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AN ASSESSMENT OF THE RISK OF HAZARDOUS MATERIALS RELEASE DURING EARTHQUAKE - THE IMPACT ON SURROUNDING COMMUNITIES

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SUMMARY

The University of Southern California, with a subcontract to Dames & Moore, is performing a research study to investigate the risk of hazardous materials release during earthquake and the impact such releases would have on surrounding communities. The study focuses on the greater Los Angeles area. The specific goals of the project are to:

1. Estimate the probability of hazardous materials releases that could pose a threat to area residents following a major southern California earthquake.

2. Estimate the size of the population that would be affected by earthquake-caused hazardous materials releases.

3. Describe hazard mitigation policies and emergency preparedness measures that currently exist to respond to the problem.

4. Outline potentially effective and acceptable policy and management options in this area.

This paper describes the chemical facility models that have been developed to date and presents materials on likely failure modes and probabilities in chemical processing and storage/transfer facilities. The paper closes with a discussion of plans for later phases of the project. The project is sponsored by the National Science Foundation, Grant No. ECE-8600292. Dr. William A. Anderson is the Program Officer.

INTRODUCTION

A major earthquake in an industrialized, densely populated area of the U.S. could lead to the release of hazardous chemicals, presenting a threat not only to those in the immediate area but also to residents of the surrounding community. Earthquakes can damage chemical storage and processing systems, start fires, and adversely affect emergency response capability. Communities typically are faced with responding to single hazardous materials releases, but in an earthquake situation, multiple accidents could occur simultaneously, compounding response problems. Hazardous materials releases have occurred even in moderate earthquakes. The release of nearly one ton of chlorine gas in the M5.9 October 1st Whittier Narrows earthquake is a recent example.

With increased public concern about accidental toxic releases, there is a need for systematic research on all factors that contribute to their occurrence, including the role of earthquakes. However, there has been very little research to date on seismic sources of hazardous materials releases, and seismic vulnerability models for chemical facilities are virtually nonexistent.

Conducting detailed seismic risk assessments and modeling potential failures is likely to be extremely time-consuming and costly; few communities can afford to conduct such studies. Our objective was to develop a method that is feasible to use by local jurisdictions (cities and counties) and that would enable these communities to determine which areas in the community are most susceptible to earthquake-generated releases.

The problem is almost bewilderingly complex. Highly hazardous materials number in the thousands, and new products are constantly being added. To make our task manageable, we decided to focus first on only two hazardous materials, chlorine and anhydrous ammonia. These two substances were selected for two reasons. First, they are present in the Los Angeles area in large quantities. Second, when accidentally released, they form clouds that spread to adjacent areas, posing a hazard to the population. In part, because of the quantities that are usually involved in airborne releases, chlorine and ammonia are responsible for the majority of fatalities and casualties in U.S. hazardous materials accidents.

Adding to the complexity, hazardous chemicals are found in many types of settings, including chemical plants, other manufacturing facilities that use chemicals, storage facilities, transshippment sites, and various transportation media (e.g., railways, pipelines). Conducting analyses of all such facilities would be truly daunting. For purposes of simplification, we confined our attention in this pilot study to fixed sites, primarily chemical processing and storage/transfer facilities. Obviously, different models would be necessary for other types of facilities and for lifelines containing hazardous substances.

The final sample of facilities selected for the study consisted of the 22 largest users of chlorine and ammonia in the greater Los Angeles area. All chlorine handlers had at least five tons of chlorine on site at any given time; the largest facilities had hundreds of tons of the substance. Anhydrous ammonia inventories ranged from two to forty tons.

METHODOLOGY

The overall strategy we developed for assessing the hazards associated with these chemical substances and this group of facilities involves seven steps (Fig. 1):

1. The use of data on inventories of hazardous materials, which are required by State laws in California, to identify where plants handling large quantities of the two hazardous chemicals are located.

2. The use of existing data on probable ground shaking intensities associated with probable southern California earthquakes.

