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THE DEVELOPMENT OF INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES TABLE FOR U.S. DOT PUBLICATION *1990 EMERGENCY RESPONSE GUIDEBOOK*

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ABSTRACT

The U.S. Department of Transportation's *1990 Emergency Response Guidebook* (ERG) [1] will provide an updated Initial Isolation and Protective Action Distances Table guiding first responders during the first 30 minutes of a toxic chemical release from a transportation accident. This paper summarizes the methodology and models used to prepare that table and discusses the major technical issues that were faced in its development. The modeling carried out for the 1990 Table was rather complex and attempted to improve, to the extent possible, the physics of the source-term release and atmospheric dispersion (compared with the methodology used in the 1987 ERG Table [2]). Realistic gaseous and liquid accident release scenarios were identified for each of 140 chemicals. The downwind impact was then computed for releases of each chemical from a variety of appropriate container sizes. The realism of the release scenarios was emphasized in the development of the 1990 Table. (For example, the 1987 Table was based on the assumption that all releases came from evaporating pools.) Among the submodels used in the source-term and transport modeling for the 1990 Table were gaseous and liquid release models for the various sizes of containers, pool evaporation models, a flashing model, and an atmospheric dispersion model. Despite the improved modeling methodology and more realistic release scenarios identified in the preparation of the 1990 Table, difficult issues still remain for future study. A key issue involves the use of the various toxicological guidelines that are presently available for the various chemicals, considering that (1) no single exposure limit has been determined for all chemicals of interest for emergency response planning, and (2) there is no uniform guidance by the toxicologists on the use of the various exposure guidelines in the presence of time-dependent exposures.

1. INTRODUCTION

This paper summarizes the mathematical modeling carried out in support of the Initial Isolation and Protective Action Distances Table contained in the *1990 Emergency Response Guidebook* (ERG) to be published by the U.S. Department of Transportation (U.S. DOT). The ERG is to be used by first responders to a transportation accident in which toxic chemicals in liquid or gaseous form have been released. The table contains "initial isolation distances" and "protective

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action distances" for which the first responder is to map out the potential hazard zones and then carry out an evacuation or protection-in-place action. The "protective action distances" for a given chemical are a function of the accidental release rates, atmospheric dispersion, and the toxicological exposure limit for that chemical. The distances provided in the table are applicable for the first 30 minutes following the start of an accident. The chemicals listed in the table were all chosen because they are considered "toxic by inhalation" by the U.S. DOT. The 1990 version of the Initial Isolation and Protective Action Distances Table (1990 Table) covers accidents involving containers ranging in size from gallon jugs to rail cars. The chemicals are transported either as pressurized gases, liquified gases, or liquids under atmospheric pressure. Sufficient physical and toxicological data were available to model 140 of the 160 chemicals that are considered toxic by inhalation. Because of the many different meteorological conditions that could be present during an accident and the many different container sizes possible, the following two-step plan was used to provide a reasonable compromise among the wide range of variables:

1. Choose one set of meteorological conditions (the same for all chemicals) that would represent conservative mixing conditions during an accident for most of the day (see Section 2).

2. Evaluate model releases from each of the possible container sizes for the chemicals to determine a good categorization scheme for spill sizes (see Section 2).

Preliminary computer runs made for each chemical and each container size indicated that the protective action distances were similar for most releases from container sizes equal to a 55-gallon drum and smaller. Similarly, releases from container sizes greater than a 55-gallon drum had similar protective action distances. Section 2 contains more detail on container size breakdown. The application of steps 1 and 2 above allowed many possible alternative chemical accident scenarios for a given chemical to be reduced to two -- a "small" spill scenario and a "large" spill scenario, both with the same set of meteorological conditions.

Once the meteorological scenario, the container sizes, and rupture-hole diameters were defined for each chemical, then the tasks that remained were to predict both the source term and the downwind dispersion of the toxic release. The objective here was to use state-of-the-art modeling methods wherever possible. Special modeling for chemicals with unique physical, chemical, or thermodynamic effects (such as fuming acids) was beyond the scope of the project. An attempt to deal with such special cases is planned for the 1993 version of the ERG.

