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HTGR

EMERGENCY PLANNING BASES FOR THE STANDARD MODULAR HIGH-TEMPERATURE GAS-COOLED REACTOR

APPLIED TECHNOLOGY

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FOR THE STANDARD MODULAR
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ABSTRACT

Bases for establishing radiological emergency response plans are developed for the Standard Modular High-Temperature Gas-Cooled Reactor (MHTGR). The approach for determining emergency planning bases for the Standard MHTGR is consistent with the approach used for light-water reactors. The scope of this report includes the application of this approach: potential radiological doses as a function of distance from the plant are presented for design basis events and events beyond the design basis, and the area over which planning for predetermined actions should be carried out for the Standard MHTGR is identified. Based on this data, NRC's agreement is requested that the emergency planning zone for the dominant exposure pathway is encompassed by the plant exclusion area boundary. Therefore, no offsite plans for rapid notification, sheltering, or evacuation of the public are required for the Standard MHTGR.

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ABBREVIATIONS

AOO	Anticipated Operational Occurrence
CFR	Code of Federal Regulations
DBE	Design Basis Event
EAB	Exclusion Area Boundary
EPA	Environmental Protection Agency
EPBE	Emergency Planning Basis Event
EPZ	Emergency Planning Zone
FEMA	Federal Emergency Management Agency
FDA	Food and Drug Administration
HPS	Helium Purification System
HTGR	High-Temperature Gas-Cooled Reactor
HTS	Heat Transport System
LWR	Light-Water Reactor
MHTGR	Modular High-Temperature Gas-Cooled Reactor
NRC	Nuclear Regulatory Commission
PAG	Protective Action Guide
PPIS	Plant Protection and Instrumentation System
PRA	Probabilistic Risk Assessment
PSID	Preliminary Safety Information Document

RCCS	Reactor Cavity Cooling System
SCS	Shutdown Cooling System
U.S.	United States

MEASUREMENTS

Ci	curie
h	hour
kg	kilogram
km	kilometer
lbm	pounds mass
m	meter
min	minute
MW(t)	megawatt thermal
Rem	roentgen equivalent mean
yr	year

1. SUMMARY

With the U.S. Nuclear Regulatory Commission (NRC) concurrence (Ref. 1), the Licensing Plan for the Standard High-Temperature Gas-Cooled Reactor (HTGR) (Ref. 2) describes an application program consistent with 10CFR50, Appendix O to support an NRC review and design certification of an advanced Standard Modular High-Temperature Gas-Cooled Reactor (MHTGR) design. Consistent with the NRC's Advanced Reactor Policy (Ref. 3), the Plan also outlines a series of preapplication activities which have as an objective the early issuance of an NRC Licensability Statement on the Standard MHTGR conceptual design.

This emergency planning bases report has been prepared as one of the submittals to the NRC in support of preapplication activities on the Standard MHTGR. Other submittals already provided include a Preliminary Safety Information Document (PSID) (Ref. 4), a Probabilistic Risk Assessment (PRA) document (Ref. 5), and a Regulatory Technology Development Plan (Ref. 6).

Top-level regulatory criteria have been identified in Ref. 7 that directly and quantifiably state a necessary and sufficient set of acceptable health and safety consequences (doses) or risks to the public. The particular top-level regulatory criteria that pertain to emergency preparedness are the dose protective action guides (PAGs) of Ref. 8 that, if exceeded, are cause for actions to reduce doses to the public.

The NRC, the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the Federal Emergency Management Agency (FEMA) have provided regulations and guidance to assure that appropriate officials will be prepared to respond to any of a spectrum of accidents.

In the event of an accident at any U.S. reactor plant, utility and government officials are expected to assess the situation and, if necessary, advise the public on an appropriate course of action to mitigate any radiological consequences. Emergency planning bases are needed, so that adequate preparation can be made to protect the public against radiological doses from either the plume or ingestion exposure pathways. More rapid actions involving the general public, and thus more extensive preparations, are required to mitigate doses from the plume exposure pathway.

Appropriate bases for establishing radiological emergency response plans are developed in this report for the Standard MHTGR. Actual plans for responding to a radiological emergency are not developed here. The approach for determining emergency planning bases for the Standard MHTGR is consistent with, and in some instances more conservative than that used for light-water reactors (LWRs). The scope of this report includes the application of this approach: potential radiological doses as a function of distance from the plant are presented for design basis events and for events beyond the design basis, and the area over which planning for predetermined actions should be carried out for the Standard MHTGR is identified. The purpose of this report is to request NRC agreement that no plans or drills for rapid notification, sheltering, or evacuation of the public are required for the Standard MHTGR.

The emergency planning bases for LWRs are described in NUREG-0396 (Ref. 9), which introduces the concept of emergency planning zones (EPZs) as the most important basis for planning response actions to protect the public. The sizes of emergency planning zones for the plume and ingestion exposure pathways were established for LWRs based on a spectrum of accident consequences with consideration of accident frequencies. The consequences considered in NUREG-0396 included those resulting from events within the design basis that were analyzed in Safety Analysis Reports, as well as events beyond the design basis that were analyzed in the Reactor Safety Study (Ref. 10). The EPZs for LWRs are codified in 10CFR50.47, which also states that the size of EPZs may be determined on a case-by-case basis for gas-cooled nuclear reactors.

The approach used for the Standard MHTGR is to also consider a spectrum of event consequences. The events include design basis events evaluated in the PSID (Ref. 4), as well as events beyond the design basis, evaluated in the PRA (Ref. 5). The expected radiological consequences of these events are compared with the PAGs from Ref. 8. The distances from the reactor beyond which PAGs are not exceeded are used to define the corresponding emergency planning zones.

The emergency planning zones are determined for the Standard MHTGR design presented in the PSID. Site parameters on which the Standard MHTGR design is based have been chosen with the intent that 85% of prospective U.S. sites be enveloped.

The plume exposure pathway has received emphasis in this report, since emergency planning requirements and drills relating to rapid notification, sheltering, and evacuation of the public are applicable over the area defined by the plume exposure pathway EPZ. The results of applying the above approach to the Standard MHTGR indicate that the potential doses at the exclusion area boundary (EAB) are less than the plume exposure pathway PAGs for sheltering (whole body dose of 1 Rem, thyroid dose of 5 Rem) for all the spectrum of events, so that the EPZ for plume exposure can be encompassed by the plant EAB [425 m (0.27 miles)]. Since the general public is outside the plume exposure EPZ, there is no need for a rapid public notification system. Provisions for sheltering or evacuation of the general public do not need to be included in the emergency plan.

Since the plume exposure pathway EPZ [425 m (0.27 miles)] is significantly smaller for the Standard MHTGR than was chosen for LWRs in NUREG-0396 [16 km (10 miles)], it is expected that the ingestion exposure pathway EPZ would also be significantly smaller for the Standard

MHTGR than that for LWRs [90 km (50 miles)]. Actions to mitigate doses from the ingestion exposure pathway do not need to be rapid, and typically involve only crop and dairy farmers and facilities that process food from within the planning zone. Consequently, consideration of the ingestion exposure pathway does not influence provisions for rapid notification, sheltering, or evacuation of the public.

The emergency planning zone for the plume exposure pathway for the Standard MHTGR is encompassed by the plant EAB [425 m (0.27 miles)]. Therefore, no plans or drills for rapid notification, sheltering, or evacuation of the public are required for the Standard MHTGR. The doses that result from accidents are low because the Standard MHTGR is designed to maintain control of radionuclide release by reliance primarily on passive features. Reliance on passive features to provide greater certainty and increased margins of safety is consistent with the NRC's expectations for advanced reactors stated in the Advanced Reactor Policy (Ref. 3).

2. INTRODUCTION

With NRC concurrence (Ref. 1), the Licensing Plan for the Standard HTGR (Ref. 2) describes an application program consistent with 10CFR50, Appendix O to support an NRC review of the Standard MHTGR design. Consistent with the NRC's Advanced Reactor Policy (Ref. 3), the Plan also outlines a series of preapplication activities which have as an objective the early issuance of an NRC Licensability Statement on the Standard MHTGR conceptual design.

This emergency planning bases report has been prepared as one of the submittals to the NRC in support of preapplication activities on the Standard MHTGR. Other submittals already provided include a PSID (Ref. 4), a PRA document (Ref. 5), and a Regulatory Technology Development Plan (Ref. 6).

The NRC, EPA, FDA, and FEMA have provided regulations and guidance to assure that appropriate officials will be prepared to respond to any of a spectrum of accidents. In the event of an accident at any U.S. reactor plant, utility and government officials are expected to assess the situation and, if necessary, advise the public on an appropriate course of action to mitigate any radiological consequences. The bases for developing radiological emergency response plans for LWRs are described in NUREG-0396 (Ref. 9), where it is observed that 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. Other elements of guidance that provide supporting information for planning and preparedness include the time-dependent characteristics of potential releases and exposures, and the kinds of radioactive materials that can potentially be released to the environment.

Two pathways of radiation exposure to the public have been identified in NUREG-0396 as being important relative to emergency preparedness: the plume exposure pathway and the ingestion exposure pathway. The plume exposure pathway consists primarily of (1) whole body external exposure to gamma radiation from the passing radioactive plume and from deposited radioactive materials, and (2) inhalation exposure from the passing radioactive plume. The ingestion exposure pathway consists primarily of exposure due to ingestion of contaminated water or foods such as milk or fresh vegetables.

The bases for developing radiological emergency response plans for the Standard MHTGR are provided in this report. These emergency planning bases and the resultant EPZs are developed in a manner consistent with and in some instances more conservative than that of NUREG-0396, so that adequate preparation can be made to protect the public against radiological doses from either the plume or ingestion exposure pathways.

2.1. OBJECTIVE AND SCOPE

The objectives of this report are to request NRC agreement with the following points:

1. That the approach used to select emergency planning bases for the Standard MHTGR is consistent with and in some instances more conservative than that used by regulatory agencies for existing reactors.

2. That emergency planning zones derived using this approach for the Standard MHTGR are appropriate.

3. That, since the plume exposure EPZ is encompassed by the plant exclusion area boundary, no plans or drills for rapid notification, sheltering, or evacuation of the public are required for the Standard MHTGR.

The scope of this report includes a description of the approach used to determine emergency planning bases for the Standard MHTGR, as well as its application to determine emergency planning bases for the plume exposure pathway. The licensing basis events that are considered to form the emergency planning basis are defined, based on the PRA, in Ref. 11, and include the design basis events discussed in the PSID (Ref. 4). The radiological consequences of the selected events are assessed for the plume exposure pathway using methods consistent with those used in the PRA (Ref. 5). The determination of appropriate emergency planning bases is made in a manner consistent with, and in some instances more conservative than, the approach and rationale in NUREG-0396 (Ref. 9), which documents the planning bases for emergency planning for light-water nuclear power plants. The implications of the resultant EPZs on emergency planning for the Standard MHTGR are briefly discussed. Actual plans for responding to a radiological emergency are outside the scope of this report.

2.2. REPORT GUIDE

Background on emergency preparedness regulations and guidance is provided in Section 3. The approach used to select emergency planning zones for the Standard MHTGR is described in Section 4. A brief description of the Standard MHTGR is provided in Section 5. The specific events that form the basis for emergency planning are described in Section 6. Representative scenarios, frequency considerations, physical phenomena, and source terms are included in the description. The potential radiological consequences of these events are discussed in Section 7 for both the plume exposure and the ingestion exposure pathways, and are compared with the PAGs from Ref. 8. The distance from the reactor beyond which no PAGs are exceeded is used to define the corresponding emergency planning zones. Section 8 discusses implications of the resultant EPZs on various aspects of emergency planning. Section 9 summarizes the requested NRC responses to this report. The radiological consequences presented in Section 7 are described in more detail in Appendix A.

3. BACKGROUND

Regulations and guidance that pertain to emergency preparedness are described and discussed in this section. The precedent for emergency planning zones smaller than those determined in NUREG-0396 is also discussed.

3.1. REGULATORY REQUIREMENTS

Top-level regulatory criteria have been identified in Ref. 7 that directly and quantifiably state a necessary and sufficient set of acceptable health and safety consequences (doses) or risks to the public.

The particular top-level regulatory criteria that pertain to emergency preparedness are the dose PAGs of EPA-520/1-75-001 (Ref. 8) which are:

1. Intervention indicated for general population if projected whole body gamma dose exceeds 1 to 5 Rem or projected thyroid dose exceeds 5 to 25 Rem from airborne radioactive materials.

2. Guides for exposure from foodstuffs, water, and material deposited on property and equipment to be determined.

Relative to item 2 above, PAGs have been provided in Ref. 12 for accidental radioactive contamination of human food and animal feeds. Intervention is indicated for food or animal feed if projected thyroid dose commitment over the lifetime of an individual exceeds 1.5 to 15 Rem or projected dose commitment to the whole body, bone marrow, or any other organ exceeds 0.5 to 5 Rem. The lower values are called Preventive PAGs. The higher values are called Emergency PAGs.

Reference 8 provides recommendations for protective action decisions to be made on the basis of comparing projected plume exposure pathway doses to PAGs. When the lower PAGs are projected to be exceeded, sheltering is recommended. When the higher PAGs are projected to be exceeded, evacuation is recommended. These recommendations, taken from Ref. 8 (Table 5.1) are given in Table 3-1. Recommendations are provided in Ref. 12 for protective actions to be taken to reduce radiation exposure to the public via the food pathway due to the occurrence of a contaminating event. If a dose commitment is projected to equal or exceed a Preventive PAG, "responsible officials should take protective actions having minimal impact to prevent or reduce the radioactive contamination of human food or animal feeds." If a dose commitment is projected to equal or exceed an Emergency PAG, "responsible officials should isolate food containing radioactivity to prevent its introduction into commerce and . . . should determine whether condemnation or another disposition is appropriate. At the Emergency PAG, higher impact actions are justified because of the projected health hazards."