3. The development of "generic" models of chemical processing facilities, and storage and transfer facilities.

4. The assessment of the earthquake vulnerability of such facilities.

5. The use of existing models for predicting the behavior of the airborne toxic clouds that would be released from a facility in the event of an earthquake-generated failure, assuming various atmospheric conditions.

6. The use of census data on population size and density in the geographic areas that are likely to be affected by the earthquake-generated releases.

7. The collection of data on local emergency response capability should a release occur following an earthquake and on the policy preferences of key actors responsible for managing the hazard.

After going through all these steps, we anticipate being able to:

1. Show which areas of the community are likely to have the most problems with airborne releases given different ground shaking intensities.

2. Identify the segments of the population that would be at risk in the event of one or more earthquake-generated accidents.

3. Indicate the extent to which key emergency response organizations in the public sector and industry safety personnel are prepared for such incidents.

GENERIC FACILITY MODELS

In this paper, two generic chemical facilities are discussed: chemical processing, and storage and transfer. Fig. 2 shows a simple flow chart of the major components of a processing facility. In general, this type of facility is comprised of many elements, however, the purposes of performing the present vulnerability analysis, only four components are significant: (1) pressurized chemical storage vessel; (2) exothermic reactor; (3) temperature control system; and (4) regenerator/separator. The selection of these particular components is based on their potential for releasing large quantities of hazardous material. Other components within the facility are also capable of releasing chemicals; however, not in large quantities. The second chemical plant model is a simple storage and transfer facility. In this type of plant, no manufacturing or processing takes place.

In developing these generic models, information on Los Angeles area chemical plants was used. By and large, there are many similarities among chemical processing facilities in Los Angeles. For example, these facilities generally follow the same process operations and are generally comprised of the same types of elements. These facilities use gaseous toxic chemicals as reactants in the manufacturing process. Examples include plants using chlorine gas as a reactant to form chlorinated hydrocarbons and plants using hydrogen flouride as a reactant to form freons (chlorofluorocarbons). Because the basic processing steps are similar (i.e., pressurized storage and transfer, reactions involving toxic gas, and post-reaction separation), the development of a generic chemical processing facility model was possible. Development of a model of chemical manufacturing facilities, on the other hand, is a complex task requiring the identification of more critical elements and steps. Since no manufacturing facilities exist in the Los Angeles area, the development of generic models for this type of facility was not pursued.

FRAGILITY MODELS

Fragility is defined as the likelihood of failure or damage. The use of this term has been quite extensive in the nuclear power plant field. Generally, probability curves are developed which associate the probability of occurrence of individual or combined failure modes with different levels of seismic loading (e.g., peak ground acceleration, Modified Mercalli Intensity, etc.). For complex facilities, it is not possible to identify just one or two failure modes which can lead to some overall failure level. Instead, all possible failure modes must be identified and their individual contribution to overall facility failure must be systematically added. For purposes of this type of vulnerability assessment, fault tree analysis has been useful. In this type of analysis, boolean techniques are utilized to model the interdependency of individual component failures. Cases where several failure modes must exist for some "fault" to occur are modeled using "AND" gates. Cases where some "fault" can occur as a result of one or more failure modes are modeled using "OR" gates. For the present example, the overall failure or fault is the release of significant toxic material. The relevant fault tree models for storage and transfer facilities, and chemical processing facilities are provided in Figs. 3 and 4, respectively. The probabilities of failure for each of the failure modes identified in Figs. 3 and 4 are now being computed as a function of various levels of earthquake shaking. The final set of curves for this step will be probability curves giving the probability of significant toxic chemical release as a function of peak ground acceleration for chemical storage and transfer, and processing facilities.

FUTURE WORK AND USE OF RESULTS

Future steps include the development of a regional vulnerability model, selection of an appropriate air dispersion model, and the development of a methodology for integrating the risk of hazardous materials releases from multiple chemical facility accidents. This methodology will then be applied to the Los Angeles area using hazardous chemical inventory data compiled by the South Coast Air Quality Management District in Los Angeles, and the City of Los Angeles Fire Department. The results of this analysis are expected to be used by key emergency response organizations in the public sector and industry safety personnel.