Section 3 reviews the toxicological limits employed for each chemical. These values were used in the computation of the boundary between acceptable and not-acceptable exposures of people located downwind of a spill. The problems here were twofold: (1) concentration histories for people downwind are often very much time-dependent, and the time-dependent nature of the toxic exposures is not accounted for in many of the published exposure guidelines, and (2) no single exposure limit was available for all 160 chemicals considered toxic by inhalation, thus preventing the use of a uniform set of toxicological limits for all chemicals. In fact, only 11 chemicals had Emergency Response Planning Guideline No. 2 limits (ERPG-2 limits) available for them. These ERPG-2 limits are the most appropriate choice for this type of short-term release to the general public. This topic is discussed in more detail in Section 3.

Sections 4 and 5 describe the various mathematical models used for the three categories of release described above (pressurized gases, liquified gases, and liquids under atmospheric pressure), including container release models, pool evaporation models, a flashing (liquid to vapor) model, and an atmospheric dispersion model.

2. TRANSPORTATION SCENARIOS AND BASIC MODELING ASSUMPTIONS

Table 1 identifies the possible container sizes for the chemicals shipped as liquids and gases for both small and large spills. For a given chemical, the data in Table 1 were compared with information provided by the U.S. DOT on the actual shipping-container sizes for that chemical. The worst-case container size (largest) was chosen for two different spill-size classifications -- "small spills" and "large spills." As mentioned above, a small spill is one from a 55-gallon drum or smaller container, while a large spill is a spill from a container larger than a 55-gallon drum. The classification of small and large spills, which applies to both liquid and gaseous releases, was determined through preliminary model runs. The definition of small spill and large spill was based on similar predicted protective action distances for chemicals in each of the two container-size categories. Although a gaseous release does not "spill" chemicals onto the ground, it could be thought of as the "spilling" of a gas from the tank into the atmosphere.

Table 1 Candidate container sizes for U.S. DOT "toxic by inhalation" chemicals.

	Liquids		Gases	
	Small Spill	Large Spill	Small Spill	Large Spill
Gallon Jug	X			
Standard Cylinders (all sizes and pressures)	X		X	
55-Gallon Drum	X			
1000-lb Cylinders		X		X
1-Ton Cylinders (high and low pressure sizes)		X		X
Jumbo Tube		X		X
2000-Gallon Tank		X		
Intermediate Bulk (small, medium, and large sizes)		X		
Tank Truck		X		
Rail Car		X		X

All chemicals were assumed to be either liquids or gases shipped at 95°F. For each liquid, the tank pressure was set to the larger of the saturation vapor pressure of the chemical or the atmospheric pressure. For each gas, the tank pressure was set to the smaller of the saturation vapor pressure of the chemical or the maximum allowable tank pressure in a given tank. For a given container, the hole diameter was based on the diameter of a valve or nozzle for that given container, as provided by the U.S. DOT. The holes were assumed to be located at the bottom of the liquid containers or at the top of the gas containers. The hole discharge coefficient was taken to be unity for both gaseous and liquid releases.

Liquid releases (nonpressurized liquids or liquified gases) were assumed to spill from the hole to form an evaporating pool. The liquified gases were further assumed to flash (liquid to vapor) as the pressurized liquid was released from the container. Aerosol entrainment was ignored due to the lack of proven models dealing with this entrainment phenomena and the subsequent evaporation of aerosol droplets. Materials shipped as pressurized gases were assumed to be released directly into the atmosphere as gases upon accidental release.

For the preparation of the 1990 Table, a 10 mph wind speed, an atmospheric temperature of 95°F, and D stability atmospheric conditions were assumed. The choice of D stability is considered conservative for mixing and dispersion during daytime conditions. The difference between D stability and F stability predictions (more representative of nighttime meteorological conditions) was not sufficiently great to justify additional columns in the table.

The size to which a liquid pool can grow is determined by the terrain and the physical properties of the liquid that is spilling. An unconfined spill on a flat, smooth surface can grow quite large. One limitation, of course, is that the evaporation rate of a pool can not exceed the spilling rate of the liquid into that pool. To bound the problem, reasonable limits were placed on the size that a pool would grow based on the size of the shipping container. A 60-foot-diameter pool was used for large spills based on an average of railway berm widths, roadway widths, and drainage separation distances. A 48-foot-diameter pool was used for small spills. This value was provided by the U.S. DOT based upon observation of the width of spread from a release from a 55-gallon drum.

