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From: Margaret Rogers

Date: June12, 1989

Subject: Acute hazardous events database — source of chemicals listed in Senate Air Toxics Legislation

Exploring on behalf of the Vinyl Institute the basis for the inclusion of polyvinyl chloride in the catastrophic release section of the Senate Air Toxics Bill, S.816, I learned that the basis for the chemicals listed is a draft document referenced above prepared by an EPA contractor. The purpose of the project begun at EPA several years ago was to "prevent another Bhopal."

In addition to polyvinyl chloride being listed, styrene, methylene chloride, and toluene diisocyanate are listed as well. There may be other chemicals of concern to the plastics industry. I just received this document June 9 and SPI staff is currently reviewing it.

The EPA staff in charge of the project believes it is a flawed database and needs significant investigation and correction to be developed into a useful database.

I look forward to discusing this document with you.

cc: Lew Freeman, SPI
Pat Toner, SPI

"(1) a status report on standard-setting under subsections (d), (f), and (g);

"(2) information with respect to compliance with such standards including the costs of compliance experienced by sources in various categories and subcategories;

"(3) development and implementation of the national urban air toxics program;

"(4) recommendations of the Chemical Safety and Hazard Investigation Board with respect to the prevention and mitigation of sudden, accidental releases; and

"(5) such recommendations for additional legislation to achieve the purposes of this section and section 129 as the Administrator may deem appropriate.

"(r) AUTHORIZATION.—There are authorized to be appropriated such sums as are necessary to carry out the provisions of this section.".

SEC. 3. The Clean Air Act is amended by adding the following new section:

"PREVENTION OF SUDDEN, ACCIDENTAL RELEASES

"SEC. 129. (a) PURPOSE AND GENERAL DUTY.—It shall be the objective of the regulations and programs authorized under this section to prevent the sudden, accidental release and to minimize the consequences of any such release of any substance listed pursuant to subsection (b) or any other

extremely hazardous substance. The owners and operators of facilities producing, processing, handling, or storing such substances have a general duty to identify hazards resulting from such releases using appropriate hazard assessment techniques, to design and maintain a safe facility taking such steps as are necessary to prevent releases, and to minimize the consequences of sudden, accidental releases which do occur. Nothing in this subsection shall be interpreted, construed, or applied to create any liability for compensation for bodily injury or property damages to any person which may result from sudden, accidental releases of such substances.

"(b) LIST OF SUBSTANCES.—The Administrator shall, not later than twelve months after the date of enactment of this section, propose and, not later than twenty-four months after such date, promulgate, a list of not less than fifty substances which may, as the result of sudden events, be released in concentrations that may reasonably be anticipated to cause acute adverse health effects in humans. The list shall be drawn from, but not be limited to, those substances on the list established by section 302 of the Emergency Planning and Community Right-to-Know Act of 1986 and shall include those substances with the greatest likelihood to cause death, injury, property damage, or evacuations as the result of sudden, accidental releases. The initial list shall include *sulfuric acid, chlorine, anhydrous ammonia, hydrochloric*

acid, sodium hydroxide, methyl chloride, phosphoric acid, ethylene oxide, toluene, vinyl chloride, methyl alcohol, nitric acid, styrene, tetrachloroethylene, ammonia, hydrogen sulfide, acetone, methylene chloride, benzene, methyl ethyl ketone, toluene diisocyanate, phosgene, polyvinyl chloride, sulfur dioxide (10 per centum or more by volume), formaldehyde, butadiene, hydrofluoric acid, and acrylonitrile. The Administrator shall from time to time (but not less often than every five years) review and revise the list established by this subsection adding substances which, as a result of sudden events, may be released in concentrations that may reasonably be anticipated to cause acute adverse health effects in humans. At the time any substance is placed on such list, the Administrator shall establish a threshold quantity for such substance, taking into account the toxicity (including short- and long-term health effects), reactivity, volatility, dispersibility, combustibility, or flammability of the substance.

"(c) HAZARD ASSESSMENTS.—

"(1) Not later than twelve months after a substance is listed under subsection (b), the owner or operator of each facility at which such substance is present in amounts greater than the threshold quantity shall conduct and complete a hazard assessment for each such substance present at the facility. The purpose of such assessment shall be to anticipate the consequences

DRAFT 31 August 1988

DRAFT FINAL

ACUTE HAZARDOUS EVENTS DATA BASE

(1988)

Prepared for:

Office of Policy Analysis

Office of Policy, Planning and Evaluation
U.S. Environmental Protection Agency
under
EPA Contract No. 68-W8-0038

Prepared by:

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

31 August 1988

ACUTE HAZARDOUS EVENTS DATA BASE

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APPENDICES

EXECUTIVE SUMMARY

PROJECT BACKGROUND

The Acute Hazardous Events Data Base (AHE/DB) has been assembled as one component of EPA's ongoing effort to assess and respond to dangers posed to the U.S. public and workers by sudden, accidental releases of toxic chemicals. The initial AHE/DB contained 3,121 event records, which through data sampling represented 6,928 events. An interim final report issued in December, 1985, titled "Acute Hazardous Events Data Base" (EPA 560-5-85-029), presented the analytic results obtained using the 1985 version of the AHE/DB.

Since 1985, the AHE/DB has been expanded by Industrial Economics, Inc. and adapted for use in support of Title I and Title III applications under the Superfund Amendments and Reauthorization Act (SARA) of 1986. The principal enhancements were to substantially expand the number of records and to augment the AHE/DB with supportive data bases containing information on the chemicals and companies involved in the reported events. These enhancements enable the AHE/DB to be more effectively used in supporting the mandates of the Accidental Release Information Program (ARIP), the activities being undertaken in the realm of Community Right-to-Know, and other applications being implemented by EPA.

Because of EPA's primary interest in events similar in some ways to the accident in Bhopal, several criteria were used to screen event data for inclusion in the AHE/DB. Emphasis was placed on incidents that had acute hazard potential, with incidents resulting in deaths, injuries, or evacuations given highest priority. Events that resulted in releases of hazardous chemicals were given priority, and those that released petroleum related and other types of substances were not included. Priority was also given to incidents involving air releases of chemicals. Events releasing large quantities of chemicals were given priority and events with releases of less than one pound of materials were not included.

AHE/DB CHARACTERISTICS

The 1988 version of the AHE/DB contains 6,305 records, which through sampling represent 11,048 separate events. The data come from 41 sources. National sources include the National Response Center (7,755 events), United Press International and Associated Press (286 events), and DOT's Hazardous Materials Information System (171 events). Other sources included EPA's

Region 7 (510 events), 26 daily newspapers (340 events), and six offices of five state governments (1,855 events). AHE/DB records encompass the period from before 1980 to 1987. However, the major data gathering effort focused on the five-year period from 1982 to 1986. The AHE/DB contains an average of 2,100 events per year for that period, ranging from 1,515 events for 1982 to 2,638 events for 1984.

The Company/Facility (COMFAC) Data Base contains information on facilities involved in the AHE/DB events. This information includes: facility name, address, unique hierarchical identifier containing the three-digit zip code for the facility and an indication of any parent/subsidiary relationships, and four-digit Standard Industrial Classification (SIC) for that facility. All facilities in COMFAC were classified into one of five categories: primary producers (facilities that produce chemicals); secondary producers (facilities that use the chemicals to produce another product); distributors; end users; and waste-related activities.

The Chemical (CHEM) Data Base contains information on the chemicals involved in the events in the AHE/DB. This information includes: chemical name, Chemical Abstracts Service (CAS) number, four-digit SIC of the originating industry, commodity or specialty chemical designation, and production characteristics. In addition, CHEM contains chemical property information such as: toxicity data, including "Immediately Dangerous to Life and Health" (IDLH) concentrations; physical characteristics, including vapor pressure, boiling point, melting point, and air half-life estimates; and hazard ranking information, including National Fire Protection Association reactivity and flammability rankings. CHEM also identifies whether or not that chemical is listed under RCRA, CERCLA, or SARA (Titles 302 and 313).

CHARACTERISTICS OF THE MORE SEVERE EVENTS

Altogether, 309 deaths are reported in the AHE/DB, plus 11,341 injuries. In the 6,567 injuries for which severity could be determined, 1,587 required hospitalization. Fire/explosion was the attributed cause almost four times as often in death/injury (D/I) events as for all events, accounting for one-fifth of the D/I events. Equipment failure was the reported cause of slightly less than half of all events, and somewhat less than one-third of the D/I events. Operator error was the reported cause in approximately one-fifth of all events and D/I events.

In-transit incidents play a slightly larger role in death/injury events than they do in overall events -- 37 percent versus 29 percent. Among in-transit events, truck transport represents a significantly increased share (66 percent versus 49

percent) and rail transport a decreased share (28 percent versus 44 percent) for events resulting in deaths/injuries as compared to all in-transit events.

Although primary producers rank second in number of death and injury events, they account for the largest share (39 percent) of events in which deaths occur. Distributors, who account for the largest number of death/injury events, account for only 7 percent of the fatalities. End users and secondary producers rank second and third in responsibility for fatalities, accounting for 21 percent and 9 percent of the deaths, respectively. Waste disposal activities account for 2 percent of the fatalities. Nineteen percent of deaths occur at facilities of unknown type.

Primary producers again rank first with regard to number of injuries -- 3,377 injuries occur at such facilities, representing 30 percent of the total. Distributors rise to the second rank when injuries are considered, accounting for 25 percent, and secondary producers account for 17 percent. End users and waste disposers account for 9 percent and less than 1 percent of the injuries, respectively. Eighteen percent occur at facilities of unknown type.

When the quantities released in death/injury events are compared to the reportable quantities (RQs) of the participating chemicals, 37 percent of the D/I events in which quantities are reported involve quantities less than the RQ, i.e., the release of such quantities usually would not be considered of sufficient concern to justify its report to the National Response Center or other jurisdiction. Only 13 percent of the D/I events involve chemical release quantities greater than 100 times the RQs of the involved chemicals.

Evacuations occurred in 855 of the total 11,048 events in the AHE/DB. Half of the remaining events did not have associated evacuations, and for an almost equal number of events it was not known whether an evacuation took place. The 29 media sources (26 newspapers, 2 wire services, and 1 trade journal) contributed 54 percent of the total number of evacuation records. In the 419 events for which the number of evacuees was identified, the total number of people evacuated was 464,677.

Injuries were associated with 40 percent of the evacuation events compared to only 9 percent of all events. Deaths were associated with 5 percent of the evacuation events compared to 1 percent of all events. For some of the evacuation events it was possible to distinguish between workers and non-workers evacuated. Of the 335,323 people evacuated in those events, 308,183 (92 percent) were residents and 27,140 (8 percent) were workers.

Distributors and primary producers account for the majority of evacuations. End users and secondary producers account for the next largest shares. Compared to their frequency of involvement in all events, distributors and end users have a higher frequency and primary producers a lower frequency of involvement in evacuation events. The rates for secondary producers and waste related are the same for all events and evacuation events.

Large Scale Domestic Release of Toxic Chemicals

Potential toxic effects vary with the toxicity and the quantity of substance released. Among the AHE/DB events, 3,415 have information on both quantities and acute toxicity. For those events, we divided quantity released by the IDLH value attributed to that chemical to establish an empirical measure of the potential toxic effects of each release. Using this measure, 29 AHE/DB events involved releases whose quantity-toxicity ratio was at least half that associated with the release at Bhopal, and 17 events involved releases whose ratio exceeded that at Bhopal.

Among the 29 high-damage-potential events, only one event reported deaths (five fatalities), six events reported injuries (ranging from one to 650 people injured), and five reported evacuations (up to 20,000 people). The average numbers of deaths, injuries, and evacuations were somewhat greater than among the AHE/DB subgroup of events reporting deaths, injuries or evacuations. However, given the vast quantity of materials released in the high-damage-potential events, the severity of these effects appears surprisingly low.

The difference between the potential for human harm and the actual consequences in these events appears to be due in part to combinations of the following factors: (1) the chemical's physical state at the time of release was liquid and much of the material remained liquid, or other physical/chemical properties prevented wide spread airborne exposure; (2) few people were close to the point of release; (3) weather conditions were favorable; (4) preparedness at the site of release included containment of materials released or other equipment or procedures to mitigate the extent of release and population exposure; or (5) evacuation or other community response may have removed potentially exposed victims. In addition, the data on these events are sometimes incomplete (e.g., the concentration of some materials released, such as sulfuric acid, may have been less than 100 percent); and quantity data represent in most cases best estimates that may overstate the actual quantity released.