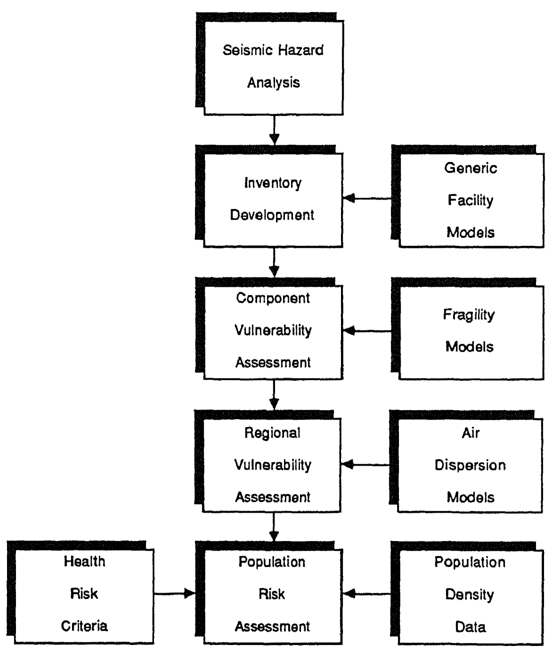

Figure 1 - Methodology For Risk Assessment Of Hazardous Materials Release During Earthquake

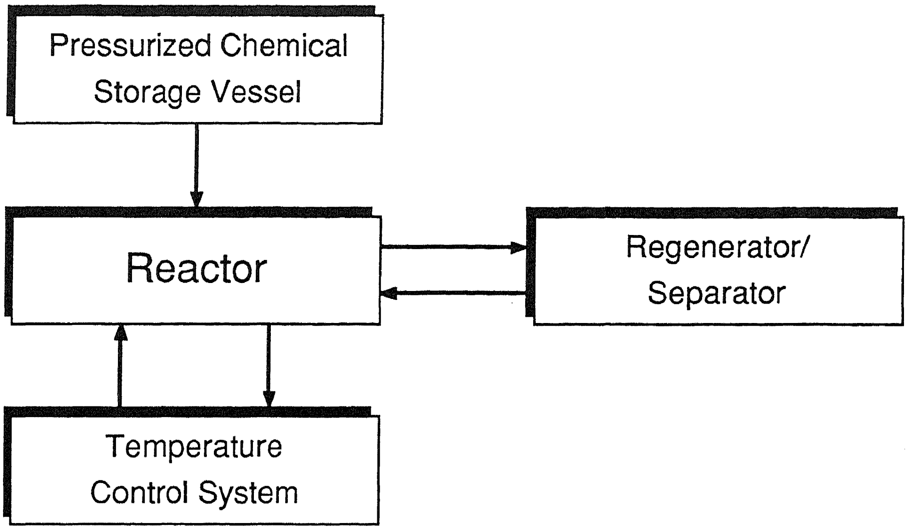

Figure 2 - Simple Flowchart of Chemical Processing Facility

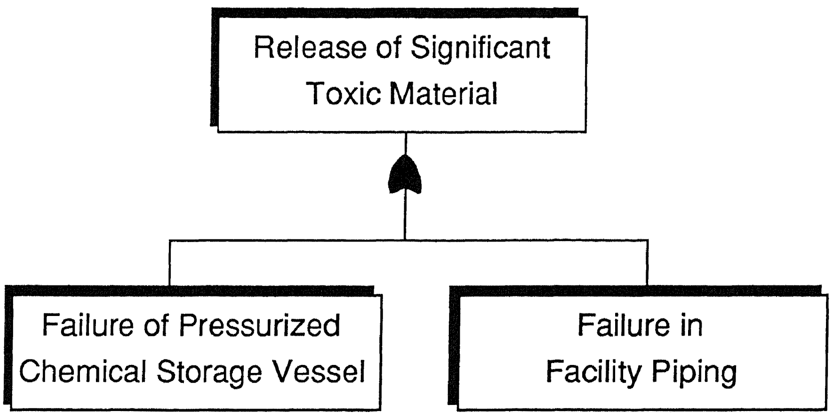

Figure 3 - Fault Tree Model for Toxic Chemical Release for Storage and Transfer Facilities