The NRC has provided implementation requirements for emergency planning in 10CFR50.47(c)(2), which states, in part:

> "Generally, the plume exposure pathway EPZ for nuclear power plants shall consist of an area about 10 miles (16 km) in radius and the ingestion pathway EPZ shall consist of an area about 50 miles (80 km) in radius . . . The size of the EPZs may also be determined on a case-by-case basis for gas-cooled nuclear reactors and for reactors with an authorized power level less than 250 MW thermal . . ."

TABLE 3-1

RECOMMENDED PROTECTIVE ACTIONS TO REDUCE WHOLE BODY AND THYROID DOSE FROM EXPOSURE TO A GASEOUS PLUME
(From Table 5.1 of Ref. 8)

Projected Dose (Rem) to the Population	Recommended Actions[a]	Comments
Whole body <1 and Thyroid <5	No planned protective actions.[b] State may issue an advisory to seek shelter and advisory to seek shelter and await further instructions. Monitor environmental radiation levels.	Previously recommended protective actions may be reconsidered or terminated.
Whole body 1 to <5 or Thyroid 5 to <25	Seek shelter as a minimum. Consider evacuation. Evacuate unless constraints make it impractical. Monitor environmental radiation levels. Control access.	If constraints exist, special consideration should be given for evacuation of children and pregnant women.
Whole body 5 and above or Thyroid 25 and above	Conduct mandatory evacuation. Monitor environmental radiation levels and adjust area for manda-ory evacuation based on these levels. Control access.	Seeking shelter would be an alternative if evacuation were not immediately possible.

[a]These actions are recommended for planning purposes. Protective action decisions at the time of the incident must take existing conditions into consideration.

[b]At the time of the incident, officials may implement low-impact protective actions in keeping with the principle of maintaining radiation exposures as low as reasonably achievable.

The size of the emergency planning zones was established for LWRs in 1978 by a task force of NRC and EPA representatives. According to NUREG-0396 (Ref. 9), the task force considered several rationales, including risk, probability, cost effectiveness, and a spectrum of accident consequences. The final EPZs were determined based on a spectrum of accident consequences with consideration of accident frequencies. The technical data supporting the EPZ selections are contained in Appendix I of NUREG-0396, which also includes a discussion of the rationale used to arrive at the planning basis. NUREG-0396 finds for LWRs that the probability of exceeding PAG doses at either the plume or the ingestion EPZ distance is about one chance in 50,000 per reactor year.

In selecting the emergency planning zones, NUREG-0396 (page 5) states:

> "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 PAGs."

10CFR50 Appendix E describes the content of the emergency response plans that are required by 10CFR50.34(a) to be submitted by an applicant for an operating license. The standards against which these plans will be evaluated are enumerated in 10CFR50.47(b), and are addressed by specific criteria in NUREG-0654 (Ref. 13). More rapid actions involving the general public, and thus more extensive preparations, are typically required to mitigate doses from the plume exposure pathway. Other than crop and dairy farmers and facilities that process food from within the planning zone, the general public is generally not included in plans to provide protection from the ingestion pathway of exposure.

3.2. REQUESTS FOR SMALLER EPZs

Consistent with the provision of 10CFR50.47(c)(2) that EPZs may be determined on a case-by-case basis for gas-cooled reactors, the Public Service Company of Colorado requested smaller EPZs (Ref. 14) for their Fort St. Vrain Nuclear Generating Station. Similar requests were made by the operators of small water-cooled power reactors. The requests were responded to favorably, as noted in the footnote on page 11 of NUREG-0654, which states:

> "The FEMA/NRC Steering Committee has concluded the small water-cooled power reactors [less than 250 MW(t)] and the Fort St. Vrain gas-cooled reactor may use a plume exposure emergency planning zone of about 5 miles in radius and an ingestion pathway emergency planning zone of about 30 miles in radius. In addition, the requirements for the alerting and notification system (Appendix 3) will be scaled on a case-by-case basis. This conclusion is based on the lower potential hazard from these facilities (lower radionuclide inventory and longer times to release significant amounts of activity for many accident scenarios). The radionuclides considered in planning should be the same as recommended in NUREG-0396/EPA-520/1-78-016."

Baltimore Gas and Electric requested an exemption from the general requirement that the plume exposure pathway emergency planning zone should consist of an area of about 16 km (10 miles) in radius. In Ref. 15, they provided material to support their determination that a plume exposure pathway EPZ beyond 3.2 km (2 miles) is not necessary to achieve the underlying purpose of the rule at the Calvert Cliffs Nuclear Power Plant. Their "determination relative to the adequacy of the proposed two-mile EPZ was achieved using the same regulatory philosophy and basic approach as that presented in NUREG-0396, but utilizing current source term information." The request has been shelved pending clarification of LWR source-term issues.

Recently, Public Service Company of New Hampshire requested an exception or waiver to applicable regulations so that they can operate the Seabrook Station with planning for a plume exposure pathway emergency planning zone of 1.6 km (1 mile) in radius (Ref. 16). The Seabrook units are large LWR plants, rated at a core power level of 3411 MW(t). Special circumstances relative to the strength of their containments have been considered in the preparation of a plant-specific PRA (Ref. 17) and a risk management and emergency planning study (Ref. 18). Despite the size of the plants, the latter study found that "even under the assumption of no immediate protective actions, the acute health risk estimated for Seabrook Station is . . . substantially less than the level of risk achieved with an EPZ distance of 10 miles as perceived in NUREG-0396. . . . Using the same rational basis as used in NUREG-0396 to select a 10-mile EPZ for all U.S. sites, the results of this study support an EPZ of less than 1 mile." The request is currently being reviewed.

These requests for smaller EPZs have been accompanied by evidence that the risk to the public outside the smaller EPZs was about the same as the risk to the public that was generally accepted when the generic EPZs were chosen in NUREG-0396 (Ref. 9). These risk arguments were made based on consideration of special aspects of the particular plant design, or based on new findings. However, the benchmark has in each case been NUREG-0396, and the approach has been to consider a spectrum of accidents as was done in NUREG-0396.

4. APPROACH TO EMERGENCY PLANNING BASES

The approach for establishing emergency planning bases for the Standard MHTGR, described in this section, is consistent with and in some instances more conservative than the approach used in NUREG-0396 (Ref. 9) for light-water nuclear power plants. The planning basis elements needed to scope the planning efforts were determined in Ref. 9 to be the distance to which planning for the initiation of predetermined protective actions is warranted, the time-dependent characteristics of potential releases and exposures, and the kinds of radioactive materials that can potentially be released to the environment. NUREG-0396 states that the most important element for providing guidance to planning officials is the distance from the nuclear facility which defines the area over which planning for predetermined actions should be carried out. This area is called an emergency planning zone (EPZ).

The approach used in NUREG-0396 to determine the EPZs is summarized in the following steps:

Step 1. Select a full spectrum of accidents for establishing the size of the EPZs, based on a probabilistic risk assessment.

Step 2. Evaluate doses, including uncertainties, as a function of distance from the plant for the accidents of Step 1.

Step 3. Choose EPZ radii by comparing dose results from Step 2 against the PAGs.

The approach used for the Standard MHTGR is consistent with the above approach except that it has been interpreted in a more conservative manner to provide enhanced margins, consistent with the NRC's

Statement of Policy on Advanced Nuclear Power Plants (Ref. 3). The EPZ radii are selected for the Standard MHTGR at distances beyond which no PAGs are expected to be exceeded for a range of accidents including accidents beyond the design basis down to a frequency of 5 x 10^{-7} per plant year. Therefore, the selected EPZs will assure that emergency plans will be prepared for the Standard MHTGR to cover essentially all the population that can potentially be exposed to doses higher than any PAGs. In contrast, NUREG-0396 selected a plume exposure EPZ beyond which the PAG for sheltering is not exceeded for accidents beyond the design basis down to a frequency of only 1.5 x 10^{-5} per reactor year. (See Fig. I-11 of Ref. 9.) At lower frequencies where the PAGs are exceeded beyond the EPZ, dose levels for which significant early injuries occur are not exceeded down to a frequency of 1.5 x 10^{-6} per reactor year.

The results of performing Step 1 are described in Section 6 of this report. The results of Step 2 are presented in Section 7. Step 3 is performed in Section 7.1 for the plume exposure pathway, and is discussed in Section 7.2 for the ingestion exposure pathway.

5. STANDARD MHTGR PLANT DESCRIPTION

The emergency planning assessment is based on the Standard MHTGR design as presented in the PSID. Detailed design descriptions are given in the PSID (Ref. 4). A brief description of the Standard MHTGR is provided here.

The Standard MHTGR plant is comprised of four reactor modules and two turbine generator sets that combine to achieve a nominal plant rating of 558 MW(e). Each reactor module is housed in a vertical cylindrical concrete enclosure that is fully embedded in the earth. Each module contains separate, vertically positioned reactor and steam generator vessels connected by a horizontal coaxial cross duct. Located within the reactor vessel is the reactor core comprised of an annular array of fueled prismatic graphite blocks. Graphite reflectors, support structures, and restraining devices are installed in the reactor vessel as well. Each reactor module has a rating of 350 MW(t).

Core heat can be removed by any one of three diverse systems. The Heat Transport System (HTS) removes the heat to the steam generator under normal operating conditions and shutdown conditions. The Shutdown Cooling System (SCS) removes core decay heat to a small shutdown cooling heat exchanger when the reactor is shutdown. The Reactor Cavity Cooling System (RCCS) is a passive system that utilizes conduction and radiation to remove heat from the core through the reactor vessel to cooling panels mounted on the walls of the reactor cavity.

Two independent and diverse means are provided to control reactor power. A control rod system inserts poison rods into channels provided in the reflector regions adjacent to the core. The control rod system is used for normal control and plant shutdown. A reserve shutdown system is also provided using boron carbide pellets that can be dropped into channels in the inner active core region. This system provides a diverse backup shutdown capability.

The Plant Protection and Instrumentation System (PPIS) provides the sense and command features necessary to detect abnormal plant conditions. The PPIS subsystems initiate plant protective actions such as reactor trips, startup of the SCS, primary coolant pumpdown with the Helium Purification Subsystem (HPS), and steam generator isolation and dump.

Site parameters on which the Standard MHTGR design is based have been chosen with the intent that about 85% of prospective U.S. sites be enveloped. The atmospheric dispersion factors assumed are typical for any potential site and are expected to envelope about 80% of all U.S. LWR sites.

6. LICENSING BASIS EVENTS FOR EMERGENCY PLANNING

From the broad spectrum of events considered in the probabilistic risk assessment of Ref. 4, a spectrum of licensing basis events (LBEs) is identified in Ref. 11 in order to facilitate regulatory evaluation of the Standard MHTGR's licensability. This section discusses the manner in which an appropriate group of events is selected from the LBEs for inclusion in the Standard MHTGR emergency planning basis. This corresponds to Step 1 of the approach in Section 4. Each selected event sequence is described along with the timing and characterization of potential radiological releases that occur during the event.

The safety approach taken in designing the MHTGR has as its primary focus control of radionuclide release by retention within the coated fuel particles. Other barriers to release include the core graphite, the primary coolant boundary, and the reactor building. These other barriers provide additional radionuclide retention and can mitigate any limited releases from the fuel that may occur. Within the design process the adequacy of this safety approach is continually reviewed utilizing probabilistic risk assessment. The risk assessment allows for consideration of a very broad spectrum of events. From this continuum, a discrete set of events are identified that characterize the Standard MHTGR's safety over the range of frequencies covered in the PRA. These licensing basis events represent a spectrum of events ranging from transients anticipated to occur during routine operation to very unlikely accidents.

The first part of this section describes how an appropriate subset of the licensing basis events was selected to form the Standard MHTGR's emergency planning basis. The second part of this section summarizes physical processes occurring in the event scenarios considered. Consequence and frequency assessment results from Refs. 4 and 5 are summarized to indicate the timing and type of release occurring in these scenarios.

6.1. SELECTION OF LBEs FOR EMERGENCY PLANNING

To facilitate regulatory evaluation of the Standard MHTGR's licensability, a set of licensing basis events characterizing the MHTGR's behavior under a range of off-normal conditions is defined. A complete description of the method employed in this selection of events is provided in Ref. 11.

A PRA (Ref. 5) of the Standard MHTGR has been performed. The assessment provides a logical and structured basis for understanding the overall safety characteristics of the plant. The transients evaluated in the assessment include internally and externally initiated events ranging in frequency from those anticipated to occur several times during the life of a single plant to extremely unlikely accidents not expected within 100 million years of plant operation (10^{-8} per plant year).