Relationship of Event Severity to Chemical Properties

Acute chemical toxicity was characterized in CHEM using values compatible with the "levels of concern (LOC)" defined in EPA's CEPP Technical Guidance Document. Relative toxicity values were obtained for approximately 62 percent of the 681 chemicals in the CHEM Data Base. These chemicals account for 82 percent of the events in the AHE/DB. Chemicals in the highest toxicity group represent only 15 percent of the chemicals in CHEM, but account for over 44 percent of the total number of events in the AHE/DB. Approximately 75 percent of the injuries and 13 percent of the deaths reported for events in the AHE/DB have toxicity ascribed as the apparent cause. In contrast approximately 25 percent of the injuries and 87 percent of the deaths were apparently caused by fires or explosions.

1. PROJECT BACKGROUND AND DATA BASE CHARACTERISTICS

1.1 PROJECT BACKGROUND

The Acute Hazardous Events Data Base (AHE/DB) has been assembled as part of EPA's review of the dangers posed to the U.S. public and industrial workers by sudden, accidental releases of toxic chemicals. Concern regarding such releases was heightened by the accidental release of a pesticide intermediate that occurred on December 3, 1984 in Bhopal, India, killing over 3,000 and injuring over 200,000. Shortly thereafter, EPA formed an Acute Hazards List Workgroup to investigate the safety-related characteristics of the U.S. industry with regard to accidental chemical releases that could pose exceptional risks to human health, and to identify those chemicals that appear to represent unusually high risks. In late May of 1985 the decision was made to assemble an Acute Hazardous Events Data Base (AHE/DB) as part of the Acute Hazards Analysis review process.

An important factor in initial AHE Data Base development was the need for it to be assembled quickly in order to support other aspects of the analysis process. A team of three contractors was formed, with Industrial Economics, Inc. responsible for overall direction. The other two contractors were Management Technology and Data Systems, Inc. (MTDS) and PEI Associates, Inc. By mid-August, the AHE/DB had been expanded to 3,121 events, which through data sampling represented 6,928 actual incidents. An interim final report titled, "Acute Hazardous Events Data Base," (EPA 560-5-85-029) was issued in December, 1985, and copies of the data base itself were made available to the public at that time.

Since 1985, the AHE/DB has been expanded and adapted for use in support of Title I and Title III applications under the Superfund Amendments and Reauthorization Act (SARA) of 1986. The principal adjustments were to augment the data base with

additional data on the chemicals and companies involved in the reported events, and to substantially expand the number of records. These adjustments enable the AHE/DB to be more effectively used in supporting the mandates of the Accidental Release Information Program (ARIP), the activities being undertaken in the realm of Community Right-to-Know, and other applications being implemented by EPA. The changes made to the AHE/DB and associated activities undertaken include:

- Additional data from previously used and new sources were coded and added to the data base, more than doubling its size.

- All data in the AHE/DB was recoded to include additional information on events, such as discerning whether or not injured people required hospitalization, distinguishing between workers and non-workers evacuated during an event, and adding new categories describing the circumstances of release for events.

- Two new data bases related to the AHE/DB were developed to augment its analytical capabilities: one contains information on the chemicals involved, and the other describes facility characteristics.

- Events in the original AHE/DB were reviewed to determine the continued relevance with respect to the revised screening criteria for the data base. As a result, 3,489 events involving polychlorinated biphenyls (PCB's), and 122 reports of events releasing only petroleum related products (e.g., kerosene, fuel oil) were moved to separate data bases. The purpose was to strengthen the AHE/DB's focus on events involving toxic chemical releases with the potential for inducing acute health effects on the exposed population. This report excludes PCBs and petroleum products from the data summaries presented.

- Some events in the original AHE/DB were edited to correct and augment the information provided. Emphasis was placed upon "serious" events, those that led to deaths, injuries or evacuation, or involved large releases of highly toxic chemicals.

- A number of analytical studies were undertaken with the expanded AHE/DB, including development of descriptive statistics on evacuation events, appraisal of the relationships

between event characteristics and chemical properties, and assessment of the type of facilities at which the accidents occurred.

o Work has begun on developing a structure for providing information to the stats and local response committees with respect to their responsibilities under Title III of SARA. This includes beginning the development of "Historical Performance at Comparable Facilities" reports.

o Analysis of the scope and comprehensiveness of the information in the AHE/DB has continued.

Because of EPA's primary interest in events similar in some ways to the accident in Bhopal, several criteria were used to screen event data for inclusion in the AHE/DB. Emphasis was placed on incidents that had acute hazard potential, with incidents resulting in deaths, injuries, or evacuations given highest priority. Events that resulted in releases of hazardous chemicals were given priority over events that released petroleum related and other types of substances. Priority was also given to incidents involving air releases of chemicals. Events releasing large quantities of chemicals were given priority and events with releases of less than one pound of material were not included.

Through imposition of these data collection criteria, the AHE/DB has been purposely biased toward events considered to have the greatest potential for sudden large scale harm to the populace due to the release of hazardous chemicals. Thus, the summary statistics obtained from the data base should not be viewed as being representative of the totality of the types of risks involved in the release of potentially hazardous materials.

1.2 METHODOLOGY

The main purpose of the AHE/DB is to provide a historical perspective on the kinds of accidental events that release potentially hazardous substances in the United States, the substances involved, the causative factors leading to their release, and their effects. The AHE/DB was not intended to provide a basis for the precise estimate of nation-wide

frequencies of events, quantities released or their consequences, but, rather to provide an assessment of the general scope of events.

1.2.1 Data Development

Our intention was to convert information from a large number of different kinds of accidental releases into a form convenient for summary and analysis. We found that no one data source was sufficiently comprehensive either in its breadth or its depth to supply the overall perspective on accidental releasee in the U.S. Thus, we adopted the approach of: (1) accessing large numbers of records from several different kinds of data sources; (2) screening out irrelevant or duplicate records; (3) taking a sample of certain categories of records; and (4) transcribing the information into a computerized data base.

Development of the current version of the AHE/DB evolved through a number of stages. The process by which data is developed and maintained in the data base, which encompasses the coding, entering and editing of the data obtained from different sources, has remained essentially the same throughout, however.

More than twenty separate contributing sources have been used to provide data to the AHE/DB. (Exhibit 1.2-1) These sources differed in the extent, quality, and type of information provided. Emphasis has been placed on locating and using sources that potentially can yield a large number of usable records -- such as DOT's "National Response Center Data Base", New Jersey's "Emergency Response/Air Release Data Base", and New York's "Attorney General's Toxic Accident Data Base" -- or those that provide information on "serious" events, i.e., those that led to deaths, injuries or evacuations.

The records included in the AHE/DB encompass the period from before 1980 to the present. However, the major data gathering effort focused on the five-year period from 1982 to 1986. The AHE/DB contains an average of 2,100 events per year for that period, ranging from 1,515 events for 1982 to 2,638 events for 1984. (Exhibit 1.2-2)

Data coding involves organizing the information provided from the different sources into the format specified in a single two-sided coding sheet (Appendix A). The coding process

organizes and characterizes the descriptive information contained in the original sources into a consistent set of categories that enable the generation of summary statistics and cross-tabulations. Because the AHE/DB is comprised of data that are taken from many different contributing sources and restructured into a single consistent format, comment sections are used in the coding form to maintain information that does not fit the coding scheme, thereby preventing the loss of important unique accident information. The comment information is usually a verbatim transcription of the text included in the record of the contributing source, and this is often quite terse. In other cases, the coders entered precis of more extensive records. As mentioned previously, the original 1985 coding format was re-organized and expanded during the present study. The choice of new categories that were added and the re-coding of the existing data from the original AHE/DB was made possible by reviewing data contained in these comment fields.

Appendix A also contains an instruction sheet developed to assist the data coders in making consistent categorical choices. Coders were junior level to senior level professionals with background training or experience in engineering, chemistry, and risk assessment, among other relevant disciplines.

A data structure for the AHE/DB in Dbase III format was developed in response to the EPA's specification that the AHE/DB be compatible with most of EPA's installed PC capability. To expedite entering the coded data into the proper dBase III format, a data entry program was developed with screens that replicated the data coding forms and with built-in error checking capability that prevented improper categories from being entered in each of the fields.

Data editing is an on-going process whose activities included assuring that the coded records accurately reflect the data source information as received, combining information from duplicate sources for the same event, and utilizing the results of in-depth reviews of events in the AHE/DB to upgrade significant records. However, neither the study team nor EPA has made an independent review or verification of the information in most of the records. Thus, we did not discover events or information about events that was not previously recorded elsewhere. Neither

did we "second-guess" the information contained in the sources used. The AHE/DB can be viewed as an accurate compilation and codification of previously reported information on acute hazardous material releases.

1.2.2 Development of Related Data Bases

Two other data bases in dBase III format have been developed to augment the AHE/DB by providing information related to the facilities at which events have occurred and data on the properties of chemicals involved in the events. Linking the AHE/DB to these other data bases facilitates the analysis of the relationships among event characteristics and facility and chemical characteristics. (Exhibit 1.2-3)

Both of the related data bases contain some information beyond that provided in the event records of the contributing sources. Working from other standard published sources, we created brief summary dossiers on the facilities and the chemicals showing up in the event records, to the extent to which they could be specifically identified.

The Company/Facility (COMFAC) data base contains information on the facilities reported to be involved in the AHE/DB events. This information includes: the facility name, its address, unique heirarchical identifier containing the three digit zip code for the facility and an indication of any parent/subsidiary relationships, and the 4-digit Standard Industrial Classification (SIC) for that facility. For some of the facilities in COMFAC information on the number of employees is also included. COMFAC is linked to the AHE/DB through the hierarchical identifier.

All facilities in COMFAC were organized into one of five categories: primary producers (facilities that produce chemicals); secondary producers (facilities that use the chemicals to produce another product); distributors; end users; and waste-related activities. Ultimately, through the information contained in COMFAC, other data sources such as the OTS Toxic Substances Inventory at the Dunn and Bradstreet ratings may be accessed to provide financial characteristics and other relevant facility information.

The Chemical (CHEM) Data Base contains information on the chemicals involved in the events in the AHE/DB. This information includes chemical identification information such as: the chemical name, its chemical abstract system (CAS) number, the 4-digit SIC of the industry that produces it, whether it is a commodity or specialty chemical, and production characteristics. In addition, CHEM contains information on chemical properties such as: toxicity information, including "Immediately Dangerous to Life and Health" (IDLH) concentrations; physical characteristics, including vapor pressure, boiling point, melting point and air half-life estimates; and hazard ranking information, including National Fire Protection Association reactivity and flammability rankings. CHEM also identifies whether or not that chemical is included on any of the following lists: SARA Section 302 list, CERCLA Reportable Quantity list, SARA Section 313 list, or RCRA Hazardous Waste list (Codes P or U).

For both COMPAC and CHEM, care was taken to eliminate redundancies in the identification of facilities and chemicals. A unique facility name was agreed upon with all other spellings or name presentations maintained for reference. Similarly, unique chemical names and CAS numbers were established.

1.3 AHE/DB CHARACTERISTICS

- The AHE/DB currently includes 6,305 records, which, through sampling, represent 11,048 events.

- Of those records, 1,045 events involved deaths or injuries.

- Of the 11,048 events, 4,770 events involved a release that affected air, 2,114 affected water, and 5,157 affected the land. (For any event more than one medium could be affected).

- Of the 11,048 events, 4,371 events related to primary producers, 1,538 to secondary producers, 2,711 to distributors, 1,239 to end-users, 156 to waste related activities, and 1,033 events occurred where the facility type was not specified.

- For events involving deaths or injuries, 273 involved primary producers, 136 secondary producers, 320 distributors, 137 end-users, and 14 waste related; facility type could not be determined for 165 D/I events.

- Of the 11,048 events, 8,513 events involved commodity chemicals, 779 involved specialty chemicals, and in the remaining 1,756 events the chemical identify either was not specified or could not be classified as specialty or commodity.

