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PLANNING BASIS FOR THE DEVELOPMENT OF STATE AND LOCAL GOVERNMENT RADIOLOGICAL EMERGENCY RESPONSE PLANS IN SUPPORT OF LIGHT WATER NUCLEAR POWER PLANTS

A Report Prepared by a
U. S. Nuclear Regulatory Commission and
U. S. Environmental Protection Agency
Task Force on Emergency Planning

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FOREWORD

The purpose of this report is to provide a basis for Federal, State and local government emergency preparedness organizations to determine the appropriate degree of emergency response planning efforts in the environs of nuclear power plants. The report is the product of a Task Force of NRC and EPA representatives formed in 1976 to address this issue. The Task Force hopes that the guidance provided here will be used to supplement the extensive emergency planning guidance already published by NRC and EPA.

This report introduces the concept of generic Emergency Planning Zones as a basis for the planning of response actions which would result in dose savings in the environs of nuclear facilities in the event of a serious power reactor accident. Application of the Task Force guidance should result in the development of more uniform emergency plans from site to site but should not result in a large incremental increase in the resources required to implement the existing planning elements. This is particularly true of recently licensed plants where planning elements have been implemented at substantial distances from reactor sites.

This report represents a consensus view of the Task Force on the planning basis guidance and on a number of important issues related to emergency planning which were considered in the development of the guidance. As of the publication date of this report, these recommendations had not been formally adopted by the NRC or EPA and therefore represent only Task Force views. However, the concept of a generic area in which to plan has received general acceptance by the variety of groups commenting on drafts of this report. If adopted by the NRC, the Task Force expects that the key elements of the guidance would be incorporated in the NRC's primary emergency planning guidance publication for States and their local governments (NUREG-75/111) and therefore used by Federal agencies as a part of the basis for concurrence in State and local government Radiological Emergency Response Plans in support of power reactor facilities.

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ON

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Two major versions of this Task Force report have been reviewed by interested Federal agencies, and a limited number of State and local government emergency preparedness representatives. Many written comments and suggestions were received on the two major draft versions and all of the comments were carefully considered in preparing the final version of this report. The report was significantly improved as a result of the comments and suggestions.

The Task Force wishes to thank all of those who provided comments and critiques of the report during the two year period of its development and in particular the Interorganizational Advisory Committee on Radiological Emergency Response Planning and Preparedness, of the Conference of (State) Radiation Control Program Directors. Members of the committee also included representatives of the National Association of State Directors for Disaster Preparedness and the U.S. Civil Defense Council.

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I. INTRODUCTION

Nuclear facility licensees are required by NRC regulations to develop emergency response plans[1]. Portions of these regulations require the licensees to coordinate their plans with State and local agencies. Published Federal guidance[2,3] recommends that State and local governments formalize their emergency response plans in support of these facilities to protect public health and safety in the unlikely event of a significant release of radioactive material from a nuclear facility to the environment.

Present Federal guidance* suggests the use of a spectrum of accidents as a basis for developing emergency response plans. For various reasons,* in 1976 an ad hoc Task Force of the Conference of (State) Radiation Control Program Directors passed a resolution requesting NRC to "make a determination of the most severe accident basis for which radiological emergency response plans should be developed by offsite agencies". Additionally, the NRC and EPA received other comments from State and local governments relating to this recommendation.

*See Appendix II.

In November 1976, a Task Force consisting of NRC and EPA representatives was convened to address this Conference request and related issues. The Task Force reviewed what is currently being done in terms of emergency planning for newly licensed plants and found that substantial efforts were being made both in on-site and off-site planning. It also reviewed current guidance from Federal Agencies regarding emergency response planning[2,3,4] and concluded that adequate guidance was available or was being developed with regard to the elements of a plan. While the previous guidance has not precisely specified distances to which planning elements should be applied, the actual current application of previous guidance on a case basis during the licensing process has in practice extended to substantial distances from reactor sites, i.e., independent of specific Low Population Zone distances used for siting purposes. However, information regarding the consequences and characteristics of the accident situation for which planning was being recommended had not been fully defined.

The Task Force accepts the principle noted in existing NRC and EPA guidance[2, 3] that acceptable values for emergency doses to the public under the actual conditions of a nuclear accident cannot be predetermined. The emergency actions taken in any individual case must be based on the actual conditions that exist and are projected at the time of an accident. For very serious accidents, predetermined protective actions would be taken if projected doses, at any place and time during an actual accident, appeared to be at or above the applicable proposed Protective Action Guides (PAGs), based on information readily available in the reactor control room, i.e., at predetermined emergency action levels(4). Of course, ad hoc actions, based on plant or environmental measurements, could be taken at any time.

The concept of Protective Action Guides was introduced to radiological emergency response planning to assist public health and other governmental authorities in deciding how much of a radiation hazard in the environment constitutes a basis for initiating emergency protective actions. These guides (PAGs) are expressed in units of radiation dose (rem) and represent trigger or initiation levels, which warrant pre-selected protective actions for the public if the projected (future) dose received by an individual in the absence of a protective action exceeds the PAG. PAGs are defined or definable for all pathways of radiation exposure to man and are proposed as guidance to be used as a basis for taking action to minimize the impact on individuals.

The nature of PAGs is such that they cannot be used to assure that a given level of exposure to individuals in the population is prevented. In any particular response situation, a range of doses may be experienced, principally depending on the distance from the point of release. Some of these doses may be well in excess of the PAG levels and clearly warrant the initiation of any feasible protective actions. This does not mean, however, that doses above PAG levels can be prevented or that emergency response plans should have as their objective preventing doses above PAG levels. Furthermore, PAGs represent only trigger levels and are not intended to represent acceptable dose levels. PAGs are tools to be used as a decision aid in the actual response situation. Methods for the implementation of Protective Action Guides are an essential element of emergency planning. These include the pre-determination of emergency conditions for which planned protective actions such as shelter and/or evacuation would be implemented offsite. Details of these methods are being provided as separate guidance[3,4] and are not included in this report.

Accident Considerations

After considerable discussion, the Task Force concluded that there was no specific accident sequence that could be isolated as the one for which to plan, because each accident could have different consequences, both in nature and degree. Further, the range of possible selections for a planning basis is very large, starting with a zero point of requiring no planning at all because significant offsite radiological accident consequences are unlikely to occur, to planning for the worst physically possible accident regardless of its extremely low likelihood. As an alternative to attempting to define a specific accident sequence, the Task Force decided to identify the bounds of the parameters for which planning is recommended based upon a knowledge of the potential consequences, timing, and release characteristics of a spectrum of accidents.

The Task Force recognized that more specific guidance with respect to accidents whose consequences would be more severe than the design basis accidents explicitly considered in the licensing process was appropriate. Additional discussions regarding the need to plan for consequences of such accidents (commonly known as Class 9 accidents*) may be found in Appendix III.

The Task Force concluded that the objective of emergency response plans should be to provide dose savings for a spectrum of accidents that could produce offsite doses in excess of the PAGs. Although the selected

*Throughout this report, "Class 9 accidents" will refer to those accidents in which there is melting of the core and/or containment failure.

planning basis is independent of a specific accident sequence, a number of accident descriptions were reviewed including the design basis accidents with various active engineered safety features, and the accident release categories of the Reactor Safety Study*[5].

Additional information regarding the rationale for the recommended planning basis,the background of Federal emergency planning efforts, the Task Force deliberations on Class 9 accidents, the relationship between emergency planning and siting criteria, and the difference between PAGs and dose criteria used for siting can be found in the appendices to this report.

*The Task Force has used information in the RSS as a basis to perform calculations which illustrate the likelihood of certain offsite dose levels given a core melt accident. Various aspects of the study have been debated by reviewers and additional programs are underway to extend or refine the study. While the RSS is considered by the Task Force to have limited use in dealing with plant/site specific factors, it provides the best currently available source of information on the relative likelihood of large accidental releases of radioactivity given a core melt event. The results derived from the RSS-based work served to confirm the Task Force judgment that offsite planning for a generic distance around nuclear power plants is prudent and useful.

II. PLANNING NEEDS

The Task Force reviewed the types of information that State and local governments need to develop emergency response plans and determined that the information fell into two categories; site specific and generic. The site specific information such as population distribution and topography must be available to State and local officials as part of the planning process. Such information is summarized in Environmental Reports and Safety Analysis Reports prepared by applicants for a permit to construct and operate a nuclear power facility and is useful for emergency planning purposes. Some generic information related to the planning effort is already being provided by Federal agencies[2,3,4]. The Federal generic guidance provided includes the topics which should be addressed in an emergency plan[2,4], protective action guides[3], the types of protective action appropriate[3] and emergency instrumentation considerations[4,6,7].

If it were possible to identify a single accident on which to base emergency response planning, one could use the release characteristics of that single accident in connection with site specific characteristics and other generic information to specify the planning effort. Having determined that a single specific accident sequence for a light water reactor nuclear power plant cannot be identified as a planning basis, the Task Force chose to provide recommendations in terms of the consequences or characteristics of accidents that would be important in determining the extent of the planning effort. The planning basis elements needed to scope the planning effort were determined to be:

1. The distance to which planning for the initiation of predetermined protective actions is warranted.
2. The time dependent characteristics of potential releases and exposures.
3. The kinds of radioactive materials that can potentially be released to the environment.

The most important guidance for planning officials is the distance from the nuclear facility which defines the area over which planning for predetermined actions should be carried out. The other elements of guidance provide supporting information for planning and preparedness.

The need for specification of distance for the major exposure pathways is evident. The location of the population for whom actions may be needed, responsible authorities who would carry out these actions and the means of communication to these authorities are all dependent on the size of the planning area.

Information on the time frames of the accidents is also important. The time between the initial recognition at the nuclear facility that a serious accident is in progress and the beginning of the radioactive release to the surrounding environment is critical in determining the type of protective actions which are feasible immediately following an accident. Likewise, knowledge of the potential duration of release and the time available before exposures are expected several miles offsite is important in determining what specific instructions can be given to the public.

A knowledge of kinds of radioactive materials potentially released is necessary to decide the characteristics of monitoring instrumentation, to develop tools for estimating projected doses, and to identify the most important exposure pathways.

In this report, emergency preparedness is related to two predominant exposure pathways. They are:

1. <u>Plume exposure pathway</u> -- The principal exposure sources from this pathway are (a) whole body external exposure to gamma radiation from the plume and from deposited material and (b) inhalation exposure from the passing radioactive plume. The time of potential exposure could range from hours to days.

2. <u>Ingestion exposure pathway</u> -- The principal exposure from this pathway would be from ingestion of contaminated water or foods such as milk or fresh vegetables. The time of potential exposure could range in length from hours to months.

The Task Force has provided separate guidance for these two exposure pathways, although a single emergency plan would include elements common to assessing or taking protective actions for both pathways.

III. RECOMMENDED PLANNING BASIS

A. Emergency Planning Zones

With regard to the area over which planning efforts should be carried out, the Task Force recommends that "Emergency Planning Zones" (EPZs) about each nuclear facility be defined both for the short term "plume exposure pathway" and for the longer term "ingestion exposure pathways." The Emergency Planning Zone concept is illustrated in figure 1. EPZs are designated as the areas for which planning is recommended to assure that prompt and effective actions can be taken to protect the public in the event of an accident. Responsible government officials should apply the applicable planning items listed in NUREG-75/111[2] in the development of radiological emergency response plans. The following are example planning elements considered appropriate for the EPZs:

(1) Identify responsible onsite and offsite emergency response organizations and the mechanisms for activating their services,

(2) Establish effective communication networks to promptly notify cognizant authorities and the public,

(3) Designate pre-determined actions as appropriate[2,3,4],

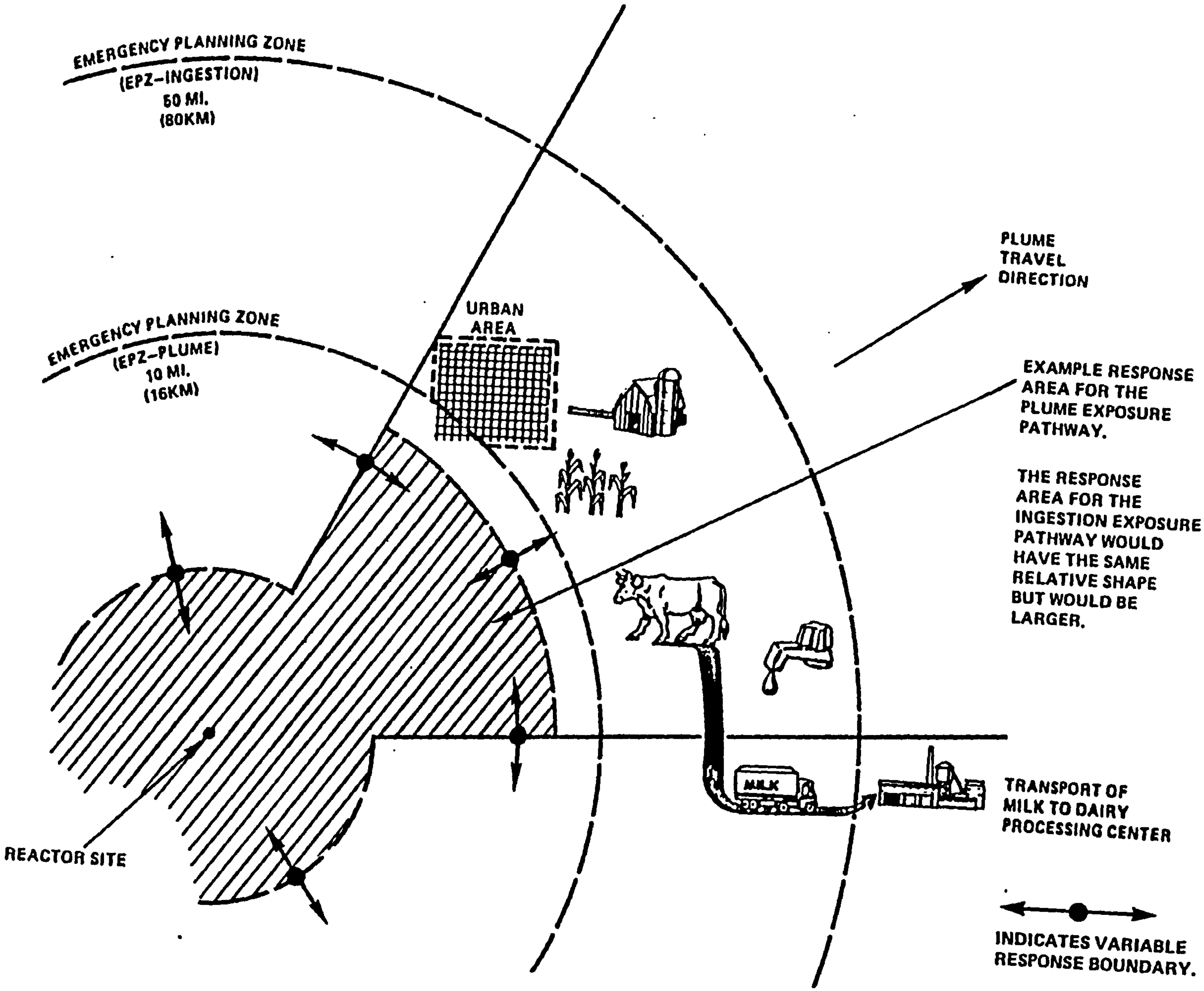

Figure 1 Concept of Emergency Planning Zones

(4) Develop procedures for use by emergency workers,

(5) Identify applicable radiation measurement equipment,

(6) Identify emergency operations centers and alternate locations, assembly points, and radiation monitoring locations,

(7) Implement training programs for emergency workers as appropriate, and

(8) Develop test procedures for emergency response plans.

Emergency planning should predetermine appropriate emergency responses within the EPZ as a function of population groups, environmental conditions[3], plant conditions[4] and time available to respond. For the plume exposure phase, shelter and/or evacuation would likely be the principal immediate protective actions to be recommended for the general public within the EPZ. The ability to best reduce exposure should determine the appropriate response. The key to effective planning is good communication to authorities who know what they are going to do under pre-determined conditions.

For the ingestion exposure Emergency Planning Zone, the planning effort involves the identification of major exposure pathways from contaminated food and water and the associated control points and mechanisms. The ingestion pathway exposures in general would represent a longer term problem, although some early protective actions to minimize subsequent contamination of milk or other supplies should be initiated (e.g., put cows on stored feed).

It is expected that judgment of the planner will be used in determining the precise size and shape of the EPZs considering local conditions such as demography, topography and land use characteristics, access routes, jurisdictional boundaries, and arrangements with the nuclear facility operator for notification and response assistance.

The EPZ guidance does not change the requirements for emergency planning, it only sets bounds on the planning problem. The Task Force <u>does not</u> recommend that massive emergency preparedness programs be established around all nuclear power stations. The following examples are given to further clarify the Task Force guidance on EPZs:

<u>No special</u> local decontamination provisions for the general public (e.g., blankets, changes of clothing, food, special showers)

<u>No stockpiles</u> of anti-contamination equipment for the general public

<u>No construction</u> of specially equipped fallout shelters

<u>No special</u> radiological medical provisions for the general public

<u>No new</u> construction of special public facilities for emergency use

<u>No special</u> stockpiles of emergency animal feed

<u>No special</u> decontamination equipment for property and equipment

<u>No participation</u> by the general public in test exercises of emergency plans.

Some capabilities in these areas, of course, already exist under the general emergency plans of Federal and State agencies.

B. Size of the Emergency Planning Zone

Several possible rationales were considered for establishing the size of the EPZs. These included risk, probability, cost effectiveness and accident consequence spectrum. After reviewing these alternatives, the Task Force chose to base the rationale on a full spectrum of accidents and corresponding consequences tempered by probability considerations. These rationales are discussed more fully in Appendix I.

The Task Force agreed that emergency response plans should be useful for responding to any accident that would produce offsite doses in excess of the PAGs. This would include the more severe design basis accidents and the accident spectrum analyzed in the RSS. After reviewing the potential consequences associated with these types of accidents, it was the concensus of the Task Force that emergency plans could be based upon a generic distance out to which predetermined actions would provide dose savings for any such accidents. Beyond this generic distance it was concluded that actions could be taken on an ad hoc basis using the same considerations that went into the initial action determinations.

The Task Force judgment on the extent of the Emergency Planning Zone is derived from the characteristics of design basis and Class 9 accident consequences. Based on the information provided in Appendix I and the applicable PAGs a radius of about 10 miles was selected for the plume exposure pathway and a radius of about 50 miles was selected for the ingestion exposure pathway, as shown in table 1. Although the radius for the EPZ implies a circular area, the actual shape would depend upon the characteristics of a particular site. The circular or other defined area would be for planning whereas initial response would likely involve only a portion of the total area.

The EPZ recommended is of sufficient size to provide dose savings to the population in areas where the projected dose from design basis accidents could be expected to exceed the applicable PAGs under unfavorable atmospheric conditions. As illustrated in Appendix I, consequences of less severe Class 9 accidents would not exceed the

PAG levels outside the recommended EPZ distance. In addition, the EPZ is of sufficient size to provide for substantial reduction in early severe health effects (injuries or deaths) in the event of the more severe Class 9 accidents.

Table 1. Guidance on Size of the Emergency Planning Zone

Accident Phase	Critical Organ and Exposure Pathway	EPZ Radius
Plume Exposure Pathway	Whole body (external)	about 10 mile radius*
	Thyroid (inhalation)	
	Other organs (inhalation)	
Ingestion Pathway**	Thyroid, whole body, bone marrow (ingestion)	about 50 mile radius***

* Judgment should be used in adopting this distance based upon considerations of local conditions such as demography, topography, land characteristics, access routes, and local jurisdictional boundaries.