3. APPLICATION OF TOXIC EXPOSURE GUIDELINES

A key issue involved in the computation of protection distances is the identification of the proper toxic exposure limit to the general population for a given chemical in a short-term toxic release scenario. The most relevant exposure guideline for such a situation is the ERPG-2 limit. The ERPG-2 exposure limits were developed by the American Industrial Hygiene Association (AIHA) Emergency Response Planning Guidelines (ERPG) Committee. The ERPG-2 limit is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action. However, ERPG-2 limits have been identified for only 11 of the 160 chemicals that were studied.

The U.S. DOT sought advice from expert toxicologists concerning alternative exposure guidelines that could be used in place of the ERPG-2s when such limits were not available. The Organization Resources Counselors, Inc. [3] recommended the following order of exposure guidelines for use, in the order of availability for a given chemical: ERPG-2, SPEGL, STEL, Ceiling TLV, EEGL, and TLV-TWA. For some chemicals, no toxicological exposure guidelines in this list were available, so estimates of short-term limits from LC50s and LCLOs had to be made instead. The ERPG-2s, SPEGLs, and EEGLs are 1-hour concentration limits, while STELs are typically 15-minute limits. Ceiling TLVs are actually maximum values not to be exceeded at any time. TLV-TWA values represent an 8-hour workday, 40-hour work week repeated exposure for workers over many years.

Once an exposure limit was defined for a given chemical, the next issue was determining how to apply the limit in a time-dependent exposure scenario. Informal discussions with two members of the AIHA ERPG Committee led to the following general practical application principles:

1. When the predicted exposure time is on the order of the time period of the guideline, then the guideline limit is to be treated as an "average concentration" over the time of exposure rather than a peak concentration never to be exceeded. (The exception is the ceiling TLVs, which are maximum not-to-be-exceeded values.)

2. When the predicted exposure time is less than 1/4 the time period of the guideline (e.g., 15 minutes for a 1-hour guideline), then the dosage allowed for that short exposure is equal to $2^*C_o{}^*t$, where "C_o" is the guideline exposure concentration and "t" is the time of exposure. Since, for example, an 8-minute exposure time can be thought of as a series of even shorter-duration exposures (i.e., exposures of less than 8 minutes), the above guidance was implemented in the modeling by using 2^*C_o as a peak concentration that is never to be exceeded for such short exposure times.

3. When the predicted exposure is greater than the time period of the guideline (e.g., 25 minutes for a 15-minute guideline), then the predicted dosage (i.e., integrated concentration over 25 minutes) can not exceed the integrated exposure guideline concentration over the guideline time period.

4. For TLV-TWAs, an exposure of 30 minutes or less is allowed an average concentration of 3 times the associated TLV-TWA.

It should be recognized that these rules were developed for general application to a wide range of chemicals. Isolated chemicals may require special consideration.

4. SOURCE-TERM MODELING

Accidental chemical releases can be either in liquid or gaseous form. Liquid releases can occur from chemicals stored as nonpressurized liquids or liquified gases. In both cases, a spill could then form an evaporating pool. Evaporation from the pool provides the toxic chemical source term for a nonpressurized liquid release. For a pressurized liquid, the source term consists of two components: evaporation from the liquid pool and a vapor release directly from the hole due to the flashing of liquid to vapor as the pressurized liquid is released from the container. Materials shipped as pressurized gases will be released directly into the atmosphere as gases upon accidental release.

For chemicals that are shipped as gases, the gas releases were modeled simply by using Perry's equations of choked flow from a hole [4]. The equation for the mass emission rate will be time dependent since the internal pressure in a given tank will vary as the tank begins to empty and the internal tank pressure drops. The actual pressure at which each chemical is shipped was used to determine the initial gas emission rate. The conservative assumption (i.e., one that maximizes the protective action distances) was made that the initial "choked flow" gas emission rate was maintained until the entire container was emptied.

For liquid spills, three modeling components were needed to simulate the source term -- the liquid spill model, the flashing of liquid-to-vapor model, and the evaporating pool model. For materials shipped in the liquid state, the assumption was made that the material would spill through a hole at the base of the shipping container. The spilling rate from a container holding a liquid chemical (liquified gas or nonpressurized liquid), was modeled using the Bernoulli equation [4]. For both liquified gases and nonpressurized liquids, a quasi-steady-state solution of the Bernoulli equation was obtained (since the spilling rate varies with the height of the liquid in the container), and then an average spilling rate over the duration of the spill was calculated.