- The AHE/DB contains information on substances and quantities released, event location, description of causative factors, and description of end effects. The latter include: deaths, injuries, evacuations of workers and non-workers, and property and environmental damage.

- The types of accidents not contained in the AHE Data Base include: citizen complaints of oily substances, foul odors, and the like; incidents that are not chemical related; and incidents in which only non-hazardous materials are involved.

- Records in the AHE/DB were gathered from 41 separate sources, the most significant of which included:

The National Response Center (U.S. Department of Transportation): Contains nationwide information on hazardous substances released to air, water, and land. Includes in-plant and transport releases. Through a stratified random sampling scheme applied to the NRC data, the 3,013 records included in the AHE/DB represent a total of 7,755 NRC-recorded events.

News Wire Service (UPI): Nationwide coverage of large events and events having severe consequences. Events involving evacuations, injuries, and deaths commonly reported in this media.

Marsh and McLennan: U.S. incidents included among the 100 worst industrial accidents from 1956 to 1984 (rated by property damage). One-tenth are transportation related; the remainder are split evenly between chemicals processing and petroleum refining.

EPA Region 7: Incidents affecting all media in Iowa, Kansas, Missouri and Nebrask-

Newspapers: News reports, mainly of large events and events having severe consequences. Regional coverage with emphasis on state events.

State Reporting Systems: Texas Air Control Board data cover air releases from manufacturing facilities. Ohio EPA data include manufacturing and transportation releases. California data emphasize transportation and releases to land. New Jersey and New York data focus on releases with potentially significant effects.

1.4 REPRESENTATIVE USES OF AHE/DB

The AHE/DB was initially designed for a limited purpose -- to set into historical perspective the list of extremely hazardous substances that EPA was developing in 1985. It performed that function, and showed that the list was relevant to the kinds of releases and the substances often released in the U.S. Of the more serious events (i.e., those with reported deaths or injuries), almost half involved the release of one or more substances on the original Extremely Hazardous Substances (EHS) list, and another 30 percent of the events involved substances with known fire or explosive hazards.

Beyond this "reality checking" function, however, EPA and others have found various additional uses for the AHE/DB.

Source of Information on Specific Events

Although the AHE/DB is not a census of events, but rather a partial and informal sampling of records of events, it is now broad enough in its coverage to be a good source of event-specific information for further inquiries. For instance:

- EPA's Office of Toxic Substances used the listing of events as a sample frame for examining ways in which the TSCA premanufacture review process might be modified to more directly focus on the potential for accidental releases. For chemicals of the type under consideration, they examined the AHE/DB records and other EPA data on the causes and consequences of accidental releases.

o A trade association that is examining how evacuations are performed in the U.S. used the AHE/DB to help in their identification of events of interest. The researchers then conducted detailed case studies on about fifty events, using documentary evidence and interviews with individuals involved.

Perspective-Setting for Specific Regulatory Actions

The sampling approach for the AHE/DB is unusual, and it would be erroneous to ascribe scientific statistical significance to the aggregated data. Nevertheless, in the process of acquiring and coding first 3,121, and now 6,305, records it is valid to examine the relative importance of various measures showing up within such an extensive collection of historical records. This report does so in its numerous figures and tables -- examining substances, causation, event types, and end effects. EPA has used this data to pursue some aspects of potential regulatory or other program implementation actions. For example:

o The Office of Pesticide Programs has examined the frequency of chlorine releases from swimming pools and their consequences versus other sources of chlorine releases in a re-examination of the use classification of swimming pool pesticidal substances.

o EPA's Office of Air and Radiation Programs has examined the environmental loadings and reported acute health effects of a set of substances in preparing for potential regulation of various sources of air releases -- do accidental releases contribute significantly to the health risks?

o The AHE/DB has been used in setting the initial threshhold levels for the Accidental Release Information Program (ARIP) -- as a means to focus attention on a small fraction of reported events most deserving of follow-up data collection.

Perspective-Setting for Policy Decisions

Similar to the topic above, the extensive nature of the AHE/DB allows us to gain some overview of what situations seem relatively more or less important, and has contributed to setting the scene for policy discussions.

- The AHE/DB was one element used in clarifying the extent of accidental releases in the U.S. and their potential for human and environmental damage, and has been used by the internal EPA workgroup implementing the SARA Title III amendments dealing with the new community right-to-know program.

- The data has been used by offices in EPA attempting to examine priorities from a comparative risk point of view, with the potential of modifying existing emphases within the Agency.

Guidance for State or Local Actions

EPA and IEc have done preliminary work in developing profiles of the types and severity of releases possible from various classes of facilities. The work on "Historical Behavior at Comparable Facilities" is experimental at this point, and it must be carefully applied. However, it is possible that aggregating records by logical groupings of events may help local officials or others to grasp the range of accident types that they may have to plan for in their local areas, even though the historical record in that specific area may be quite thin. In some cases, we have supplied printed or computer records to EPA regional, state, or local officials. In addition, we have discussed a more generalized profile format with people involved in the Massachusetts State Emergency Response Commission (SERC) activities and with several Local Emergency Planning Committees (LEPCs) in Massachusetts.

1.5 REPORT ORGANIZATION

The remainder of this report is divided into two major sections and ten appendices. The major sections are:

- Characteristics of the More Severe Events, and
- Characteristics of All Events.

The section on the more severe events discusses events involving either deaths, injuries, or evacuations from the perspective of extent of damage, circumstances of release (such as location, cause, process state, transit mode, etc.), types of facilities involved, chemicals participation, and the relationship of events severity to chemical properties.

The section on all events provides a similar overview of information assembled for all events in the AHE Data Base, including those not involving deaths, injuries, or evacuations. Frequently reported chemicals, quantities released, media affected, environmental and property damage, and evacuations are discussed. The section on the circumstances of release describes end effects, event location, cause, production configuration, in-transit mode, and relationships between these factors and quantity released for all events.

The seven appendices provide detailed background material regarding the information contained in the AHE Data Base. The Data Coding and Format Sheets (Appendix A) identify the information included in a complete record, although few records include all of this data. Data Source Profiles (Appendix B) identify the principal characteristics of the source data files that provide the information assembled within the AHE Data Base. Appendix C provides a list of all chemicals included in the data base, including their common name; 4-digit SIC code of the producing sector; their Chemical Abstracts Service (CAS) identification number; and the number of incidents, injuries, and fatalities with which they are associated. Appendices D, E, and F provide summary outputs of AHE Data Base information for all events, for death or injury events, and for evacuation events. Appendix G provides a similar summary for those events reporting a spill/vapor release or fire/explosion as the worst end-effect.

2. CHARACTERISTICS OF THE MORE SEVERE EVENTS

2.1 DEATH OR INJURY EVENTS

Each of the original records coded into the data base was examined for indications of human casualties. In most cases, the record unambiguously indicated whether or not the event led to deaths or injuries. Altogether, injuries were reported in 9.2 percent of the events, and fatalities in 1.1 percent of the events. Another 8.4 percent of the records indicated injuries as unknown, and 6.0 percent of the records listed deaths as unknown. (Exhibits 2.1-1 and 2.1-2) Although some other records in the data base may represent events that involved injuries or deaths, it was not possible to estimate the degree of under-reporting without follow-up on event reports.

Some cautions are necessary in interpreting the reported casualty data:

- Reported Deaths or Injuries: Only a few of the events in this study have been independently verified, either by EPA or its contractors. Thus, one should interpret these data as "deaths or injuries reported by one or more of the contributing sources."

- Causation: Direct evidence of causation rarely exists in the contributing sources of these records. Some of the deaths or injuries reported to have occurred in association with a particular event may not, in fact, have been caused by the event. For example, some casualties may well have been caused by a triggering accident that released a substance into the environment (e.g., a truck driver whose injuries were caused by a collision, and not the succeeding exposure to released materials.) Whenever possible, deaths explicitly resulting from a collision were removed from the data base. However, it is not possible to identify how many of the deaths and injuries remaining in the data base fall into this type of situation.

o Range of Severity: Although some records indicate in detail the type and severity of the reported injuries, most records do not. To categorize the severity of injuries for these records, where possible we coded whether or not the injured parties were hospitalized. This then served as a surrogate for injury severity. While this categorization provides some resolution of the question of severity, it should be noted that not all data sources provided information on hospitalizations and not all hospitalizations are necessarily serious. Thus, even in the case of hospitalizations an individual "injury" could range from temporary respiratory or eye irritation treated on-site to critical injury leading to prolonged hospital treatment.

o Numbers: Some of the source records provide counts of injuries that suggested precision, whereas others (explicitly or implicitly) were approximate counts. If the source provided a number, it was recorded, but sometimes it was necessary to translate phrases such as "a few" or "about 50" into specific numbers. Thus, the accuracy of the individual records composing the data base is highly variable.

Although there is understandable interest in making nation-wide estimates of deaths and injuries, the study was not designed with that purpose in mind. Rather, the objective was to better understand the nature, causes, and effects of accidental releases. Before drawing conclusions regarding national totals, the reader should carefully assess the cautionary notes above and consider the following factors:

o Twenty-nine media sources (26 daily papers, two wire-services, and one trade journal) contributed only six percent of the total number of events, but those events represented 29 percent of the total death/injury events. Although these sources together cover the period 1980 to 1986, no one source was exhaustively searched for the entire period, and most were systematically searched for four years or less. (Exhibit 1.2-3 and Appendix D)

o Although each of the 26 daily papers had a separate regional focus, some also reported moderate to severe accidents from other parts of the country. Some events appeared in two or three of these sources, as well as occasional other sources. Thus, it is believed that most of the serious events that received national media attention during the period have been included in the data base.

o On the other hand, some events involving human casualties showed up in only one of the sources searched. This suggests that one would find other events of similar magnitude both by searching additional years for the sources used in this study, and by examining other media sources with different regional specializations.

o Some kinds of events may not be reported to one of the contributing sources due to the circumstances under which the events occurred, such as an event involving casualties that are limited to the work-place. Federal OSHA and state occupational safety and health records have not been examined to determine the extent of over-lap between those records and the ones in the AHE Data Base. Thus, it is not possible at this point to estimate how many additional records might be identified by accessing those sources.

o Many of the reports were obtained from sources that obtained the data during the initial stages of the incident, and the recorders of the data also were responsible for coordinating aspects of the emergency response effort. Such reports tend to be preliminary in nature -- frequently being incomplete in some ways, and in some cases containing inaccurate information.

2.1.1 Extent of Damage

o One thousand forty-five events (9.5 percent of all events) involve deaths or injuries. The total number of deaths is 309 and the total number of injuries is 11,341. (Exhibit D-2)*

o In the 6,567 injuries for which the severity is known, 1,587 required hospitalization. (Exhibit D-2)

o For events in which the number of injuries is known, the average number of injuries is 11.4, and the average number of injuries requiring hospitalization is 2.7. (Exhibit D-2)

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* Exhibits using an alphabetic designation, such as D-2, refer to exhibits in the Appendices.

o For events in which deaths are reported to have occurred, the average number of deaths is 2.7. (Exhibit D-2)

2.1.2 Circumstances of Release

o Vapor releases are reported as an end effect in 63.3 percent of the D/I events, spills in 56.0 percent, fire in 25.8 percent, and explosion in 17.8 percent. (Exhibit 2.1-6)

In-Plant Events

o For both all events and death/injury (D/I) events, storage and process locations jointly account for half of the reported events. Valves and pipes is the second most frequently involved location in all events, but ranks third among D/I events. (Exhibit 2.1-3)

o Reports of unknown location approximately double for D/I events; but the percentages for events at process vessels, storage locations, vehicles not in transit, heating/cooling, and other locations remain nearly the same for all events and D/I events. Reports of events in valves, piping and fittings decrease by ten percent when D/I events are compared to all events. (Exhibit 2.1-3)

o Fire and explosion is reported as the attributed cause almost four times as often in D/I events as for all events, accounting for 5.4 percent of all events and 20.4 percent of D/I events. Equipment failure is the reported cause of slightly less than half of all events (46.8 percent), but somewhat less than one-third of the D/I events (29.9 percent). Operator error is the reported cause in 18 to 19 percent of all events and D/I events. (Exhibit 2.1-4)

o Steady state conditions is the event context in more than half of all events, and approximately 40 percent of D/I events. Maintenance operations and start-up both are reported twice as frequently as event contexts for D/I events as for all events. Unknown context increases from approximately one-quarter of all events to nearly one-third of D/I events. (Exhibit 2.1-5)