** Processing plants for milk produced within the EPZ should be included in the emergency response plans regardless of their location.

***The recommended size of the ingestion exposure EPZ is based on an expected revision of milk pathway Protective Action Guides based on FDA-Bureau of Radiological Health recommendations. The Task Force understands that measures such as placing dairy cows on stored feed will be recommended for projected exposure levels as low as about 1.5 rem to the infant thyroid. Should the current FRC guidelines, 10 rem[8], be maintained, an EPZ of about 25 miles would achieve the objectives of the Task Force.

C. Time Factors Associated with Releases

The planning time frames are based on design basis accident considerations and the results of calculations reported in the Reactor Safety Study[5]. The guidance cannot be very specific because of the wide range of time frames associated with the spectrum of accidents considered. Therefore, it will be necessary for planners to consider the possible different time periods between the initiating event and arrival of the plume and possible time periods of releases in relationship to time needed to implement protective actions. The Reactor Safety Study indicates, for example, that major releases may begin in the range of one-half hour to as much as 30 hours after an initiating event and that the duration of the releases may range from one-half hour to several days with the major portion of the release occurring well within the first day. In addition, significant plume travel times are associated with the most adverse meteorological conditions that might result in large potential exposures far from the site. For example, under poor dispersion conditions associated with low windspeeds, two hours or more might be required for the plume to travel a distance of five miles. Higher windspeeds would result in shorter travel times but would provide more dispersion, making high exposures at long distances much less likely. Therefore, in most cases, significant advance warning of high concentrations should be available since NRC regulations[1,4] require early notification of offsite authorities for major releases of radioactive material. The warning time could be somewhat different for reactors with different containment characteristics than those analyzed in the Reactor Safety Study. The range of times, however, is judged suitably representative for the purpose of developing emergency plans. Shorter release initiation times are typically associated with design basis events of much smaller potential consequences or with the more severe Reactor Safety Study accident sequences.

The planning basis for the time dependence of a release is expressed as a range of time values in which to implement protective action. This range of values prior to the start of a major release is of the order of one-half hour to several hours. The subsequent time period over which radioactive material may be expected to be released is of the order of one-half hour (short-term release) to a few days (continuous release). Table 2 summarizes the Task Force guidance on the time of the release.

The time available for action is strongly related to the time consumed in notification that conditions exist that could cause a major release or that a major release is occurring. Development and periodic testing of procedures for rapid notification are encouraged.

Table 2 - Guidance on Initiation and Duration of Release

Time from the initiating event to start of atmospheric release	0.5 hours to one day
Time period over which radioactive material may be continuously released	0.5 hours to several days
Time at which major portion of release may occur	0.5 hours to 1 day after start of release
Travel time for release to exposure point (time after release)	5 miles - - 0.5 to 2 hours 10 miles - - 1 to 4 hours

D. Radiological Characteristics of Releases

To specify the characteristics of monitoring instrumentation,* develop decisional aids to estimate projected doses, and identify critical exposure modes, planners will need information on the characteristics of potential radioactivity releases. For atmospheric releases from nuclear power facilities, three dominant exposure modes have been identified. These are (1) whole body (bone marrow) exposure from external gamma radiation and from ingestion of radioactive material; (2) thyroid exposure from inhalation or ingestion of radiodines; and

*An Interagency Task Force on Emergency Instrumentation (offsite) is now preparing guidance(7) on the type and quantity of instruments needed for the various exposure pathways. Federal agencies represented on the Instrumentation Task Force include NRC, EPA, DCPA, HEW, and DOE.

(3) exposure of other organs (e.g., lung) from inhalation or ingestion of radioactive materials. Any of these exposure modes could dominate (i.e., result in the largest exposures) depending upon the relative quantities of various isotopes released.

Radioactive materials produced in the operation of nuclear reactors include fission products and transuranics generated within the fuel material itself and activation products generated by neutron exposure of the structural and other materials within and immediately around the reactor core. The fission products consist of a very large number of different kinds of isotopes (nuclides), almost all of which are initially radioactive. The amounts of these fission products and their potential for escape from their normal places of confinement represent the dominant potential for consequences to the public. Radioactive fission products exist in a variety of physical and chemical forms of varied volatility. Virtually all activation products and transuranics exist as non-volatile solids. The characteristics of these materials shows quite clearly that the potential for releases to the environment decreases dramatically in this order: (1) gaseous materials; (2) volatile solids; and (3) non-volatile solids. For this reason, guidance for source terms representing hypothetical fission product activity within a nuclear power plant containment structure emphasizes the development of plans relating to the release of noble gases and of volatiles such as iodine. However, consideration of particulate materials should not be completely neglected. For example, capability to determine the presence or absence of key particulate radionuclides will be needed to identify requirements for additional resources.

Table 3 provides a list of key radionuclides that might be expected to be dominant for each exposure pathway. More detailed lists of core inventories are presented in Chapter 15 of recent Safety Analysis Reports and in Appendix V of the Reactor Safety Study. Both of these sources give details on the time histories of the release fractions for a spectrum of postulated accidents.

Table 3

RADIONUCLIDES WITH SIGNIFICANT CONTRIBUTION TO DOMINANT EXPOSURE MODES

Radionuclides with Significant Contribution to Thyroid Exposure

Radionuclide	Half Life (days)
I-131	8.05
I-132	0.0858
I-133	0.875
I-134	0.0366
I-135	.028
Te-132	3.25
Kr-88	0.117

Radionuclides with Significant Contribution to Whole Body Exposure

Radionuclide	Half Life (days)
I-131	8.05
Te-132	3.25
Xe-133	5.28
I-133	0.875
Xe-135	0.384
I-135	.028
Cs-134	750
Kr-88	0.117
Cs-137	11,000

Radionuclides with Significant Contribution to Lung Exposure* (Lung only controlling when thyroid dose is reduced by iodine blocking or there is a long delay prior to releases).

Radionuclide	Half Life (days)
I-131	8.05
I-132	0.0858
I-133	0.875
I-134	0.0366
I-135	.028
Cs-134	750
Kr-88	0.117
Cs-137	11,000
Ru-106	365
Te-132	3.25
Ce-144	284

*Derived from the more probable Reactor Safety Study fuel melt categories and from postulated design basis accident releases.

IV. CONCLUSIONS

In summary, the Task Force concludes that:

- A spectrum of accidents (not the source term from a single accident sequence) should be considered in developing a basis for emergency planning.

- The establishment of Emergency Planning Zones of about 10 miles for the plume exposure pathway and about 50 miles for the ingestion pathway is sufficient to scope the areas in which planning for the initiation of predetermined protective action is warranted for any given nuclear power plant.

- The establishment of time frames and radiological characteristics of releases provides supporting information for planning and preparedness.

- If previous consideration has been given to the basic planning elements put forth in existing guidance documents[2,3,4], the establishment of Emergency Planning Zones should not result in large incremental increases in required planning and preparedness resources.

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GLOSSARY

Class 9 Accident — An accident considered to be so low in probability as not to require specific additional provisions in the design of a reactor facility. Such accidents would involve sequences of successive failures more severe than those postulated for the purpose of establishing the design basis for protective systems and engineered safety features. (Class 9 event sequences include those leading to total core melt and consequent degradation of the containment boundary and those leading to gross fuel clad failure or partial melt with independent failures of the containment boundary).

Consequences — The results or effects (especially projected dose rates) of a release of radioactive material to the environment.

Core Melt Accident — A postulated reactor accident in which the fuel melts because of overheating.

Emergency Planning Zone (EPZ)	A generic area defined about a nuclear facility to facilitate emergency planning offsite. It is defined for the plume and ingestion exposure pathways. In relation to emergency response an EPZ is an area in which best effort is performed making use of existing emergency plans and is not an area in which particular criteria must be met.
Ingestion Exposure Pathway	The principal exposure from this pathway would be from ingestion of contaminated water or foods such as milk or fresh vegetables. The time of potential exposure could range in length from hours to months.
Planning Basis	Guidance in terms of (1) Size of Planning Area (Distance); (2) Time Dependence of Release; and (3) Radiological Characteristics of Releases.

Plume Exposure Pathway

The principal exposure sources from this pathway are: (a) whole body external exposure to gamma radiation from the plume and from deposited materials and (b) inhalation exposure from the passing radioactive plume. The time of potential exposure could range in length from hours to days.

Projected Dose

An estimate of the radiation dose which affected population groups could potentially receive if protective actions are not taken.

Protective Action

An action taken to avoid or reduce a projected dose. (Sometimes referred to as protective measure).

Protective Action Guide

Projected absorbed dose to individuals in the general population which warrants protective action following a contaminating event.

Source Term

Radioisotope inventory of the reactor core, or radioisotope release to the environment, often as a function of time.

APPENDIX I

RATIONALE FOR THE PLANNING BASIS

A. General Considerations

The Task Force considered various rationales for establishing a planning basis; including risk, probability, cost effectiveness, and consequence spectrum. After studying the various approaches discussed below, the Task Force chose to base the rationale for the planning basis on a spectrum of consequences, tempered by probability considerations.

With respect to the risk* rationale, such an approach would establish "planning guidance" that could be compared with the risks associated with non-nuclear accidents. This rationale would seemingly give a uniform basis for emergency planning and would clearly indicate the level of risk that could be mitigated by advanced planning. However, emergency planning for non-nuclear hazards is not based upon quantified risk analyses. Risk is not generally thought of in terms of probabilities and consequences, rather it is an intuitive feeling of the threat posed to the public. Reactors are unique in this regard: radiation tends to be perceived as more dangerous than other hazards because the nature of radiation effects are less commonly

*Risk is defined as accident consequences times the probability of accident occurrence.

understood and the public generally associates radiation effects with the fear of nuclear weapons effects. In addition, a risk-related rationale might imply the determination of an acceptable level of risk which is outside the scope of the Task Force effort. Choosing a risk comparable to non-nuclear events, therefore, was not directly used as the rationale for an emergency planning basis.

With respect to a probability rationale, one could arrive at "planning guidance" by selecting an accident probability below which development of an emergency plan could not be justified. Factors favoring using this rationale center around providing a quantitative probability basis, which could be compared with the probabilities of other types of emergencies for which plans are prepared.

Factors arguing against the probability rationale are similar to those against the risk approach. Emergency planning is not based upon quantified probabilities of incidents or accidents. On the basis of the accident probabilities presented in the Reactor Safety Study (nuclear and non-nuclear) society tolerates much more probable non-nuclear events with similar consequence spectrums without any specific planning. Radiological emergency planning is not based upon probabilities, but on public perceptions of the problem and what could be done to protect health and safety. In essence, it is a matter of prudence rather than necessity.

A generic "probability of an event" appropriate for planning has many implications felt to be outside the scope of the Task Force objective. However, the concept of accident probability is important and does have a place in terms of evaluating the range of the consequences of accident sequences and setting some reasonable bounds on the planning basis. The probability rationale was used by the Task Force to gain additional perspective on the planning basis finally chosen.

With respect to a cost-effectiveness rationale, the level of emergency planning effort would be based on an analysis of what it costs to develop different levels of such a plan and the potential consequences that could be averted by that degree of development. The factor favoring the cost-effectiveness rationale is that an emergency plan could be developed on the basis of cost per potential health effect averted. Factors arguing against the cost-effectiveness rationale are the difficulty in arriving at costs of plan development and maintenance and considerations that general and radiological emergency response plans have already been developed. In addition, absent an actual accident, it would be very difficult to assign a dollar value to the effectiveness of the plan in terms of health effects averted.

Lastly, the calculated consequences from a spectrum of postulated accidents was considered as the rationale for the planning basis.

Such a rationale could be used to help identify desirable planning elements and establish bounds on the planning effort. Further, a planning basis could be easily stated and understood in terms of the areas or distances, time frames and radiological characteristics that would correspond to the consequences from a range of possible accidents. Consequence oriented guidance would also provide a consistency and uniformity in the amount of planning recommended to State and local governments. The Task Force therefore judged that the consequences of a spectrum of accidents should be the principal rationale behind the planning basis.

B. Consequence Considerations

The Task Force considered the complete spectrum of accidents postulated for various purposes, including those discussed in environmental reports (i.e. best estimate Class 1 through 8 accidents), accidents postulated for purposes of evaluating plant designs (e.g. the DBA/LOCA), and the spectrum of accidents assessed by the Reactor Safety Study. The Task Force concluded that the environmental report discussions (Class 1-8) were too limited in scope and detail to be useful in emergency planning.

1. Design Basis Accidents

Under NRC Regulations, the site/reactor design combination must be such that the consequences of design basis accidents are below the plume exposure guidelines of 10 CFR Part 100. The design basis loss-of-coolant accident (DBA-LOCA) has been typically the most severe design basis accident in that it results in the largest calculated offsite doses of any accident in this class. The DBA-LOCA is not a realistic accident scenario in that the release magnitudes are much more severe than would be realistically expected and may exceed that of some core-melt type accidents. A best estimate assessment of the release following a LOCA would be significantly smaller than the DBA-LOCA used for siting purposes. An analysis of this accident has been performed for most of the power plants licensed or under review by NRC to determine the dose/distance relationships as computed by traditionally conservative assumptions used under 10 CFR Part 100 requirements. Results of this study are presented later in this appendix. The study concluded that the higher PAG plume exposures of 25 rem (thyroid) and 5 rem (whole body) would not be exceeded beyond 10 miles for any site analyzed. Even under the most restrictive PAG plume exposure values of 5 rem to the thyroid and 1 rem whole body, over 70 percent of the plants would not require any consideration of emergency responses beyond 10 miles. It should be noted that even for the DBA-LOCA, the lower range of the plume PAGs would likely not be exceeded outside the low population zone (LPZ) for average meteorological conditions.

For the ingestion pathways, under the same DBA-LOCA conditions, the downwind range within which a PAG of 1.5 rem thyroid could be exceeded would be limited to within 50 miles even under the conservative 10 CFR 100 assumptions. The 50 mile distance is also justified as a maximum planning distance because of likely significant wind shifts within this distance that would further restrict the radius of the spread of radioactive material.

2. <u>Class 9 Accidents</u>

"Class 9" accidents cover a full spectrum of releases which range from those accidents which are of the same order as the DBA-LOCA type of releases; i.e., doses on the order of PAGs within 10 miles; to those accidents which release significant fractions of the available radioactive materials in the reactor to the atmosphere, thus having potential for life-threatening doses. The lower range of the spectrum would include accidents in which a core "melt-through" of the containment would occur. As in the DBA-LOCA class, the doses from "melt-through" releases (involving thousands of curies) generally would not exceed even the most restrictive PAG beyond about 10 miles from a power plant. The upper range of the core-melt accidents is categorized by those in which the containment catastrophically fails and releases large quantities of radioactive materials directly to the atmosphere because of over-pressurization or a steam explosion. These accidents have the potential to release very large quantities (hundreds of millions of curies) of radioactive materials. There is a full spectrum of releases between the lower and upper range with all of these releases involving some combination of atmospheric and melt-through accidents. These very severe accidents have the potential for causing serious injuries and deaths. Therefore, emergency response for these conditions must have as its first priority the reduction of early severe health effects. Studies[6,7] have been performed which indicate that if emergency actions such as sheltering or evacuation were taken within about 10 miles of a power plant, there would be significant savings of early injuries and deaths from even the most "severe" atmospheric releases.

For the ingestion pathways, (due to the airborne releases and under Class 9 accident conditions), the downwind range within which significant contamination could occur would generally be limited to about 50 miles from a power plant, because of wind shifts during the release and travel periods. There may also be conversion of iodine in the atmosphere (for long time periods) to chemical forms which do not readily enter the ingestion pathway. Additionally, much of the particulate materials in a cloud would have been deposited on the ground within about 50 miles.

C. Probability Considerations

An additional perspective can be gained when the planning basis is considered in terms of the likelihood (probability) of accidents which could require some emergency response.

Probabilities can be used to give a perspective to the emergency planner by comparing the chance of a reactor accident to other emergencies for which plans and action may be required. This consideration forms an additional basis upon which the Task Force selected the planning basis. The Reactor Safety Study (RSS) estimated the probabilities* of various severe accidents occurring at nuclear power plants. The probability of a loss-of-coolant accident (LOCA) from a large pipe break was estimated to be approximately one chance in 10,000 ($1x10^{-4}$) of occurring per reactor-year. LOCA accidents would not necessarily lead to the melting of the reactor core since emergency core cooling systems (ECCS) are designed to protect the core in such an event. In fact, other accident initiating events such as the loss-of-coolant accident from a small pipe break or transient events have a higher chance of leading to core-melting than do large LOCA accidents. Core-melt type accidents were calculated to have a probability of about one chance in 20,000 of occurring per reactor-year. There is a significant degree of uncertainty associated with both of the above probability estimates.

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* Use of the RSS probability estimates, in the context of emergency planning, has been thoroughly examined. It is recognized that there is a large range of uncertainties in these numbers (as indicated in the Risk Assessment Review Group Report, NUREG/CR-0400), but the perspective gained when considering the probabilities is important in making a rational decision concerning a basis for emergency planning.

The degree of uncertainty is such that no differentiation can be confidently made, on a probabilistic basis, between the DBA/LOCA and the releases associated with less severe core-melt categories.

As discussed in Appendix III, the Task Force has concluded that both the design basis accidents and less severe core-melt accidents should be considered when selecting a basis for planning predetermined protective actions and that certain features of the more severe core-melt accidents should be considered in planning to assure that some capability exists to reduce the consequences of even the most severe accidents. The low probabilities associated with core-melt reactor accidents (e.g. one chance in 20,000 or 5×10^{-5} per reactor-year) are not easy to comprehend and additional perspectives are useful. Within the next few years, there will have been accumulated approximately 500 reactor-years of civilian nuclear power plant operation in this country. Less than 30% of all core melt accidents would result in high exposure outside the recommended planning distances. Therefore, over this time period* the probability of an accident within the USA with exposures exceeding the plume or ingestion PAGs <u>outside</u> the planning basis distances would be about 1.5×10^{-5}** x 500 or about 1 chance in

* The Reactor Safety Study explicitly limits its analyses to the first 100 reactors and five years (through 1980).

** This estimate is based upon the assumptions of the RSS. It should be noted that there is a large uncertainty on this number.

100. To restate this, there is about a 1% chance of emergency plans being activated in the U.S. beyond the recommended EPZs within the next few years. For a single State, this probability drops appreciably. For a State with ten reactors within or adjacent to its borders, the probability of exceeding PAGs outside the planning basis radius for the plume exposure pathway is about $1.5 \times 10^{-5} \times 10$ or about one chance in 6000 per year according to the Reactor Safety Study analysis.

For perspective, a comparison between reactor accidents and other emergency situations can be made. Considerations of emergency planning for reactor accidents are quite similar to many other emergencies; floods, for example, have many characteristics which are comparable. Timing, response measures and potential consequences, such as property damage are similar for both events.

Flood risk analysis has been carried out by the Flood Insurance Program of the Department of Housing and Urban Development and the Corps of Engineers. Flood plains have been designated for all areas of the country by computing the probability of being flooded within a certain period of time; ie., the 100-year flood plain designates those areas which can be expected to be under water when the worst flood in a century occurs. Even with this relatively high probability of severe flood occurrence there are no explicit requirements for emergency response planning.

Hurricanes and tornadoes are two potential threats for which some emergency planning is required. Approximately 2 hurricanes per year may be expected to hit the Atlantic coastal States which require emergency response. For individual States, the hurricane frequency ranges from 0.01 to 0.65 per year. Tornadoes have a very high probability of occurrence per year. A severe tornado can be characterized by wind speeds of over 200 miles per hour. Such tornadoes are capable of lifting cars off the ground, tearing roofs and walls off frame houses, overturning trains, and uprooting or snapping most trees. Emergency actions would probably be taken for such tornadoes. The frequency of severe tornadoes for individual States, ranges from about 0.1 to 4 per year.