Utilizing this understanding of the plant, the LBE derivation has been performed with confidence that the resulting set of events selected is both appropriate to the Standard MHTGR and complete. Reference 11 identifies 19 licensing basis events, which characterize the potential safety challenges to the Standard MHTGR. These events include (1) Anticipated Operational Occurrences (AOOs), events expected once or more in the plant's lifetime; (2) Design Basis Events (DBEs), events of lower frequency not expected to occur in the plant's lifetime; and (3) Emergency Planning Basis Events (EPBEs), events of still lower frequency not expected to occur in the lifetime of all Standard MHTGRs. This spectrum of events is distributed among the AOO, DBE, and EPBE regions of Fig. 6-1. The justification for frequencies which define

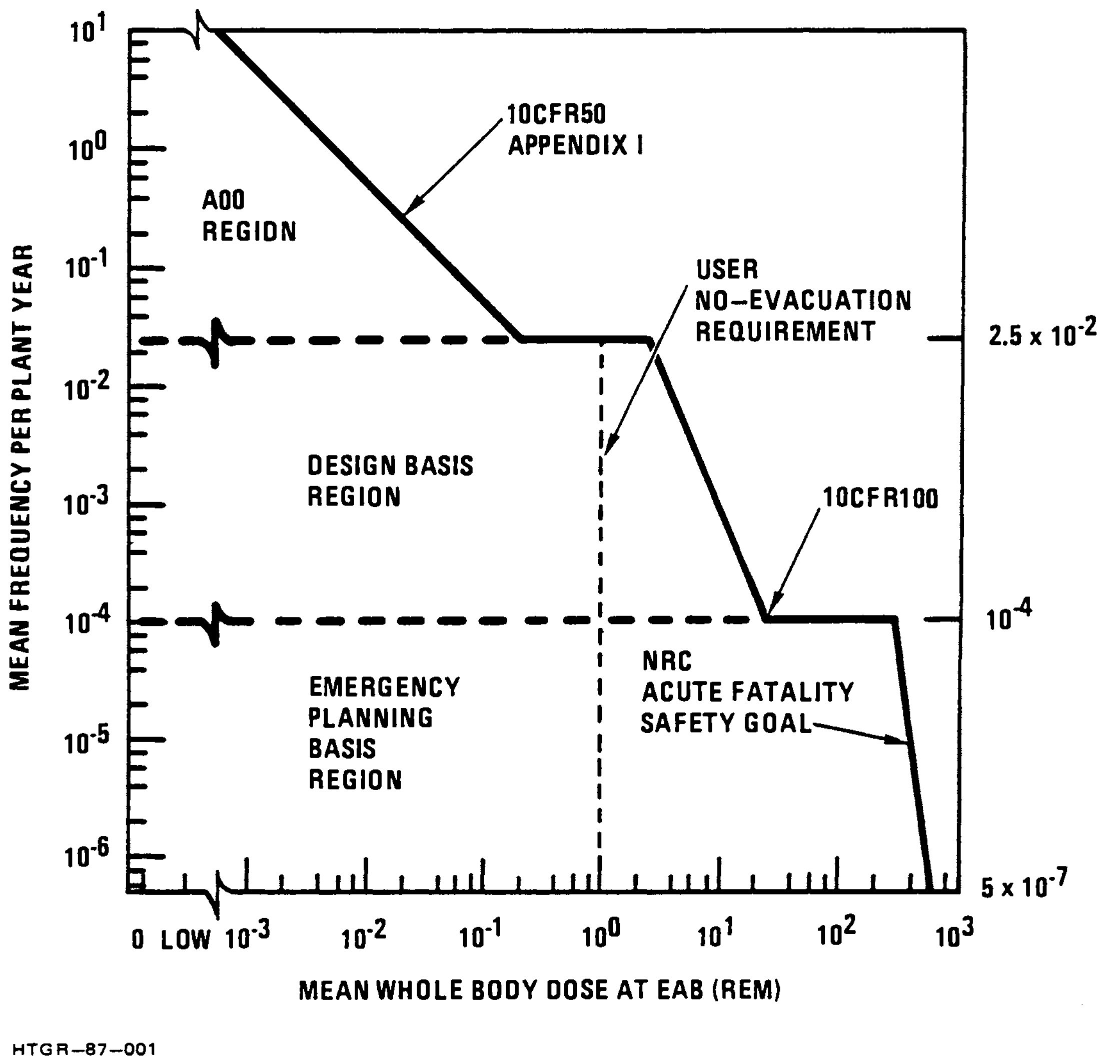

Fig. 6-1. Licensing basis regions for licensing basis event selection

the region boundaries in Fig. 6-1 is given in Ref. 19. However, it is worth noting here that the lower frequency cutoff of 5×10^{-7} per plant year encompasses the frequencies of LWR emergency planning accidents considered in NUREG-0396 (Ref. 9). Such LWR accidents include core melts in which the PAG doses are not exceeded at the EPZ (1.5×10^{-5} per year) and core melts in which life threatening doses are not exceeded at the EPZ (1.5×10^{-6} per year).

From this spectrum of LBEs, only the DBEs and the EPBEs are considered for emergency planning, because some of these unlikely events have the potential for releases that may be of importance in emergency planning. Out of these, only six events involve fission product release and concomitant offsite dose. It is these six events, described in Section 6.2, that are selected as the bases for MHTGR emergency planning.

Table 6-1 lists each event considered in emergency planning with its brief descriptive title. These events are initiated by primary coolant leaks, steam generator leaks, and earthquakes. Section 6.2 provides more detailed descriptions of each event scenario and summarizes the frequency and consequence assessments from Refs. 4 and 5 for each event.

6.2. DESCRIPTION OF LICENSING BASIS EVENTS SELECTED

Each licensing basis event corresponds to a particular event sequence. Included are events within the design basis and events beyond the design basis. This section describes the physical phenomena occurring in each of the particular events listed in Table 6-1. The kinds of radioactive materials that can be released to the environment, as well as the time-dependent characteristics of the potential releases and exposures, are discussed in this section. More detailed descriptions for each event are found in Ref. 11.

TABLE 6-1
LICENSING BASIS EVENTS CONSIDERED IN EMERGENCY PLANNING

Licensing Basis Events	LBE Designation
Moisture inleakage without SCS cooling	DBE-7
Primary coolant leak	DBE-10
Primary coolant leak without HTS and SCS cooling	DBE-11
Moisture inleakage with delayed steam generator isolation and without forced cooling	EPBE-1
Moisture inleakage with delayed steam generator isolation	EPBE-2
Primary coolant leak in four modules with neither forced cooling nor HPS pumpdown	EPBE-3

6.2.1. Design Basis Events

Only three of the design basis events identified in Ref. 11 (DBE-7, DBE-10, and DBE-11) result in offsite dose. This section describes the physical processes that occur during each of these DBEs. Table 6-2 summarizes the time-dependent characteristics for representative isotopes released during each DBE.

6.2.1.1. Moisture Inleakage Without SCS Cooling (DBE-7). DBE-7 is a moderate-sized steam generator leak without forced circulation cooling. Since both the Heat Transport System (HTS) and the Shutdown Cooling System (SCS) are unavailable, the affected module experiences a pressurized conduction cooldown in which heat is removed by conduction, radiation, and convection to the passive Reactor Cavity Cooling System (RCCS). The integrated inleakage of moisture into the primary coolant during this DBE is estimated in Ref. 4 as less than 270 kg (600 lbm). In Ref. 5, the mean frequency of events phenomenologically similar to DBE-7 is assessed as 4×10^{-5} per plant year.

During DBE-7, the primary system pressure increases due to (1) mass additions caused by the ingress of steam and the reaction of steam with graphite, and (2) temperature increases caused by the failure of forced core cooling. DBE-7 considers the bounding case, in which the relief valve is assumed to open and reclose at 10 h after the onset of the leak, when the primary system pressure reaches its peak value. During the time the relief valve is open, about 15% of the primary coolant and the fission products it contains are released to the reactor building and, subsequently, to the atmosphere. At the time of release, 8% of gaseous fission products in failed fuel have been released to the primary coolant by hydrolysis of the fuel kernel, 0.05% of fission products sorbed in bulk moderator graphite have been released by oxidation, and small amounts of halogens and noble gases have been released from the fuel to the primary coolant due to elevated temperatures. In addition, 60% of the fission products plated out on metallic surfaces have been

TABLE 6-2
SUMMARY OF ENVIRONMENTAL RELEASES FOR DBEs CONSIDERED IN EMERGENCY PLANNING

Event	Release Description[a]	Release Timing Description (h)		Cumulative Release to the Environment (Ci)			
		Start	Duration[b]	Kr-88	Sr-90	I-131	Cs-137
DBE-7	8	10	2×10^{-2}	7.5×10^{-2}	4.0×10^{-3}	2.9×10^{-1}	7.9×10^{-1}
	Total	10	2×10^{-2}	7.5×10^{-2}	4.0×10^{-3}	2.9×10^{-1}	7.9×10^{-1}
DBE-10	8	0	1	2.2	8.5×10^{-5}	7.5×10^{-3}	2.9×10^{-3}
	Total	0	1	2.2	8.5×10^{-5}	7.5×10^{-3}	2.9×10^{-3}
DBE-11	8	0	8	2.4×10^{-1}	1.6×10^{-6}	4.2×10^{-2}	2.2×10^{-5}
	Total	0	100	3.3×10^{-1}	7.3×10^{-6}	2.6	3.8×10^{-5}

(a)Cumulative release is given for first 8 h following the start of release and for total release.

(b)Duration is time of significant release from reactor building.

released to the primary system from steam-induced vaporization and recirculation prior to the time the relief valve opens. Time-dependent characteristics of potential releases to the environment during DBE-7 are found in Table 6-2 for a representative group of radionuclides.

6.2.1.2. Primary Coolant Leak (DBE-10). DBE-10 is a moderate-sized primary coolant leak with forced core cooling. Reference 5 assesses the mean frequency of events phenomenologically similar to DBE-10 as 2×10^{-2} per plant year.

In DBE-10, most of the initially circulating and liftoff activity in the primary coolant loop is released to the reactor building during the initial depressurization since primary coolant pumpdown to storage is ineffective in reducing the release. Most of this activity is released during the initial 6 min of depressurization. Beyond this time, hydrostatic displacement of helium is the only mechanism available by which fission products remaining in the primary circuit may escape. After 1 h, hydrostatic displacement is essentially complete so that no additional fission product release from the vessel occurs. The time-dependent manner in which a representative group of radionuclides are released during DBE-10 is summarized in Table 6-2.

6.2.1.3. Primary Coolant Leak without HTS and SCS Cooling (DBE-11). DBE-11 considers the plant response to a small primary coolant leak without forced circulation cooling. Since neither the HTS nor the SCS is available, the affected module experiences a depressurized conduction cooldown in which heat is removed via conduction and radiation to the RCCS. Reference 5 assesses the mean frequency of events phenomenologically similar to DBE-11 as 3×10^{-3} per plant year.

In DBE-11, only a fraction of the circulating activity is released during the initial depressurization because the Helium Purification Subsystem pumpdown of primary coolant to storage is successful. Specifically, 57% of the initial circulating activity is released from the reactor vessel during the depressurization, which is estimated to take 20 h. The lift-off of plateout activity is negligible for the small leak size considered in this event. Fractional fuel body activity is released slowly as the core temperatures rise during the initial heatup phase of the conduction cooldown transient. Fission products are released to the environment through the reactor building, although the release is reduced by radioactive decay, settling, and plateout. Time-dependent characteristics for a representative group of radionuclides that are potentially released to the environment during DBE-11 are found in Table 6-2.

6.2.2. Emergency Planning Basis Events

Reference 11 identifies three emergency planning basis events which result in doses that encompass the doses resulting from all the event sequences located within the EPBE region. (See Fig. 6-1.) The EPBEs are events beyond the design basis. Physical processes occurring during each EPBE are summarized below. Table 6-3 summarizes the time-dependent releases during each EPBE for a group of representative radionuclides.

6.2.2.1. Moisture Inleakage with Delayed Steam Generator Isolation and without Forced Cooling (EPBE-1). EPBE-1 is a moderate-sized steam generator leak in which the SCS is unable to provide forced circulation cooling. Reactor trip and steam generator isolation are delayed because of moisture monitor failure. The subsequent delay in the steam generator to dump its inventory results in nearly 3000 kg (6600 lbm) of steam entering the primary system. This ingress is sufficient to lift the primary system relief valve, and the valve is assumed to fail open. Since neither the HTS nor SCS is available following main loop trip, core heat is removed via conduction and radiation to the RCCS. Prior to depressurization through the open relief valve, the thermal transient is similar to a pressurized conduction cooldown; afterwards, it is similar to a depressurized conduction cooldown. In Ref. 5, the mean frequency of events phenomenologically similar to EPBE-1 is assessed as 7×10^{-6} per plant year.

TABLE 6-3
SUMMARY OF ENVIRONMENTAL RELEASES FOR EPBEs CONSIDERED IN EMERGENCY PLANNING

		Release Timing Description (h)		Cumulative Release to the Environment (Ci)			
Event	Release Description[a]	Start	Duration[b]	Kr-88	Sr-90	I-131	Cs-137
EPBE-1	8	0.1	8	9.6	3×10^{-2}	3.4	3.1
	Total	0.1	100	9.8	3×10^{-2}	4.6	3.3
EPBE-2	8	0.1	8	2.6	8.3×10^{-2}	3.4	1.6×10^{1}
	Total	0.1	24	2.7	8.4×10^{-2}	3.4	1.7×10^{1}
EPBE-3	8	0	8	8.2×10^{-1}	6.1×10^{-6}	1.4×10^{-2}	9.0×10^{-5}
	Total	0	100	1.6	2.8×10^{-5}	8.8	1.5×10^{-4}

[a]Cumulative release is given for first 8 h following the start of release and for total release.

[b]Duration is time of significant release from reactor building.

At about 0.8 h, when the relief valve fails open, 6% of gaseous fission products from initially failed fuel are released to the primary coolant by hydrolysis, and 0.16% of fission products sorbed in bulk moderator graphite are released by graphite oxidation. Fuel release due to elevated temperatures is insignificant. These activities, along with 100% of initially circulating activity and 60% of plated-out activity, removed from surfaces due to steam-induced vaporization and recirculation, are available for release with the primary coolant. Primary coolant activity rapidly depressurizes through the open relief valve into the reactor building, through the building dampers, and into the atmosphere. As the core temperatures rise, thermal expansion of vessel gases will transport a fraction of the fission products out of the reactor vessel into the reactor building. These fission products will be released slowly to the atmosphere via reactor building leakage, although the release is attenuated by radioactive decay, settling, and plateout. Releases for a representative group of radionuclides during two time periods following EPBE-1 are listed in Table 6-3.

6.2.2.2. Moisture Inleakage with Delayed Steam Generator Isolation (EPBE-2). EPBE-2 is a moderate-sized steam generator leak in which forced circulation cooling is provided by the SCS. Reactor trip and steam generator isolation are delayed due to moisture monitor failure. The integrated inleakage of moisture is assessed as 3000 kg (6600 lbm). Plant response is similar to EPBE-1 except the SCS is successful in providing forced cooling in EPBE-2. In Ref. 5, the mean frequency of events phenomenologically similar to EPBE-2 are assessed as 5×10^{-6} per plant year.