In-Transit Events

o In-transit incidents play a slightly larger role in death/injury events than they do in overall events -- 37.0 percent versus 28.9 percent. (Exhibit 2.1-7)

o Truck transport represents a significantly increased share (65.6 percent versus 48.6 percent) and rail transport a decreased share (28.2 percent versus 43.5 percent) for events resulting in deaths/injuries than for all in-transit events. (Exhibit 2.1-8)

o Collision is reported as the in-transit cause twice as frequently for D/I events than for all events. Leaks account for the largest share (46 percent) of in-transit releases for both D/I events and all events. (Exhibit 2.1-9)

2.1.3 Types of Facilities Involved

Industry sectors were identified for the responsible parties in 84 percent of the 1,045 events reporting deaths and/or injuries by assigning 4-digit Standard Industrial Classification (SIC) codes. Sources for assigning SIC codes included the Dun & Bradstreet Reference Book and identifying information in the event records. Five industry groups were classified: Primary Producers, including Chemical and Allied Products, and Petroleum Refining and Allied Products (SICs 28 and 29); Secondary Producers, including all other manufacturing sectors (SICs 20 to 39, except 28 and 29); Distributors, those firms involved in transporting, storing, and distributing chemical products (SICs 40 to 47, 50 and 51); End Users, including residential and commercial users (SICs 01 to 17, 48, 49 except 495, and 52 to 99); and Waste Disposal (SIC 495).

o Of all death/injury events, the largest share (30.6 percent) were associated with distributors. Primary producers, who receive principal emphasis in most emergency response planning, were responsible for a slightly smaller share, at 26.1 percent. Secondary producers and end users were responsible for equivalent shares of death/injury events at 13.0 percent and 13.1 percent, respectively. Waste disposal facilities accounted for only 1.3 percent of the D/I events. (Exhibit 2.1-10)

o Although primary producers rank second in the number of death/injury events, events at these facilities account for the largest share (41.4 percent) of the deaths that occur. Distributors, who account for the largest number of events, account for only 7.1 percent of the fatalities. End users and secondary producers rank second and third in responsibility for fatalities, at 20.7 percent and 9.4 percent shares, respectively. Waste disposal activities account for 2.3 percent of the fatalities. (Exhibit 2.1-11)

o Primary producers again rank first with regard to number of injuries -- 3,377 injuries occur at such facilities, representing 29.8 percent of the total. Distributors rise to the second rank when injuries are considered, accounting for 24.6 percent, and secondary producers account for 17.0 percent. End users and waste disposers account for 9.4 percent and 0.7 percent of the injuries, respectively. Eighteen percent of all injuries occur at facilities of unknown type. (Exhibit 2.1-12).

o The frequency at which fatalities occur among all events at each facility type is shown in Exhibit 2.2-13. Primary producers account for 43.6 percent of the 10,015 events for which facility type could be determined, and of those events 46 (or 1.1 percent) result in fatalities. Secondary producers incur a comparable frequency of fatalities (1.2 percent) among their events, while distributors incur only an 0.5 percent frequency of fatalities. End users and waste disposers incur somewhat higher frequencies, at 1.7 percent and 1.9 percent, respectively. However, the number of events in these two categories is small, and the higher frequencies may represent the reporting of only the more severe events for end users and waste disposers.

o Similar results are obtained when injury frequency is considered, except that in this case distributors are ranked first, with 11.8 percent of all events reported at distributors resulting in injuries. End users and waste disposal rank second and third, at 10.6 percent and 9.0 percent respectively. Primary producers and secondary producers report injuries less frequently when releases occur, experiencing 6.1 percent and 8.3 percent injury frequencies, respectively. (Exhibit 2.1-14)

o Vapor releases are the most frequently reported end effect associated with D/I events for all facility types, except distributors. In the case of distributors, spills are the most frequently reported end effect (at 81.6 percent), with vapor

releases second at 57.5 percent of the events. Fires and explosions each account for 20 to 37 percent of the D/I events for all facility types, except distributors and waste dispoeers. Fires are reported in only 14.1 percent of the events at distributors, and explosions in 8.4 percent, fires are reported in half the events at waste dispoeers. (Exhibit 2.1-15)

2.1.4 Chemicals Participation

o The eleven chemicals most frequently reported in association with death/injury events account for up to 45 percent of such events (see Exhibit 2.1-16 for a graph of ten of these substances by share of death or injury events).*

- Chlorine is involved in the largest number of events (125), representing 12 percent of death/injury events; five deaths and 1,086 injuries occur in these events. (Exhibits 2.1-16 and 2.1-17)

- Hydrochloric acid, ammonia (anhydrous), and sulfuric acid are involved, respectively, in 68, 67 and 63 death/injury events, together representing 20 percent of such events and accounting for 6 deaths and 1,598 injuries. (Exhibits 2.1-16 and 2.1-17)

- The seven chemicals next most frequently reported in conjunction with death/injury events (sodium hydroxide, ammonia, nitric acid, toluene, styrene, toluene diisocyanate, and phosphoric acid) account for 13 percent of such events; 42 deaths and 1,293 injuries occur in these events. (Exhibits 2.1-16 and 2.1-17)

o Chlorine is the most frequently reported chemical associated with death/injury events at primary producers, secondary producers, end users, and wests related; and ranks fourth at distributors. Chlorine is involved in 22 percent of

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* Because any given event may involve more than one chemical, there can be overlap in the numbers of events, deaths, and injuries when discussing the participation of more than one chemical. Therefore, all percents or combined totals of events, deaths or injuries in this section should be interpreted as upper bounds.

the D/I events at primary producers; 15 percent of D/I events at secondary producers; and 5 percent of D/I events at distributors. (Exhibits E-7, E-9, E-11, and E-13)

o After chlorine, the next three most frequently reported chemicals involved in D/I events at primary producers are ammonia (anhydrous), hydrochloric acid, and sulfuric acid; together they account for 55 events (20 percent of the total) at primary producers. (Exhibit E-7)

o At secondary producers, the four most frequently reported chemicals, in addition to chlorine, are ammonia, ammonia (anhydrous), hydrochloric acid, and toluene diisocyanate; together they account for 28 D/I events (21 percent of the total) at secondary producers. (Exhibit E-9)

o At distributors, the three most frequently reported chemicals associated with D/I events are sulfuric acid, hydrochloric acid, and ammonia (anhydrous). Together they account for 77 events (24 percent of the total) at distributors. (Exhibit E-11)

o The average quantities released per event are shown in Exhibit 2.1-17 for the nineteen chemicals representing the largest number of D/I events. Among death/injury events for the top eleven most frequently reported chemicals, sulfuric acid releases involve on average the largest quantities (51,000 pounds), followed by nitric acid (17,000 pounds), and hydrochloric acid and sodium hydroxide (each at 11,000).

o When the quantities released in death/injury events are compared to the reportable quantities (RQs) of the participating chemicals, 37.0 percent of the D/I events in which quantities are known involve quantities less than the RQ, i.e., the release of such quantities usually would not be considered of sufficient concern to justify its report to the National Response Center or other jurisdiction. (Exhibit E-4)

o Only 13.1 percent of the D/I events involve chemical release quantities greater than 100 times the RQs of the involved chemicals. (Exhibit E-4)

2.1.5 Relationship of Event Severity To Chemical Properties

Information on five physical and toxicological properties -- acute toxicity, flammability, reactivity, volatility, and processing mode -- was entered into CHEM for the chemicals associated with events in the AHE/DB. The data were collected from various sources, which are identified in the subsections below. In addition, information on the physical state of the participating chemicals was provided by the AHE/DB records for most events. Exhibit 2.1-18 summarizes the type of information used and the hazard rating scales employed for each property. The following analyses are based on the chemical properties of only the primary substance involved in each event.

Acute Toxicity

Acute toxicity of chemicals was characterized in CHEM using values compatible with the "levels of concern (LOC)" defined in EPA's CEPP Technical Guidance Document. 1/ Where available, National Institute for Occupational Safety and Health (NIOSH) measures designated by the term "Immediately Dangerous to Life and Health (IDLH)" were used to indicate the concentration (in g/m3) at which each chemical poses a significant risk if it is accidentaly released. Where IDLH values had not been developed by NIOSH, proxy values were estimated on the basis of animal lethality values using methods designated in the CEPP Technical Guidance Document.

The IDLH values were grouped into five LOC categories, termed LRATEs, as shown in Exhibit 2.1-18. The higher LOC categories correspond to hazard categories previously established by organizations attempting to segregate chemicals with regard to the hazards attending their usage. LRATEs 3 and 4 correspond to EPA's "highly toxic" criteria for categorizing chemicals for reporting under SARA Title III Sections 311 and 312. LRATE 2 is equivalent to SARA Title III's "toxic" reporting category. LRATEs 1 and 0 designate the lowest LOC categories.

1/ U.S. EPA Chemical Emergency Preparedness Program, Site Specific Technical Guidance for Hazards Analysis: Emergency Planning for Extremely Hazardous Substances, Draft August 1987.

o LRATEs were determined for approximately 62 percent of the 681 chemicals in CHEM, as shown in Exhibit 2.1-19 by the distribution of all event chemicals for the five LRATE levels.

o The chemicals for which LRATEs were determined account for 82 percent of the events in the AHE/DB, as shown by the distribution of all events for the five LRATE levels in Exhibit 2.1-20.

o Forty-six percent of the total number of events in the AHE/DB involved chemicals in the highest toxicity group (LRATE 4), although only 18 percent of the number of chemicals fall into the LRATE 4 category. A slightly higher number of chemicals (25 percent) involved in death/injury events were in the highest toxicity group. (Exhibits 2.1-19 and 2.1-20)

o Relatively few of either death/injury or all events involved chemicals in the LRATE 3 category. This is generally consistent with the lower frequency of LRATE 3 chemicals in the CHEM data base. (Exhibits 2.1-19 and 2.1-20)

Flammability

Information on the flammability of chemicals was obtained primarily from the National Fire Protection Association (NFPA), which has rated substances for flammability (FRATE) on a scale of 0 to 4, with FRATE 4 being the most hazardous level. 2/ In cases where NFPA ratings were not available, flash points and boiling points were used to assign similar ratings based on a National Academy of Sciences (NAS) scheme. 3/ When neither NFPA ratings nor physical property data were available, FRATEs were assigned according to the NFPA criteria based on available qualitative information.

2/ National Fire Protection Association (NFPA), Fire Protection Guide on Hazardous Materials, 1984.

3/ National Academy of Sciences (NAS), System for Evaluation of Bulk Water Transportation of Industrial Chemicals; A Report to the Department of Transportation, U.S. Coast Guard, 1974.

o Information on flammability was obtained for approximately 65 percent of the chemicals in CHEM. These chemicals represent 84 percent of all events in the AHE/DB. (Exhibits 2.1-19 and 2.1-20)

o Forty percent of all events involved non-flammable substances (FRATE 0), and approximately 30 percent involved chemicals in the two highest flammability rating groups (FRATEs 3 and 4). The distribution of death/injury events by flammability rating is similar to the distribution for all events, with the exceptions of a larger percent in the unknown category and a smaller percent in the high flammability category. (Exhibit 2.1-20)

Reactivity

Reactivity was characterized using the NFPA definition -- "the susceptibility of materials to release energy either by themselves or in combination with water". Observed responses to fire exposure, shock, and pressure are used to determine such susceptibility. As with flammability, NFPA assigns degrees of reactivity (RRATE) on a scale of 0 to 4.

o Reactivity ratings (RRATEs) were determined for only 40 percent of the chemicals in CHEM. Very few of the chemicals rated for reactivity are highly reactive -- only 3.8 percent are rated at RRATEs 3 and 4. A similar pattern holds for death/injury events, although in this case RRATEs could be identified for 56 percent of the chemicals. (Exhibit 2.1-19)

o A comparable pattern is reflected in the number of events, with only 3.3 percent of all events and 1.9 percent of death/injury events involving chemicals with RRATEs 3 and 4. (Exhibit 2.1-20)

Volatility

Vapor pressure, which indicates the escaping tendency of molecules from liquids or solids, is used as the measure of volatility in CHEM. Ratings of high, moderate, and low volatility (VRATES) were assigned to the chemicals using criteria (identified in Exhibit 2.1-18) that had been established by

previous investigators. 4/ 5/ These categories are compatible with the chemical selection criteria used for the SARA Title III Section 305(b) Review of Emergency Systems.

o Vapor pressures have been identified for only 32 percent of the chemicals in CHEM thus far. These chemicals participate in half of all AHE/DB events. The rated chemicals are evenly divided into the low, moderate and high volatility groups. (Exhibits 2.1-19 and 2.1-20)

o The distribution of events indicates that slightly more of the events (for which chemical vapor pressure is known) involve chemicals in the low volatility group. A similar pattern is seen for the death/injury subset of events. (Exhibit 2.1-20).