Severe reactor accidents are at least 100 times less likely to occur than these other disasters requiring emergency response. We nevertheless believe, that it is appropriate to develop flexible emergency response capabilities which will assure that consequences from nuclear reactor accidents are minimized.

D. Emergency Planning Considerations Derived from Siting, Meteorological Models and Licensing Criteria

1. Siting

As indicated in 10 CFR Part 100 (Siting Criteria), an applicant for a construction permit to build a nuclear power plant must designate an exclusion area, a low population zone (LPZ) and a population center based upon consideration of population distribution. The exclusion area must be of such a size that an individual located at any point on its boundary for two hours immediately following the onset of a postulated design basis accident fission product release from the reactor plant would not receive a total radiation dose to the whole body of 25 rem or 300 rem to the thyroid from radioactive plume exposure. The LPZ must be of such a size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud during its entire period (30 days) of passage would not receive a total radiation dose to the whole body of 25 rem or 300 rem thyroid. Calculated doses are usually substantially less than these doses. Protective measures are not assumed to be taken to avoid or mitigate these doses during the denoted time periods. In addition, site related requirements are placed on the exclusion area and the LPZ. The licensee must have authority over all activities within the exclusion area, which normally requires ownership of the area. There must be a reasonable probability that appropriate protective measures, including evacuation, could be taken for the residents in the LPZ in the event of a serious accident. Dose guideline values are not given for the population center, although the expected doses would be less than within the LPZ. Demographic characteristics within 50 miles of sites are discussed in detail in Environmental Reports and in Chapter 2 of Safety Analysis Reports for each nuclear power plant and in Reference 1.

Assumptions used by the NRC staff to assess conformance with these regulations are contained in various Regulatory Guides (e.g. Regulatory Guides 1.3 and 1.4) and the NRC staff's Standard Review Plans for Chapter 15 of Safety Analysis Reports submitted by applicants for construction permits and operating licenses. Although various assumptions are utilized in this guidance, certain common features are shared: systems containing potentially significant quantities of radionuclides are postulated to fail for an unspecified reason, releasing all or substantial fractions of their inventories from their normal location to the reactor plant containment structure;* various installed safety systems in the containment designed to mitigate the consequences of the postulated release, are assumed to be inoperable at the time of the event,

*In particular, for the worst case DBA/LOCA postulated for containment design, 100% of the noble gases and 50% of the radioiodines in the reactor core are presumed to be released from the core and primary pressure boundary to the containment, which is assumed to isolate and leak at a specified volumetric leak rate.

or are assumed to be operating in a degraded mode, or combinations thereof; the resulting fractional release to the atmosphere is assumed to occur at ground level under extremely unfavorable dispersion conditions, i.e., under conditions such that the calculated dose for the given fractional release would not be exceeded more than five percent of the time at the site under review; and dose models which overestimate the dose on a plume centerline for the given release fraction are used in the dose calculation. For all of these postulated, simultaneously occurring circumstances, 10 CFR Part 100 dose guideline values must not be exceeded at the specified distances from the site.

Perspective on the implications of these 10 CFR 100 reactor siting criteria for emergency planning can be obtained by relating the calculated doses to the EPA PAGs, to guidelines for milk ingestion, and to certain meteorological aspects of dispersion in the atmosphere. For ground level releases, without a wind shift, dose decreases with downwind distance (r) in proportion to r^{-a}, where a is between 1.5 and 3, depending on the stability class prevailing at the time.[2] (Stability classes are measures of atmospheric dispersion and are classified by the letters A through G, with A denoting extremely dispersive conditions (see Table I-1)[3]). For the NRC staff assumption conditions (e.g., class F conditions with low wind

Table I-1 — RELATION OF TURBULENCE TYPES TO WEATHER CONDITIONS

A — Extremely unstable conditions
B — Moderately unstable conditions
C — Slightly unstable conditions
D — Neutral conditions*
E — Slightly stable conditions
F — Moderately stable conditions

	Daytime insolation			Nighttime conditions	
Surface wind speed, m/sec	Strong	Moderate	Slight	Thin overcast or $\geq 4/8$ cloudiness†	$\leq 3/8$ cloudiness
<2	A	A–B	B		
2	A–B	B	C	E	F
4	B	B–C	C	D	E
6	C	C–D	D	D	D
>6	C	D	D	D	D

*Applicable to heavy overcast, day or night.

†The degree of cloudiness is defined as that fraction of the sky above the local apparent horizon which is covered by clouds.

REF: METEOROLOGY AND ATOMIC ENERGY - 1968 speed) and for "average" dispersion conditions (e.g., class D stability), a value of $\underline{a} = 1.5$ provides a good approximation for purposes of projecting dose rates with distance from an exclusion area boundary. Table I-2 and figure I-1 illustrate this dose rate decrease. For illustrative purposes, figure I-1 also shows the decrease for values of $\underline{a}$ equal to 1 and 2. Except for stability class A, which seldom occurs, dose rate should decrease with distance within the $1/r$ and $1/r^2$ curves in this figure, barring a significant wind shift during a release period.

For purposes of this discussion, dose vs distance extrapolations of the exclusion radius dose rate for LWR accidents are of the greatest interest. Table I-2 presents projected upper bound (no wind shift) values of 2 hour whole body and thyroid doses at various distances given a 25 rem and 300 rem dose level at an exclusion radius (r_0). For a site with an exclusion radius of one mile, the upper limits of the proposed EPA PAGs for plume exposures would be exceeded within 3 miles (whole body PAG) and 5 miles (thyroid PAG) of the reactor plant containment structure; the lower limits could be exceeded within 8 miles (whole body) and 15 miles (thyroid) of the reactor plant containment structure. For a site with an exclusion radius of 0.5 miles (about the median for currently licensed plants),

TABLE I-2

UPPER BOUND PLUME EXPOSURE PATHWAY

PROJECTED DOSES BASED ON

10 CFR PART 100.11 VALUES

r/r_o	$(r/r_o)^{-1.5}$	0 to 2 HR DOSE LIMIT (REM) Whole Body	THYROID	ETA (hrs)
1.	1.	25	300	0.5
1.5	0.54	14	162	0.75
2	0.35	8.8	105	1
3	0.19	4.8	57	1.5
4	0.13	3.3	39	2
5	0.089	2.2	27	2.5
6	0.068	1.7	20	3
8	0.044	1.1	13	4
10	0.032	0.8	9.6	5
15	0.017	0.43	5.2	7.5
20	0.011	0.28	3.3	10

NOTES: (1) Dose = Dose commitment on plume centerline.

(2) r_o = Exclusion area boundary, or exclusion radius for a given site; r/r_o = multiple of exclusion radius; lefthand column can be read as miles if r_o = 1 mile.

(3) Presumes 100% of noble gases and 50% of radioidines in core inventory released to containment, constant volumetric leak rate from containment, "five percentile" meteorology, straight line of sight travel of the plume, and conservative dose factors for plume exposure.

(4) ETA = Estimated time of arrival of plume front based on r_o = 1 mile and 2 mph wind speed. Higher wind speeds reduce travel times and calculated doses.

DOSE FALLOFF WITH DISTANCE

(ALONG ACTUAL PLUME TRACK)

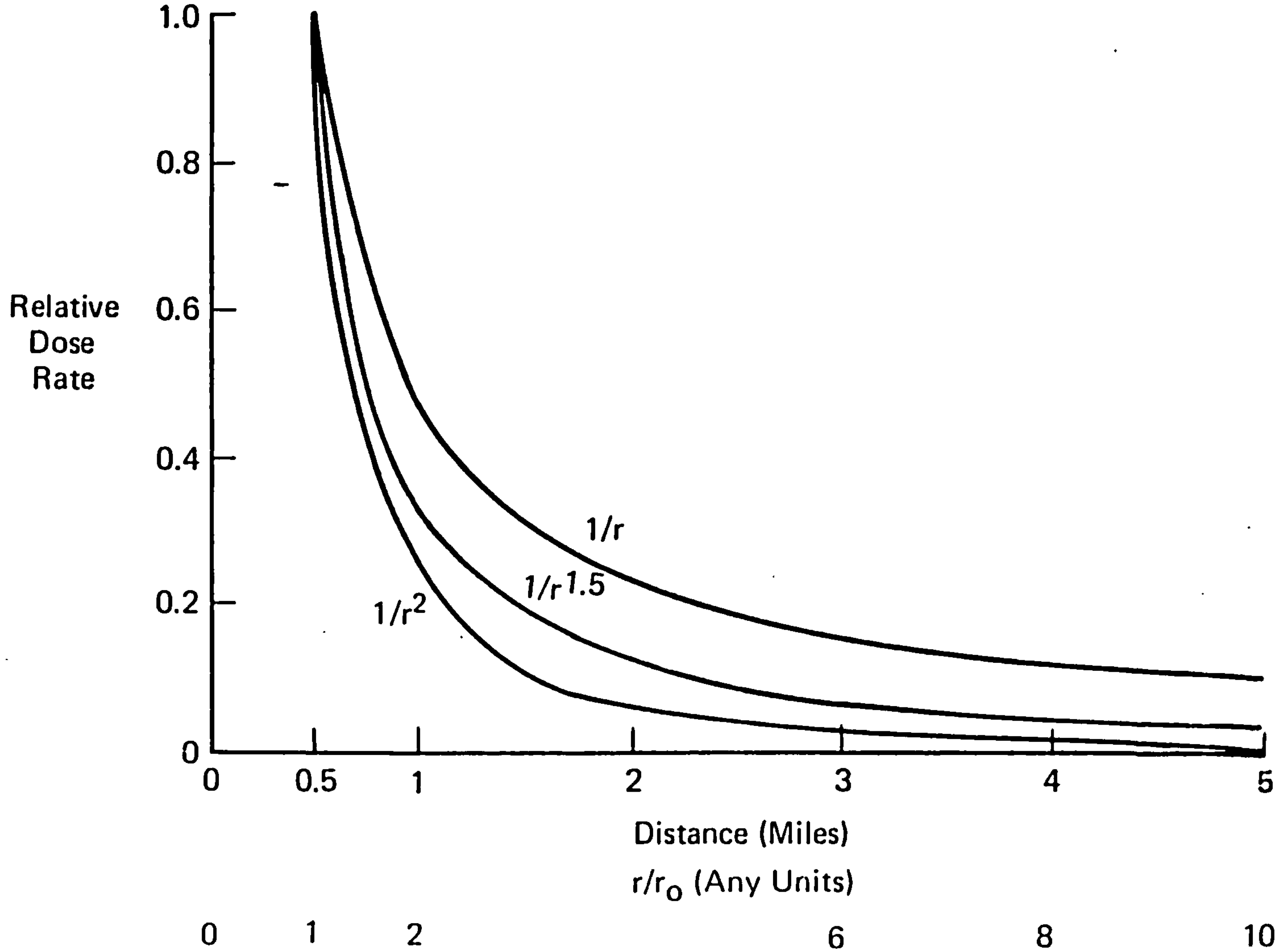

FIGURE I-1

these limits could be exceeded within half the denoted distances. Calculated course-of-accident doses could be several times larger than the above values.

A second perspective from which to peruse the data in table I-2 is that of the thyroid PAGs for the milk ingestion pathway. The ratio of thyroid dose commitment factor (related to air concentration) for the milk pathway to the inhalation (plume exposure) pathway is of the order of 300 for I-131.* From this perspective it is clear that, without a wind shift during the release period, potential dose commitments via the milk pathway could exceed the ingestion PAG for tens of miles from the reactor site for the presumed conditions, given the presence of dairy herds and pasture in the downwind direction. Clearly, wherever there is a potential to exceed a plume exposure PAG for the thyroid, there is a much greater potential to exceed the milk pathway thyroid PAG. Alternately, much lower releases of radioiodine could result in projected doses in excess of the ingestion PAG without there being a potential to exceed plume exposure PAGs.

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*For a core release, I-131 activity would be about one eighth the total radioiodine activity. Initially (for a day or so) I-133 or I-135 activities would be dominant. Thus, although I-131 would dominate the projected dose commitment rate, the key early indicators for monitoring purposes would be the hard (1-2 MeV) gamma emissions from I-135.

2. Meteorological Considerations

Although actual atmospheric diffusion is unlikely to behave as simple theory would suggest, initial projections of dose during an incident would most likely be based in part on the simple, theoretical, gaussian plume model (i.e., Pasquill diffusion). Shown in figure I-2 are theoretical "widths" of gaussian shaped plumes[4] (the concentration of a pollutant at the selected width of the plume is about 1% of the center-line concentration). Travel times of plume fronts for different wind speeds are also illustrated in figure I-2. Stability class, wind speed and wind direction might be considerably different at the same time at different locations in the vicinity of a site and local topography could significantly influence wind patterns. Nevertheless, the information displayed in figure I-2 could be useful for scoping initial emergency response actions, especially for those areas within a couple of miles of a site. For example, for a wind speed of 2 miles per hour and class F stability (corresponding roughly to the meteorological conditions assumed for the worst case (5%) design basis accident considered for purposes of containment design), a plume front would not arrive at a location two miles downwind for almost one hour. For this hypothetical case, given timely warning, and using crosswind travel, an individual could, barring any obstacles, walk out of the potentially impacted area before the plume front extends to two miles, Three sigma half-widths of Gaussian shaped plumes vs downwind distance, for Pasquill stability classes B, Γ and F. Also shown are travel times of plume fronts for wind speeds of 1, 2 and 5 m/sec, and crosswind travel times for travel speeds of 2, 5 and 10 mph.

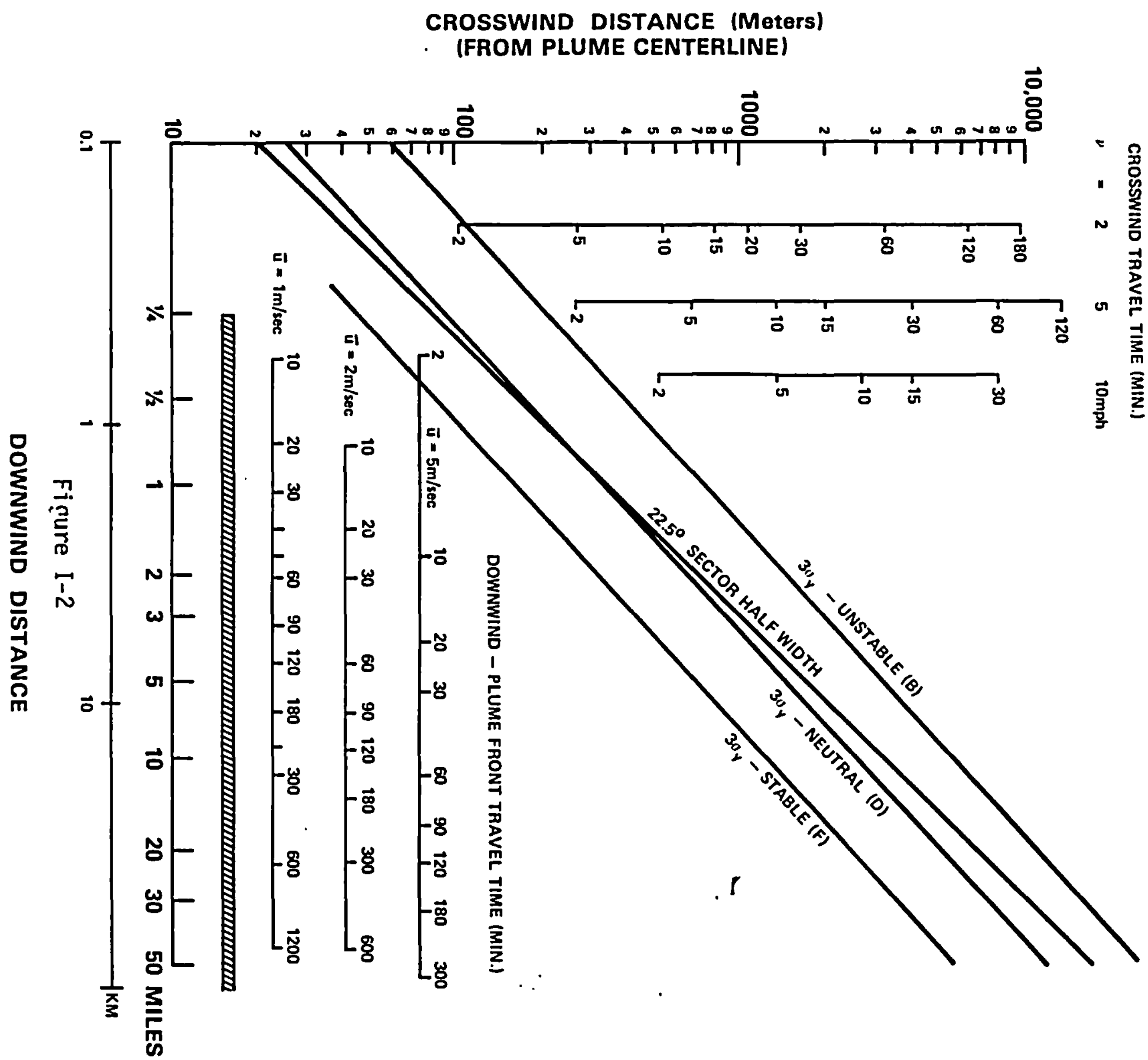


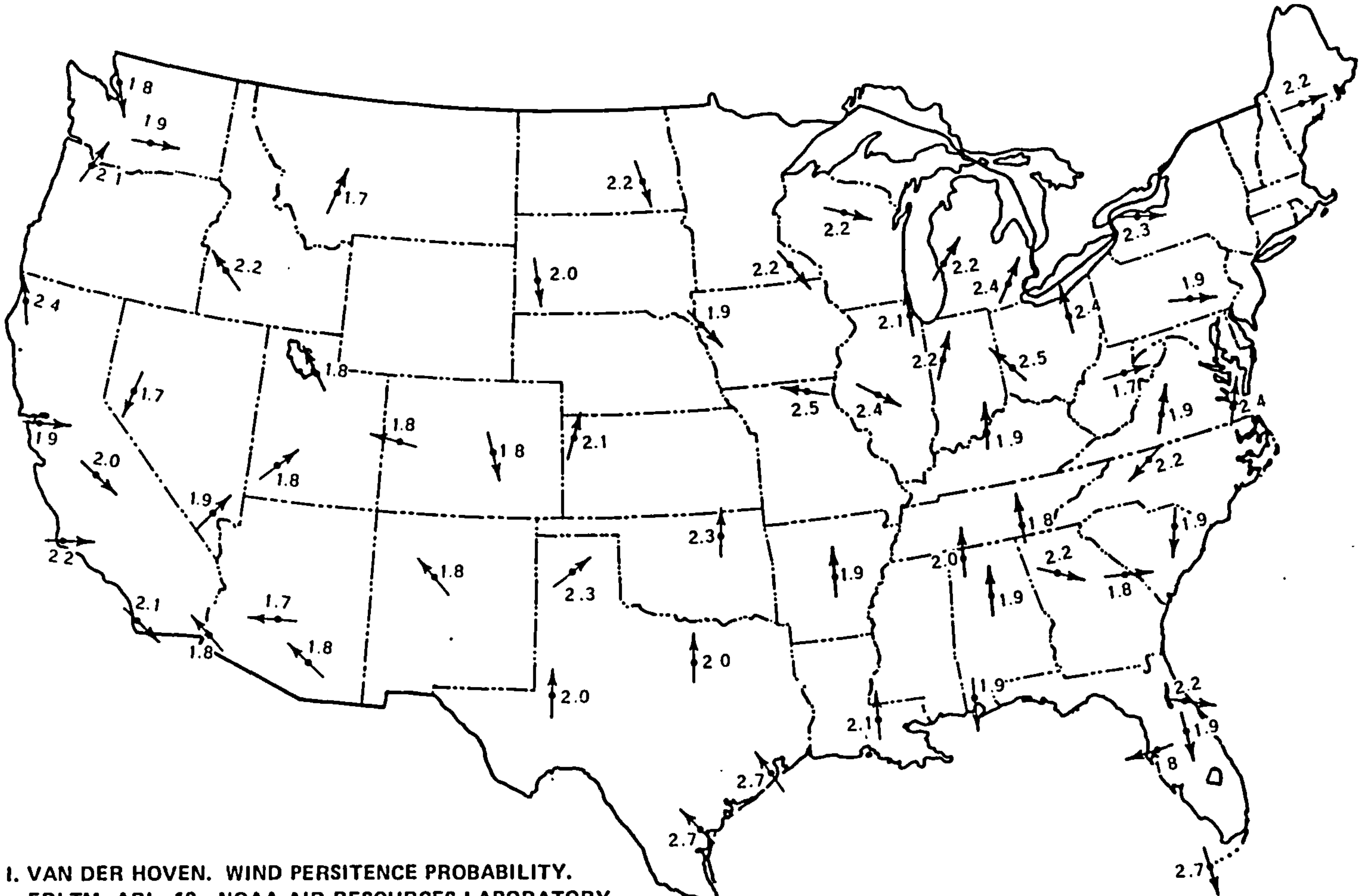
Figure I-2

since the individual would have to travel for about six minutes to do so. Generally, higher wind speeds result in lower dose rates for a given release fraction (source term), but time of arrival of a plume front at a specific distance is shorter.