For liquified gases, it is possible that the liquid will partially "flash" directly to vapor because of the sharp reduction in pressure (to ambient level) that occurs upon release. The flashing process was modeled using the heat balance equation for a single component liquid, assuming a constant-temperature liquid [5]. The flashing process is only of importance for chemicals that have boiling points lower than the ambient temperature ($95^{o}F$). The specific heat, the latent heat of fusion, and the boiling point of the chemicals are the physical properties required for modeling the flashing process. The specific heat and the latent heat of fusion were not available for all of the chemicals that could flash. Conservative estimates were made of values for any missing physical properties.

Liquid that spills from a container (excluding the fraction of that liquid that flashes) will form a pool that will then evaporate. Evaporation rates from pools were estimated using one of three models. The first model is the Wu-Schroy ("Emissions from Spills") model for evaporating pools [6]. The Wu-Schroy model appears to represent the state-of-the-art in modeling evaporation rates from liquid pools. The model simultaneously solves the mass and heat-balance equations for liquid pools to estimate time-dependent emission rates. Heat transfer to the pool is accounted for by balancing conduction to the ground, convection to the atmosphere, solar radiation effects, and the latent heat effects of evaporation of the pool's liquid.

Since the Wu-Schroy model requires values for many physical properties, such as the Antoine constants and Schmidt number, that were not always available for each chemical, it was not applied for all the chemicals listed as toxic by inhalation. Therefore, two submodels of the Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE) computer program were used. The ARCHIE program is used to conduct consequence analysis for postulated accident scenarios [7]. The program was developed for the Federal Emergency Management Agency (FEMA), the U.S. DOT, and the U.S. Environmental Protection Agency (U.S. EPA).

The first submodel of the ARCHIE program used was the Emission Rates from Liquid Pools model [8] (also known as the ESL model), used to estimate the evaporation rates from liquid pools. The ESL model was developed by the U.S. Air Force Engineering and Services Laboratory. This model was useful because it (1) provides a simple solution to the evaporating pool problem, and (2) requires fewer physical properties and thus permitted runs of a few more chemicals than the Wu-Schroy model allowed. The ESL model discussed here is a simplified version of a more complex model also developed by the U.S Air Force Engineering and Services Laboratory, based on work done by Ille and Springer [9].

The ESL model is a steady-state model that correlates the evaporation rates of any chemical of interest with that of hydrazine. The model is valid for discharged liquid within the ambient temperature range. This model was applied to the liquid pool scenarios for chemicals that boil at temperatures greater than 0°C. Compared with the Wu-Schroy model predictions, the ESL model gave conservative estimates about 75% of the time for nonpressurized liquids (for 29 chemicals run with both models).

It should be noted here that the ARCHIE program itself defaults to the worst case for liquified gas discharge scenarios by setting the source term equal to the spilling rate, thus assuming 100% flashing and aerosol entrainment, whenever the temperature of the chemical in its container exceeds its boiling point by 6°C or more. Since one of the assumptions in the modeling work done for the ERG was to ignore aerosol entrainment, the two evaporation rate submodels were applied to the liquified gases by running the submodels independently of the ARCHIE program.

For liquified gases that boil upon release at temperatures between 0°C and 89°C (here the ARCHIE program would have predicted 100% flashing and aerosol entrainment), the downwind predictions of the ESL model were less conservative than those of the Wu-Schroy model for seven chemicals for which both models could be run. Therefore, it appears that the use of this simplified model most likely gave nonconservative predictions for this group of chemicals for which it had to be used (those that lacked the physical properties to run the Wu-Schroy model). While this is not desirable, it was determined that the use of this model had a potential nonconservative effect for only five of the chemicals for which it was used, based on a review of the final results of the entire modeling process. Furthermore, those five belong to the set of chemicals for which very conservative flashing predictions were made because data on the physical properties needed for an accurate flashing calculation were not available. Since the flashing component of the source term tended to strongly outweigh the evaporation component of the source term, the net effect of using the ESL model results for these five chemicals was minimized.