Physical State

The chemicals's physical state at the time of the event is used in this part of the analysis. Therefore, different events with which a chemical is associated may involve different physical states.

o Information regarding the physical state of the primary substance is available for 99 percent of the events in the AHE/DB. (Exhibit D-1)

o Liquids predominate in both death/injury events and all events, being designated as the chemical state in 72 percent of D/I events and 73 percent of all events. (Exhibits D-1 and E-1)

o Gases are the second most common physical state occurring in 32 percent of death/injury events and 27 percent of all events. (Exhibits D-1 and E-1)

4/ Versar, Inc., Physical-Chemical Properties and Categorization of RCRA Wastes According to Volatility, prepared for U.S. Environmental Protection Agency, February 1985.

5/ U.S. EPA Office of Toxic Substances, Section 305(b) Review of Emergency Systems -- Chemical Selection Criteria, Draft January 1987.

Processing Mode

As a proxy for processing mode, the chemicals were designated as either commodity or specialty. This proxy is based on the assumption that commodity chemicals, which are produced in large quantities, are likely to be produced by continuous processing modes; whereas specialty chemicals, produced in small quantities to meet more narrowly defined specifications, are more likely to be batch processed.

o Approximately 42 percent of the chemicals in CHEM are commodity chemicals, 35 percent are specialties, and 24 percent could not be designated. (Exhibit 2.1-19)

o Seventy-seven percent of all events involve commodity chemicals, and only seven percent involve specialty chemicals. Although the shares of death/injury events involving commodity and specialty chemicals are similar to the shares for all events, the distribution of chemicals involved in death/injury events is more heavily weighted by commodities (Exhibits 2.1-19 and 2.1-20)

Variation of Event Severity With Chemical Properties

Acute hazardous events can be separated into two groups depending upon whether a fire or explosion did or did not occur. In those cases where a fire or explosion was reported as an end effect, the severity of the event, in terms of number of injuries or deaths, appears to be predominantly determined by the characteristics of the fire or explosion, as discussed in Section 2.1. In those events where a fire or explosion was not an end effect, it is assumed that an important factor contributing to the severity of the event is the toxicity of the chemicals involved. Since multiple end effects often are reported for a single event, individual records were examined in order to consider all information when classifying the cause of the deaths or injuries.

Variation With Toxicity

o Approximately 75 percent of the injuries and 13 percent of the deaths reported for events in the AHE/DB were apparently caused by toxicity. (Exhibit 2.1-21)

o In the subset of events involving deaths and injuries thought to be caused by chemical toxicity, more than two-thirds of the events with rated chemicals involved highly toxic (LRATE 4) chemicals. (Exhibit 2.1-22)

o Events involving chemicals with a high LRATE have a much wider range of severity (in terms of numbers of deaths plus injuries) than those with a low LRATE. (Exhibit 2.1-22) A chi-square analysis of the grouped data suggests that this phenomenon for death and injury events is due to the underlying distribution of the two variables in the data set rather than any dependence upon one another.

o Chi-square analysis on the toxicity ratings of chemicals involved in all events in the AHE/DB for which the primary end effect was a vapor release or spill suggests that a relationship exists between event severity and chemical toxicity. The analysis indicates that severity is related to toxicity in terms of whether or not deaths or injuries will occur, but that the degree of severity, i.e., number of deaths or injuries, does not depend on toxicity. That is, if an accidental release of a highly toxic chemical occurs, the event is more likely to cause deaths and/or injuries, but we can not predict how many.

Variation of Events Severity With Flammability and Reactivity

o Approximately 87 percent of the deaths and 25 percent of the injuries reported for events in the AHE/DB were apparently caused by fire or explosion. (Exhibit 2.1-21)

o There is no apparent relationship between the severity of events, as measured by the numbers of injuries plus deaths, and the flammability or reactivity ratings of the chemicals involved. (Exhibits 2.1-23 and 2.1-24)

2.2 EVACUATION EVENTS

The expanded coding format for the present version of the AHE/DB allowed each record to incorporate information on whether or not an evacuation was required, how many people were evacuated, and of those, how many were residents and how many were workers. Evacuations occurred in 855 of the total 11,048 events (7.7 percent) in the AHE/DB. Of the remainder, 5,094 (46.1 percent) of the events did not have associated evacuations, and for an almost equal 5,089 events (46.1 percent) it was not known whether an evacuation took place. The 29 media sources (26 newspapers, 2 wire services, and one trade journal) contributed 54 percent of the total number of evacuation records.

Similar caveats to those discussed for death and injury events apply to this analysis, particularly regarding the number of people evacuated and the distribution among residents and workers.

2.2.1 Extent of Damage

- 855 events (7.7 percent of all events) were reported to involve evacuations. In the 419 events for which the number of evacuees was identified, the total number of people evacuated was 464,677. (Exhibits D-1 and D-2)

- Injuries were associated with 40.1 percent of the evacuation events compared to only 9.2 percent of all events. (Exhibit 2.2-1) Deaths were associated with 4.7 percent of the evacuation events compared to 1.1 percent of all events (Exhibit 2.2-2).

- For some of the evacuation events it was possible to distinguish between workers and non-workers evacuated. Of the 335,323 people evacuated in those events, 308,183 (91.9 percent) were residents and 27,140 (8.1 percent) were workers. (Exhibit D-2)

- When the number of people evacuated was reported, the average number of evacuees per event was 1,109. For those events in which a distinction was made between residents and workers, the average number of residents evacuated was 1,034, and the average number of workers was 91. (Exhibit D-2)

2.2.2 Circumstances of Release

o In-transit events play a slightly larger role in evacuation events -- 34.6 percent for evacuation events versus 28.9 percent for all events. (Exhibit 2.2-3).

o Spills are reported as an end effect in 50.1 percent of evacuation events, vapor release in 76.1 percent, fire in 32.5 percent, and explosion in 15.1. Fires and explosions are reported nearly five times more frequently for evacuation events than for all in-plant events. Vapor releases are also more frequently reported, and spills less frequently, as end effects in evacuation events than in all events. (Exhibit 2.2-4).

In-Plant Events

o Storage locations are involved in 34.9 percent of in-plant evacuation events, compared to 28.0 percent involvement in all events. Vehicles-not-in-transit account for 5.5 percent of evacuation events and 2.8 percent of all events. Process locations account for a smaller share of evacuation events (19.7 percent) when compared to all events (22.4 percent), as do valves and pipes (14.3 percent for evacuation events versus 25.3 percent for all events). (Exhibit 2.2-5).

o Fires and explosions are reported as the attributed cause four times more frequently in evacuation events (22.2 percent) as compared to all in-plant events (5.4 percent). Sparking and lightning, and arson and vandalism are also more frequently reported as causes in evacuation events. Equipment failure represents the event cause in 46.8 percent of all events, but only 32.4 percent of evacuation events. (Exhibit 2.2-6).

o Steady state condition is the in-plant event context in over half of all events (51.0 percent) and evacuation events (56.0 percent). Start-up conditions are reported as the in-plant event context three times more frequently for evacuation events (4.5 percent) than for all events (1.8 percent), while loading and unloading is reported half as frequently (9.1 percent) in evacuation events as in all events (16 percent). (Exhibit 2.2-7)

o Disposal locations are responsible for 83.6 percent of the amounts released in in-plant evacuation events, compared to 6.0 percent for all in-plant events. The large share of disposal locations in in-plant evacuation events is attributable to a single large quantity release. (Exhibit 2.2-8).

o Fire and/or explosion, which is the attributed cause for 5.8 percent of the amount released in all in-plant events, accounts for 84.6 percent of the amount released in in-plant evacuation events. (Exhibit 2.2-9).

In-Transit Events

o Truck and rail modes are equally involved in evacuation events -- 49.3 percent of evacuation events involve truck modes and 46.3 percent involve rail. This is approximately the same percentages as their shares for all events. (Exhibit 2.2-10).

o Derailment is the attributed cause in 24.7 percent of the evacuation events, which is approximately four times more frequent than derailment's share of all events (6.5 percent). Collisions are the attributed cause in 21.3 percent of the evacuation events, occurring almost twice as frequently as collisions's share of all events (11.7 percent). (Exhibit 2.2-11).

o Rail-associated releases account for two-thirds of the quantity released in in-transit evacuation events. However, rail represents only 22.1 percent of the quantity released in all in-transit events. (Exhibit 2.2-12).

2.2.3 Types of Facilities Involved

o Of the 855 events reporting evacuations, 65.4 percent occur at fixed facilities. (Exhibit F-1)

o Industry sectors were identified for the responsible parties in 78 percent of the 855 events reporting evacuations. (Exhibit 2.2-13)

- Distributors (25.8 percent) and primary producers (24.8 percent) account for the majority of evacuations. End users (14.2 percent) and secondary producers (12.4 percent) account for the next largest shares. Waste-related activities account for only 1.2 percent of the evacuation events. (Exhibit 2.2-13)

- Compared to their frequency of involvement in all events, distributors and end users have a slightly higher frequency and primary producers a significantly lower frequency of involvement in evacuation events. The rates for secondary producers and waste related are slightly lower for evacuation events than for all events. (Exhibit 2.2-13)

- At primary producers, 4.9 percent of the events reported evacuations, 6.8 percent at secondary producers, 8.2 percent at distributors, and 9.8 percent of the events at end-users. (Exhibit 2.2-14).

- On average, more people are evacuated in a distributor-related event than for any other sector. Distributors account for 25.8 percent of the evacuation events, resulting in 36.8 percent of all people reported evacuated. In contrast, end-user-related evacuation events tend to involve a smaller number of evacuees, with the 14.2 percent end-user share of evacuation events contributing to 7.1 percent of all reported evacuees. (Appendix D)

- Of the 298 events in which the types of evacuees can be identified as worker or resident, residents on average account for 91.9 percent of the number of people evacuated and workers account for 8.1 percent. In the end-user and secondary chemical producer sectors, a greater than average share of workers are evacuated, 20.0 percent and 37.2 percent respectively, while distributors report almost no workers evacuated (1.0 percent). (Exhibit 2.2-15).