In the foregoing, on several occasions note was made of the possible influence of a wind shift. Clearly, upon a wind shift the plume exposure dose commitment rate of persons in the original downwind direction, due to the passage of a plume, would end, and a different population dose commitment rate would begin in the new downwind direction.

NOAA[5] has analyzed National Weather Station meteorological data across the United States and has presented results in the form of graphical displays of the probability of hours of wind persistence in 22.5^{o} and 67.5^{o} sectors (Figure I-3 and I-4). The study concludes that there is an even chance of a significant wind shift occurring in the next two to four hours at any given location in the United States. A few general observations are of import to emergency planning and/or response:

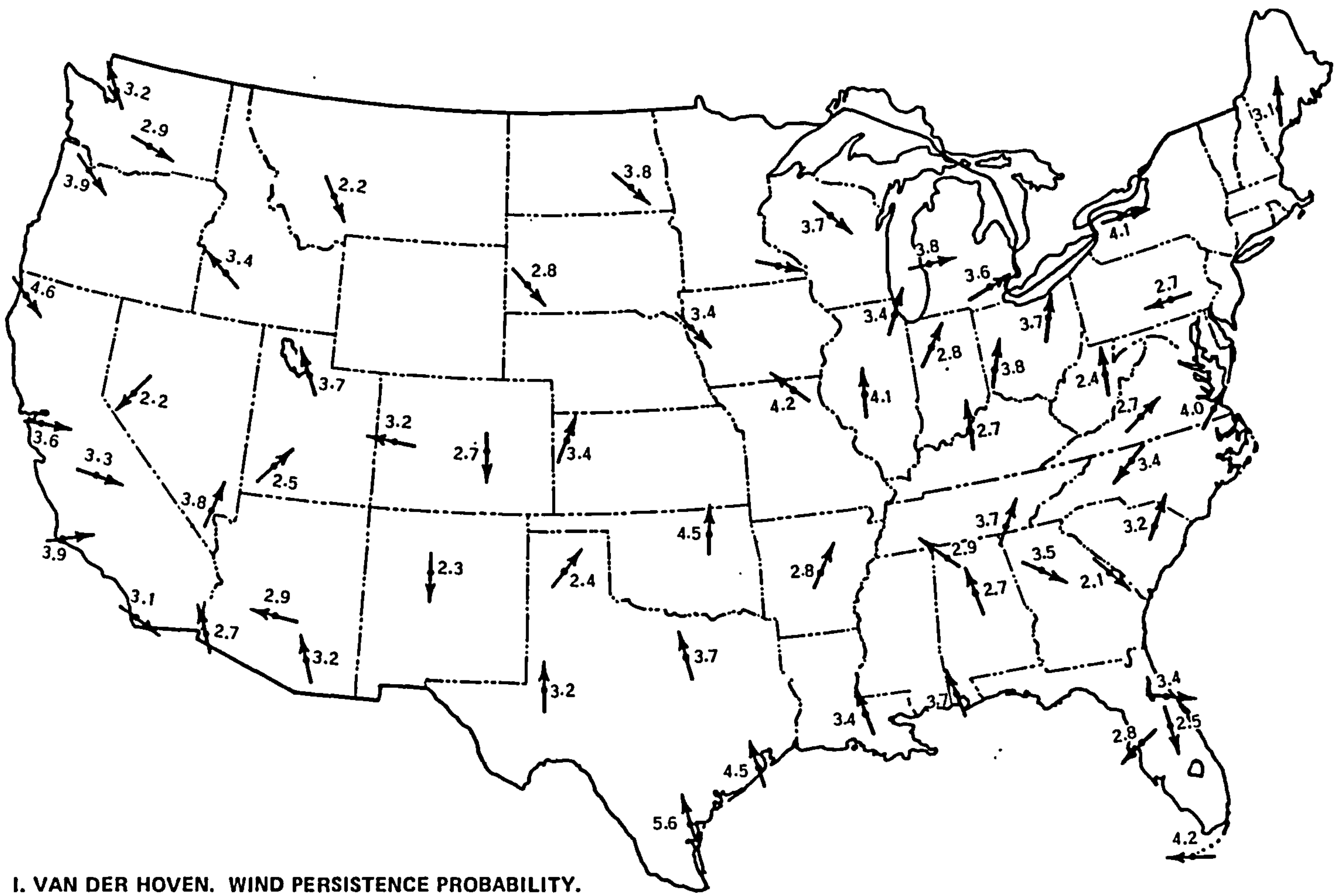
". . . the higher the wind speed, the greater is the tendency for the wind to remain in a given direction. Conversely, it is in the lowest wind speed categories of calm and 1 to 5 mph that the least direction persistence is found."



REF. I. VAN DER HOVEN. WIND PERSITENCE PROBABILITY.
ERLTM–ARL–10. NOAA AIR RESOURCES LABORATORY.
SILVER SPRING, MD. 20910

Highest 50-percent probability of hours of wind persistence in a 22½° sector centered on the indicated directions.

Figure I-3.



REF. I. VAN DER HOVEN. WIND PERSISTENCE PROBABILITY.
ERLTM–ARL–10. NOAA AIR RESOURCES LABORATORY.
SILVER SPRING, MD. 20910

Highest 50-percent probability of hours of wind persistence in a 67½° sector centered on the indicated directions.

Figure I-4.

and ". . . wind roses (frequency) that favor a particular sector will also tend to persist in that sector."

Three caveats to the meteorological discussion are worth noting. The first has to do with precipitation. Rainfall could occur either at the time of a radioactive release or some time during transport, possibly many miles away from the source of the release. Rainfall is usually a very efficient scavenger of particles in the atmosphere. Should a radioactive release to the atmosphere occur during rainfall, one should expect to find relatively greater ground deposition close to the source of the release, independent of the height of the release, than one would find during clear weather. Under rainy conditions, relatively less air and ground concentrations of radioactive material should be found at greater distances from the source of the release. On the other hand, a release could occur during dry weather yet the release could intercept a rainfall at some distance away; at this distance particles could be deposited on the earth, vegetation, structures, water, etc., very efficiently. In a strong rainfall a substantial fraction of deposited radioactive material could even be washed away. Rainfall interception could be the most important meteorological phenomena of concern for the case of a strongly elevated release, such as due to plume rise of a thermally hot release which is probable with larger accidents.

The second caveat concerns real world meteorology. As noted earlier, plumes or puffs do not normally follow straight lines, especially in low wind speed conditions. Nor do they maintain a constant windspeed and stability. Puffs can double back and return from where they came and slow down or speed up. Clearly, the track of a major radioactive release would be of great interest and concern. As illustrated in Figure 7.15 of reference (3), radiation signals well above natural background should be observed even miles away from a plume at the center of which the dose rate is as low as one rem per hour, and even less. Such plumes could be tracked using aircraft and generally available instrumentation such as Geiger counters and "cutie pies."

It is also important to realize that a substantial amount of energy could be associated with major releases. This energy will tend to lift the radioactive material off of the ground and form a cloud or plume. If this occurs, tracking of the material could be much more difficult since the wind direction can change dramatically with attitude.

3. <u>Licensing Considerations</u>

NRC regulation require applicants for licenses to construct and operate nuclear power facilities to make accident dose calculations. Such calculations take into consideration plant designs and site characteristics. They are based in part on the DBA-LOCA accident scenario.

Inherent in the consequence calculations for the postulated DBA-LOCA is the presumption of "five percentile" meteorology, i.e., the presumption that atmospheric dispersion at a site at the time of the postulated accident should be more favorable (leading to lower doses) ninety-five percent of the time. Alternately, given the postulated accident, the odds are at least twenty to one against the doses being as large as calculated for the DBA-LOCA. This "five-percentile" meteorology is derived from measurements made at the site during, or previous to, the construction period. It can nominally be characterized by class F stability and very low wind speeds (e.g., 2 miles/hour or less), i.e., the very conditions for which a wind shift is most likely. These data are presented in Chapter 2 of current Safety Analysis Reports for each nuclear power facility and are given as funcions of elapsed time and distance.

The results of the conservative licensing calculations for the DBA-LOCA vary from plant-to-plant because of plant design and variation in meteorology. For this reason a large number plants were analyzed in order to report the likely range of the conservative DBA-LOCA doses. Data from seventy safety analysis reports were collected and used for this purpose. The seventy plants consisted of 129 separate nuclear units. The resulting distribution of DBA-LOCA doses calculated for these facilities are indicative of plants that are now operating and plants that will be operating in the near future.

An example of the results of such calculations is shown in figure I-5. As is seen in the figure, the major portion of the radioactive material will be released in the first few hours, after the accident. Fortunately, for release durations of more than a couple of hours there will be significant wind shifts and cloud meander (especially associated with the 5% to meteorological conditions postulated). Therefore, for purposes of these calculations it was assumed that the dose of any individual would be limited to that of the first two hours after the accident.

The results of the analysis are depicted in figures I-6 through I-9. Figure I-6 shows the 2 hour thyroid dose versus distance for the 50 percentile and 10 percentile cases. The 50 percentile curve is the median dose for all 129 units; thus half of the units had doses less than that indicated and the other half had greater doses. The 10 percentile curve means that 10% of the units had doses greater than that indicated. This figure also shows a rapid decrease in thyroid dose out to almost 10 miles with a leveling off at greater distances. It shows that at ten miles, the 2 hour thyroid dose would be typically about 4 rem and that in a few cases it may exceed 10 rem. Figure I-7 takes the same data but plots the dose at 10 miles against the cumulative frequency of reactor units. It can be seen that the DBA-LOCA doses were calculated to exceed the lower PAG range for only 30% of the units.

Figure I-8 and I-9 provide similar plots for the whole body

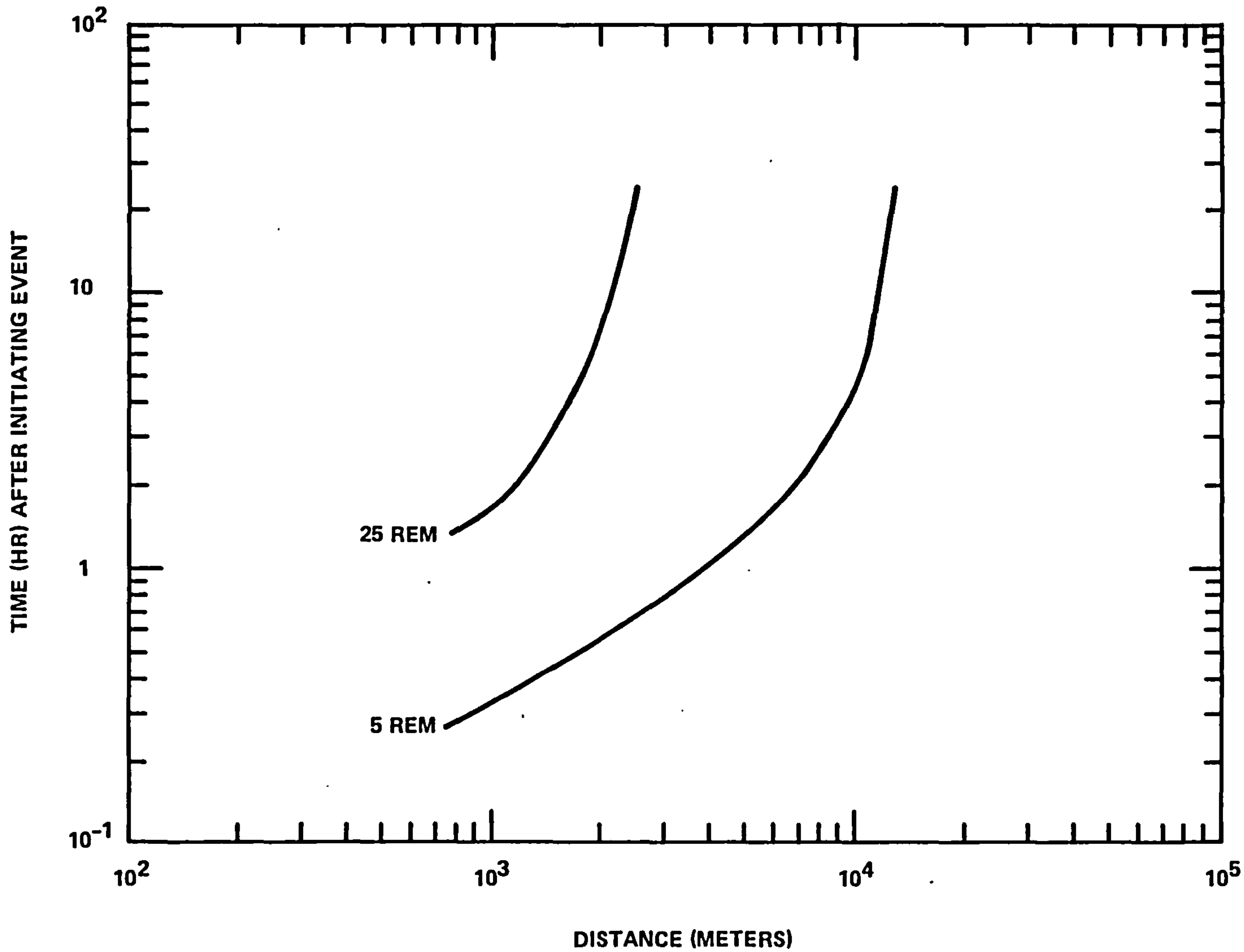


Figure I-5. Example of Time–Dose–Distance Relationships for Thyroid Inhalation Dose From DBA/LOCA (5% Meteorology and Straightline Plume Trajectory)

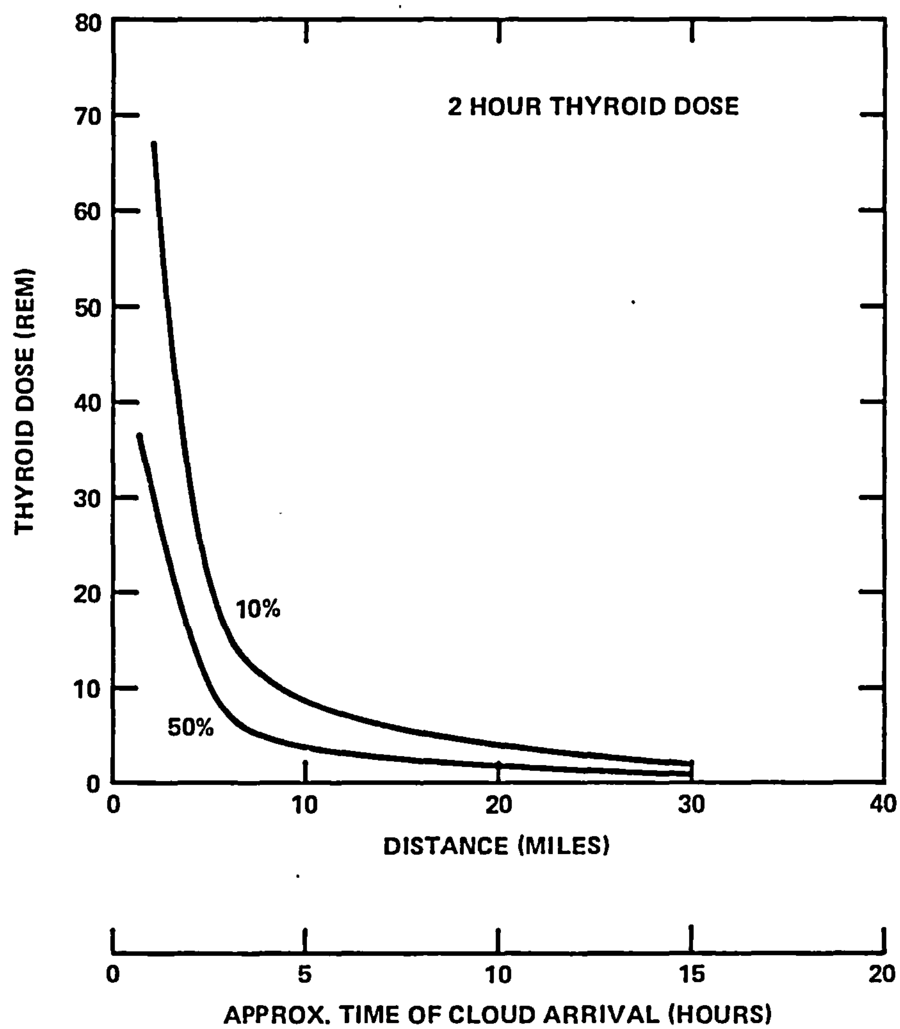


Figure I-6. Centerline Dose Versus Distance for Licensing Calculation of DBA/LOCA at 2 Hours Assuming 5 Percentile Meteorology and Straight Line Plume Trajectory.

