. Some of the models are simple to use and others require significant modelling experience to understand and run. Therefore, another issue that needs to be addressed when considering purchasing and using one of these packages is the level of expertise of the user(s).

Consequence Analysis and Consequence Models

The next topic to address is the software package itself. As was mentioned earlier, hazard analysis or consequence models and chemical databases are the two major types of software in this market. Caution must be used when purchasing a modelling package. There are several hazard analysis models on the market that range in use from predicting the impacts of large oil spills on water to predicting migration of chemicals through soil and groundwater. The types of models that are most applicable to spill response planning are those that predict chemical movement through the environment and the concentration at a particular time and location. In addition, these are usually used in combination with source term, fire and explosion models that can predict distances to specified thermal radiation or overpressure values.

As stated earlier, LEPCs are required to develop contingency plans under SARA Title III. The models are best used in the process of scenario development and evaluation. Potential scenarios would be developed based on information provided on the amounts and types of hazardous materials stored and transported in a given area. Once credible scenarios are developed, they can be evaluated to see what the potential consequences are. Assumptions must be credible and scenarios realistic or the output from the model will not be representative of what would happen during a hazmat incident. An example of this would be the loading of Liquefied Petrloeum Gas (LPG) at a facility. Usually, the tanker delivering the LPG contains a larger amount of the material than is stored on-site. In addition, incidents are more likely to occur during transfer operations (usually due to human error). Therefore, analysis of potential releases at the site should include analysis of the potentially larger release from the tank truck or railcar that is unloading the material. Consequence models would allow an analyst to estimate the potential consequences resulting from a release of a hazardous material.

Consequence modelling can be defined as the use of mathematical representations of conservation and physical laws to analyze and quantify potential damaging effects of hazardous events, usually by loss of containment. There are several types of models that can be used for many potential scenarios. The goal of using a consequence model is to estimate the potential impacts of a hazardous materials release. In order to do this, the user must determine the impact of interest (fire, explosion, toxic dispersion, etc.), identify factors affecting its impact and identify as appropriate model to estimate the magnitude of those impacts. There are also different models of varying complexity that can be used for the same events. Both screening level and detailed models are available. Good models for the situation at hand will accurately describe the phenomena being studied, not require the use of unavailable data and yield results in a useful form. The types of models that will be discussed in the remainder of this paper are source term, dispersion, fire and explosion models.

Source term models characterize the important features of the initial release and provide necessary input to the other models. Important information that is used as input for source term analysis are such things as the amount of material discharged, the rate of discharge (instantaneous or continuous), temperature and pressure. This information will allow the user to accurately characterize the release. Source term models address topics such as the formation and spreading of liquid pools and resultant evaporation and boiling off of material, the actual amount released, two phase flow, and temperature and pressure inside the pipe or vessel, at the release point, and immediately outside the pipe or vessel. An example of this would be the initial drop in temperature resulting from the release of a liquefied gas. Source term models also address intermediate phenomena such as gas expansion, two-phase flow, aerosolization, rainout and entrainment.

Dispersion models enable the user to predict the path and size of a plume of a cloud of a toxic or flammable gas or the vapors evaporating off of a spreading liquid pool. The models can predict downwind travel to such concentrations as the lower flammable limit of the material or specified toxic concentrations (e.g. the IDLH) at various times after the spill has taken place. The resultant plume can then be superimposed over a map of the area of concern to determine affected areas (e.g. sensitive population centers such as schools and hospitals). When using a dispersion model, the user must be careful to choose the limiting concentration. Values such as the lower flammable limit (LFL) are straightforward, but choosing a limiting concentration for toxic hazards can be more complex. Toxicity data can be limited on many materials. In addition, the duration of potential exposure also needs to be considered. Dispersion models are also sensitive to such factors as temperature, pressure, humidity, etc.

Fire and explosion models can predict other consequences of hazardous materials incidents. Releases of hazardous materials often result in the potential for a fire or explosion. These models can predict distances of concern for such consequences as thermal radiation from liquid pools that have ignited, distances to specified radiant heat values for fireballs, and overpressure distances from vapor cloud explosions. Important material characterisitcs used in fire modelling are flash point, autoignition temperature, ignition energy, the flammability limits (LFL and UFL), and the heat of combustion. The types of models used for fires are pool fire, flame jet, fireball and vapor cloud fire models. Damage criteria used in fire models are injury to people, ignition of combustibles and damage to structures or equipment. Damage can be caused by steady state radiation from pool fires or flame jets or unsteady radiation from fireballs and vapor cloud fires.

Explosion models allow the user to model deflagrations, detonations and Boiling Liquid Expanding Vapor Explosions (BLEVEs). These results can be used in the same way as the dispersion models as well as to gauge the potential for damage to buildings and other infrastructure based historical information as to what they can stand (e.g. the minimum amount of overpressure to break the glass in a car windshield).

Conclusion

Consequence models, if used properly, can be an invaluable tool to fire departments that can give them accurate estimates of the potential consequences that may result from hazardous materials incidents to which they may be called on to respond. Their use for LEPCs in the development of response plans required under SARA Title III and for emergency planning in general is also of great benefit, as they provide a technically sound basis for any decisions that are made regarding planning for hazardous materials incidents. As you look towards the future, making intelligent decisions regarding planning for hazardous materials emergencies will become more important. The advantages provided to emergency response organizations by consequence modelling packages should not be overlooked. Proper use of these applications in the emergency response planning stage will facilitate timely and efficient response to hazardous materials emergencies and reduced risk to fire service personnel and the general public.

Suggested Reading

1. Bishop, J., "ER Planning; Computer Systems Allow Integrated Planning, Real-Time Aid in Emergency Response," Hazmat World, July, 1991, p. 48.

2. Fingas, M., "Computer Models and Data Bases for Spills," Spill Technology Newsletter, April-June, 1989, p.4.

3. Fleischer, M., "Mathematical Modelling of Chemical Spills on Land; Predicting Evacuation Zones in the Main Objective of SPILLS," Ecolibrium, 11(4), 1982, p. 10.

4. Isman, W., "Analyze Your Need for a Haz-Mat Team," NFPA Journal, September/October, 1991, p. 18.

5. Newsom, D., "ARCHIE Promotes Dialogue between Industry, LEPCs," Hazmat World, July, 1991, p. 53.

6. Tokle, G., Henry, M., "Where do we Stand on Haz-Mat Response?,"NFPA Journal, January/February, 1992, p. 36.

7. "Toxic Spill Challenges Emergency Response Teams," Hazmat Transportation News, July 6, 1992, p. 111.

8. Wilms, P. "Surveying Today's Fire Service Software," NFPA Journal, May/June, 1991, p. 91.