2.2.4 Chemicals Participation

o The ten chemicals most frequently reported in association with evacuation events account for up to 42 percent of such events.* (Exhibit 2.2-16)

- Chlorine is involved in the most (93) events, representing 10.9 percent of evacuation events. (Exhibit 2.2-16)

- Hydrochloric acid, ammonia (anhydrous), and sulfuric acid are involved in 79, 68, and 31 evacuation events, respectively. Together, they account for 21 percent of such events. (Exhibit 2.2-16)

- The six chemicals next most frequently reported in conjunction with evacuation events account for 11 percent of such events. (Exhibit 2.2-16)

o Chlorine is the most frequently reported chemical associated with evacuation events at primary producers, secondary producers, end users, and waste related; and ranks fourth at distributors. Chlorine accounts for 18 percent of the evacuation events at primary producers; 11 percent of the events at secondary producers; 4 percent at distributors, 17 percent at end users, and 40 percent at waste disposal. (Exhibits F-7, F-9, F-11, F-13 and F-15)

o After chlorine, the next five most frequently reported chemicals at primary producers are hydrochloric acid, ammonia (anhydrous), sulfuric acid, nitric acid and ammonia; together they account for 66 events, 31 percent of the 212 events occurring at primary producers. (Exhibits F-6 and F-7)

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* Because any given event may involve more than one chemical, there can be overlap in the numbers of events, deaths, and injuries when discussing the participation of more than one chemcial. Therefore, all percents or combined totals of events, deaths or injuries in this section should be interpreted as upper bounds.

o At secondary producers, the three most frequently reported chemicals, in addition to chlorine, are ammonia (anhydrous), ammonia, and nitric acid; together they account for 21 events (20 percent of the total) at secondary producers. (Exhibit F-9)

o At distributors, the three most frequently reported chemicals are hydrochloric acid, ammonia (anhydrous), and sulfuric acid. Together they account for 53 events (24 percent of the total) at distributors. (Exhibit F-11)

o The average quantities released per event are shown in Exhibit 2.2-16 for the 21 chemicals representing the largest number of evacuation events. Among evacuation events, methyl alcohol releases on average involve the largest quantities (1,000,000 pounds), followed by butadiene (170,000 pounds), and sulfuric acid (130,000 pounds).

o When the quantities released in evacuation events are compared to the reportable quantities (RQs) of the participating chemicals, 26.7 percent of the evacuation events in which quantities are reported involve quantities less than the RQ, i.e., the release of such quantities usually would not be considered of sufficient concern to justify its report to the National Response Center or other jurisdiction. (Exhibit F-4)

o Only 19.5 percent of the evacuation events involve chemical release qualities greater than 100 times the RQs of the involved chemicals. (Exhibit F-4)

2.3 MOST SEVERE EVENTS INVOLVING ATMOSPHERIC RELEASES OF ACUTELY TOXIC OR EXPLOSIVE CHEMICALS

2.3.1 General Characteristics

o Air releases of toxic chemicals that led to two or more deaths are listed in Exhibit 2.3-1. Thirty-seven such events were identified as having occurred during the five-year period from 1982 to 1986, or an average of seven events per year. These events in total were reported to have led to 135 deaths.

o The most serious single event with respect to mortality was an explosion and fire associated with gun powder and fire works that led to 21 deaths in June 1985.

- Three quarters of the most severe events reporting fatalities were limited to two or three deaths, and only two (five percent) of the events led to ten or more deaths.

- Events involving forty or more injuries are listed in Exhibit 2.3-2. Forty-six such events were identified as having occurred during the five year period from 1982 to 1986, or an average of nine events per year. These events led to 4,411 injuries.

- The most serious single event with respect to injuries reported was a vapor release of aldicarb oxime in August 1985 to which 430 injuries were attributed.

- Nearly three quarters of the most severe events involving injuries had 90 or fewer reported injuries, while only four events (nine percent) led to 200 or more injuries.

- Events involving 2,000 or more evecuees are listed in Exhibit 2.3-3. Thirty-seven such events were reported during the five year period from 1982 to 1986, representing an average of seven per year. These events led to a reported 190,575 total evacuees

- The most serious event with respect to number of evacuees was an explosion and fire associated with the release of 22,500 pounds of phosphorus, reportedly causing the evacuation of 40,000 people in July 1986.

- More than two-thirds of the most severe evacuation events involved 4,000 or fewer evacuees, while three events (eight percent) led to 10,000 or more evacuees.

- Transportation events played a large role in the most severe evacuation events, accounting for nearly half (17) of the 37 evacuation events. In contrast, transportation events represent only 29 percent of the events in the entire AHE/DB. Furthermore, transportation events did not represent a large proportion of the death and injury events, accounting for 13 percent of the events with deaths and 37 percent of the events involving injuries. (Exhibit E-19) The most severe transportation event with fatalities involved four deaths.

o The number of the most severe events involving death, injury, and evacuation events, shown in Exhibits 2.3-1 to 2.3-3, appears to have remained relatively constant over the 1982 to 1986 period, except that more events were reported in 1985. The apparent increase in 1985 may have been a result of greater public interest and more comprehensive reporting of such events in the immediate aftermath of the Bhopal tragedy rather than an actual increase in the occurrence of accidents. The number of severe incidents listed in Exhibits 2.3-1 to 2.3-3 is too few and the time frame too short to provide a reliable basis for evaluating these types of trends.

2.3.2 Significance of Event End Effects

o The most significant factor in the determination of the severity of events involving fatalities appears to be whether a firs or explosion occurred. Most (86 percent) of the events in which two or more deaths occurred (listed in Exhibit 2.3-1) involved fire and/or explosion.

o Five (14 percent) of the events listed in Exhibit 2.3-1, occurred in situations where chemical toxicity appeared to be the primary factor in determining event severity, i.e., where spill or vapor release occurred but fire and explosion did not. In all cases, these toxicity-dominated events were restricted to two or fewer deaths.

o On the other hand, toxicity appears to be a somewhat more important contributing factor affecting the severity of events involving injuries. For injury events, toxicity was indicated to be the primary factor in 26 (57 percent) of the most severe events, and to account for three of the four events leading to 200 or more injuries.

o Fire and/or explosion appears to play the most significant role in determining the severity of evacuation events, accounting for 26 (70 percent) of the 37 evacuation events listed in Exhibit 2.3-3 and all of the most severe events, each of which led to reported evacuations of 10,000 or more people.

2.3.3 Large Scale Domestic Releases of Extremely Toxic Chemicals

Potential toxic effects vary with the toxicity and the volume of substance released. Three thousand four hundred fifteen events in the AHE/DB have information on both quantities and acute toxicity. For those events, we divided quantity released by the IDLH value attributed to that chemical to establish an approximate relative measure of the potential toxic effects of each release. Exhibit 2.3-4 lists the 29 events in the AHE/DB having largest quantity/IDLH values.

o By this measure, 29 events involved releases whose quantity-toxicity ratio was greater than half that associated with the release at Bhopal, and 17 events involved releases whose ratio exceeded that at Bhopal.

o Among the 29 high-damage potential events in Exhibit 2.3-4, one event reported deaths (five fatalities), five events reported injuries (ranging from one to 650 people injured), and five reported evacuations (up to 20,000 people) -- a somewhat greater frequency of severe consequences than that observed among all events. The average numbers of deaths, injuries, and evacuations also were somewhat greater than the AHE/DB subgroup of events reporting deaths, injuries or evacuations. However, given the vast amount of materials released in the events listed in Exhibit 2.3-4, the frequency and severity of these effects is surprisingly lower than might be expected.

o The difference between the potential for human harm and the actual consequences in these events appears to be due in part to combinations of the following factors:

- The chemical's physical state at the time of release was liquid and much of the material remained liquid, or other physical/chemical properties prevented widespread airborne exposure.

- Few people were close to the point of release.

- Weather conditions were favorable.

- Preparedness at the site of release included containment of materials released, or other equipment or procedures to mitigate the extent of release and population exposure.

- Evacuation or other community response may have removed potentially exposed victims.

o In addition, the data on these events are sometimes incomplete (e.g., the concentration of some materials released, such as sulfuric acid, may have been less than 100 percent); in most cases, quantity data represent best estimates that may overstate the actual quantity released.

2.3.4 Comparison with Major Industrial Disasters of Similar Origin

o Ten of this century's largest industrial disasters related to large scale atmospheric releases of toxic or explosive chemicals are listed in Exhibit 2.3-5. Bhopal is by far the most severe, accounting for more than 3,000 deaths to date, with reports of more than 200,000 injuries, including 40,000 classified as serious.

o The most serious event of this type to occur in the U.S. is the explosion of a fertilizer ship in Texas City in 1947. The death total of 552 associated with this ammonium nitrate related event places it with only three other events listed in Exhibit 2.3-5 (in addition to Bhopal) where the death toll exceeded 500.

o Toxicity acted as the primary factor in only two of the events. One of these was the 1976 release of TCDD in Seveso, Italy that caused 700 homes to be permanently abandoned and hundreds of animals to die, but did not involve any human fatalities. Thus, Bhopal is the only large scale event related primarily to toxicity factors in which a large number of people have died.

o The average number of fatalities for the ten events listed in Exhibit 2.3-5 is nearly 600, far larger than any of the U.S. events from the AHE/DB listed in Exhibit 2.3-1 for the 1982 to 1986 period. The largest number of fatalities among the latter events is 21.

o An important factor contributing to the total number of deaths in Bhopal was the lack of warning and instructions in proper response given to the populace over the period of release. In Seveso, Italy hundreds of animals were killed because they

could not be evacuated effectively. The long term effect of the event was the contamination of the soil and the abandonment of a large land area.

- Thus, the data in Exhibit 2.3-5 indicate that events of this magnitude have to date been associated either with situations in which massive explosions have occurred or in which toxic materials have been allowed to reach the surrounding populace without a timely or effective response by the public officials.

3.0 CHARACTERISTICS OF ALL EVENTS

3.1 EXTENT OF DAMAGE

- Injuries are reported in 9.2 percent of the 11,048 events in the AHE/DB. (Exhibit 2.2-1)

- Deaths are reported in only 1.1 percent of the events. (Exhibit 2.2-2)

- Evacuations are reported in only 7.7 percent of the events; however, in 46 percent of the events it was not stated whether evacuation was required. (Exhibit D-1)

- A total of approximately one-half million people have been evacuated in all events which recorded the number of evacuations. This total excludes non-specific descriptions of number of people evacuated, such as "several people" or "all employees." (Exhibit D-2)

- In 298 events, accounting for 335,323 evacuees, it was possible to distinguish between the evacuation of residents and workers. These evacuation events involved a total of over 308,000 residents and 27,000 workers. (Exhibit D-2)

- When evacuations are reported, an average of 1,109 people per event are evacuated. The number of people evacuated ranges from 10 people to 20,000 people. (Exhibit D-2)

- Property damage was reported in 13.6 percent of all events. In 43.1 percent of the events property damage is stated not to occur, and in 43.4 percent of the events it is not stated whether such damage occurred. Estimates of property damage are usually exprssed in very general terms; they range up to $100 million for one event. (Exhibit D-1)

- Similarly, less than three percent of the 11,048 events involve environmental damage, while one-third are reported not to involve environment damage. In the majority of events (64.2 percent), it was not stated whether environmental damage occurred. (Exhibit D-1)

3.2 CIRCUMSTANCES OF RELEASE

- Of the 11,048 events, 71 percent occur at a fixed location; the remainder occur during transit. (Exhibit 2.2-3)

- Spills are reported as an end effect in 68.0 percent of the events; vapor release in 39.6 percent; fire in 6.9 percent; and explosion in 3.0 percent. The severity of end effects was estimated to be (in decreasing order) explosion, fire, vapor release, spill, and unknown. Note that multiple end-effects may be reported; therefore, percents do not total to 100 percent. (Exhibit 2.2-4)

- Of the 7,756 events for which quantity released was reported, the 3.0 percent of events releasing more than 100,000 pounds accounted for 88.1 percent of the quantity released. (Exhibits 3.2-1 and D-6).