50% Curve is Median of 67 Actual Site Calculations
10% Curve is Highest 10% of Calculations

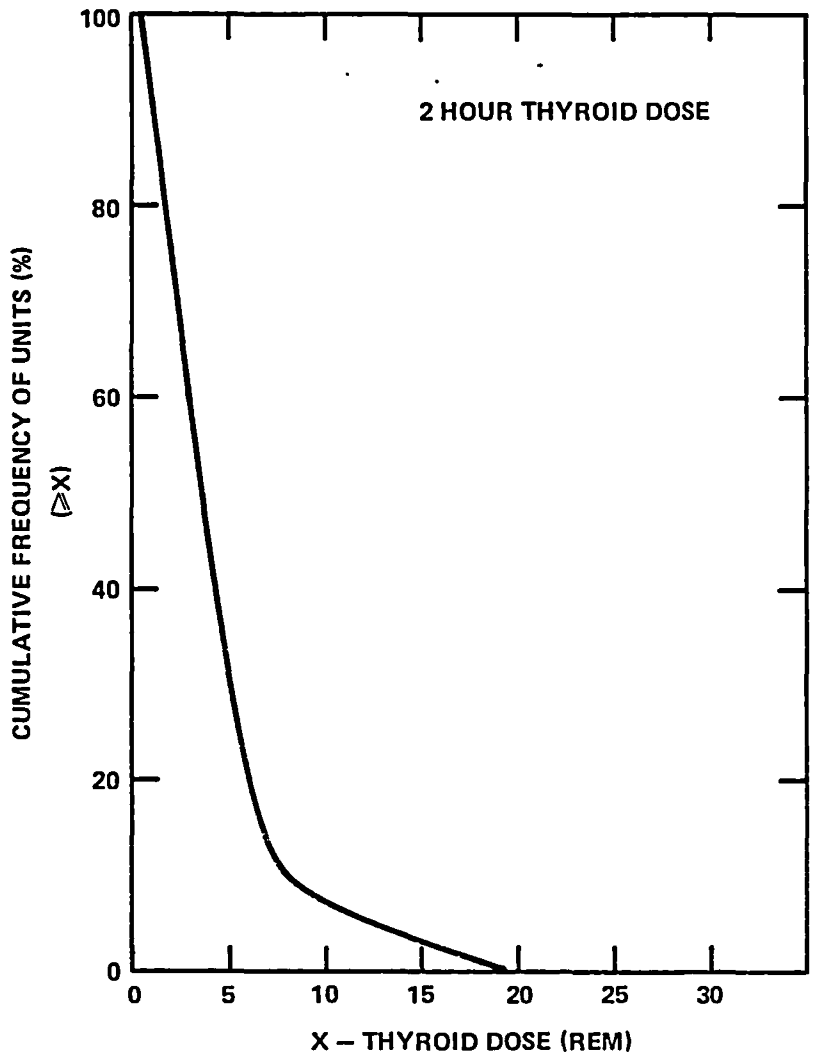


Figure I-7. Cumulative Frequency of Units Versus Dose at 10 Miles for Licensing Calculation of DBA/LOCA at 2 Hours Assuming 5 Percentile Meteorology and Straight Line Trajectory.

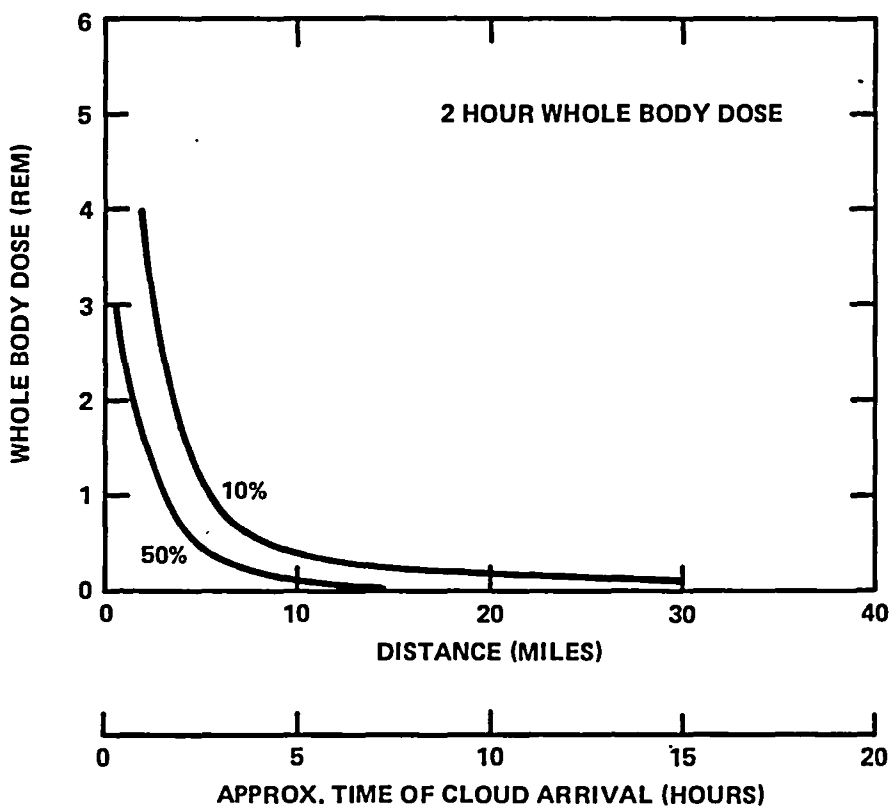


Figure I-8. Centerline Dose Versus Distance for Licensing Calculation of DBA/LOCA at 2 Hours Assuming 5 Percentile Meteorology and Straight Line Plume Trajectory.

50% Curve is Median of 67 Actual Site Calculations
10% Curve is Highest 10% of Calculations

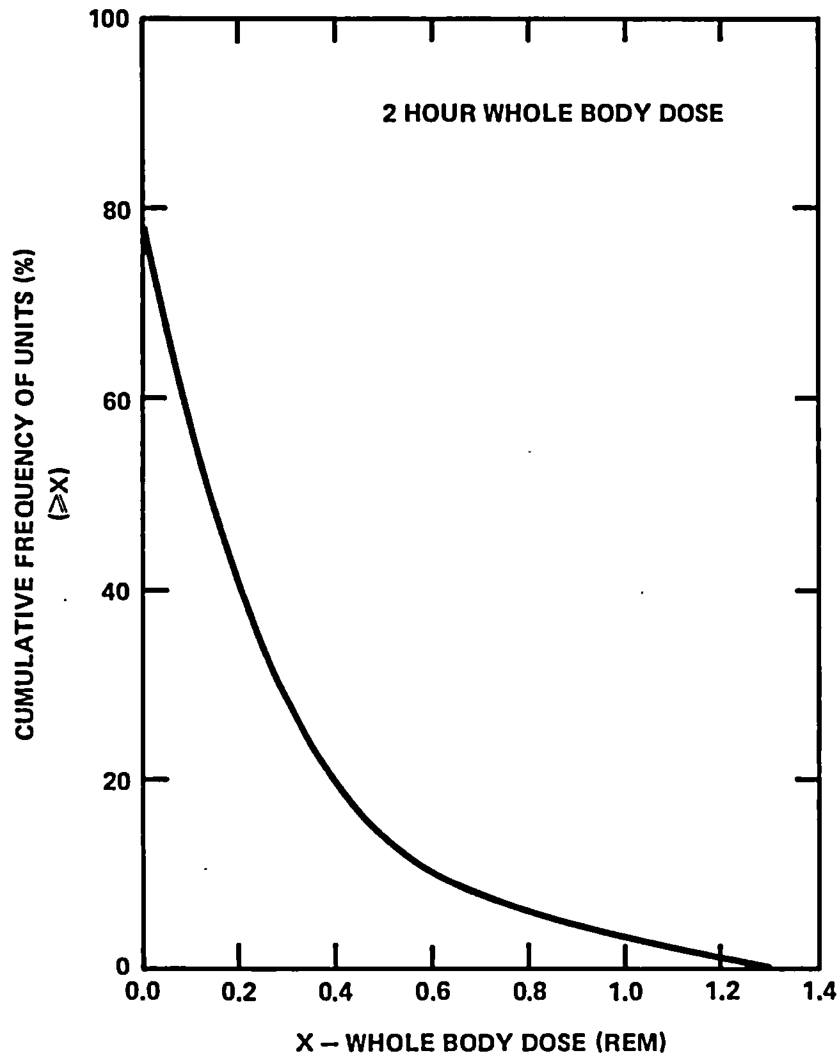


Figure I-9. Cumulative Frequency of Units Versus Dose at 10 Miles for Licensing Calculation of DBA/LOCA at 2 Hours Assuming 5 Percentile Meteorology and Straight Line Trajectory.

dose case. The results are similar to the thyroid case. The dose is seen to sharply decrease within 10 miles and to decrease slowly at greater distances. At 10 miles the whole body dose for the median plant was about 1/10 of a rem and very few plants had doses in excess of 1/2 rem whole body.

From these results, the Task Force concluded that about a 10 mile Emergency Planning Zone for the plume exposure pathway was justified to assure that predetermined actions would be planned in those areas where PAGs could be exceeded in the event of a release comparable to a design basis accident.

For the ingestion pathway, figure I-10 was developed showing a distance relationship of potential dose to an infant's thyroid from milk consumption. As was done for the plume exposure, conservative calculational techniques were used to attempt to bound the results of the ingestion exposure. For example, the straight line trajectory was used with no credit taken for wind shifts. All of the assumptions of the Reactor Safety Study for the calculation of thyroid dose from milk ingestion were used for this analysis. The results of figure I-10 show that for the DBA-LOCA, ingestion doses above PAG's are unlikely to occur beyond about 50 miles from power plants

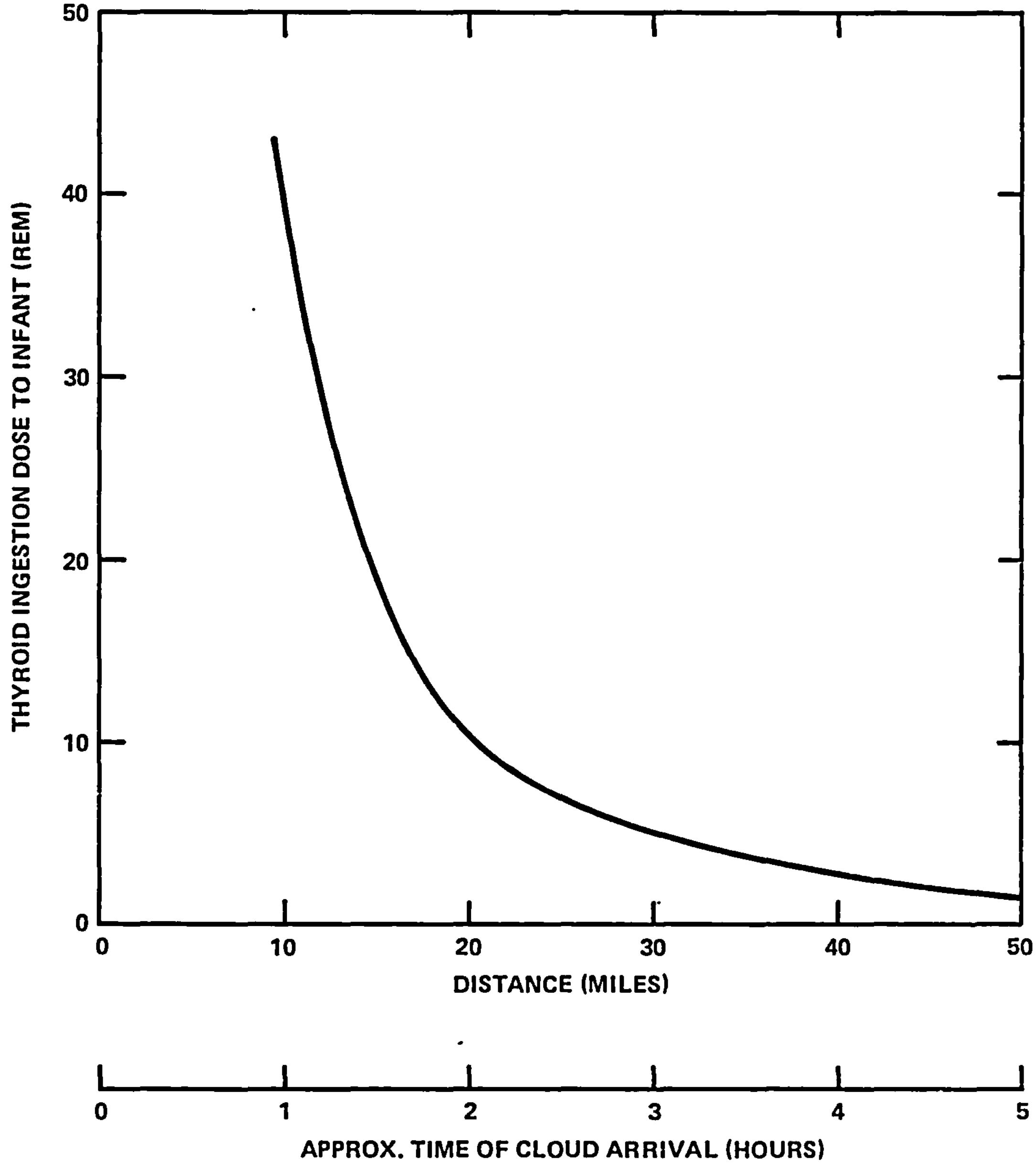


Figure I-10. Maximum Thyroid Dose (Milk Pathway) to Infant Versus Distance, From I-131, for DBA/LOCA Assuming Worst Possible Meteorology and Straight Line Trajectory.

E. Emergency Planning Consideration Derived from The Reactor Safety Study (WASH-1400)

The Reactor Safety Study (RSS) attempts to provide a detailed quantitative assessment of the probability and consequences of "Class 9" accidents. The study concluded that the public risk from nuclear reactor accidents was dominated by accidents in which there was substantial damage to the reactor core and that the probabilities of such accidents were very small.* Since emergency planners are encouraged to develop response plans which will be flexible enough to respond to most accident situations, some understanding of "Class 9" accidents and the relationships between them and emergency planning is needed.

The Reactor Safety Study developed the mathematical techniques and data base to provide an understanding of these relationships. To obtain an appreciation for the distances to which or areas within which emergency planning might be required, a perspective on the relative probabilities of certain critical doses as a function of distance from the power plant for these accidents

*Probability of a "core-melt" accident was estimated to be approximately 1 in 20,000 (5×10^{-5}) per reactor year. There is a large uncertainty on this number.

is needed. A set of such curves has been prepared for all of the RSS accident release categories (figure I-11). These curves include both Pressurized and Boiling Water Reactor (PWR & BWR) accidents. Doses are given for the critical values for which emergency planners should be concerned. One and five rem whole body doses correspond to the lower range of the PAGs; 50 rem whole body corresponds to the dosage at which early illnesses start to occur; and 200 rem whole body is the dose at which significant early injuries start to occur. As can be seen from figure I-11, core melt accidents can be severe, but the probability of large doses drops off substantially at about 10 miles from the reactor. Similar conclusions can be reached by evaluating the other critical organs of lung and thyroid shown in figures I-12 and I-13, respectively. For the lung, the doses of 5, 25, 300 and 3000 rem were plotted as a function of distance and probability of occurence. For the thyroid, the reference doses of 5, 25, 300 rem, which correspond to the lower and upper PAG levels, and the guideline exposure used for siting purposes are presented.

Given a core melt accident, there is about a 70% chance of exceeding the PAG doses at 2 miles, a 40% chance at 5 miles, and a 30% chance at 10 miles from a power plant. That is, the probability of exceeding PAG doses at 10 miles is 1.5×10^{-5}

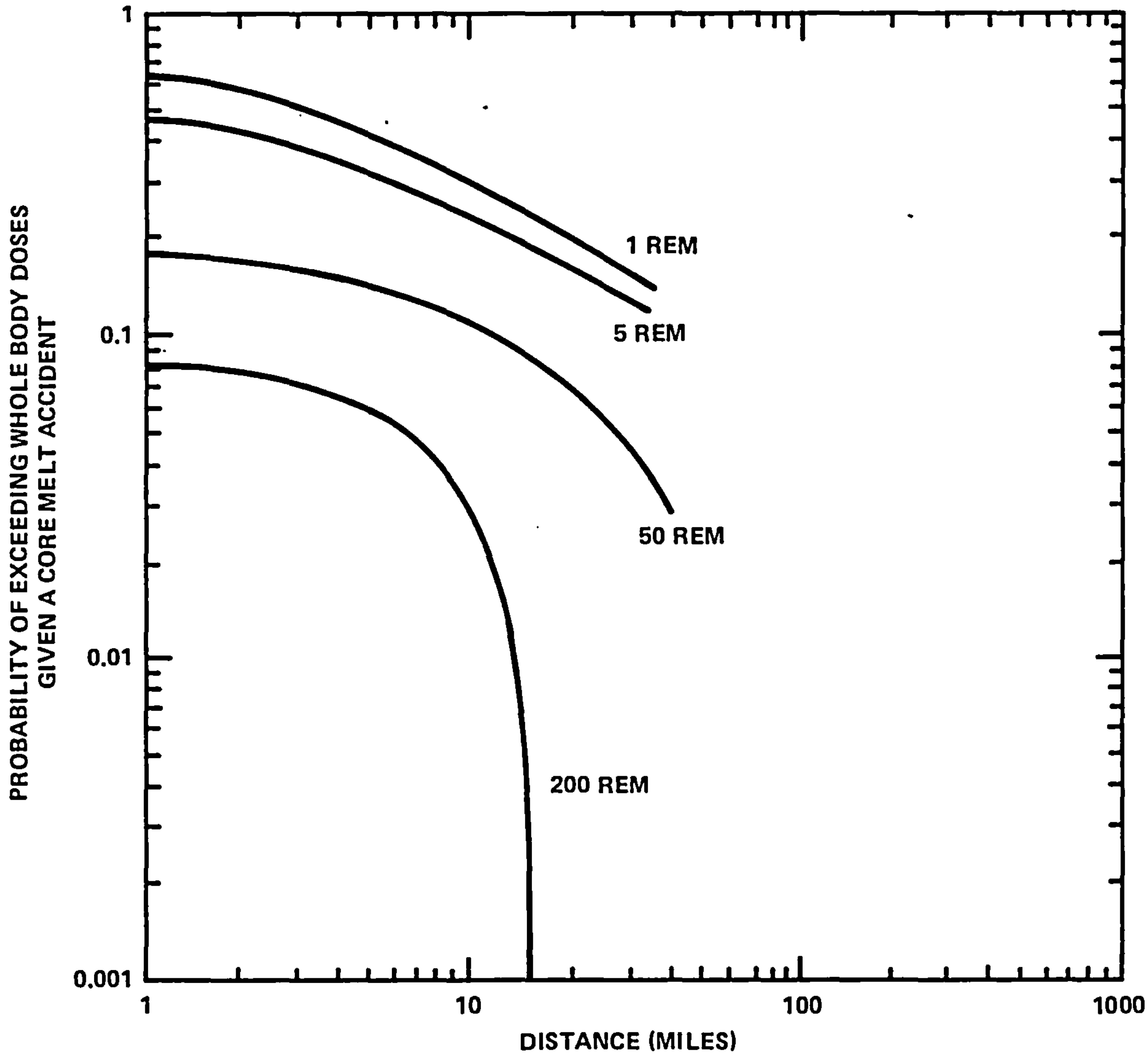


Figure I-11. Conditional Probability of Exceeding Whole Body Dose Versus Distance. Probabilities are Conditional on a Core Melt Accident (5×10^{-5}).

Whole body dose calculated includes: external dose to the whole body due to the passing cloud, exposure to radionuclides on ground, and the dose to the whole body from inhaled radionuclides.

Dose calculations assumed no protective actions taken, and straight line plume trajectory.