As in EPBE-1, high pressure from moisture inleakage causes the primary relief valve to lift, and it fails to reclose. In Ref. 5, it is conservatively assumed that when the relief valve fails open, all of the vessel inventory is released into the reactor building except for any attenuation due to radioactive decay. Hence, the fission products released from the vessel include 100% of circulating activity, 60% of plateout activity released due to steam-induced vaporization and recirculation, 0.011% of activity from the core graphite released due to oxidation, 0.26% of the noble gases and 0.18% of the volatile activity due to hydrolysis of initially failed fuel. Table 6-3 lists releases for a representative group of radionuclides during two time periods following EPBE-2.

6.2.2.3. Primary Coolant Leak in Four Modules with neither Forced Cooling nor Pumpdown (EPBE-3). A range of events initiated by primary coolant leaks were assessed in Ref. 5 as falling in the EPBE region. EPBE-3 considers the bounding case in terms of fission product release, which is a small primary coolant leak without forced circulation cooling that is initiated by an earthquake. The earthquake causes small primary coolant leaks in all four modules. Reference 5 assesses the mean frequency of events phenomenologically similar to EPBE-3 as 3×10^{-5} per plant year.

In EPBE-3, the HPS pumpdown of primary coolant to storage has failed. Hence, the primary system slowly depressurizes over a period of 25 h. After the initial depressurization, fission products are released by (1) hydrostatic displacement of helium in the vessel by air in the reactor building, and (2) thermal expansion of gases in the vessel as the core temperatures rise. Hydrostatic displacement is assumed to proceed slowly over about 100 h. Vessel release is attenuated by radioactive decay and holdup as the reactor begins to cool (after 100 h). Release to the environment is through reactor building leakage, reduced by plateout, settling, and decay in the building. Release estimates for a representative group of isotopes that significantly contribute to offsite dose during EPBE-3 are given for two time intervals in Table 6-3.

7. ASSESSMENT FOR EMERGENCY PLANNING ZONES

This section provides the emergency planning zone assessment for the Standard MHTGR. While both the plume exposure and the ingestion exposure pathways are discussed, the plume exposure pathway has received emphasis in this report. The plume exposure pathway doses for each selected LBE, given in Section 6, are assessed here versus distance from the plant. This addresses Step 2 in the approach to emergency planning bases described in Section 4. The doses are then compared to the lower plume exposure pathway PAGs. Based on this comparison, an appropriate plume exposure pathway EPZ is selected for the Standard MHTGR. This dose/PAG comparison and EPZ selection process addresses Step 3 of the approach given in Section 4. The assessment of ingestion exposure pathway doses and comparison with ingestion pathway PAGs is briefly discussed.

For the events selected in Section 6 to form the basis for emergency planning, plume exposure doses at the plant EAB were assessed previously: EPBE doses were assessed in the PRA (Ref. 5); DBE doses were assessed in the PSID (Ref. 4). In those studies time-dependent radiological doses were calculated using time-dependent source terms that are accident scenario specific.

The PRA and PSID dose assessments included an evaluation of dose uncertainties at the EAB. The method uses simplified mathematical algorithms which describe the phenomena controlling the plume exposure pathway dose as functions of variables with the uncertainties that affect the radiological consequences. The scenario-dependent algorithms are used in a Monte Carlo error propagation computer program to calculate the resultant dose by sampling from the input variable distributions. The input variables include among others the atmospheric dispersion factor X/Q with uncertainty. The meterological data was chosen to bound 85% of potential U.S. sites, and is expected to envelope about 80% of all U.S. LWR sites. In this manner probability distributions for the plume exposure doses were obtained at the EAB.

The plume exposure dose assessments for these events are extended in this section to distances beyond the EAB using the methods for assessing radiological doses that were described in the PRA and the PSID. Dose uncertainties were also analyzed using methods consistent with those described in the PRA and the PSID, to determine confidence levels on the doses and to provide guidance on the selection of the plume exposure pathway EPZ. Section 7.1 presents the plume exposure pathway dose assessment and chooses a plume exposure pathway EPZ.

Ingestion exposure doses are discussed in Section 7.2 for the infant thyroid pathway, which is the most limiting ingestion pathway, and provide guidance for the selection of the ingestion exposure pathway EPZ.

7.1. PLUME EXPOSURE PATHWAY

The plume exposure pathway is dominated by two exposure sources (Ref. 9):

1. External exposure to whole body gamma radiation.
2. Internal inhalation exposure.

The time of potential exposure could range from hours to days. Rapid actions involving the general public, and thus extensive preparations, are typically required to mitigate plume exposure pathway doses in excess of PAGs.

The plume is assumed to disperse according to a Gaussian distribution. The plume exposure pathway doses are conservatively calculated assuming the individual is surrounded by a semi-infinite cloud of uniformly concentrated radioactivity, consistent with standard industry practice (e.g., Ref. 20). The dose for an individual at a given location is assessed assuming no protective action (e.g., no evacuation or sheltering). Therefore, the assessed dose is for the maximum exposed individual.

Both the external and the inhalation plume exposure doses are assessed as a function of distance from the plant. The whole body gamma dose is accumulated to an individual over the duration of the release (see Tables 6-2 and 6-3 in Section 6). The inhalation thyroid dose assessment includes the dose commitment to an adult over a 50-yr period following the exposure period, consistent with standard industry practice embodied in Ref. 21. These doses were evaluated for exposure periods of 30 days, although the actual releases occur over much shorter periods of time, ranging from minutes to about four days, as indicated in Tables 6-2 and 6-3.

The calculated expected doses at the EAB are less than the plume exposure PAGs for sheltering (whole body dose of 1 Rem, thyroid dose of 5 Rem) for all of the events selected in Section 6 to form the emergency planning basis. The results of the dose assessment are shown for all the EPBEs in Figs. 7-1 and 7-2, where the mean whole body and thyroid doses versus distance are plotted. The consequences of DBEs are less severe than those calculated for the less likely EPBEs. This is illustrated in Figs. 7-3 and 7-4, which show the mean whole body and thyroid doses, respectively, versus distance from the plant for all the DBEs. Appendix A presents the dose assessment results, including uncertainties, that provide the basis for these figures. All doses beyond the EAB decrease as expected for a ground level released plume. For perspective, the normal background dose to the whole body during a 30-day period is $\sim 8 \times 10^{-3}$ Rem. This is based on an annual background dose at sea level in the U.S. of about 0.1 Rem (Ref. 22). As seen in Figs. 7-1 and 7-3, the calculated whole body doses from the Standard MHTGR events

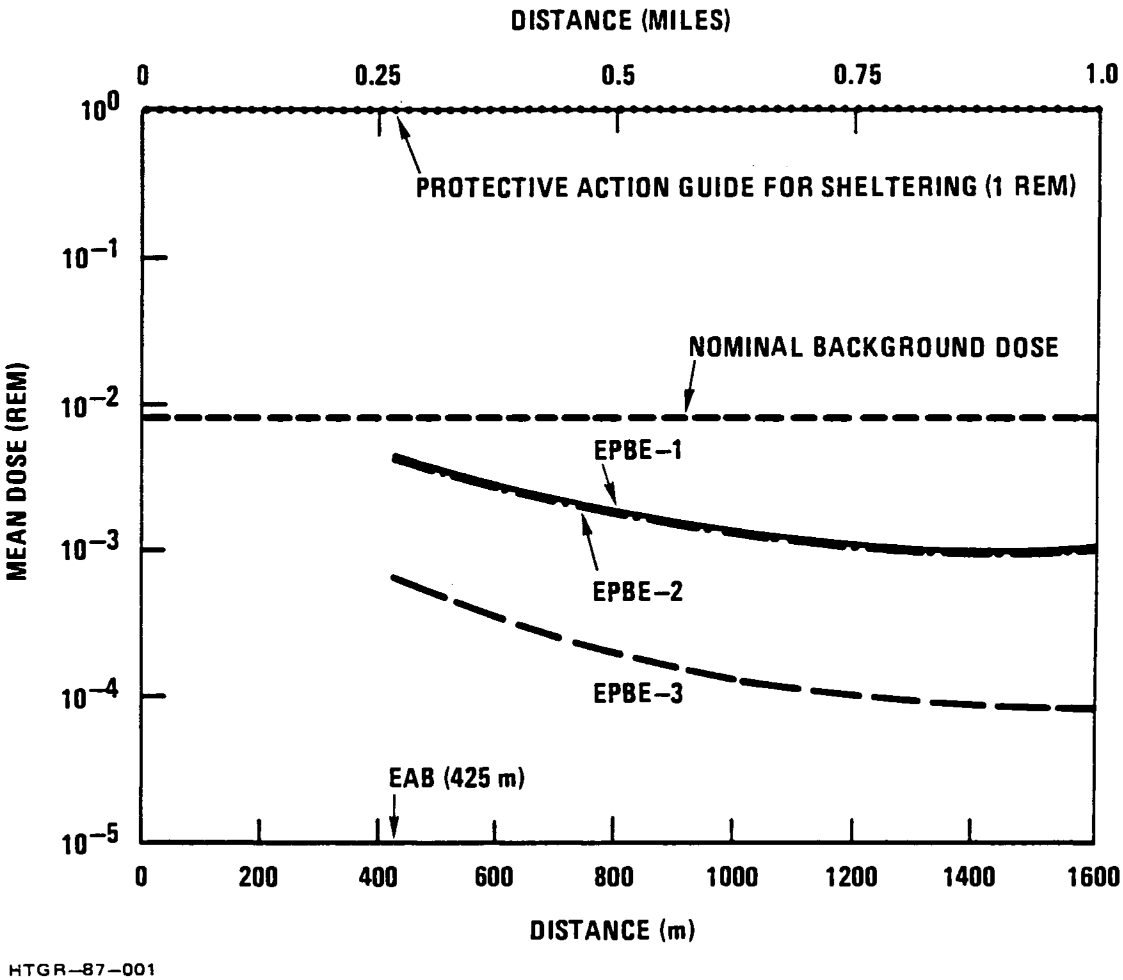

Fig. 7-1. Mean whole body gamma dose versus distance for all EPBEs for an individual with no protective actions

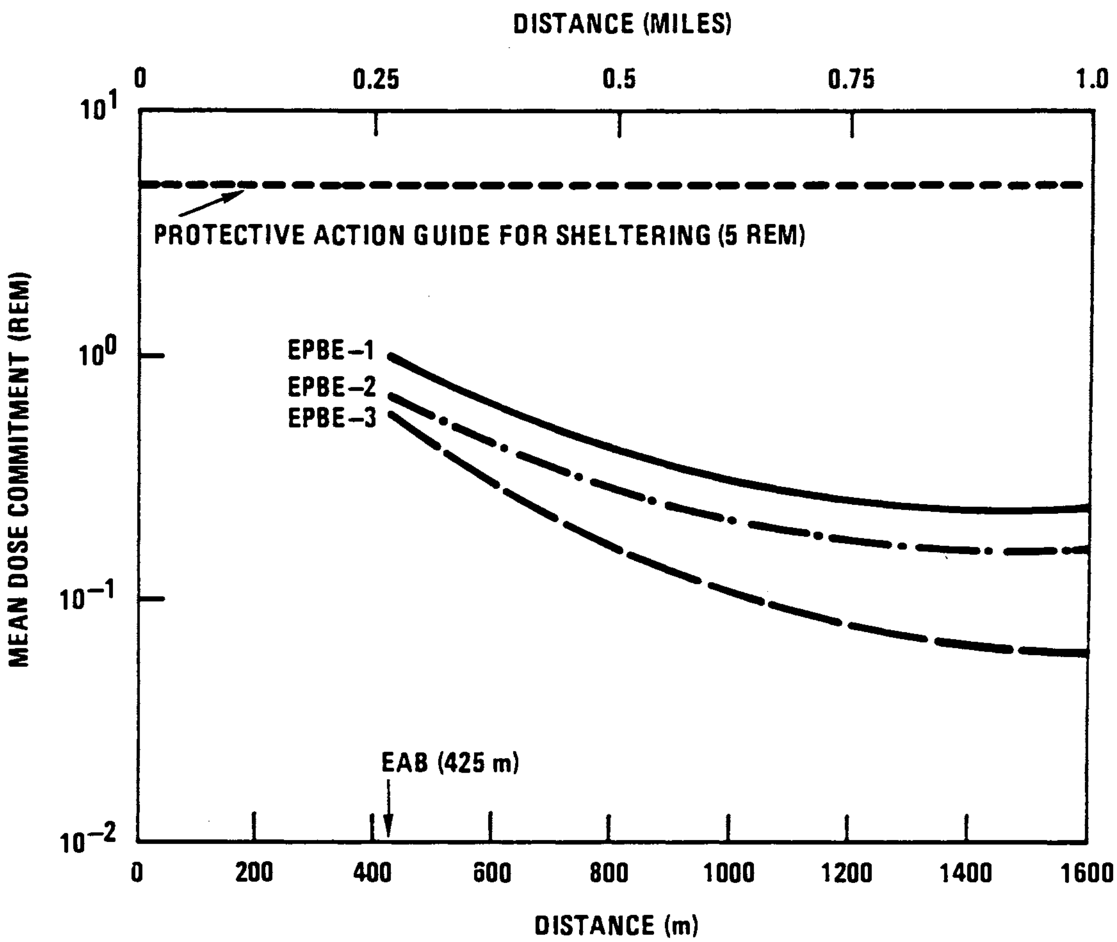

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Fig. 7-2. Mean thyroid inhalation dose commitment versus distance for all EPBEs for an individual with no protective actions