3.2.1 In-Plant Events

- Storage vessels, process vessels, and valves or piping account for approximately equal shares of the 7,850 in-plant events. (Exhibit 2.2-5)

- Storage vessels account for 76.0 percent of the quantity released in in-plant events. However, when deaths or injuries are involved, "vehicles not in transit" accounts for 50.4 percent of the quantity released, with waste disposal and pollution control equipment accounting for another 35.2 percent. These large shares of the D/I events are attributable to single large events in each case. (Exhibit 3.2-2)

- Equipment failure is identified as the cause of 46.8 percent of all events occurring in-plant, but accounts for only 32.2 percent of the quantity reported released in-plant. In comparison, operator error is the attributed cause in 18.2

percent of the in-plant events, accounting for 45.7 percent of the quantity released. For D/I events, sparking and lightning account for 2.1 percent of the events, but over 50 percent of the quantity released. The large share attributable to sparking and lightning is due to a single large event. (Exhibits 2.1-4 and 3.2-3)

- In-plant events primarily occur under steady state conditions (51.0 percent) or during loading or unloading operations (16.0 percent). Operational configuration is not reported for one-quarter of the incidents. (Exhibit 2.2-7)

- Less than six percent of the in-plant events account for over 92 percent of the amount released. Those events greater than 100,000 pounds in release size (3.2 percent of in-plant events) account for over 89 percent of the quantity released. (Exhibits 3.2-1 and D-6)

- Events involving releases over 100,000 pounds account for the majority of material released for all in-plant locations except valves/pipes, heating/cooling, other, and unknown locations. (Exhibits 3.2-4 through 3.2-9)

- The majority of events listing equipment failure, upset conditions, fire/explosion, high temperature and pressure, power related, sparking and lightning, other, and unknown causes release less than 1,000 pounds. The majority of events listing operator error, arson and vandalism, and disposal related activities as causes release less than 10,000 pounds. (Exhibits 3.2-10 through 3.2-18)

- Events involving releases over 100,000 pounds account for the majority of material released for all causes except disposal related, power related, and unknown causes. (Exhibits 3.2-10 through 3.2-18)

- Over 80 percent of the material released in all in-plant event contexts, except other and unknown categories, are from events releasing 50,000 or more pounds. (Exhibits 3.2-19 through 3.2-23)

3.2.2 In-Transit Events

- In-transit events account for 28.9 percent of the events. (Exhibit 2.2-3)

- Slightly less than half of all in-transit events (48.6 percent) involve trucks; another 43.5 percent involve rail cars. (Exhibit 2.2-10)

- Of the releases of hazardous materials during transportation, 46.2 percent are the result of a leak, 11.7 percent are the result of a collision, 6.9 percent are from overturned trucks, and 6.5 percent are from derailments. (Exhibit 2.2-11)

- Over half of the events for each transit mode, except pipelines, involve releases of less than 1,000 pounds. The majority of events occurring in pipelines release over 1,000 pounds. (Exhibits 3.2-24 through 3.2-28)

- The quantity reported released in events occurring in pipelines accounts for approximately half of the total quantity released in in-transit events. However, the bulk of this was contributed by a few large pipeline spills; otherwise, pipelines are responsible for only a small fraction of release events and quantities. The quantities reported released in rail and truck events respectively account for 22.1 and 18.8 percent of the total quantity reported released in in-transit events. (Exhibit 3.2-29)

- Events involving releases over 100,000 pounds account for almost all of the quantity reported released in pipeline and barge events. In rail events, incidents involving over 50,000 pounds account for over 85 percent of the quantity raported released; while for trucks, releeses of over 50,000 pounds account for more than 40 percent of the amount of material released. (Exhibits 3.2-24 through 3.2-28)

- Over 70 percent of the in-transit events involving rail release less than 1,000 pounds, over half release 100 pounds or less, and 23.6 percent release 10 pounds or less. (Exhibit 3.2-25)

- No event involving "other" transit modes (usually airplanes) has a reported quantity of over 25,000 pounds. (Exhibit 3.2-28)

- For all in-transit event causes except over-turned trucks, the majority of material is from events releasing over 100,000 pounds. For over-turned trucks as the cause of release, approximately 50 percent of the material is released in events with release sizes ranging from 1,000 to 50,000 pounds. (Exhibits 3.2-30 through 3.2-33)

3.3 TYPES OF FACILITIES INVOLVED

- Industry sectors were identified for the responsible parties in 90.6 percent of the 11,048 events in the AHE/DB. The reported responsible parties range from primary producers to end-users, with 39.6 percent of the events occurring in the Chemicals and Allied Products and Petroleum Products (Primary) sectors. Over twenty-four percent of the events occur in the transportation/distribution sector, 13.9 percent in the secondary producer sector, 11.2 percent in end-user applications, 1.4 percent in waste-related activities, and 9.4 percent unknown. (Exhibit 2.2-13)

- Primary producers account for a greater percentage of reported deaths and injuries than all other industry sectors. Distributors account for the largest share of evacuees. (Exhibits D-8, D-11, D-14, D-17, and D-20)

- While secondary producers account for only 14 percent of all events, they release over 40 percent of the total reported quantity in the AHE/DB. Distributors and end-users, on the other hand, have twice as large a share of events as they do of quantity released.

3.4 CHEMICALS PARTICIPATION

o The ten chemicals most frequently reported in association with AHE/DB accidental release events are involved in up to 43 percent of such events (Exhibits 3.4-1 and 3.4-2) *

- Sulfuric acid is involved in the most (1,058) events, representing 9.6 percent of all events; five deaths and 380 injuries occur in these events. (Exhibits 3.4-1 and 3.4-2)

- Chlorine, ammonia (anhydrous), and hydrochloric acid are involved, respectively, in 765, 644, and 536 events, together representing 18 percent of such events and accounting for seven deaths and 2,304 injuries. (Exhibits 3.4-1 and 3.4-2)

- The other six chemicals (sodium hydroxide, methyl chloride, phosphoric acid, ethylene oxide, toluene, and vinyl chloride), most frequently reported in conjunction with AHE/DB events are involved in 16 percent of such events; 20 deaths and 685 injuries occur in these events. (Exhibits 3.4-1 and 3.4-2)

o Sulfuric acid is the most frequently reported chemical associated with events at all facility types except waste related. Sulfuric acid is involved in 11 percent of the events at primary producers; 11 percent of the events at secondary producers; and 9 percent of the events at distributors. (Exhibits D-9, D-12, and D-15)

o After sulfuric acid, the next four most frequently reported chemicals at primary producers are chlorine, ammonia (anhydrous), methyl chloride, and ethylene oxide; together they account for 1,219 events, 28 percent of the 4,371 events occurring at primary producers. (Exhibits D-8 and D-9)

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* Because any given event may involve more than one chemical, there can be overlap in the numbers of events, deaths, and injuries when discussing the participation of more than one chemical. Therefore, all percents or combined totals of events, deaths, or injuries in this section should be interpreted as upper bounds.

- At secondary producers, the four most frequently reported chemicals, in addition to sulfuric acid are chlorine, ammonia (anhydrous), hydrochloric acid, and phosphoric acid; together they account for 341 events, 22 percent of the 1,538 events occurring at secondary producers. (Exhibit D-12)

- At distributors, the four most frequently reported chemicals, in addition to sulfuric acid, are sodium hydroxide, hydrochloric acid, ammonia (anhydrous), and phosphoric acid. Together they account for 623 events, 23 percent of the 2,711 events occurring at distributors. (Exhibit D-15)

- The average quantities released per event are shown in Exhibit 3.4-2 for the twenty chemicals participating in the largest average number of events. Methyl alcohol releases involve the largest quantities (100,000 pounds), followed by sulfuric acid (86,000 pounds), and sodium hydroxide (81,000 pounds).

- When the quantities released in events are compared to the reportable quantities (RQs) of the participating chemicals, 31.3 percent of the events in which quantities are reported involve quantities less than the RQ, i.e., the release of such quantities usually would not be considered of sufficient concern to justify its report to the National Response Center or other jurisdiction. (Exhibit D-5)

- Only 12.6 percent of the events involve chemical release quantities greater than 100 times the RQs of the involved chemicals. (Exhibit D-5)

3.5 GEOGRAPHIC PATTERNS

The geogrephic distribution by state of all events, death events, injury events, and evacuation events are shown schematically in Exhibits 3.5-1 through 3.5-4. It is important to note three caveats with regard to the patterns shown in these exhibits:

- The existence of high numbers of incidents in some states may be a result of effective enforcement by those states of the requirement that such incidents be reported; lower numbers of incidents in other states may be a result of less aggressive enforcement.

- The distribution of events by state also reflects the geographic emphasis of the data collection process, which attempted to minimize such biases but was restricted by the need to access more readily available data sources, such as those that had been computerized. Exhibit 3.5-5 graphically depicts the coverage achieved in each state. California, Texas, New York, and New Jersey received the most comprehensive scrutiny.

- We would also expect the geographic distribution of events to be dependent upon the level of manufacturing activity in the state. That is, states with extensive manufacturing activity, hence chemical activity, are likely to have higher numbers of incidents. Exhibit 3.5-6 shows that California, Texas, New York, Illinois, and Michigan all had manufacturing values of shipments exceeding 120 billion dollars in 1985.

Exhibits 3.5-1 to 3.5-4 show the following:

- Texas is the only state with more than 930 events. Ohio, New Jersey, California, and Louisiana have the four next largest numbers of incidents. (Exhibit 3.5-1)

- New York and New Jersey have the largest number of events involving deaths, and Texas has the third largest number of death events. (Exhibit 3.5-2)

- New Jersey has the largest number of incidents involving injuries. California has the second largest, followed by Texas, Louisiana, Illinois, Ohio, and New York. (Exhibit 3.5-3)

- The trend for evacuation events is similar to that for injury events. New Jersey leads in number of events involving evacuations, followed by California. (Exhibit 3.5-4)

- For each of the spatial distributions, the majority of states fall in the category representing the lowest frequency of events: 42 states have fewer than 310 total events, 44 states have fewer than five death events, 43 states have fewer than 40 injury events, and 43 states have fewer than 33 evacuation events.

Exhibit 2.2-16

SUBSTANCES MOST FREQUENTLY REPORTED IN EVACUATION EVENTS

RANK	SUBSTANCE NAME *	# OF EVENTS **	# EVAC ALL SUBS	TOTAL QUANTITY RELEASED (Lbs.)	AVERAGE QUANTITY RELEASED (Lbs.) ***	LARGEST QUANTITY RELEASED (Lbs.)
1	CHLORINE	93	38,126	53,000	1,200	20,000
2	HYDROCHLORIC ACID	79	49,693	1,500,000	52,000	1,125,000
3	AMMONIA (ANHYDROUS)	68	12,201	450,000	12,000	160,000
4	SULFURIC ACID	31	15,055	1,600,000	130,000	1,500,000
5	NITRIC ACID	21	17,142	150,000	17,000	135,000
6	AMMONIA	21	5,158	180,000	20,000	112,500
7	VINYL CHLORIDE	14	17,686	150,000	38,000	150,000
8	HYDROGEN SULFIDE	12	3,022	1,700	330	1,000
9	SODIUM HYDROXIDE	12	5,070	41,000	8,100	30,000
10	STYRENE	12	17,250	160,000	26,000	82,500
11	TOLUENE DIISOCYANATE	11	4,959	16,000	5,400	15,000
12	ETHYLENE OXIDE	11	9,725	350,000	88,000	202,500
13	PHOSGENE	10	1,159	100	50	90
14	TOLUENE	10	2,450	47,000	16,000	30,000
15	PHOSPHORIC ACID	10	18,760	300,000	100,000	300,000
16	POLYVINYL CHLORIDE	9	18,250	0	0	0
17	BENZENE	9	4,800	20,000	9,800	12,000
18	SULFUR DIOXIDE	8	630	0	0	0
19	FORMALDEHYDE	8	2,414	340,000	120,000	466,590
20	BUTADIENE	8	3,982	470,000	170,000	93,750
21	METHYL ALCOHOL	8	3,278	2,000,000	1,000,000	1,875,000

* All substances are commodity chemicals.

** This includes all events in which the substance appears as a primary, secondary, or tertiary substance.

*** Average quantities are computed using only those events that reported quantities.

Exhibit 2.3-1

AIR RELEASES OF TOXIC CHEMICALS LEADING TO TWO OR MORE DEATHS
(1982 - 1986)

DATE	SUBSTANCES RELEASED			END EFFECTS				NUMBER OF INJURIES	NUMBER OF DEATHS	NUMBER OF EVACUEES
	SUBSTANCE 1	SUBSTANCE 2	SUBSTANCE 3	1ST	2ND	3RD	4TH			
04-Apr-86	GUNPOWDER			EX	FI	UU	UU	0	8	0
01-May-86	ACETALDEHYDE			SP	EX	FI	VR	0	4	288
13-Jun-86	UNKNOWN			EX	FI	UU	UU	4	3	0
27-May-86	POLYVINYL CHLORIDE	TOLUENE DIISOCYANATE	METHYLENE CHLORIDE	FI	EX	VR	UU	0	2	0
17-Jan-86	AMMONIUM DICHROMATE			EX	FI	VR	UU	18	2	0
06-Jul-86	TRICHLOROETHYLENE			SP	VR	UU	UU	25	2	0
08-Jun-86	BUTADIENE	FORMALDEHYDE		SP	EX	FI	VR	5	2	2,000
25-Jun-85	GUNPOWDER/FIREWORKS			EX	FI	UU	UU	5	21	0
20-May-85	GUNPOWDER			FI	EX	UU	UU	0	9	0
05-Dec-85	HYDROGEN	NAPHTHA		EX	FI	VR	UU	45	5	0
26-Apr-85	POTASSIUM	SODIUM NITRATE		EX	UU	UU	UU	18	3	0
29-May-85	AMMONIA			EX	UU	UU	UU	10	3	0
20-Dec-85	XYLENE	TOLUENE	METHYL ETHYL	FI	EX	UU	UU	7	3	0
18-Apr-85	TOLUENE			EX	FI	UU	UU	1	3	0
06-Feb-85	NITROGLYCERINE			EX	UU	UU	UU	0	2	0
18-Jul-85	METHYL ALCOHOL	VARNISH		FI	EX	UU	UU	1	2	100
19-Jan-85	SULFUR			FI	EX	SP	UU	7	2	0
04-Apr-85	ACETYLENE			FI	EX	UU	UU	0	2	0
03-Mar-85	HYDROFLUORIC ACID			SP	VR	UU	UU	0	2	0