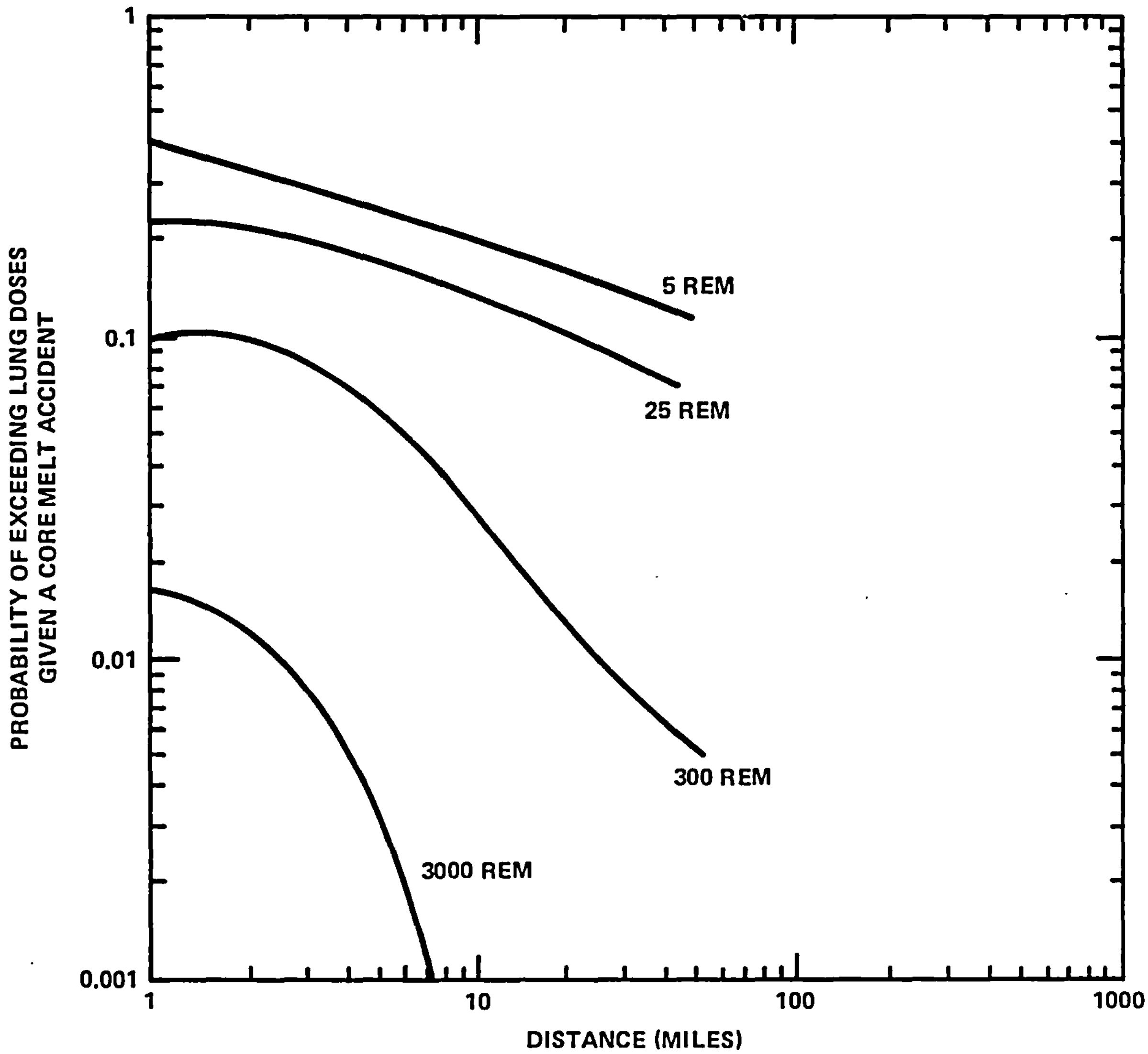


Figure I-12. Conditional Probability of Exceeding Lung Doses Versus Distance. Probabilities are Conditional on a Core Melt Accident (5×10^{-5}).

Lung dose calculated includes: external dose to the lung due to the passing cloud, exposure to radionuclides on ground, and the dose to the lung from inhaled radionuclides within 1 year.

Dose calculations assumed no protective actions taken, and straight line trajectory.

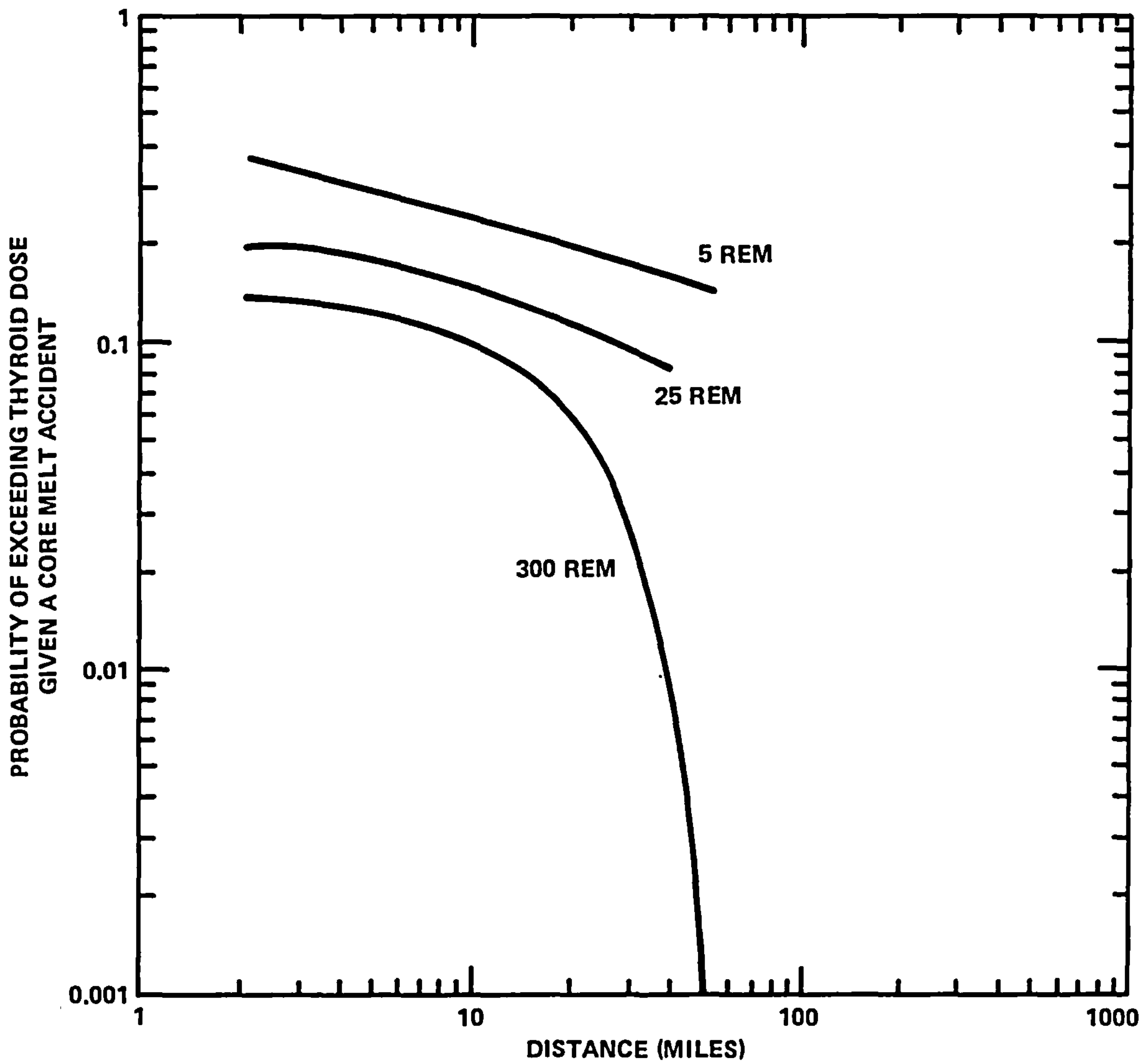


Figure I-13. Conditional Probability of Exceeding Thyroid Doses Versus Distance. Probabilities are Conditional on a Core Melt Accident (5×10^{-5}).

Thyroid dose calculated includes: external dose to the thyroid due to the passing cloud, exposure to radionuclides on ground, and the dose to the thyroid from inhaled radionuclides.

Dose calculations assumed no protective actions taken, and straight line trajectory.

per reactor year* (one chance in 50,000 per reactor-year) from the Reactor Safety Study analysis.

Based in part upon the above information the Task Force judged that a 10 mile plume EPZ would be appropriate to deal with core melt accidents.

Potential ingestion doses to the thyroid (through the cow/milk pathway) from core melt accidents are given in figure I-14. The distance for which emergency planning is needed is not easily determined from the information given in the figure. It is evident that doses can potentially be quite high out to considerable distances.

The current PAG for milk ingestion is 30 rem thyroid to an individual and 10 rem thyroid to a suitable sample of the population (usually calculated on the basis of an infant's thyroid). Given a core melt accident, there is a near 100% chance of exceeding the 10 rem thyroid PAG from milk ingestion at 1 mile, about an 80% chance at 10 miles and a 40% chance at 25 miles from a power plant. A planning basis for milk ingestion on the order of 25 miles would therefore approximately correspond to the 10 mile plume exposure distance

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*There is a large uncertainty on this number.

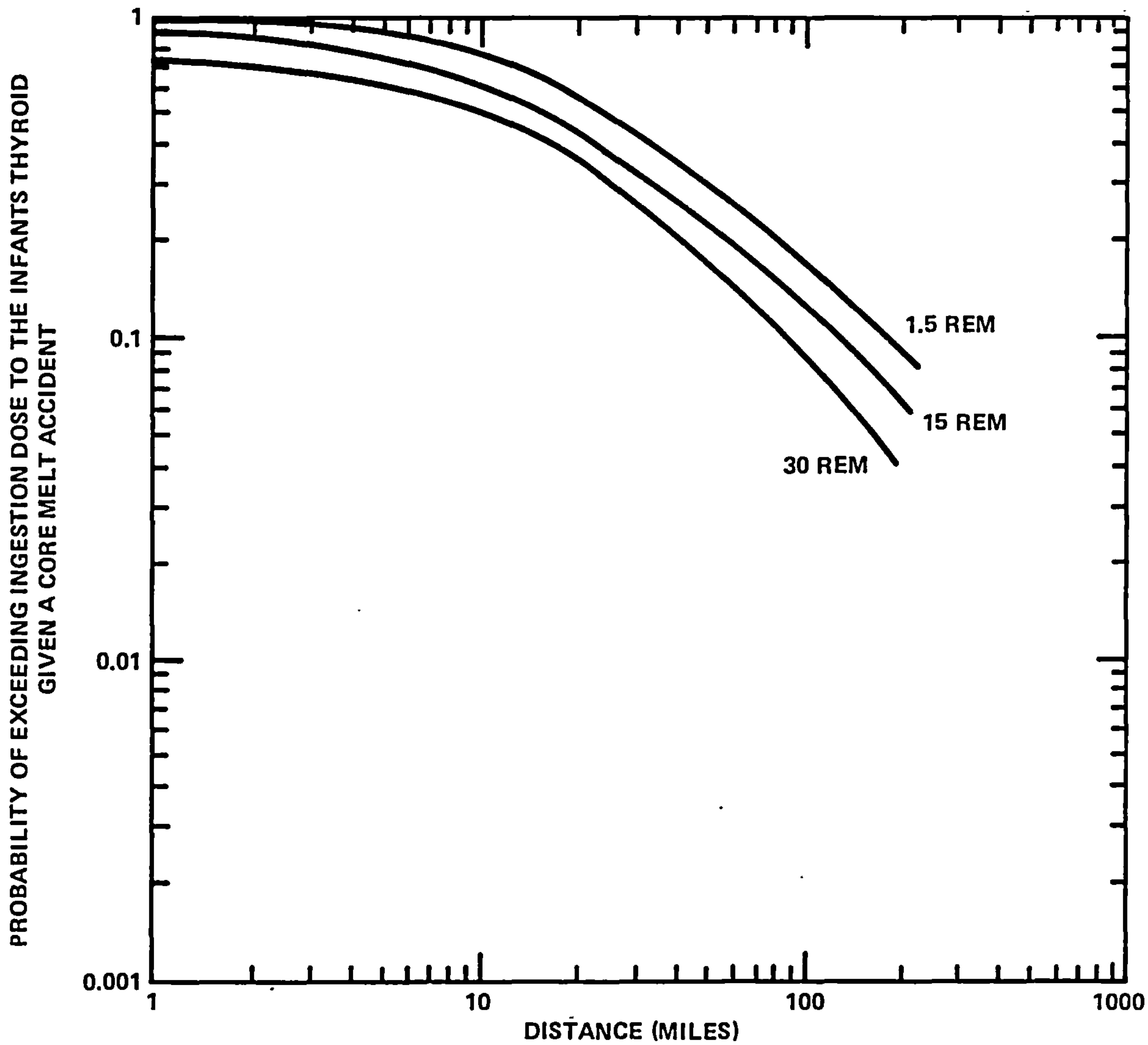

Figure I-14. Conditional Probability of Exceeding Thyroid Dose to an Infant Versus Distance. Probabilities are Conditional on a Core Melt Accident (5×10^{-5}).

Thyroid dose calculated is due solely to radionuclide ingestion through the milk consumption pathway.

Dose calculations assumed no protective actions taken, and straight line trajectory.

if current FRC guidance were used. However, because the Task Force is aware that revision of the FRC guides may result in recommendations for certain types of preventive measures (such as putting cows on stored feed) at projected doses substantially below these levels,* the Task Force chose an ingestion pathway EPZ on the order of 50 miles.

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*The recommended size of the ingestion exposure EPZ is based on an expected revision of milk pathway Protective Action Guidelines by FDA-Bureau of Radiological Health. The Task Force understands that measures such as placing dairy cows on stored feed will be recommended for projected exposure levels as low as about 1.5 rem to the infant thyroid. Should the current FRC guidelines be maintained, an EPZ of about 25 miles would be recommended by the Task Force.

F. Examination of Offsite Emergency Protective Measures for Core Melt Accidents

A recent study (6, 7) has been published which is of general use to those responsible for emergency response planning for reactor accidents in understanding the "Class 9" accident relationships and specifically the core "melt-through" and "atmospheric" accident classes. This study was undertaken to evaluate, in terms of public radiation exposure and health effects, the relative merits of possible offsite emergency protective measures for response to potential nuclear reactor accidents involving serious reactor accidents. Three types of protective measures were examined and compared: evacuation; sheltering followed by population relocation, and medical (iodine) prophylaxis. This study was based upon the Reactor Safety Study results and methodologies. The conclusions of the study not only give a perspective on the relative merits of a given protective measure, the conclusions also confirm the Task Force recommendations on the distances and times for which planning is appropriate.

Figures I-15 and I-16 give the additional perspective of the study on the probabilities and needs for emergency planning in terms of the core "melt-through" and "atmospheric" categories and a range of expected emergency actions. Figure I-15 shows the probabilities of exceeding thyroid and whole body PAGs versus distance from the reactor, conditional on the occurrence of a "melt-through" release. The probabilities are calculated for an individual located outdoors, and are presented for both lower and upper PAG levels for each organ. A similar curve is shown in figure I-16 for the "atmospheric" releases.

The figure indicates that both whole body and thyroid PAGs are likely to be exceeded at very large distances* from the reactor (and correspondingly over very large areas) if an "atmospheric" accident were to occur. Doses in excess of threshold levels for early health effects are confined to smaller areas much closer to the reactor. Therefore, in the unlikely event that an accident of this magnitude were to occur, responsible authorities might choose to direct their available

*Caution must be used in interpreting the large distances indicated. The RSS consequence model assumes an invariant wind direction following the release of radioactive material. However, because of the time required by the cloud to travel large distances, it is likely that the wind directions will, in fact, shift and that the predicted dose levels would not be observed at the reported radial distance. Rather, the distance applies more closely to the trajectory of the released cloud.

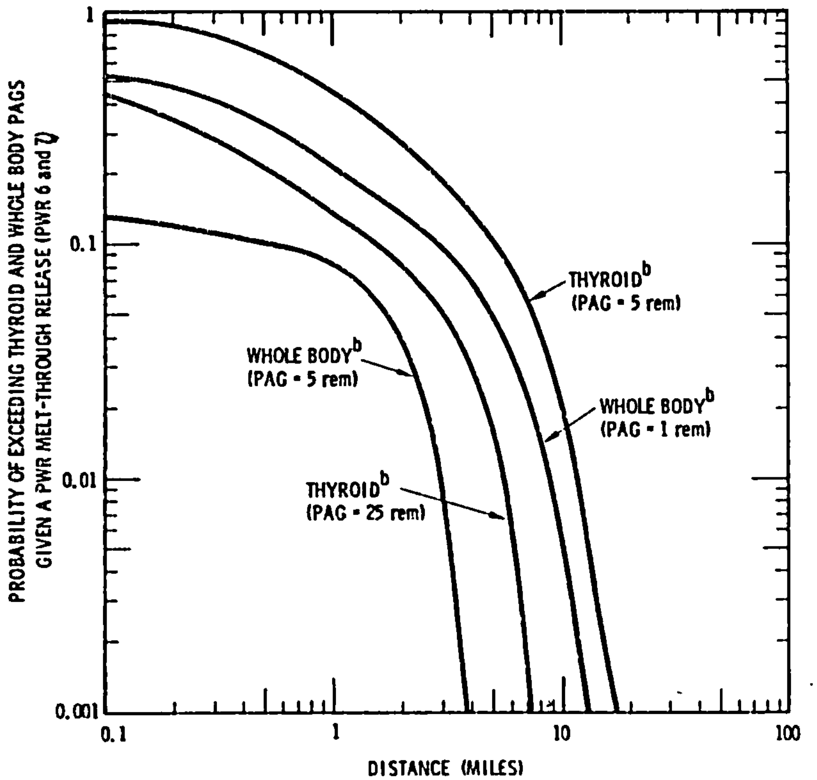

Figure I-15. Conditional Probability of Exceeding Thyroid and Whole Body Protective Action Guides (PAGs) Versus Distance for an Individual Located Outdoors.[a] Probabilities are Conditional on a PWR "Melt-Through" Release (PWR 6 and 7).

[a]Shielding factor for airborne radionuclides = 1.0. Shielding factor for radionuclides deposited on ground = 0.7. 1-day exposure to radionuclides on ground.

[b]Whole body (thyroid) dose calculated includes: external dose to the whole body (thyroid) due to the passing cloud and 1-day exposure to radionuclides on ground, and the dose to the whole body (thyroid) from inhaled radionuclides within 1 year.

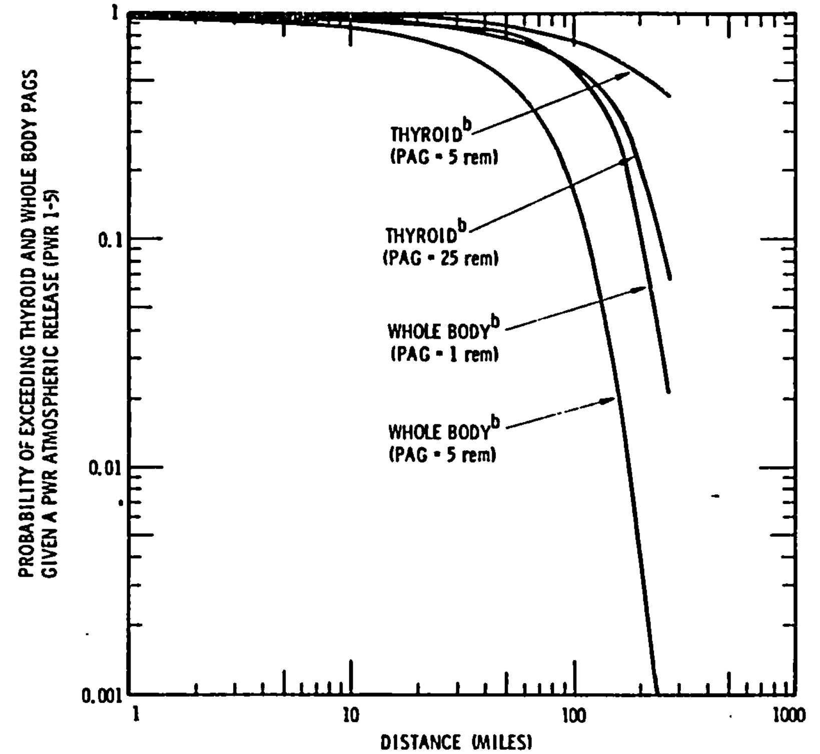

Figure I-16. Conditional Probability of Exceeding Thyroid and Whole Body Protective Action Guides (PAGs) Versus Distance for an Individual Located Outdoors.[a] Probabilities are Conditional on a PWR "Atmospheric" Release (PWR 1-5).