For chemicals with a low boiling point (classified here as chemicals that boil at temperatures less than 0°C), a second evaporation rate submodel in ARCHIE was employed. This second submodel, developed specifically for the ARCHIE program by Arthur D. Little, Inc. [7], correlates estimated pool-burning velocities with experimentally derived boiling rates. Compared with the Wu-Schroy model predictions, this submodel yielded estimated evaporation rates that were about three times more conservative (for seven chemicals run with both models).

5. ATMOSPHERIC DISPERSION MODELING

Since the hazard zone changes with time following a transportation accident, a time-dependent dispersion analysis that correctly predicts the evolution of the plume and that correctly handles a time-dependent source was required. For the Guidebook, the integrated exposure and the maximum concentration for the first 30 minutes following the accident were used to determine the protective action distances.

None of the existing steady-state, Gaussian-plume dispersion models can predict the evolution of the plume associated with a transportation accident. Yet these models do have the advantage of being based on a great deal of empirical data and are generally accepted in the field. The model developed for this study is, in essence, a time-dependent analog of the standard Gaussian plume model, with the dispersion coefficients determined so that agreement is realized for a steady-state plume from a continuous source [10]. It is worth noting that the protective action distances obtained for a continuous release are often several times greater than those obtained when the transient nature of the source and plume are correctly modeled. In fact, the protective action distances thus predicted are so large as to be utterly useless as guidelines for emergency response personnel. Thus, the need for a time-dependent model is a very real one from both a conceptual and a practical standpoint.

The baseline case used in all of the Guidebook calculations is a point source with a time-dependent release rate. Dispersion was modeled using D atmospheric stability and a wind speed of 10 mph. Two protective action distances were predicted: one corresponding to the peak concentration and the other corresponding to the average concentration or, equivalently, the integrated dose. In the former case, the protective action distance was determined as that distance where a specified peak concentration was exceeded (using 2^*C_0 for short exposure times). In the latter case, the protective action distance was determined as that distance where a specified dosage or, alternatively, an average concentration, was exceeded (using C_0 for long exposure times). Based on the exposure guidelines, the critical peak concentration and the critical average concentration were different for each of the exposure limits (except the ceiling TLVs), with the peak concentration always being larger (by a factor of two) than the average concentration. The larger protective action distance of the two predictions was used for the 1990 Table.

6. DISCUSSION OF RESULTS

A sample of the 1990 ERG Initial Isolation and Protective Action Distances Table appears here as Table 2. The 1990 Table is intended to provide the first responder with enough information, in conjunction with guidance in the text, to map out the potential hazard zones during the first 30 minutes of a chemical accident.

Included in the 1990 Table are the protective action distances and initial isolation distances for each chemical that is classified as toxic by inhalation by the U.S. DOT in order of chemical ID number. The protective action distances are used to define the "protective action zone," which is the zone that people should be denied access to, move out of, or be protected-in-place in, depending on the circumstances. The initial isolation distances are computed as a function of the protective action distances and are the recommended distances to first evacuate people in all direction from a spill.

The 1990 Table is divided into two major headings, "Small Spills" and "Large Spills." As discussed above, small spills are from container sizes less than or equal to a 55-gallon drum, while large spills are from all larger container sizes. The actual range of container sizes normally used was available for each chemical. Computer modeling was done for two containers per chemical. The largest size of the actual container sizes appropriate for a given chemical (in each spill-size category) was used to determine the source terms. Once the source terms were determined, the vapor dispersion calculations could be made and compared with the exposure guidelines to give the protective action distances.

For the sake of simplicity in applying the table, the protective action distances were rounded up (or "binned") to 0.2, 0.4, 0.8, 1.0, 2.0, 3.0, 4.0 and 5.0 miles. Five miles is the farthest distance that appears in the table based on the

Table 2 Example of the Draft Version of the 1990 INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES TABLE