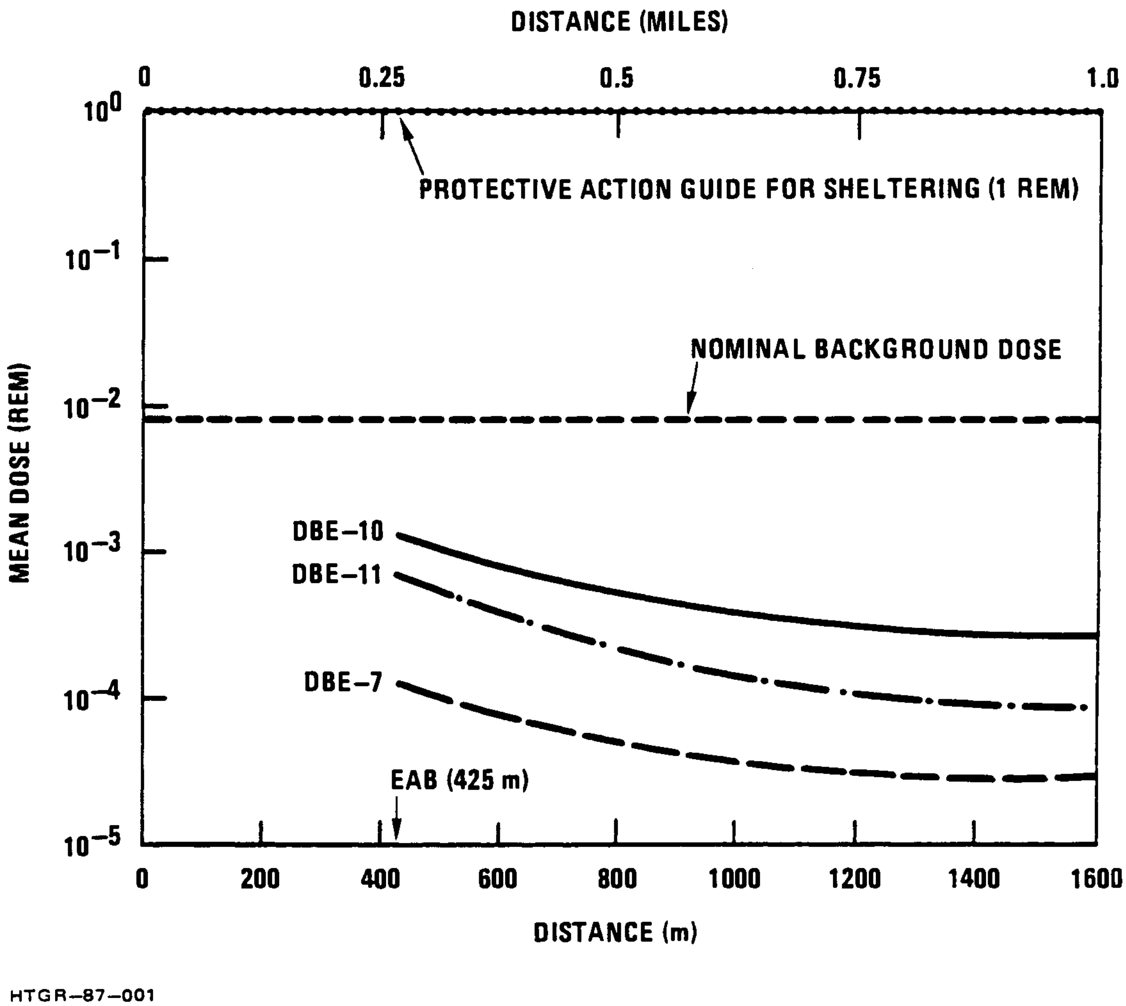

Fig. 7-3. Mean whole body gamma dose versus distance for all DBEs for an individual with no protective actions

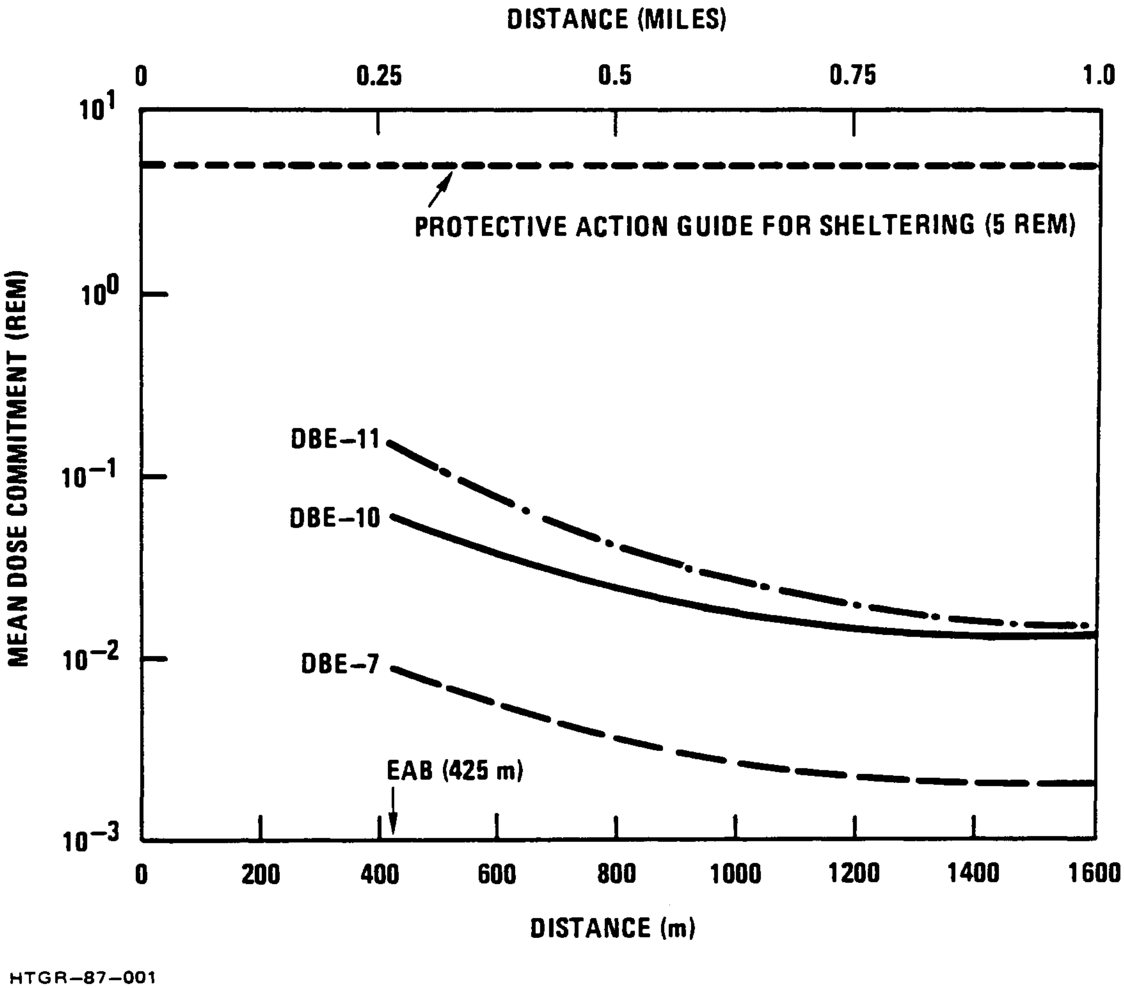

Fig. 7-4. Mean thyroid inhalation dose commitment versus distance for all DBEs for an individual with no protective actions

are lower than the normal background dose accumulated over a 30-day period.

Since the PAGs for sheltering are not exceeded beyond the EAB, the EPZ for plume exposure can be encompassed by the plant exclusion area boundary.

In NUREG-0396, the conservatively calculated consequences of the traditional design basis accidents were considered when the EPZs were selected. The conservative (ninety-fifth percentile) consequences of the DBEs for the Standard MHTGR are shown versus distance in Appendix A. Whole body doses are also shown in Appendix A (Figs. A-1 through A-3); thyroid doses are shown in Figs. A-7 through A-9. It can be seen that even these (ninety-fifth percentile) consequences do not exceed the PAGs for sheltering beyond the 425-m (0.27-mile) EAB.

From the results, it is noted that the thyroid doses are more limiting with respect to the PAG for sheltering than are whole body doses. The event beyond the design basis that poses the highest risk of inhalation doses in excess of the PAG for sheltering is a moisture inleakage with delayed steam generator isolation and without forced cooling (EPBE-1). The conditional probability that the PAG would be exceeded beyond the EPZ distance for that event is only 3.5%. In contrast, for events beyond the design basis, there is about a 30% chance of exceeding the PAG for sheltering at 16 km (10 miles) from an LWR power plant given a core melt accident. (See page I-37 of Ref. 9.)

Since the PAGs for sheltering are not expected to be exceeded beyond the plant exclusion area boundary of 425 m (0.27 mile) for all EPBEs and DBEs, the EPZ distance for plume exposure equivalent to the distance to the plant EAB is appropriate for the Standard MHTGR. The likelihood that PAGs would be exceeded beyond that distance is very low.

7.2. INGESTION EXPOSURE PATHWAY

The principal exposure from the ingestion exposure 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 general public is typically not involved in plans to provide protection from the ingestion pathway of exposure. The emergency response plans for this pathway are not as extensive as those required for the plume exposure pathway.

The most sensitive segment of the population to the ingestion exposure pathway is the infant, and the most sensitive organ is the thyroid because of its small size and the assumed dietary reliance on cow's milk (Ref. 9). The limiting ingestion dose pathway is for radioiodines by the atmosphere-grass-cow-milk-infant chain.

The analyses of the ingestion dose commitments are ongoing. Since the inhalation dose commitment to the adult thyroid is low for all EPBEs and DBEs (see Section 7.1), it is expected that the ingestion dose commitments to the infant thyroid will also be low for the Standard MHTGR.

When the ingestion dose commitments to the infant thyroid have been analyzed, they will be compared with the 1.5 Rem Preventive PAG on which the ingestion exposure EPZ was based in NUREG-0396. The distance from the plant beyond which the Preventive PAG is not expected to be exceeded, for all EPBEs and DBEs, will be chosen as the ingestion exposure EPZ radius. It is expected that the ingestion exposure EPZ radius for the Standard MHTGR will be significantly smaller than ingestion exposure EPZ radii chosen previously, including the 90-km (50-mile) radius that was chosen in NUREG-0396 for LWRs. This expectation is particularly supported when the difference is considered between the plume exposure EPZ radius for the Standard MHTGR [encompassed by the 425-m (0.27-mile) EAB] and that for LWRs [16 km (10 miles)].

8. EMERGENCY PLANNING IMPLICATIONS FOR STANDARD MHTGR

As mentioned in Section 3, the requirements which must be met by emergency plans for nuclear power plants are described in 10CFR50 Appendix E and NUREG-0654 (Ref. 13). These requirements were established for plants which have the potential for exceeding PAGs at the EAB. As demonstrated in Section 7, the Standard MHTGR does not exceed plume exposure PAGs at the EAB for any event with a mean frequency above 5×10^{-7}/plant-year. Therefore, the EPZ for plume exposure has been chosen to coincide with the site exclusion area boundary. Because of this choice, no member of the general public resides within the EPZ. Also, as noted in Section 7, the ingestion pathway EPZ for the Standard MHTGR is expected to be significantly smaller than that for LWRs. As a result, the potential public impact should be significantly less for the Standard MHTGR.

Even though the emergency planning regulations discussed in Section 3 were written primarily for LWRs, all of the topics included in the regulations will be reflected in the emergency plans for the Standard MHTGR. The Standard MHTGR's emergency plans will contain, but not necessarily be limited to, information needed to demonstrate compliance with the elements set forth in 10CFR50, Appendix E, i.e., organization for coping with radiological emergencies, assessment action, activation of emergency organization, notification procedures, emergency facilities and equipment, training, maintaining emergency preparedness, and recovery. In addition, the emergency response plans submitted will contain information needed to demonstrate compliance with the applicable portions of the standards described in 10CFR50.47(b). However, because of the Standard MHTGR's reduced exposure potential for the general public, it is not necessary to include every aspect of these standards in the plan. It is fitting that some of the requirements be waived to reflect the advantages of the small amounts of radioactivity released from the Standard MHTGR during postulated accidents. Several appropriate exemptions from the requirements and guidance given in 10CFR50.47, 10CFR50 Appendix E, and their implementation guidance documents (Refs. 9 and 13) have been identified. These exemptions are discussed in the following sections. As the design and emergency plans for the Standard MHTGR develop, additional exemptions may arise due to the differences between the Standard MHTGR and LWRs.

8.1. PLUME EXPOSURE PATHWAY

8.1.1. Emergency Action Levels

Reference 13 contains definitions of four classes of Emergency Action Levels for nuclear power plants. In ascending order of severity, these classes are (1) Notification of Unusual Events, (2) Alert, (3) Site Area Emergency, and (4) General Emergency. The most severe of these, General Emergency, reflects conditions where "releases can be reasonably expected to exceed EPA Protective Action Guideline exposure levels offsite for more than the immediate site area." At this emergency action level, sheltering of the public begins and evacuation is seriously considered. An example initiating condition for the General Emergency class, from Ref. 13, is when "effluent monitors detect levels corresponding to 1 Rem/h whole body or 5 Rem/h thyroid at the site boundary under actual meteorological conditions."

For the Standard MHTGR, Section 7 demonstrates that reaching the levels of radioactivity release such that plume exposure PAGs might be exceeded offsite is not likely to occur for any of the events in the emergency planning basis. Since PAGs are not expected to be exceeded offsite, there is no need for the General Emergency class. Therefore, the Emergency Action Levels for the Standard MHTGR should contain only the first three classes defined in Ref. 8; that is, Notification of Unusual Event, Alert, and Site Area Emergency. The thyroid dose rate may briefly (less than 3 min) exceed 5 Rem/h at the site boundary for some EPBEs with frequencies below 10^{-4} per plant year. A short-term dose rate in excess of 5 Rem/h does not in itself indicate that PAGs are exceeded for the Standard MHTGR, as discussed in Appendix A. The exemption from a General Emergency therefore properly reflects the enhanced safety of the Standard MHTGR and avoids the adverse and disruptive implications of considering a General Emergency.