[a]Shielding factor for airborne radionuclides = 1.0. Shielding factor for radionuclides deposited on ground = 0.7. 1-day exposure to radionuclides on ground.

[b]Whole body (thyroid) dose calculated includes: external dose to the whole body (thyroid) due to the passing cloud and 1-day exposure to radionuclides on ground, and the dose to the whole body (thyroid) from inhaled radionuclides within 1 year.

resources towards limiting the life- and injury-threatening doses to individuals in those closer areas. Then, if sufficient resources are available, protective measures might also be implemented for individuals at larger distances for whom PAGs are, or are likely to be, exceeded.

Mean** numbers of projected early fatalities and injuries within selected radial intervals, conditional on an "atmospheric" release are compared for evacuation and sheltering strategies in figures I-17 and I-18. Seven strategies are included, as defined in the key to these figures. Strategy 1 assumes that no immediate protective actions are taken. 2, 3, and 4 are selected sheltering strategies. Strategies 3 and 4 represent sheltering for regions in which a large fraction of homes have basements. Effective exposure durations to ground contamination for these two strategies are 1 day and 6 hours, respectively. Strategy 2 represents sheltering for regions in which most homes do not have basements, with 6 hours of effective exposure to ground contamination. Strategies 5, 6, and 7 represent evacuation with 5, 3 and 1 hours of delay time, respectively. The results presented in figures I-17 and I-18 assume a uniform population density of 100 people per square mile. The corresponding

** The mean refers to the average of 91 stratified weather sequences which were used to calculate a frequency distribution of early public health effects.

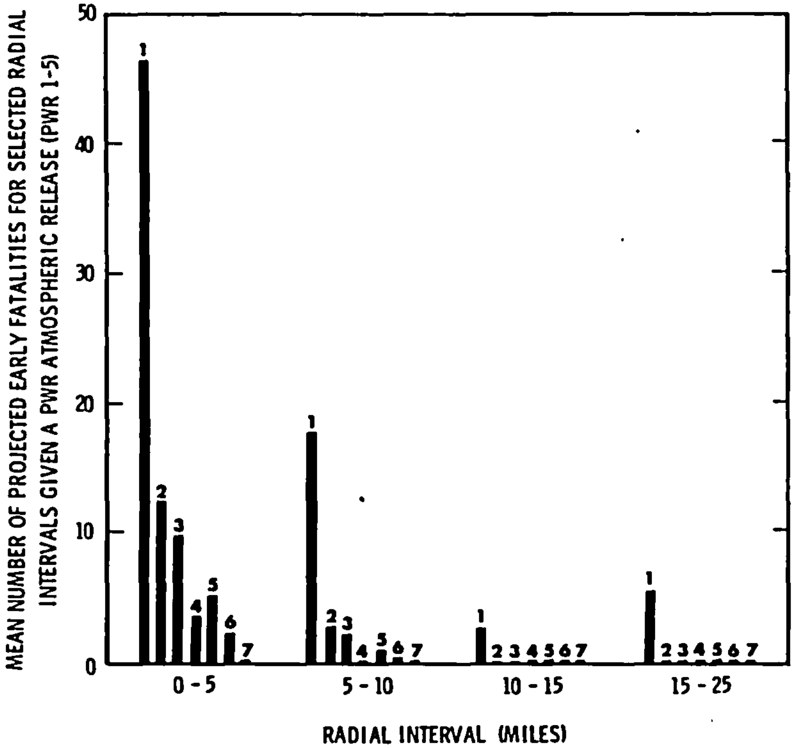

Figure I-17. Mean Number of Projected Early Fatalities Within Selected Radial Intervals for Evacuation and Sheltering Strategies, Given a PWR "Atmospheric" Release (PWR 1-5). A Uniform Population Density of 100 Persons per Square Mile is Assumed.

Key:
1. No immediate protective action, SF's[a] (0.75, 0.33),[b] 1-day exposure to radionuclides on ground.
2. Sheltering, SF's (0.75, 0.33), 6-hour exposure to radionuclides on ground.
3. Sheltering, SF's (0.5, 0.08), 1-day exposure to radionuclides on ground.
4. Sheltering, SF's (0.5, 0.08), 6-hour exposure to radionuclides on ground.
5. Evacuation, 5 hour delay time, 10 MPH.
6. Evacuation, 3 hour delay time, 10 MPH.
7. Evacuation, 1 hour delay time, 10 MPH.

[a]Shielding factors (airborne radionuclides, ground contamination).

[b]Shielding factors for no protective action were chosen to be the same as for sheltering in areas where most homes do not have basements (see reference 6).

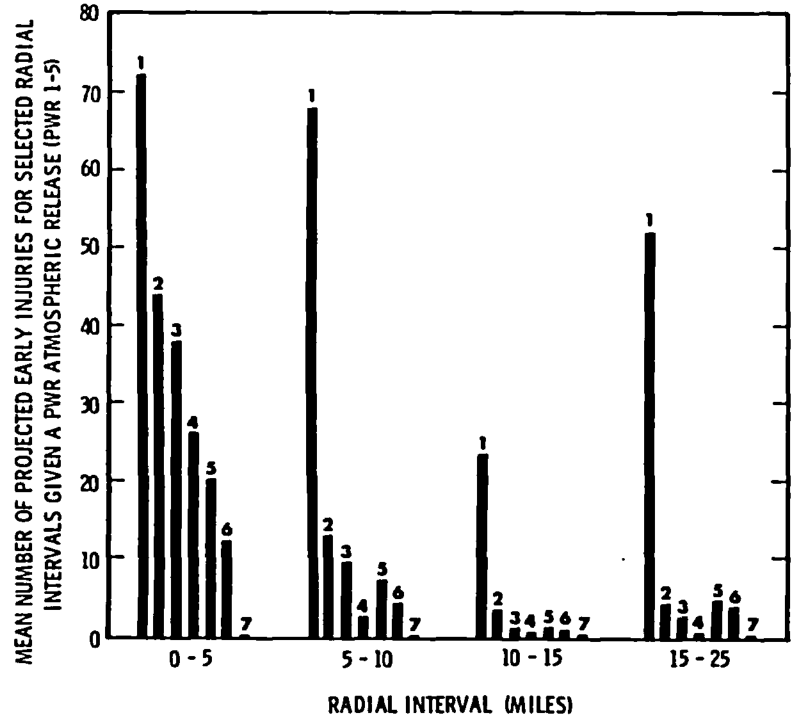

Figure I-18. Mean Number of Projected Early Injuries Within Selected Radial Intervals for Evacuation and Sheltering Strategies, Given a PWR "Atmospheric" Release (PWR 1-5). A Uniform Population Density of 100 Persons per Square Mile is Assumed.

Key:
1. No immediate protective action, SF's[a] (0.75, 0.33),[b] 1-day exposure to radionuclides on ground.
2. Sheltering, SF's (0.75, 0.33), 6-hour exposure to radionuclides on ground.
3. Sheltering, SF's (0.5, 0.08), 1-day exposure to radionuclides on ground.
4. Sheltering, SF's (0.5, 0.08), 6-hour exposure to radionuclides on ground.
5. Evacuation, 5 hour delay time, 10 MPH.
6. Evacuation, 3 hour delay time, 10 MPH.
7. Evacuation, 1 hour delay time, 10 MPH.

[a]Shielding factors (airborne radionuclides, ground contamination).

[b]Shielding factors for no protective action were chosen to be the same as for sheltering in areas where most homes do not have basements (see reference 6).

number of projected early fatalities and injuries for any particular site would depend on the actual population distribution surrounding the site. Nevertheless, the relative comparison of numbers for the strategies indicated is nearly independent of the population distribution within a given interval.

Several observations can be drawn from the results presented in figures I-17 and I-18. Most early fatalities resulting from "atmospheric" accidents are projected to occur within approximately 10 miles of the reactor, while early injuries are likely out to somewhat larger distances.* Within 5 miles of the reactor, evacuation appears to be more effective in reducing the number of early health effects than sheltering, as long as the delay time and nonparticipating segment of the population are kept sufficiently small. This distinction is not as apparent in the 5 to 10 mile interval. Throughout both of the intervals from 0 to 10 miles, the importance of a rapid and efficient implementation of either evacuation or sheltering is evident (small delay times for evacuation, small ground exposure times for sheltering).

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*Projected early fatalities and injuries in the 15 to 25 mile interval are higher than for the 10-15 mile interval because the interval is twice as wide.

Note that evacuation (i.e., removal of population from hazardous area) with delay times of 1 hour or less will reduce the projected number early public health effects to roughly 0 in any radial interval, and will always be the most effective response measure for a severe accident, if it can be achieved. In the intervals beyond 10 miles, there is little apparent distinction between the effectiveness of evacuation and sheltering strategies in terms of projected early fatalities or injuries. The mean number of early fatalities is 0 in both of these intervals, and projected early injuries, although not 0, are greatly reduced for each of the protective strategies investigated.

Several important conclusions about the relative effectiveness of the protective measures examined, the distances to which or areas within which they might be required, and the time available for their implementation, were drawn by the study from the results provided by these analyses. For the "melt-through" class, projected whole body and thyroid doses in excess of PAGs for those organs are, for all practical purposes, confined to areas within 10 miles of the reactor. Emergency response planning for this type of accident should therefore be primarily directed towards limiting the dose to those individuals located within that distance. Evacuation appears to provide the greatest benefit of any protective measure.

However, sheltering, particularly in areas where most homes have basements, also offers substantial benefit, and may in many cases offer an acceptable alternative to evacuation. Iodine prophylaxis, if administered in sufficient time, could also offer substantial reduction in the projected dose to the thyroid.

"Atmospheric" accidents could result in the occurrence of significant numbers of early fatalities and injuries. However, doses in excess of threshold levels for significant early health effects (about 200 rem whole body) are generally confined to areas much closer to the reactor. Therefore, given an "atmospheric" accident, responsible authorities should concentrate their immediately available resources on limiting the life- and injury-threatening doses to individuals in those closer areas.* Within 5 miles of the reactor, evacuation appears to be more effective than sheltering in reducing the number of early health effects, as long as the delay time and nonparticipating fraction of the population can be kept sufficiently small. Between 5 and 10 miles, this distinction is not as apparent, and sheltering in areas where basements are widely available (followed by rapid relocation) may be as effective as evacuation with relatively small delay times. For all affected

*Then, when time permits, protective measures might be implemented for individuals at larger distances for whom PAGs are, or are likely to be, exceeded.

areas within approximately 10 miles of the reactor, the speed and efficiency with which either evacuation or sheltering and relocation are implemented strongly influence the number of projected early health effects. For areas beyond 10 miles, there is little apparent distinction between the effectiveness of evacuation and sheltering strategies in terms of projected early fatalities or injuries. Therefore, although protective actions may be required for individuals located in areas further than 10 miles from the reactor for an "atmospheric" release, the actual measures used and how rapidly or efficiently they are implemented, will not strongly influence the number of projected early health effects.

REFERENCES FOR APPENDIX I

(1) D. Bunch, K. Murphy and J. Reyes. Demographic Statistics Pertaining to Nuclear Power Reactor Sites. (Draft) NUREG-0348. USNRC Washington, D. C. 20555 Dec. 1977

(2) D. Bruce Turner. Workbook of Atmospheric Dispersion Estimates. AP-26. USEPA Office of Air Programs, Research Triangle Park, NC 27711. 1970 Revision.

(3) USAEC. Meteorology and Atomic Energy - 1968. D. Slade, ed TID-24190. National Technical Information Service, Springfield, Va. 22151

(4) J. A. Martin, Jr. Doses While Traveling Under Well Established Plumes. Health Physics Jr. V. 32, n.4, pp. 305-307, April 1977.

(5) I. Van der Hoven. Wind Persistence Probability. ERLTM-ARL-10. NOAA Air Resources Laboratory, Silver Spring, MD 20910

(6) Aldrich, D. C., Examination of Offsite Radiological Emergency Protective Measures For Nuclear Reactor Accidents Involving Core Melt, MIT, Department of Nuclear Engineering, March, 1978.

(7) Aldrich, D. C., et al, "Examination of Offsite Emergency Protective Measures For Core Melt Accidents," American Nuclear Society Topical Meeting, Newport Beach, Ca., May, 1978.

APPENDIX II

BACKGROUND CONCERNING THIS REPORT

The commercial nuclear power industry has expanded greatly in the last several years and is expected to grow even larger in the years ahead as more plants go into operation. The industry to date has had an excellent safety record. The Federal government recognizes this excellent safety record and the efforts by the nuclear industry to continue to reduce even further the likelihood of accidents. It also recognizes, however, that the probability of an accident involving a significant release of radioactive material, although small, is not zero. It has been and continues to be Federal policy to adopt a cautious attitude with respect to the potential of these facilities for the release of radioactive materials in hazardous quantities. Such emergency situations are the focus of attention of Federal radiological emergency preparedness activities.

A. NRC Reactor Siting and Emergency Planning Regulations

The U. S. NRC, as the agency with the principal regulatory authority for the construction and operation of nuclear power plants, has long recognized that emergencies could arise in the operation of such plants. One of its regulations, Reactor Site Criteria (10 CFR Part 100 published in 1962[(1)]) states that a capability for taking protective measures on behalf of the public in the event of a serious accident should be established within a region called the low population zone (LPZ) surrounding a nuclear power plant site. Whether a specific number of people can, for example, be evacuated from a specific area, or instructed to take shelter, on a timely basis will depend on many factors such as: egress routes, availability of sheltering, the scope and extent of advance planning, and the actual distribution of residents within the area.

In 1970, explicit requirements for plans to cope with emergencies were published in 10 CFR 50, Appendix E. In accordance with provisions of the Atomic Energy Act of 1954, these requirements are directed to applicants who apply for licenses to operate these facilities rather than to State or local governments. With respect to a planning basis, NRC regulations in 10 CFR 50, Appendix E, do not provide explicit guidance as to the character or magnitude of accidental releases to the environment which should be considered in the development of nuclear facility or State and local government emergency plans. The Appendix E regulations also do not include any explicit references to the low population zone or other particular geographical areas other than "within and outside the site boundary". They do, however, require that applicants for construction permits for these facilities provide sufficient information to "assure compatibility of proposed (facility) emergency plans with facility design features, site layout, and site location with respect to such considerations as access routes, surrounding population distributions, and land use".

Neither the NRC nor the other Federal agencies have statutory authority over State and local governments with respect to emergency planning related to nuclear facilities. In the regulation of nuclear power plants, however, NRC requires licensees to develop an emergency response plan which contains provisions for the protection of the public. The implementation of any protective actions offsite, however, is necessarily the responsibility of offsite organizations. The NRC requires that the licensee develop procedures for notifying local, State and Federal agencies. NRC also requires that licensees' emergency plans contain agreements reached with local, State and Federal agencies which provide for the early warning of the public and the implementation of any appropriate protective actions.

B. Federal Guidance Effort

The legal authority and responsibility of local, State and Federal governments for offsite response was recognized when 10 CFR 50, Appendix E was published. NRC regulations require licensees to incorporate provisions for participation by offsite authorities or organizations whose assistance may be required in the event of a radiological emergency in periodic drills to test response plans. As the NRC staff gained experience with these requirements, it became concerned with the abilities of State and local governments to discharge their responsibilities should the need ever arise. This concern in part gave rise to a Federal Register Notice[2] which started an Interagency program for providing radiological emergency response planning guidance and related training to State and local government organizations. NRC exercises the lead role in this activity and several Federal Agencies, including EPA, participate. Guidance has been published by NRC, EPA and other Federal agencies for use by State and local governments in developing radiological emergency response plans.

It has been Federal policy to encourage planning for a variety of radiological consequence situations "within and outside the site boundary" and the Task Force reemphasizes the necessity for emergency planners to consider a wide spectrum of situations. Existing Federal guidance documents are constructive in this regard. But these documents are not sufficiently definitive as evidenced by the continuing dialogue among Federal, State and local agencies and licensees on this subject. Existing Federal guidance which bears on the basis for developing offsite emergency plans is summarized below.

1. 1970 - "The licensee should give particular attention to protective measures that may be necessary for individuals within the low population zone ..."[3]

2. 1974 - The NRC staff's acceptance criteria for preliminary planning at Preliminary Safety Analysis Report (PSAR) review stage refers to a basis of "calculated radiological dose consequences of an airborne release following the most serious design basis accident."[4]

3. 1974 - The NRC's principal guidance document[5] for State and local government emergency planners contains the following under an introductory heading of "Magnitude of the Accident:" "The evaluation of sites and plant designs, required testing programs, and quality assurance for the operation of such facilities all provide substantial assurance that accidents with serious consequences to the public health and safety are not likely to occur. Nevertheless, highly unlikely sequences of events are postulated and their potential consequences analyzed by the applicant in the Safety Analysis Report which accompanies each application and by the (NRC)

staff in its Safety Evaluation Report for each plant. The (NRC) considers that it is reasonable, for purposes of emergency planning relative to nuclear facilities, to prepare for the potential consequences of accidents of severity up to and including the most serious design basis accident analyzed for siting purposes."

..."The (NRC) recognizes that accidents with more severe potential consequences than design basis accidents can be hypothesized. However, the probability of such accidents is exceedingly low. Emergency plans properly designed to cope with design basis accidents would also provide significant protection against more severe accidents, since such plans provide for all of the major elements and functions of emergency preparedness. An added element of confidence can be gained, however, if States and local governments assure that their plans for responding to radiological emergencies are coordinated with their plans for dealing with floods, earthquakes, or other disaster situations which might necessitate large scale displacement of people and the provision of shelter, food, medical aid, and other emergency services. Communications, traffic control, evacuation, public notification and other emergency responses will tend to be the same whether or not the emergency involves radiological considerations. The (Department of Energy's) Radiological Assistance Program (RAP), the Federal Interagency Radiological Assistance Plan (IRAP) and other Radiological Emergency Assistance Plans, which are a part of the Federal capability, provide significant additional emergency resources in the event of a serious accident."

This introductory text in the "Guide and Checklist"[5] document was written for the express purpose of providing interpretive guidance to the meaning of the enumerated checklist elements in this document.

4. 1975 - With respect to evacuation as a protective measure, applicants are requested to provide "plots showing projected ground-level doses for stationary individuals, -- resulting from the most serious design basis accident analyzed in the Safety Analysis Report. These should be based on the same isotopic release rates to the atmosphere and the same dispersion model as are acceptable for use in Chapter 15 of the PSAR for the purpose of showing conformance to the siting dose criteria of 10 CFR Part 100."[6]

5. 1975 - With respect to the levels at which emergency actions should be initiated, EPA issued as Agency guidance, portions of the "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" which provided PAGs for plume exposure and application procedures for these PAGs.(7) These bear on the areas or distances for which plans might be implemented.

6. 1977 - "Planning and implementation of measures to cope with plant related emergencies outside the site boundary with particular emphasis on the low population zone should be a coordinated effort involving the licensee, and local, State, and Federal agencies having emergency responsibilities."(8)

C. Reactor Accident Considerations

Current NRC regulatory practice requires that events which may be anticipated to occur one or more times during the lifetime of a facility lead to no significant releases of radioactive material to the environment. No design or mode of operation is, however, entirely risk free. Despite the efforts made to prevent accidental releases of significant quantities of radioactive material, the possibility does in fact exist that such accidents may occur. Each application for a license is accompanied by a detailed assessment of such postulated accidents, and NRC staff performs an independent evaluation of these accidents before a nuclear facility license is granted.