		SMALL SPILLS (Leak or spill from a small package or small leak from a large package.)		**LARGE SPILLS** (Leak or spill from a large package or spill from many small packages.)	
ID No.	NAME OF MATERIAL	First, **ISOLATE** in all directions- (feet)	Then **PROTECT** those persons in the DOWNWIND direction- (miles)	First, **ISOLATE** in all directions- (feet)	Then **PROTECT** those persons in the DOWNWIND direction- (miles)
1005	AMMONIA	150	0.2	300	1.0
1005	AMMONIA, ANHYDROUS, liquefied	150	0.2	300	1.0
1005	AMMONIA SOLUTION with more than 50% ammonia	150	0.2	300	1.0
1005	ANHYDROUS AMMONIA	150	0.2	300	1.0
1008	BORON TRIFLUORIDE	1500	5.0	1500	5.0
1016	CARBON MONOXIDE	150	0.4	150	0.8
1017	CHLORINE	900	3.0	1500	5.0
1023	COAL GAS	300	1.0	1500	5.0
1026	CYANOGEN	300	1.0	300	1.0
1026	CYANOGEN, liquefied	300	1.0	300	1.0
1026	CYANOGEN GAS	300	1.0	300	1.0
1040	ETHYLENE OXIDE	150	0.8	600	2.0
1041	CARBON DIOXIDE- ETHYLENE OXIDE MIXTURE, with more than 6% ETHYLENE OXIDE	150	0.8	1200	4.0
1041	ETHYLENE OXIDE-CARBON DIOXIDE MIXTURE, with more than 6% ETHYLENE OXIDE	150	0.8	1200	4.0
1045	FLUORINE, compressed	600	2.0	600	2.0
1048	HYDROGEN BROMIDE, anhydrous	1500	5.0	1500	5.0
1050	HYDROCHLORIC ACID, anhydrous	600	2.0	1200	4.0
1050	HYDROGEN CHLORIDE, anhydrous	600	2.0	1200	4.0
1051	HYDROCYANIC ACID	600	2.0	600	2.0
1051	HYDROGEN CYANIDE, anhydrous, stabilized	600	2.0	600	2.0
1052	HYDROFLUORIC ACID, anhydrous	300	1.0	900	3.0
1052	HYDROGEN FLUORIDE, anhydrous	300	1.0	900	3.0
1053	HYDROGEN SULFIDE	1500	5.0	1500	5.0
1053	HYDROGEN SULFIDE, liquefied	1500	5.0	1500	5.0

assumption of a 10 mph wind speed for 30 minutes. Figure 1 shows the process used to determine the final binned protective action distances for a given chemical.

The modeling methodology described here was applied to as many of the toxic by inhalation chemicals as possible. For some chemicals, too many physical properties were unknown to run any of the required source-term models, while some other chemicals were missing toxicological data. Of the original list of 160 chemicals requiring analysis, 140 were modeled to completion (process shown in Figure 1). The remaining chemicals were assumed to behave like other chemicals with similar physical and toxicological properties that could be modeled, or else were treated using very conservative assumptions. The 1990 Table lists a total of 216 chemicals; the additional 56 chemicals listed are synonyms of chemicals on the original list of 160 toxic by inhalation chemicals.

To use the Initial Isolation and Protective Action Distances Table, the first responder must initially carry out the following steps:

1. Identify the material by its ID number and name,
2. Read the recommended emergency actions for the chemical of interest.

Once these above steps have been taken, the table can be used as follows:

1. Look up the chemical in the table by ID Number, it will be in the table only if it is considered toxic by inhalation,
2. Decide if the incident classifies as a small or a large spill,
3. Look up the initial isolation distance and the protective action distance in the table,
4. Determine the wind direction,
5. Map out the initial isolation zone, as described below, and
6. Map out the protective action zone, as described below.

The 1990 ERG defines an initial isolation zone and a protective action zone as presented in Figure 2. The initial isolation zone is a circle with a radius equal to the initial isolation distance (the spill site being at the center of the circle). The protective action zone is defined as a square with length and width equal to the protective action distance. The main reason for using a square is that it approximates a 60-degree sector from the spill location and should give reasonable protection against wind shifts for a 30-minute time period. Note that a 60-degree sector leads to a maximum width (the direction oriented normal to the direction of the wind) of magnitude equal to the protective action zone. The extra area outside the 60-degree arc but inside the square provides extra protection against unpredictable wind shifts. The other reason for making the zone in the shape of a square is for simplicity.

7. FUTURE RESEARCH

Although significant improvements have been made in both the development of the accident scenarios and in the modeling of the source release/atmospheric dispersion for the 1990 Table, there are areas where additional research is needed in the preparation of the 1993 Table. The three most important areas are discussed below.