Exhibit 2.3-2

AIR RELEASES OF TOXIC CHEMICALS LEADING TO FORTY OR MORE INJURIES
(1982 - 1986)

DATE	SUBSTANCES RELEASED			END EFFECTS				NUMBER OF INJURIES	NUMBER OF DEATHS	NUMBER OF EVACUEES
	SUBSTANCE 1	SUBSTANCE 2	SUBSTANCE 3	1ST	2ND	3RD	4TH			
08-Jul-86	PHOSPHORUS			EX	FI	VR	SP	400	0	40,000
27-Mar-86	HYDROCHLORIC ACID			SP	VR	UU	UU	115	0	0
26-Aug-86	ACRYLONITRILE			EX	FI	VR	UU	111	0	500
25-Apr-86	UNKNOWN			FI	VR	UU	UU	90	0	0
21-Feb-86	CHLORINE			SP	VR	UU	UU	71	0	740
22-Jul-86	ETHYLENE GLYCOL			SP	VR	UU	UU	65	0	0
16-Jul-86	SULFURIC ACID			SP	VR	UU	UU	50	0	0
30-May-86	UNKNOWN			VR	UU	UU	UU	40	0	5,000
11-Aug-85	ALDICARB OXIME	METHYLENE CHLORIDE		VR	UU	UU	UU	430	0	3,100
21-Jan-85	DIMETHOATE			VR	SP	UU	UU	200	0	0
26-Jun-85	PARATHION	PARAQUAT	GASOLINE	VR	FI	EX	UU	134	0	2,000
21-Mar-85	POLYVINYL CHLORIDE			VR	FI	UU	UU	90	1	8,250
27-Jun-85	MALATHION	PARAQUAT	METHYL BROMIDE	VR	FI	UU	UU	90	0	1,000
20-Apr-85	METHYL ETHYL KETONE	PHOSGENE	HYDROGEN CYANIDE	FI	VR	UU	UU	80	0	74
05-Sep-85	UNKNOWN			VR	UU	UU	UU	72	0	260
16-Jul-85	POLYVINYL CHLORIDE	HYDROCHLORIC ACID		FI	VR	UU	UU	56	0	10,000
26-Jul-85	CHLORINE			VR	UU	UU	UU	55	0	0
13-Apr-85	BENZENE	SULFURIC ACID	URANIUM	EX	FI	VR	UU	51	0	0
19-Apr-85	POLYCHLORINATED BIPHENYLS	PLASTIC	METHYL ETHYL KETONE	FI	VR	SP	UU	50	0	50
22-Nov-85	SILVER CYANIDE			EX	VR	UU	UU	46	0	200
04-Aug-85	EXPLOSIVES			FI	EX	UU	UU	45	0	4,500
05-Dec-85	HYDROGEN	NAPHTHA		EX	FI	VR	UU	45	5	0
30-Sep-85	CARBON MONOXIDE			VR	UU	UU	UU	42	0	0
27-Aug-85	URANIUM OXIDE			SP	VR	UU	UU	40	1	0
13-Mar-85	ACRYLIC RESIN			VR	SP	UU	UU	40	0	0

Exhibit 2.3-1 (continued)

AIR RELEASES OF TOXIC CHEMICALS LEADING TO TWO OR MORE DEATHS
(1982 - 1986)

DATE	SUBSTANCES RELEASED			END EFFECTS				NUMBER OF INJURIES	NUMBER OF DEATHS	NUMBER OF EVACUEES
	SUBSTANCE 1	SUBSTANCE 2	SUBSTANCE 3	1ST	2ND	3RD	4TH			
20-Dec-84	SOLVENT			VR	FI	EX	UU	7	3	0
15-Aug-84	ACETONE	NITRIC ACID		EX	FI	VR	UU	1	3	100
11-May-84	PLASTICS	POLYSTYRENE	URETHANE	FI	UU	UU	UU	0	3	0
16-Aug-84	COAL TAR	LIGHT OIL		EX	FI	UU	UU	21	2	0
22-Aug-84	SPECIALTY OILS			FI	UU	UU	UU	1	2	0
13-Dec-84	SULFURIC ACID			EX	FI	UU	UU	0	2	0
27-May-83	EXPLOSIVES			EX	FI	UU	UU	1	11	0
04-Dec-83	PETROLEUM PRODUCTS	INSECTICIDE	ANTIFREEZE	FI	EX	VR	UU	4	5	1,600
25-Jan-83	EXPLOSIVES			EX	FI	UU	UU	0	4	0
28-Aug-83	SODIUM NITRATE			EX	FI	UU	UU	10	4	0
16-Nov-83	EXPLOSIVES			FI	EX	UU	UU	26	2	173
03-Oct-83	METHYL BROMIDE	MALATHION		EX	FI	VR	UU	5	2	0
21-Jul-83	METHANE	CHLORINE		EX	FI	SP	UU	9	2	0
14-Jun-83	METHYL ISOBUTYL KETONE	2-NITROPROPANE		VR	UU	UU	UU	0	2	0
18-May-82	NITROGEN			VR	UU	UU	UU	3	2	0
02-Jun-82	NITRIC ACID			EN	FI	VR	P	64	2	5,000
13-Jan-82	HYDROGEN SULFIDE			VR	UU	UU	UU	15	2	0
14-Jan-82	UNKNOWN			EX	FI	UU	UU	11	2	550
	FIVE YEAR TOTAL							324	135	9,811

End Effect Codes: SP - spill; VR - vapor release; FI - fire; EX - explosion; UU - unknown

Exhibit 2.3 - 2 (continued)

AIR RELEASES OF TOXIC CHEMICALS LEADING TO FOUR OR MORE INJURIES
(1982 - 1986)

DATE	SUBSTANCES RELEASED			END EFFECTS				NUMBER OF INJURIES	NUMBER OF DEATHS	NUMBER OF EVACUEES
	SUBSTANCE 1	SUBSTANCE 2	SUBSTANCE 3	1ST	2ND	3RD	4TH			
22-Dec-82	METHYLACRYLATE			SP	VR	UU	UU	355	0	400
13-Sep-82	SODIUM HYDROSULFIDE	PARAQUAT	ORTHENE	VR	FI	VR	UU	100	0	1,500
12-Nov-82	ETHYLENE OXIDE	FLUOROCARBON		SP	VR	UU	UU	77	0	1,000
31-Oct-82	CHLORINE			SP	VR	UU	UU	76	1	0
02-Jun-82	NITRIC ACID			EX	FI	VR	SP	64	2	5,000
02-Jun-82	PHOSGENE	TOLUENE DIISOCYANATE		VR	SP	UU	UU	60	1	0
13-Oct-82	VINYL BENZENE			SP	VR	UU	UU	51	0	350
22-Oct-82	TRICHLOROETHYLENE			SP	VR	UU	UU	40	0	300
FIVE YEAR TOTAL								4,411	12	93,224

End Effect Codes: SP - spill; VR - vapor release; FI - fire; EX - explosion; UU - unknown

Exhibit 2.3-2 (continued)

AIR RELEASES OF TOXIC CHEMICALS LEADING TO FORTY OR MORE INJURIES
(1982 - 1986)

DATE	SUBSTANCES RELEASED			END EFFECTS				NUMBER OF INJURIES	NUMBER OF DEATHS	NUMBER OF EVACUEES
	SUBSTANCE 1	SUBSTANCE 2	SUBSTANCE 3	1ST	2ND	3RD	4TH			
06-Oct-84	MALATHION			VR	UU	UU	UU	161	0	0
10-May-84	HYDROCARBONS	BENZENE	LACQUER	EX	FI	VR	UU	125	1	0
22-Jan-84	PHOSPHOROUS OXICHLORIDE			SP	VR	[illegible]	UU	125	0	0
15-Nov-84	METHYL ISOCYANATE			VR	UU	UU	UU	111	0	600
08-Jan-84	HYDROGEN SULFIDE	AMMONIA		SP	VR	UU	UU	78	0	1,200
1(Aug-84	FERTILIZERS	PESTICIDES	HERBICIDES	UU	UU	UU	UU	64	0	0
17-Jul-84	AMMONIA			EX	VR	UU	UU	60	0	0
25-Oct-84	CHLORINE			SP	UU	[illegible]	UU	48	0	0
30-Mar-84	SULFURIC ACID			SP	VR	[illegible]	UU	40	0	200
15-Jun-83	PARATHION			VR	UU	UU	UU	118	0	1,500
10-Aug-83	SODIUM HYDROSULFITE			SP	FI	VR	UU	70	0	200
25-Jul-83	UNKNOWN			EX	FI	[illegible]	VR	40	0	300
04-Apr-83	NITRIC ACID			SP	VR	[illegible]	UU	40	0	5,000

Exhibit 2.3-3

AIR RELEASES OF TOXIC CHEMICALS LEADING TO TWO THOUSAND OR MORE EVACUEES
(1982 - 1986)

DATE	SUBSTANCES RELEASED			END EFFECTS				NUMBER OF INJURIES	NUMBER OF DEATHS	NUMBER OF EVACUEES
	SUBSTANCE 1	SUBSTANCE 2	SUBSTANCE 3	1ST	2ND	3RD	4TH			
08-Jul-86	PHOSPHORUS			EX	FI	VR	SP	400	0	40,000
04-Aug-86	CHLORINE			FI	VR	UU	UU	34	0	6,800
30-May-86	UNKNOWN			VR	UU	UU	UU	40	0	5,000
08-Jun-86	BUTADIENE	FORMALDEHYDE		SP	EX	FI	VR	5	2	2,000
16-Jul-85	POLYVINYL CHLORIDE	HYDROCHLORIC ACID		FI	VR	UU	UU	56	0	10,000
21-Mar-85	POLYVINYL CHLORIDE			VR	FI	UU	UU	90	1	8,250
22-Jun-85	METHYL BROMIDE	PHOSPHATE	AMMONIUM NITRATE	FI	VR	UU	UU	12	0	7,500
27-Nov-85	LINURON			FI	EX	VR	UU	13	0	5,825
04-Aug-85	EXPLOSIVES			FI	EX	UU	UU	45	0	4,500
09-Jun-85	VINYL CHLORIDE	CALCINED ALUMINA		EX	FI	SP	UU	0	0	4,000
25-May-85	HYDROCHLORIC ACID	HYDROFLORIC ACID	SULFURIC ACID	EX	FI	SP	VR	21	0	3,800
10-Jun-85	ETHYLENE OXIDE	BUTYL ACRYLATE		EX	FI	SP	UU	0	0	3,500
11-Aug-85	ALDICARB OXIME	METHYLENE CHLORIDE		VR	UU	UU	UU	430	0	3,100
16-Mar-85	TOLUENE DIISOCYANATE			EX	FI	VR	UU	25	0	3,000
10-Aug-85	CHLORINE			VR	UU	UU	UU	3	0	3,000
04-Sep-85	HYDROCHLORIC ACID			SP	VR	UU	UU	0	0	2,000
26-Jun-85	PARATHION	PARAQUAT	GASOLINE	VR	FI	EX	UU	134	0	2,000
29-Mar-85	OCTYL ALCOHOL			SP	FI	UU	UU	0	0	2,000
14-May-84	SULFURIC ACID	COPPER SULFATE	AMMONIUM PERSULFATE	SP	VR	UU	UU	21	0	3,500
29-Dec-84	UNKNOWN			SP	VR	UU	UU	0	0	2,500
31-Dec-84	ETHYLENE OXIDE			SP	VR	UU	UU	0	0	2,500
01-Jun-84	HYDROCHLORIC ACID			SP	VR	UU	UU	4	0	2,000
10-Apr-84	METHYL ALCOHOL	PLASTIC		SP	FI	UU	UU	0	0	2,000