The NRC staff has provided guidance to applicants as to the type of accidents to be considered in the design of nuclear power plants (see for example, Sections 2.3 and 15 of Regulatory Guide 1.70[9] and particularly Table 15-1 of that guide). The recommended approach by the NRC staff is to organize the postulated accidents to ensure that a broad spectrum of events have been considered and then to categorize the events by type and expected frequency so that only the limiting (i.e., more severe) cases in each group need to be quantitatively analyzed.

NRC staff has categorized postulated accidents into four major groups as follows:

1. Events of moderate frequency (anticipated operational occurrences) leading to no significant radioactive releases from the facility.

2. Events of low probability with potential for small radioactive release from the facility.

3. Events of very low probability with potential for large radioactive releases from the facility and whose consequences are evaluated to establish the performance requirements of engineered safety features and to evaluate the acceptability of the reactor site. These events, some of which assume unlikely failures or fission product releases are referred to as design basis accidents (DBAs).

4. A fourth group of accidents, the so-called "Class 9"* accidents, which include any situation not specifically included in the foregoing groups of events and which typically are represented by some combination of failures which lead to coremelting and/or containment failure. These larger events are generally considered in the regulatory process by reducing their probability of occurrence to acceptably low values through design of the plant and its engineered safety features. This group includes external events such as severe natural phenomena as well as accidents initiated within the

*The first three groups have also been divided into eight categories in some accident assessments. The eight categories plus a "Class 9" category are defined in the proposed Annex to Appendix D to 10 CFR Part 50 dated December 1, 1971. (Also listed in NUREG 0099, Regulatory Guide 4.2, Appendix I).

facility. Unlike groups 1 through 3, the consequences of events in group 4, are not specifically analyzed in most applications.

One design basis accident in the third group routinely considered in the safety analysis performed by the staff is a loss-of-coolant accident (LOCA) where it is assumed that a large fission product release from the containment also occurs. The analysis of this accident is used in connection with the site suitability evaluations done to establish compliance with 10 CFR Part 100 of the NRC regulations by comparing computed accident consequences with exposure guidelines given in the regulations.

The Task Force considers the events described in NRC Regulatory Guide 1.70 as a useful source of information on the type of events in groups 1 through 3 above. Each application will have detailed information on these possible events, including important plant and site-specific factors that affect the probability and consequences of accidents. Safety Analysis Reports submitted by licensees are not likely to include a discussion of Class 9 accidents. Other documents, such as the Reactor Safety Study[10], discuss the Class 9 type accidents and their consequences. The Task Force believes that the findings on types of severe accidents reported in WASH-1400 provide a useful supplement to the Safety Analysis Reports in developing a basis for emergency planning.

The current version of NRC Regulatory Guide 1.70 requests applicants to provide two separate analyses of accident consequences: one using conservative assumptions to verify that plant design is adequate and a second using best estimate assumptions. One purpose for the latter assessment is to illustrate the margins of conservatism used in designing plant engineered safety features. This provision is a recent addition and consequently there are few analyses of this type actually available. Therefore, while the nuclear facility Safety Analysis Report will contain a great deal of information on credible accidents and how they are accommodated by design, there is likely to be little information provided on the expected consequences of such initiating events.

Best estimate consequences of a number of representative initiating events are addressed in the staff's environmental impact statements. The Task Force has reviewed the summary information on accident consequences provided in connection with these statements and we conclude that these best estimate analyses are too limited in scope and detail to be useful in emergency planning. It is apparent, however, from these analyses as well as from the NRC Regulatory Guide 1.70 analyses, that best estimate consequences are likely to be a factor of 10 or so smaller, from the standpoint of meteorological considerations alone, than the consequences of accidents as typically presented in Safety Analysis Reports and in NRC staff safety evaluation reports for the purpose of site and plant design feature evaluation.

D. Establishment of the Task Force

To prepare adequate emergency response procedures, basic information regarding an accident, such as the time characteristics of an accident, the radioactive material release characteristics, and the extent of the area potentially impacted is required. Past practice has been to use a spectrum of accidents, including design basis accidents for emergency response planning. These accidents, however, were developed for the specific purposes of reactor siting and the design of containment and engineered safety features. Further, the description of the DBAs in Safety Analysis Reports does not always contain the information needed for developing emergency response plans. In addition, since the publication of the Reactor Safety Study in 1975, there has been some concern and confusion among State and local goverment emergency response planning and preparedness organizations as to how the accidents described in the Reactor Safety Study relate to emergency planning.

As a result of some perceived confusion in how accident analyses should relate to emergency planning, the Conference of (State) Radiation Control Program Directors passed a resolution in 1976 requesting NRC to "make a determination of the most severe accident basis for which radiological emergency response plans should be developed by offsite agencies." Additionally, the NRC and EPA received correspondence from a few States, and local governments in this regard.

In response to this dialogue, a Task Force consisting of NRC and EPA representatives was assembled to address this Conference request and related issues in November 1976. The Task Force interpreted the request as a charge to provide a clearer definition of the types of radiological accidents for which States and local governments should plan and develop preparedness programs.

REFERENCES

1. Title 10 Code of Federal Regulations, Part 100 Reactor Site Criteria.

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APPENDIX III

RELATED ISSUES CONSIDERED BY THE TASK FORCE

Certain issues related to providing a more definitive planning basis were considered by the Task Force. These issues were examined in the light of existing Federal guidance and particularly in light of guidance promulgated by the former AEC regulatory arm (Now the NRC).

There are four principal issues:

A. Issue: Whether and to what extent, so-called "Class 9" events having consequences beyond the most serious design basis accidents analyzed for siting purposes, should be considered in developing emergency plans.

Commentary:

The Task Force believes that States should be encouraged to develop a breadth, versatility and flexibility in emergency response preparations and capabilities - and that some consideration of Class 9 events in emergency planning is consistent with this view. Further, the potential consequences of improbable but nevertheless severe power reactor accidents, while comparable in some sense to severe natural or man-made disasters which would trigger an ultimate protective measure such as evacuation, do require some specialized planning considerations. We do not suggest that these specialized planning considerations are or ought to be excessively burdensome. Rather, we recommend that they be considered and developed as a matter of prudence.

The Task Force recognized from the start that there is no specific design basis accident or Class 9 accident scenario which can be isolated as the one for which to plan because each such accident would have different consequences, both in nature and degree. It is for this reason that NRC and EPA have encouraged State and local agencies to concentrate their efforts on devising response preparations and capabilities that are versatile and that also take into account the unique aspects of radiological accidents.

The Reactor Safety Study (RSS)[2] provides a detailed assessment of the probability and consequences of Class 9 accidents. Various aspects of that study have been debated by reviewers. Additional programs are underway to extend or refine the study. It should be noted that the RSS is based on an analysis of two specific reactors, and the consequences presented are based on a spectrum of data compiled from many sites. The report therefore is of limited use in dealing with plant/site specific factors.

Nonetheless, the RSS provides the best currently available source of information on this subject.

The Task Force had to decide whether to place reliance on general emergency plans for coping with the events of Class 9 accidents for emergency planning purposes, or whether to recommend developing specific plans and organizational capabilities to contend with such accidents. The Task Force believes that it is not appropriate to develop specific plans for the most severe and most improbable Class 9 events. The Task Force, however, does believe that consideration should be given to the characteristics of Class 9 events in judging whether emergency plans based primarily on smaller accidents can be expanded to cope with larger events. This is a means of providing flexibility of response capability and at the same time giving reasonable assurance that some capability exists to minimize the impacts of even the most severe accidents.

For example, if we are dealing with a very large release of radioactive material, the principal goal is to prevent serious adverse health effects to individuals. The measures required to minimize health effects and to cope with secondary effects of a large accidental release (such as land or water contamination, and the housing and feeding of any people required to be relocated for substantial time periods) would, in all likelihood, require the involvement of Federal agencies in addition to State and local governments.

The planning basis recommended by the Task Force therefore includes some of the key characteristics of very large releases to assure that site specific capabilities could be effectively augmented with general emergency preparedness (response) resources of the Federal government should the need arise.

NRC and other Federal agency emergency planning guidance has perhaps been misinterpreted as reflecting a position that no consideration should be given to so-called Class 9 accidents for emergency planning purposes. The Task Force, after considering the published guidance and available documentation,[1-4] concludes that Class 9 accidents have been given some consideration in emergency planning. It has been, and continues to be the Federal position that it is possible (but exceedingly improbable) that accidents could occur calling for additional resources beyond those that are identified in specific emergency plans developed to support specific individual nuclear facilities. Further, the NRC and Federal position has been and continues to be, that as in other disaster situations, additional resources would be mobilized by State and Federal agencies.

B. Issue: Is there a need to plan beyond the Low Population Zone?

Commentary

The Low Population Zone (LPZ) is determined in accordance with the requirements of NRC Reactor Siting Criteria, 10 CFR Part 100[5]. While the consequences of postulated design basis accidents would be expected to be substantially lower than the guideline values of 10 CFR Part 100, there are three reasons why some planning beyond the LPZ is useful:

First, if an accidental release were as severe as the design basis releases analyzed for purposes of 10 CFR Part 100, doses could be above the Protective Action Guide (PAG)[6] levels beyond the LPZ. In this instance, the responsible officials should take reasonable and practical measures to reduce exposures to individuals beyond the LPZ.

Second, the deposition of radioactivity, and its subsequent uptake in foodstuffs such as milk products could be significant beyond the LPZ even if the plume exposure pathway doses did not exceed the PAG level at the LPZ outer boundary, because of the reconcentration of certain radionuclides in the food chain. Emergency protective measures in that situation should be taken to minimize exposures from the food chain via the ingestion pathway.

Third, there is a very small probability that releases larger than those from design basis accidents used in evaluating the acceptability of the reactor site could occur which could have consequences substantially in excess of the PAG levels outside the LPZ outer boundary. As discussed in Issue "A" the Task Force concluded that such larger accidents should be considered in developing the basis on which emergency plans are developed.

The Task Force considered these factors in establishing the size of the emergency planning zone. Two basic options were considered. One option was to develop site specific guidance based on the low population zone (LPZ) with some modifications to better assure that actions could be extended beyond the LPZ if needed. The second option was the concept of a planning area completely independent of the LPZ. The Task Force recognized that the LPZ is included in NRC regulations for siting of nuclear facilities, and is closely connected to design basis accident consequences. We also recognized that actual emergency response actions would be based on proposed Protective Action Guides. Given these factors, the Task Force concluded that the concept of Emergency Planning Zones (EPZs) around each nuclear power facility would best serve to scope the desired spectrum of situations for which emergency planning should be accomplished. EPZs for both the "plume exposure pathway" and the "ingestion exposure pathway" are proposed. The separation of this concept from NRC siting considerations is discussed in Issue D.

While the Task Force recognizes that there are site-to-site variations in LPZs, due in part to varying features of the plant, the Task Force concluded that the size of the EPZs need not be site specific. The principal reason for this is that the size of the LPZ is determined primarily by the type and extent of engineered safety features installed in the reactor plant and their response to design basis accidents. The loss of either some or all engineered safety features are postulated in Class 9 accidents. If the engineered safety features are lost during an accident, then the LPZ has no meaning with regard to the size of the areas around the plant in which emergency response would be appropriate.

A principal aim in establishing EPZs is to foster a breadth, versatility and flexibility in response preparation and capabilities in a systematic manner. From the standpoint of general emergency planning guidance, emergency planning needs seem to be best served by adopting uniform Emergency Planning Zones for initial planning studies for all light water reactors.

C. Issue: Whether there is a conflict between Protective Action Guides for plume exposures and dose criteria for siting and design of nuclear power facilities.

Commentary

The Reactor Site Criteria (10 CFR Part 100) require that an applicant identify an area surrounding a nuclear power reactor, defined as a Low Population Zone (LPZ). The consequences of the most severe "design basis accidents" analyzed for siting purposes should not result in exposures in excess of 300 rem to the thyroid from radioiodine exposure or 25 rem to the whole body for an individual located at any point on the outer boundary of the Low Population Zone (LPZ).

Protective action guides (PAGs) for plume exposure have been provided to State and local government agencies for use as EPA agency guidance in developing State and local government radiological emergency response plans for areas around nuclear facilities. One might reasonably ask whether it is inconsistent for the Federal government to recommend the development of plans to implement protective actions at projected dose levels lower than the projected doses associated with siting criteria. The discussion that follows reviews this issue.

The dose guideline values in 10 CFR Part 100 do not constitute acceptable limits for emergency doses to the public under accident conditions. The numerical values of 25 rem whole body and 300 rem thyroid can be considered values above which prevention of serious health effects would be the paramount concern. Good health physics practice would indicate that radiological exposures of these magnitudes should not be allowed to take place if reasonable and practical measures can prevent such exposures.

The assumptions used for siting purposes in calculating the doses that could result from design basis accidents are conservative. The actual doses that would result from releases postulated to occur from a design basis accident therefore would be expected to be much lower than the dose guidelines of 10 CFR Part 100 under most meteorological conditions. The inhalation and direct exposure doses from the releases postulated for design basis accidents are not likely to exceed the PAG levels beyond the LPZ under average meteorological conditions. It has been, however, the NRC's position that a spectrum of postulated conditions be considered in emergency planning including adverse meteorological conditions.

Protective Action Guides were devised for purposes of dose savings and are defined as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. Emergency response plans should include them as trigger values to aid in decisions to implement protective actions, and responsible officials should plan to implement protective actions if projected doses exceed the PAGs. The PAGs, which have numerical values smaller than the 10 CFR Part 100 guidelines*, are decision

*The PAGs for the plume exposure pathway are expressed as a range of 1 to 5 rem whole body dose and 5 to 25 rem thyroid dose to individuals in the population. PAGs for the ingestion exposure pathway have no parallel in the 10 CFR Part 100 guidelines.

aids in devising best efforts, considering existing constraints. They have been set at levels below those that would produce detectable short term biological effects and at levels that would minimize long term biological effects. In the event of an accident they should be considered as criteria against which available options for various types of emergency actions can be weighed. Officials responsible for implementing the protective actions must take into account constraints that exist at the time and use professional judgment in determining the actions appropriate to protect the public.

The nature of PAGs is such that they cannot be used to assure that a given exposure to individuals in the population is prevented. In any particular response situation, a range of doses will be projected, principally depending on the distance from the point of the radioactive release. Some of these projected doses may be well in excess of PAG levels and clearly warrant the initiation of any feasible protective actions. This does not mean, however, that doses above PAG levels can be prevented, or that emergency response plans should have as their objective preventing exposures above PAG levels. Furthermore, PAGs represent only trigger levels and are not intended to represent acceptable dose levels. PAGs are tools to be used as a decision aid in the actual response situation.

As discussed above, PAGs and Part 100 dose guidelines serve distinctly separate functions. The concept of Emergency Planning Zones (EPZs) introduced in this report is an attempt to provide guidance on the areas for which offsite officials should be prepared to make judgments using the PAGs, to initiate predetermined actions.

D. Issue: Whether the guidance in this document for offsite emergency planning can be separated from siting considerations in the NRC licensing process.

Commentary

The NRC siting criteria as related to accidental releases of radioactivity are given in 10 CFR Part 100 of the Federal regulations, and are supplemented by the Statement of Considerations published with this regulation in 1962 and in various regulatory guides and standard review plans used by the NRC staff. These criteria are used in the review of applications for nuclear power plant construction permits, operating licenses and operating license amendments. The evaluation performed under 10 CFR 100 primarily involves; (1) assuring that possible effects of all relevant natural and man-made phenomena on the nuclear facility have been identified and expressed as design conditions for the facility, (2) determining that adequate engineered safety features have been provided to assure that postulated releases of radioactivity resulting from design basis accidents will not lead to radiological exposures that are in excess of the numerical guidelines of 10 CFR Part 100 at specified offsite locations, even under adverse meteorological conditions, (3) evaluating the distance to the nearest densely populated area to allow calculation of the offsite location at which certain of the Part 100 exposure guidelines must be met, and (4) evaluating the general current and projected population density around the proposed facility out to about 30 miles. The first three evaluation areas are reexamined at the operating license review stage and occasionally over the plant lifetime as facility or site conditions change. The fourth area (population density) is only evaluated in a prospective manner to assure the use of low population density sites when such are available and is generally not reexamined. The objective of the evaluations performed during the Part 100 siting review is to assure that the risk from any accident (including a Class 9 accident) is low.

The definition of the Low Population Zone (LPZ) in 10 CFR Part 100 states that it is an area which contains residents, the total number and density of which are such that there is a reasonable probability that protective measures could be taken, in their behalf in the event of serious accident. The outer boundary of the LPZ is one of the locations at which Part 100 exposure guidelines must be met. The outer boundary of the LPZ must also be less than a fixed fraction of the distance to the nearest boundary of a densely populated center containing more than about 25,000 residents. These are not in practice siting constraints because restrictions on the 2 hour exposure from design basis accidents at the site (exclusion area) boundary generally provide ample time to take action within a few miles to cope with postulated design basis releases and because additional engineered safety features could be added to the facility design, at some additional cost, to allow the outer boundary of the LPZ to be as small as the site boundary.

The current NRC staff evaluation of emergency plans for a particular facility is substantially independent of the siting criteria. The staff review includes facility emergency plans and plans for at least the offsite area referred to in 10 CFR Part 100 as the Low Population

Zone (LPZ) and in current licensing reviews often extends to substantially longer distances, particularly for the ingestion pathway. Emergency plans are reviewed by the NRC staff during the construction permit and operating license review stages and audited during the plant lifetime.

Emergency offsite response to large accidents may be less effective for sites located in an area of general high population density. Such sites, which may have adequate engineered safety features to meet the explicit criteria of 10 CFR Part 100, tend to be eliminated by the NRC staff guidelines on the general population density around prospective sites.

We recognize that there would be a reduction in exposures through the emergency response of the facility staff and local authorities even <u>without</u> planning. This is based on experience in coping with more common emergencies such as those associated with large chemical releases or dam failures. It seems reasonable that some additional reduction in exposures may be obtained by certain planning activities related to emergency preparedness at any site. However, the reduction in exposures from planned actions would be difficult to take into account in a quantitative or qualitative way in siting reviews.

In view of the above we conclude that although there is an indirect relationship between siting and emergency planning, the two can and should be considered separately in the NRC licensing process. Some clarification of the NRC regulations may be desirable to make clear the separation of these issues in the licensing process.

Appendix III

REFERENCES

1. Radiological Incident Emergency Response Planning, Fixed Facilities and Transportation: Interagency Responsibilities, Federal Preparedness Agency General Services Administration, Federal Register Notice, Vol. 40, No. 248, December 24, 1975.

2. Reactor Safety Study: An Assessment of Accident Risks In U. S. Commercial Nuclear Power Plants, (NUREG-75/014), October 1975, WASH-1400, U. S. Nuclear Regulatory Commission.

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16. ABSTRACT *(200 words or less)*

This report suggests a planning basis for State and local government emergency organizations to determine the scope of planning efforts for nuclear power plants. The Task Force determined that a specific single accident could not be identified as the planning basis. Instead, the Task Force recommended establishing two generic Emergency Planning Zones (EPZs) around light water nuclear power plants. The inner zone of about 10 miles would be established for the plume exposure pathways and an outer zone of about 50 miles would be established for the ingestion exposure pathways. The precise size and shape of the EPZs would be based on the judgement of the emergency planner after considering local conditions. The Task Force concluded that planning for predetermined protective actions, such as sheltering in the plume exposure zone, is warranted within these zones in the event of a serious accident at a power plant. The Task Force also recommended time frames and radiological characteristics of the accidents for use in determining the appropriate emergency actions which could be taken to reduce the accident consequences. The Task Force concluded that if the basic planning elements in existing emergency planning guidance documents are already being considered, the establishment of EPZs should not result in large increases in State and local government emergency planning and preparedness costs.

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