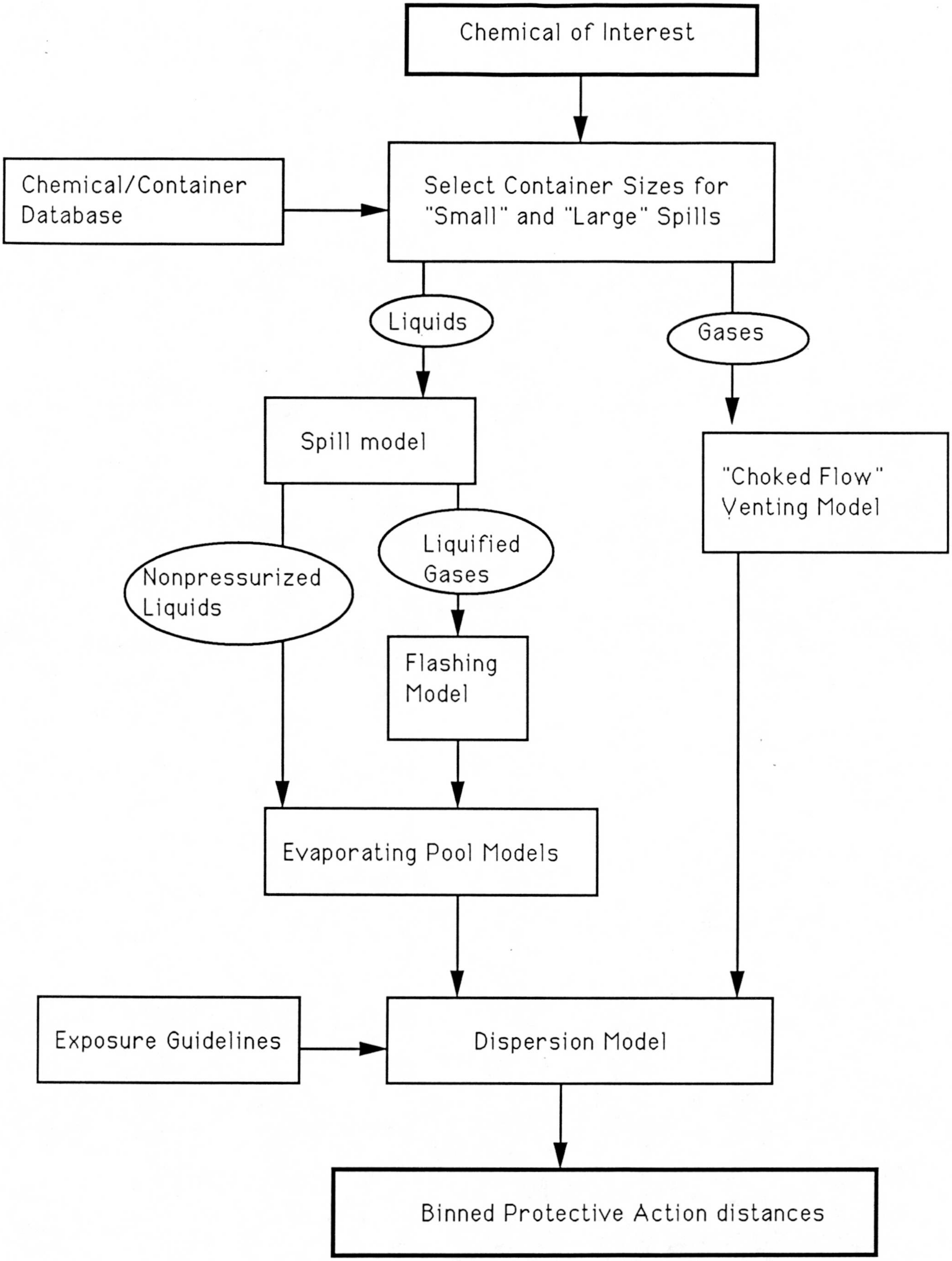

Figure 1 Process for determining the final binned protective action distances.