8.1.2. Exercises and Drills

10CFR50 Appendix E describes the elements required to be included in emergency plans. Among them is a provision for training and exercising emergency personnel. Exercises are required to test the adequacy of implementing procedures and methods, to test emergency equipment and communications networks, and to ensure that emergency organization personnel are familiar with their duties.

The emergency plans for the Standard MHTGR need not include provisions for exercises or drills pertaining to sheltering and evacuation, since the 5 Rem PAG which is the trigger for consideration of sheltering and evacuation will not be reached. As was shown in Section 7, the maximum thyroid dose at the EPZ does not exceed 1 Rem for the Standard MHTGR.

8.1.3. Public Notification

NUREG-0654 (Ref. 13) gives guidance for the time allowed to notify state and local offsite authorities for all of the classes of Emergency Action Levels. This time is stated to be a maximum of 15 min, depending on the anticipated severity of the event. In addition, NUREG-0654 states that the emergency communication system must have the capability to provide "both an alert signal and an informational or instructional message to the population on an area wide basis" throughout the EPZ, within 15 min. However, for the Standard MHTGR, no member of the general public resides in the EPZ, which is encompassed by the plant EAB.

As discussed in Section 8.1.1, it is not expected that an Emergency Action Level beyond a Site Area Emergency will occur at a Standard MHTGR site. At the Site Area Emergency level, offsite doses remain below the levels of PAGs, and NUREG-0654 contains no requirement that the general public be informed. Only notification of state and local agencies and the NRC is required. Therefore, there is no need for special, rapid public notification procedures and equipment.

8.2. INGESTION EXPOSURE PATHWAY

At the present stage of conceptual design of the Standard MHTGR, details of the emergency plans for limiting public exposure from the ingestion pathway following a postulated accident have not been developed. The emergency response plans required for this pathway are not as extensive as those required for the plume exposure pathway.

Section 7 notes that an appropriate EPZ for ingestion exposure from the Standard MHTGR will be significantly smaller than the 90-km (50-mile) radius imposed on LWRs. Since the potential impact on the food chain is expected to be much less for the Standard MHTGR, the precautions to protect the public may be similarly reduced. As the design and analysis of the Standard MHTGR progress, specific areas may arise in which the unique characteristics of the Standard MHTGR lead to suggestions for changes in the guidance for MHTGR emergency plans. As they do, a basis for the suggested changes will be developed and presented to the NRC for approval. Until specific changes are identified and supported, the Standard MHTGR emergency plan for ingestion exposure will follow regulations and guidance provided for LWRs with the exception of the radius of the ingestion EPZ.

9. REQUESTED NRC RESPONSE

This document has been prepared for submittal to the Advanced Reactor Group of the Nuclear Regulatory Commission in support of the HTGR Licensing Plan (Ref. 2). It, along with its companion documents, the PSID (Ref. 4) and the PRA document (Ref. 5), is intended to demonstrate the Standard MHTGR's compliance with the top-level regulatory criteria (Ref. 7). Consistent with these intended uses, the NRC is requested to address and respond to the following questions:

1. Does the NRC agree that the approach used for selecting the emergency planning bases for the Standard MHTGR is appropriate, adequate, and consistent with while in some instances more conservative than NUREG-0396 (Ref. 9)?

2. Does the NRC agree that the Standard MHTGR design is capable of meeting the plume exposure Protective Action Guides at the Emergency Planning Zone specified for the Standard MHTGR?

3. Does the NRC agree that an Emergency Planning Zone for plume exposure encompassed by the plant exclusion area boundary is adequate for the Standard MHTGR?

4. Does the NRC agree that no plans or drills for rapid notification, sheltering, or evacuation of the public are required for the Standard MHTGR beyond the plant exclusion area boundary?

10. REFERENCES

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16. "Applicant's Petition Under 10CFR 2.758 and 10CFR 50.47(c) with Respect to the Regulations Requiring Planning for a Plume Exposure Pathway Emergency Planning Zone in Excess of a One-Mile Radius," Public Service Company of New Hampshire, et al, (Seabrook Station, Units 1 and 2), Docket Nos. 50-443-OL and 50-444-OL, Offsite Emergency Planning Issues, December 18, 1986.

17. Pickard, Lowe and Garrick, Inc., "Seabrook Station Probabilistic Safety Assessment," prepared for Public Service Company of New Hampshire and Yankee Atomic Electric Company, PLG-0300, December 1983.

18. Pickard, Lowe and Garrick, Inc., "Seabrook Station Risk Management and Emergency Planning Study," prepared for New Hampshire Yankee Division of Public Service of New Hampshire, PLG-0432, December 1985.

19. "Licensing Basis Event Selection Criteria," HTGR-86-001, Rev. 1, February 1986.

20. Slade, David H., editor, "Meteorology and Atomic Energy 1968," U.S. Atomic Energy Commission Report TID-24190, 1968.

21. U.S. Nuclear Regulatory Commission, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50, Appendix I," Regulatory Guide 1.109, Rev. 1, October 1977.

22. CRC Handbook of Radiation Measurement and Protection, Vol. II: Biological and Mathematical Information, A. Brodsky (editor), CRC Press, 1982.

APPENDIX A
RADIOLOGICAL CONSEQUENCE ASSESSMENT FOR SELECTED LBEs

A dose assessment of the LBEs described in Section 6 is presented in this Appendix. The purpose of this assessment is to provide the dose information needed in Section 7 to determine the plume exposure pathway EPZ distance for the Standard MHTGR plant. Dose results as a function of distance are provided for each LBE. Also provided are the uncertainties in the dose estimates. Dose rates versus time at the EAB are presented for the LBE with the highest assessed doses.

Six LBEs have been identified on which to base emergency response planning. Dose characteristics (e.g., dose versus distance) for each event are needed to provide guidance for EPZ selection. Doses are assessed in this appendix for the plume exposure pathway, which is dominated by two exposure sources:

1. External exposure to whole body gamma radiation.
2. Internal inhalation exposure.

The whole body gamma doses accumulated by an individual over the course of the events as a function of increasing distance from the plant are given in Figs. A-1 through A-6* for a ground level released plume. The fifth, median, and ninety-fifth percentile doses are presented. The fifth percentile doses are lower bound doses which are exceeded 95% of the time, whereas the upper bound ninety-fifth percentile doses are exceeded 5% of the time. All the LBEs exhibit very low doses as compared to the whole body gamma PAG for sheltering of 1 Rem (Ref. 8). Whole body doses beyond the EAB decrease as expected for a ground level

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*All figures in Appendix A appear at the end of the appendix.

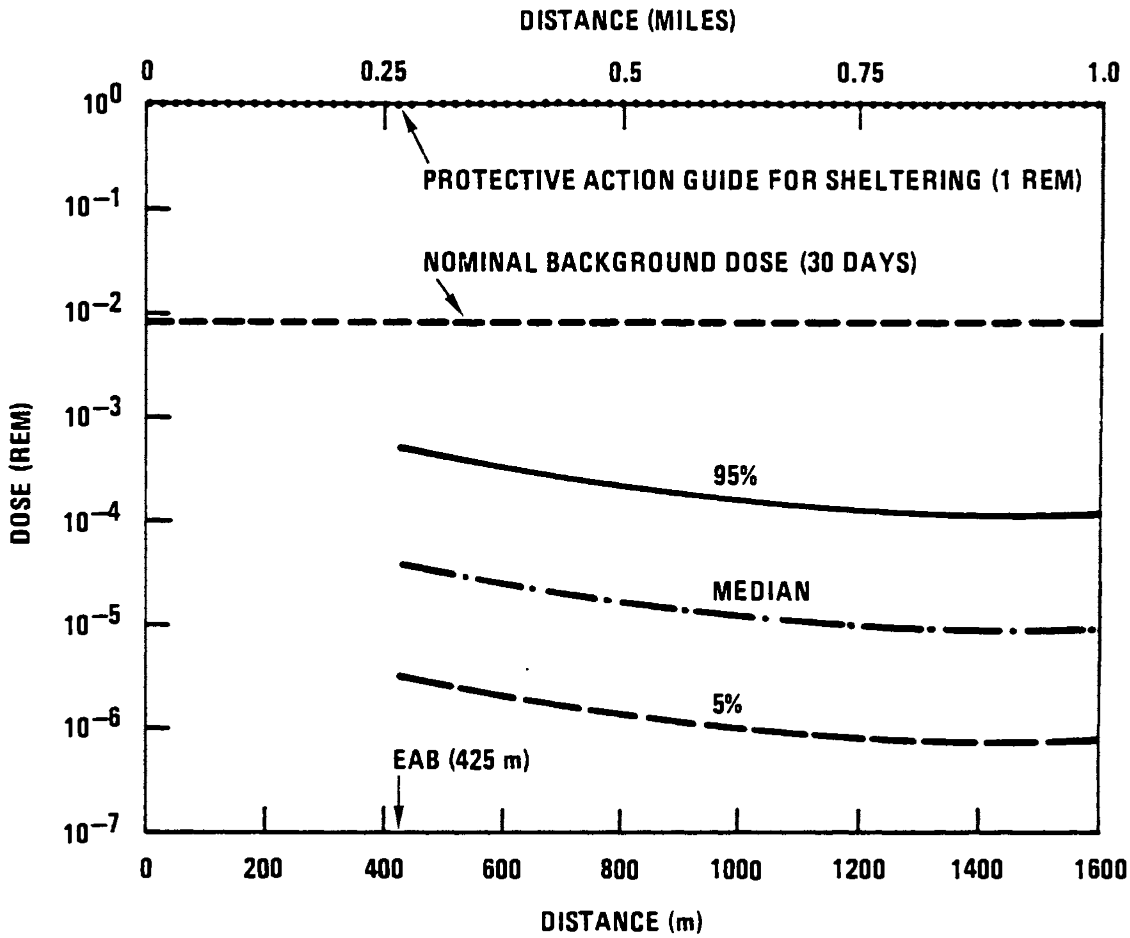
released plume. These doses were evaluated for exposure periods of 30 days, although the actual releases occur over much shorter periods of time, ranging from minutes to about 4 days, as indicated in Tables 6-2 and 6-3. The predicted LBE doses can be compared to the background exposure for an individual living in the U.S. The normal annual background whole body dose level at sea level is about 0.1 Rem (Ref. 22). Assuming that the background dose rate is constant with time, the normal background dose during a 30-day period is approximately 8×10^{-3} Rem. This dose is shown on Figs. A-1 through A-6 as a benchmark representing the normal dose beyond the EAB.

The inhalation thyroid dose commitments accumulated by an individual versus distance for ground level release are presented in Figs. A-7 through A-12. The fifth, median, and ninety-fifth percentile doses are displayed along with the 5 Rem inhalation thyroid PAG for sheltering (Ref. 8). Inhalation thyroid doses for DBE-7, -10, and -11 are below the PAG with considerable margin even when considering the ninety-fifth percentile doses (Figs. A-7 through A-9). EPBE-1 through -3 doses are also below the PAG at the ninety-fifth percentile, although with less margin.

For the events shown in Figs. A-1 through A-12, the most severe accident for the plume exposure pathway is EPBE-1. This event involves moisture ingress, followed by depressurization through a pressure relief valve, and a depressurized conduction cooldown. Since the depressurization is fairly rapid, the dose at the EAB is incurred over a relatively short period of time. Figs. A-13 and A-14, respectively, show the whole body gamma and thyroid inhalation dose rates at the EAB versus time after the start of the event. The whole body gamma dose rate is always much lower than 1 Rem/h. The thyroid inhalation dose rate exceeds 5 Rem/h only briefly, within minutes after the relief valve opens and fails to reclose, and subsequently decreases steadily. Unless the dose rate is monitored continuously, the occasion of its exceeding 5 Rem/h may or may not be noticed. Even so, a short term dose rate in excess of

5 Rem/h does not indicate that a serious accident is underway, since it has been shown above that PAGs for sheltering are not exceeded for the Standard MHTGR events that form the emergency planning basis.

Based on this assessment of plume exposure pathway doses, it is concluded that the inhalation thyroid dose is the most limiting plume exposure dose for the Standard MHTGR LBEs. Even so, substantial margin exists between the median inhalation thyroid doses and the PAG for sheltering at the EAB. Furthermore, this margin is found to increase with distance from the plant.