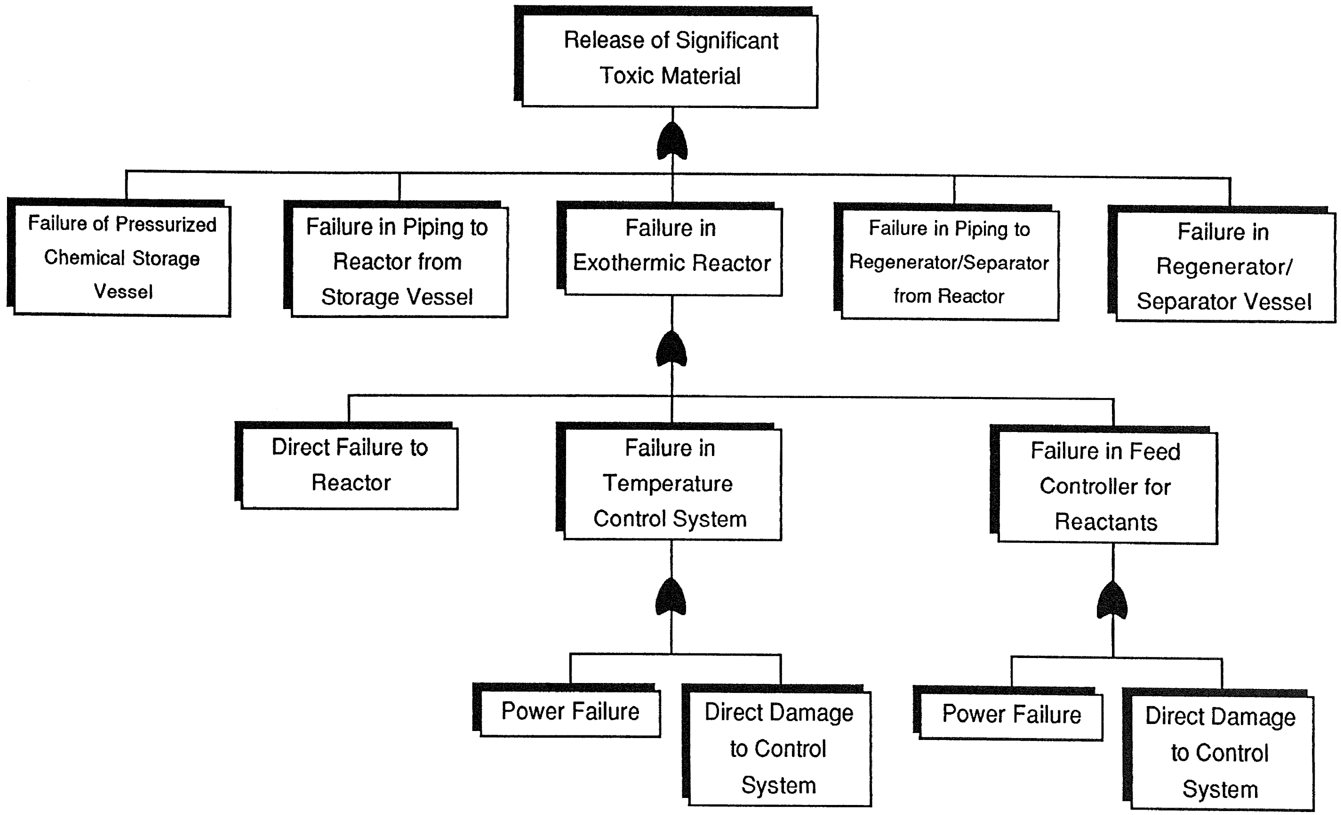

Figure 4 - Fault Tree Model for Toxic Chemical Release for Chemical Processing Facilities