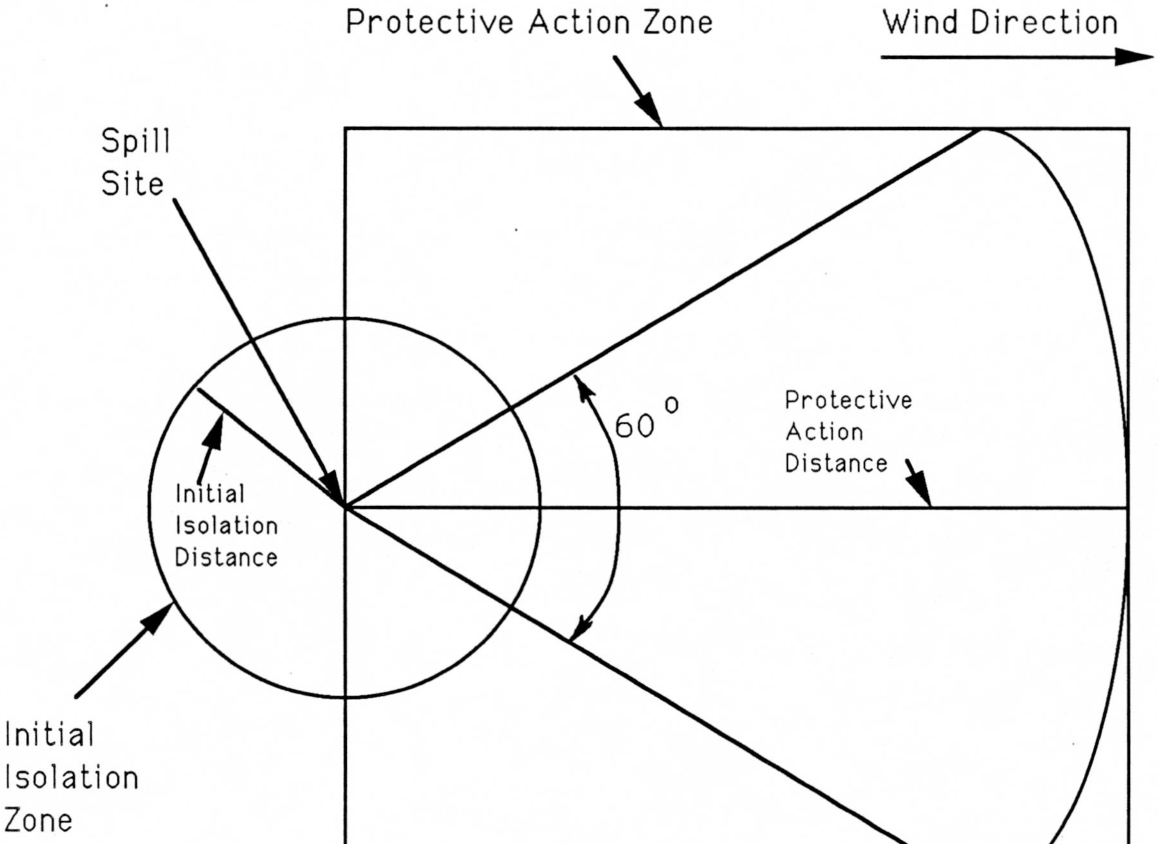

Figure 2 Initial Isolation Zone and Protective Action Zone.

The first area involves the further refinement of the approach in applying the available toxicological guidelines. A committee of expert toxicologists is needed to provide guidance on such matters as (1) an improved treatment for chemicals with no available toxicological data, (2) an improved treatment (if needed) of the time-dependent exposure methodology used in preparing the 1990 Table, and (3) how best to minimize the intrinsic differences that occur in the prediction of downwind hazard distances when different exposure guidelines are used for different chemicals.

A second area involves source term/dispersion modeling issues. A model is needed to predict the amount of of aerosol entrainment for pressurized liquids and to treat the effects of aerosols on the dispersion of the toxic cloud. Also, the importance of heavy gas effects should be studied to determine if the dispersion calculations would be improved for those chemicals that behave as heavy gases once released. Furthermore, special modeling for chemicals with unique physical, chemical, or thermodynamic effects (such as fuming acids) needs to be addressed.

A third area involves the need of a more detailed search for, and perhaps the estimation/computation of, physical property data for various exotic chemicals. For many of the chemicals shipped as liquids, there were not enough physical properties known to apply the more physically correct source-release models. In a few cases, there were not even enough physical property data available to run any of the source-release models.

It is anticipated that work in each of these areas will lead to further improvements for the 1993 Table.

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