HTGR–87–001

Fig. A-1. Whole body gamma dose for DBE-7 versus distance for an individual with no protective actions

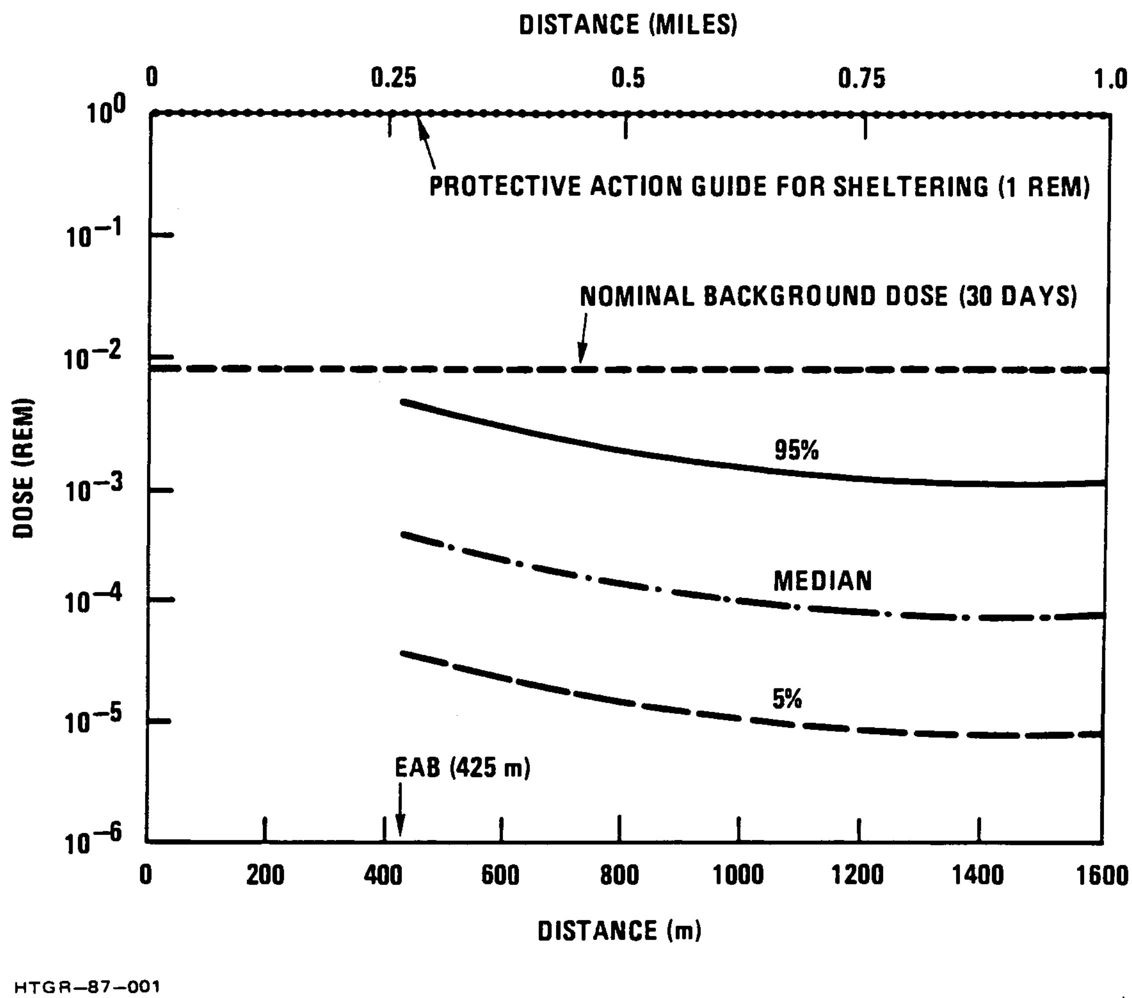
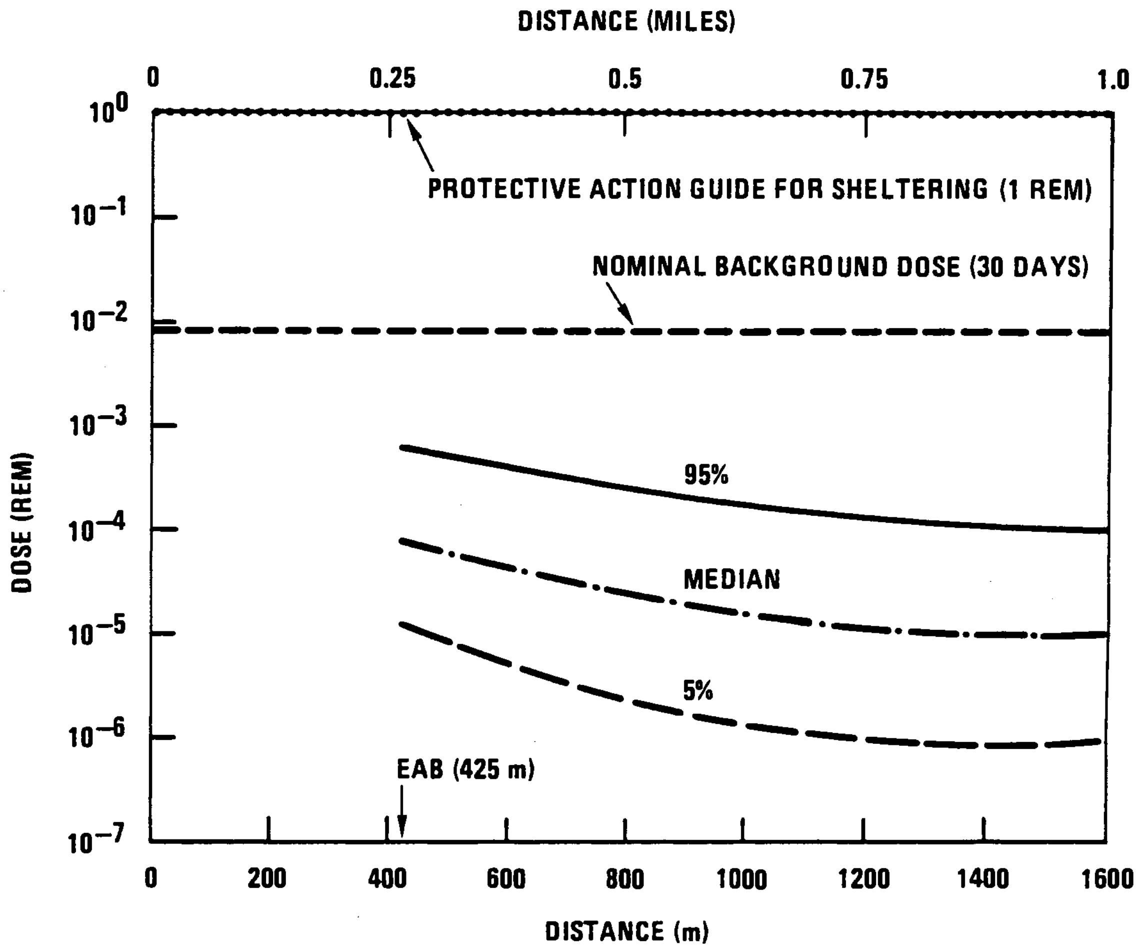
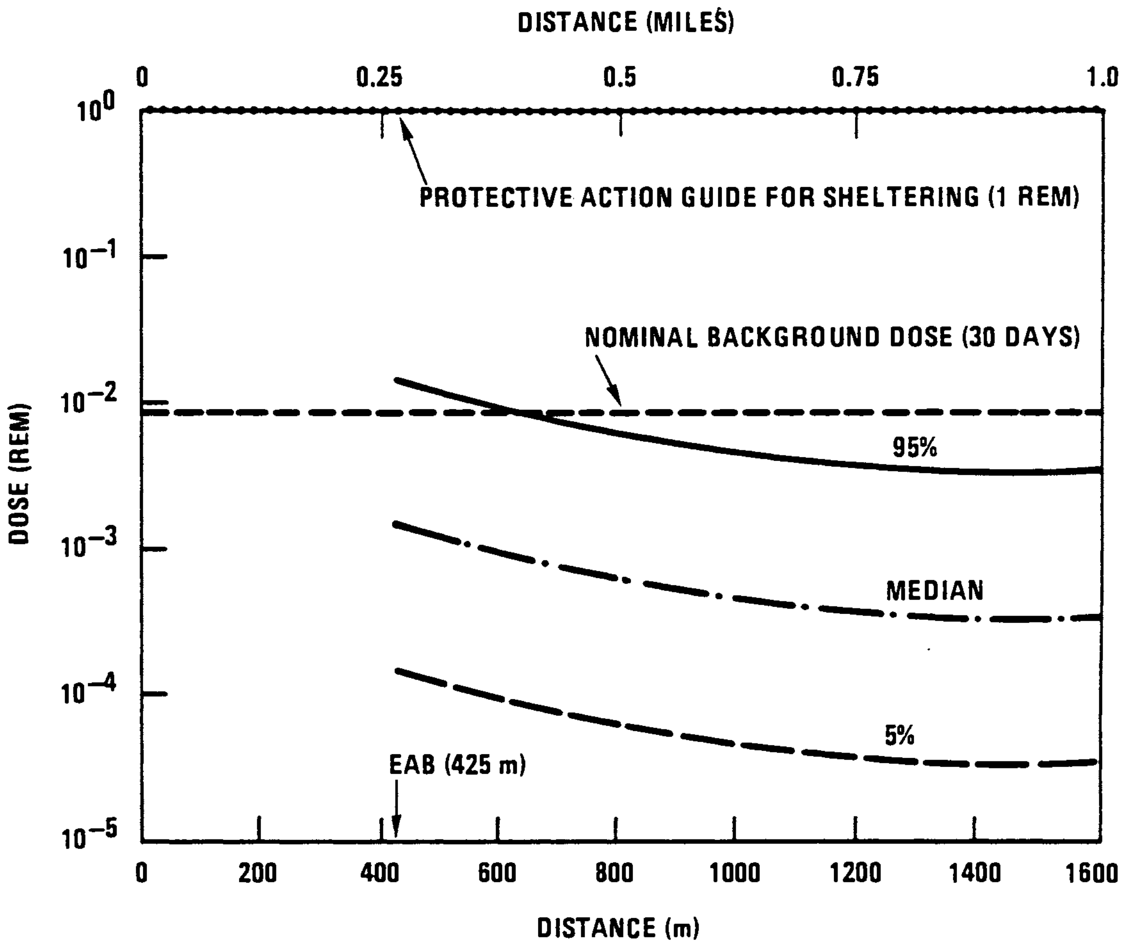


Fig. A-2. Whole body gamma dose for DBE-10 versus distance for an individual with no protective actions



HTGR—87—001

Fig. A-3. Whole body gamma dose for DBE-11 versus distance for an individual with no protective actions



HTGR-87-001

Fig. A-4. Whole body gamma dose for EPBE-1 versus distance for an individual with no protective actions

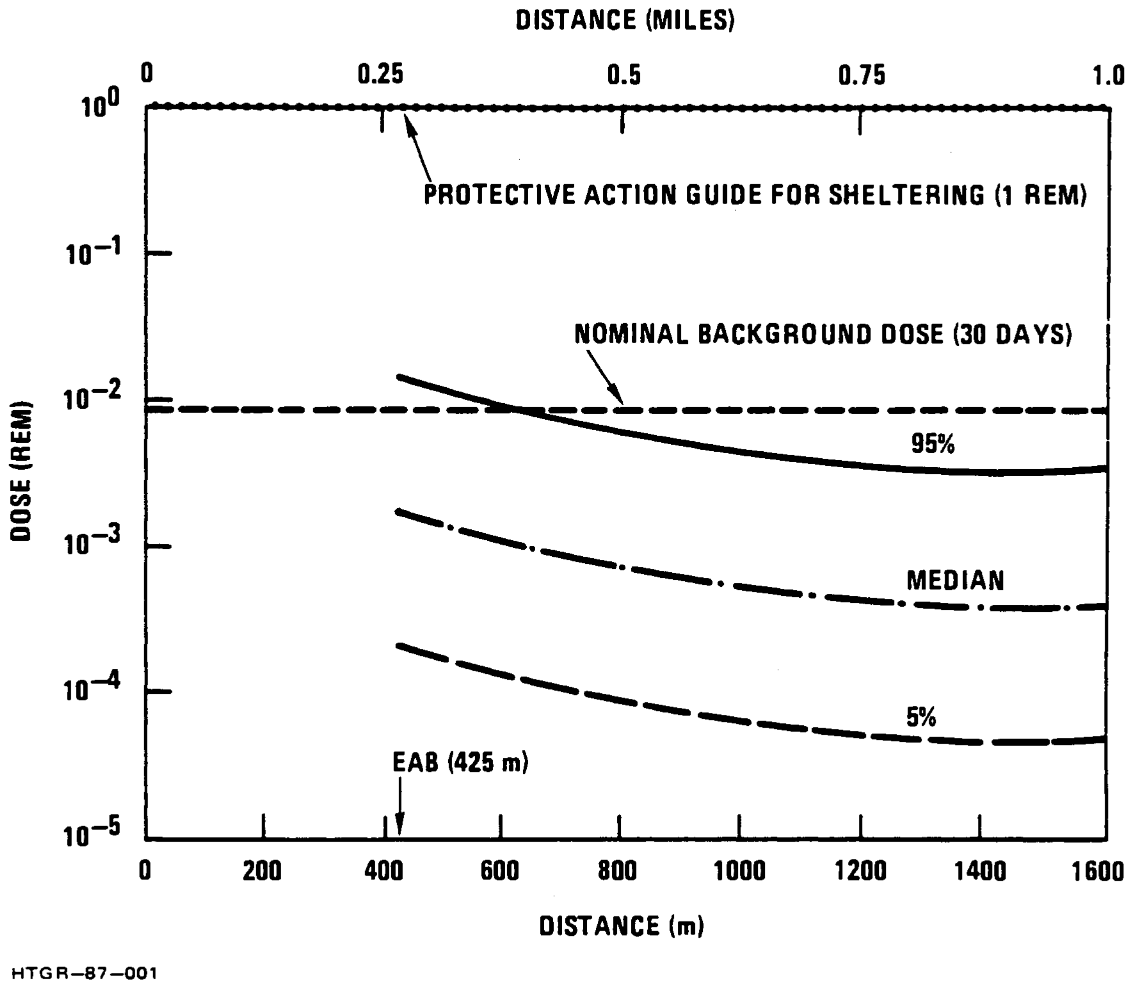


Fig. A-5. Whole body gamma dose for EPBE-2 versus distance for an individual with no protective actions

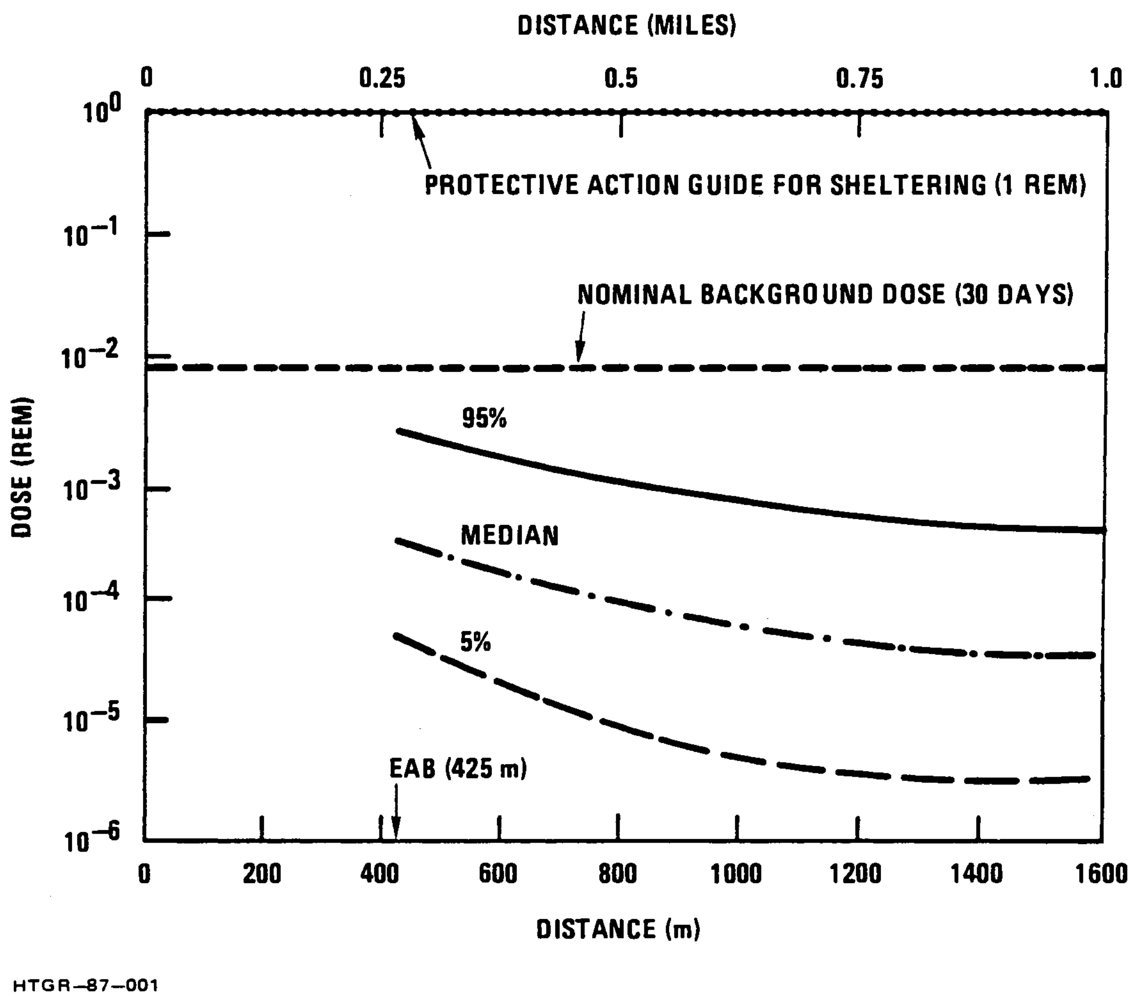


Fig. A-6. Whole body gamma dose for EPBE-3 versus distance for an individual with no protective actions

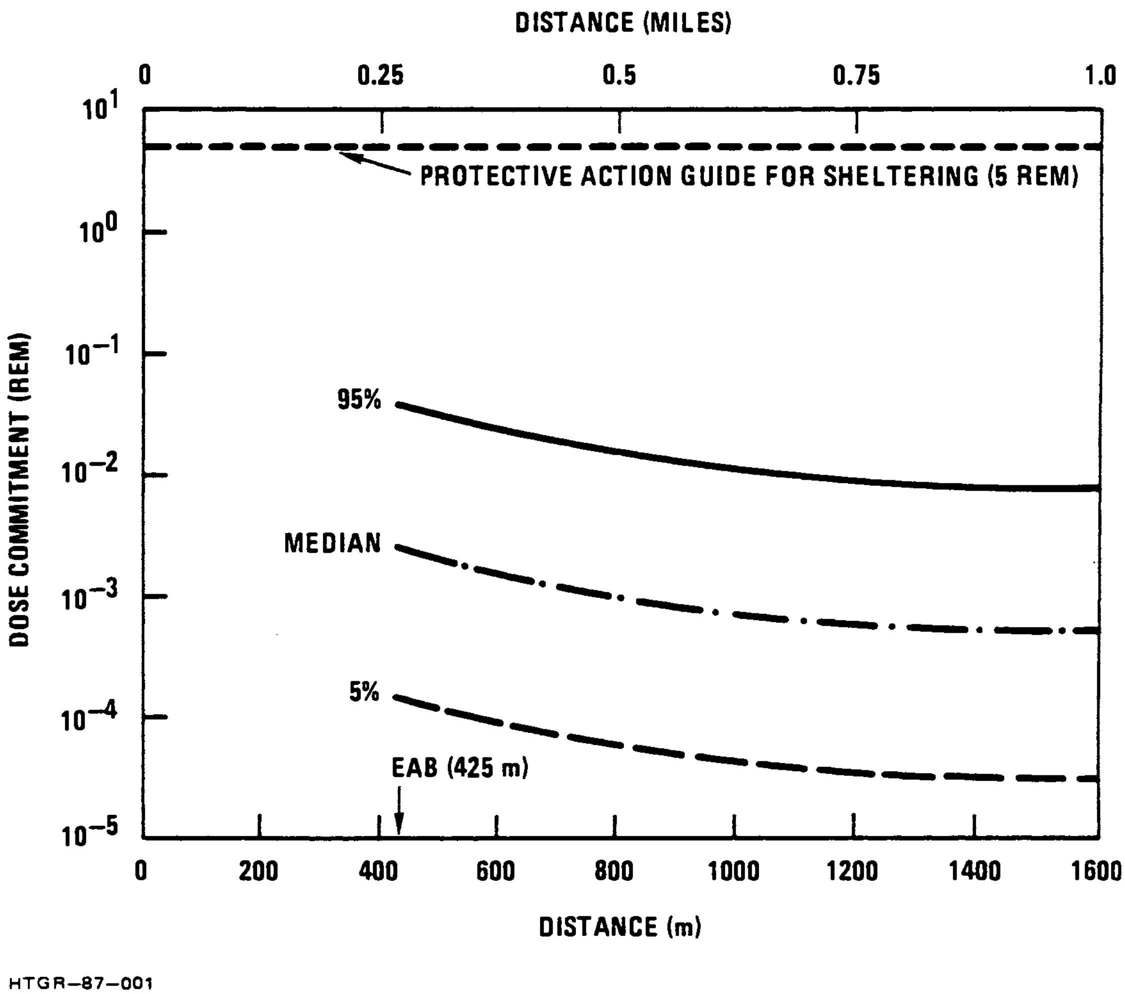


Fig. A-7. Thyroid inhalation dose commitment for DBE-7 versus distance for an individual with no protective actions

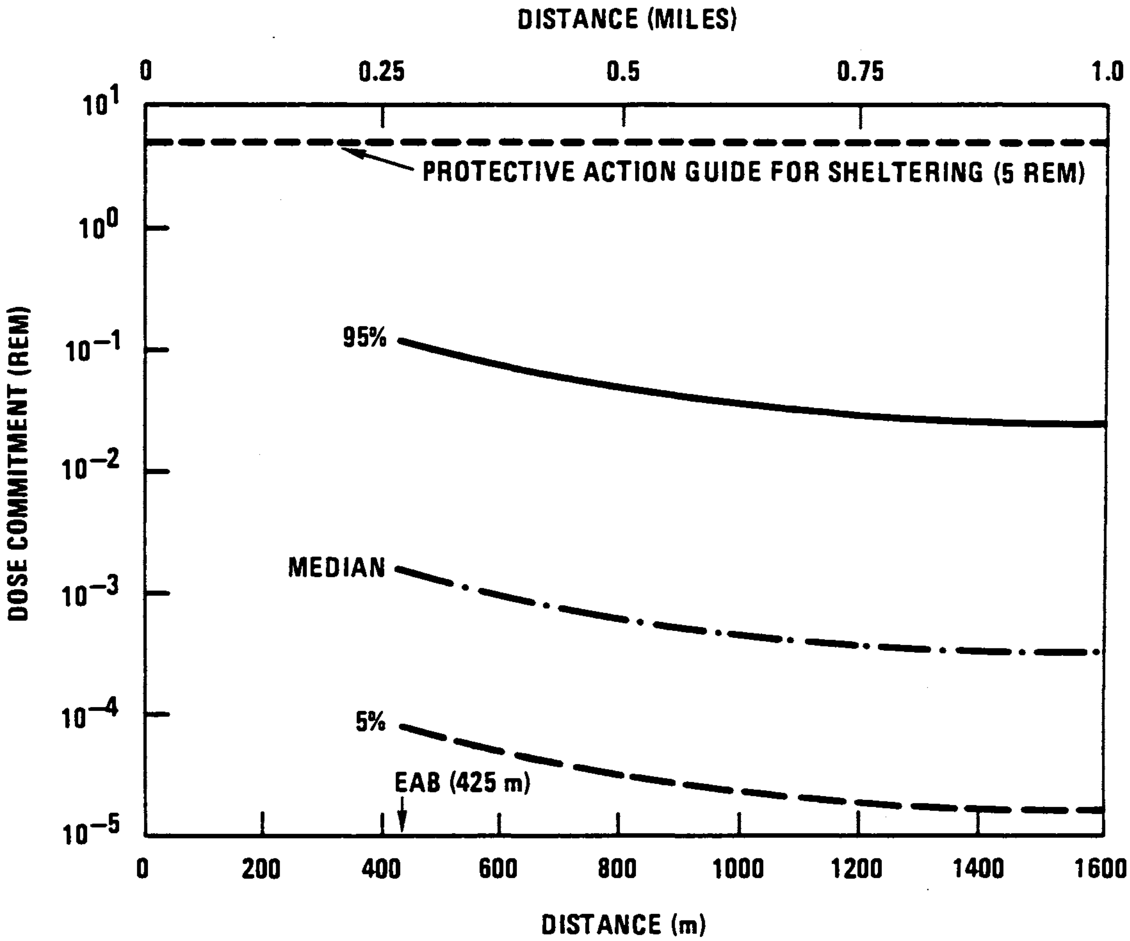


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Fig. A-8. Thyroid inhalation dose commitment for DBE-10 versus distance for an individual with no protective actions

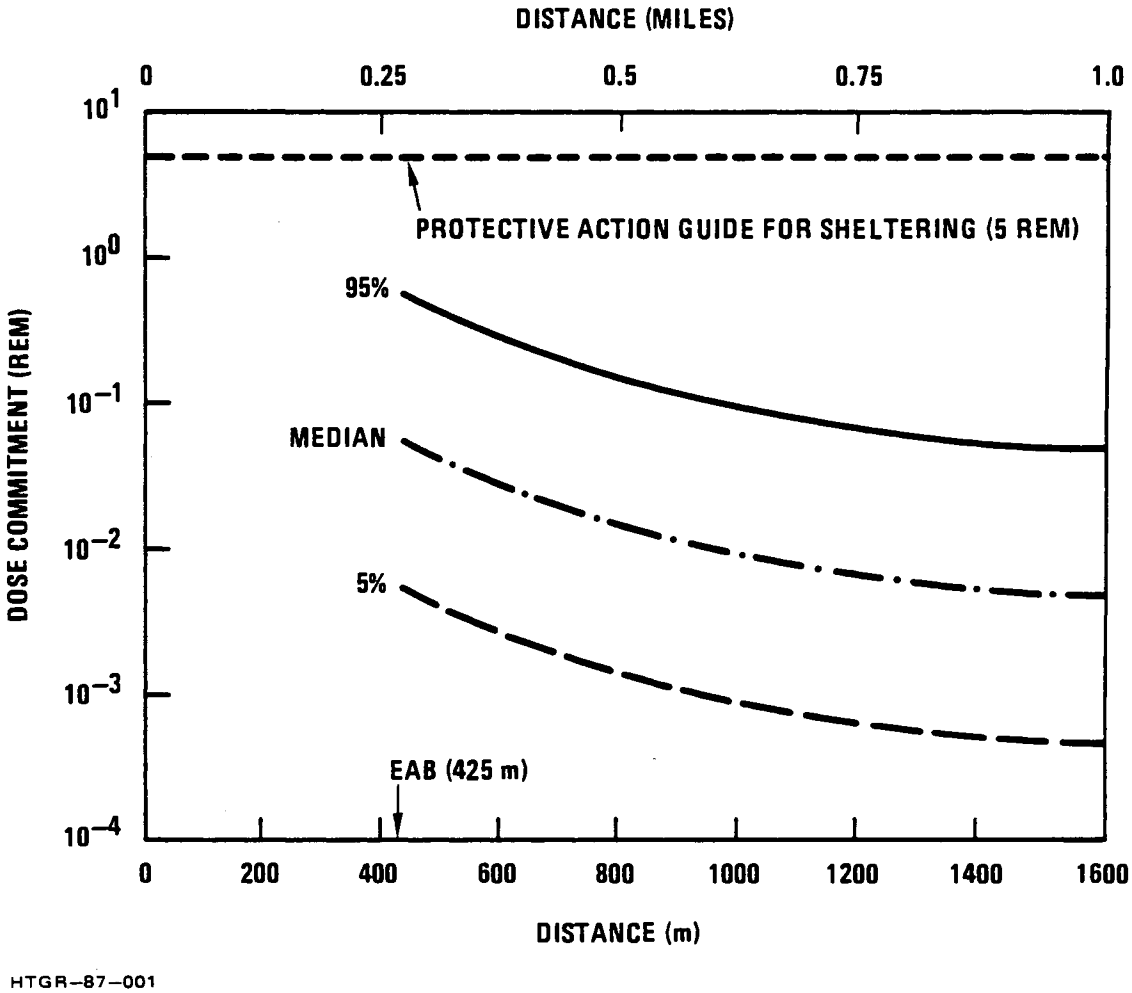

Fig. A-9. Thyroid inhalation dose commitment for DBE-11 versus distance for an individual with no protective actions

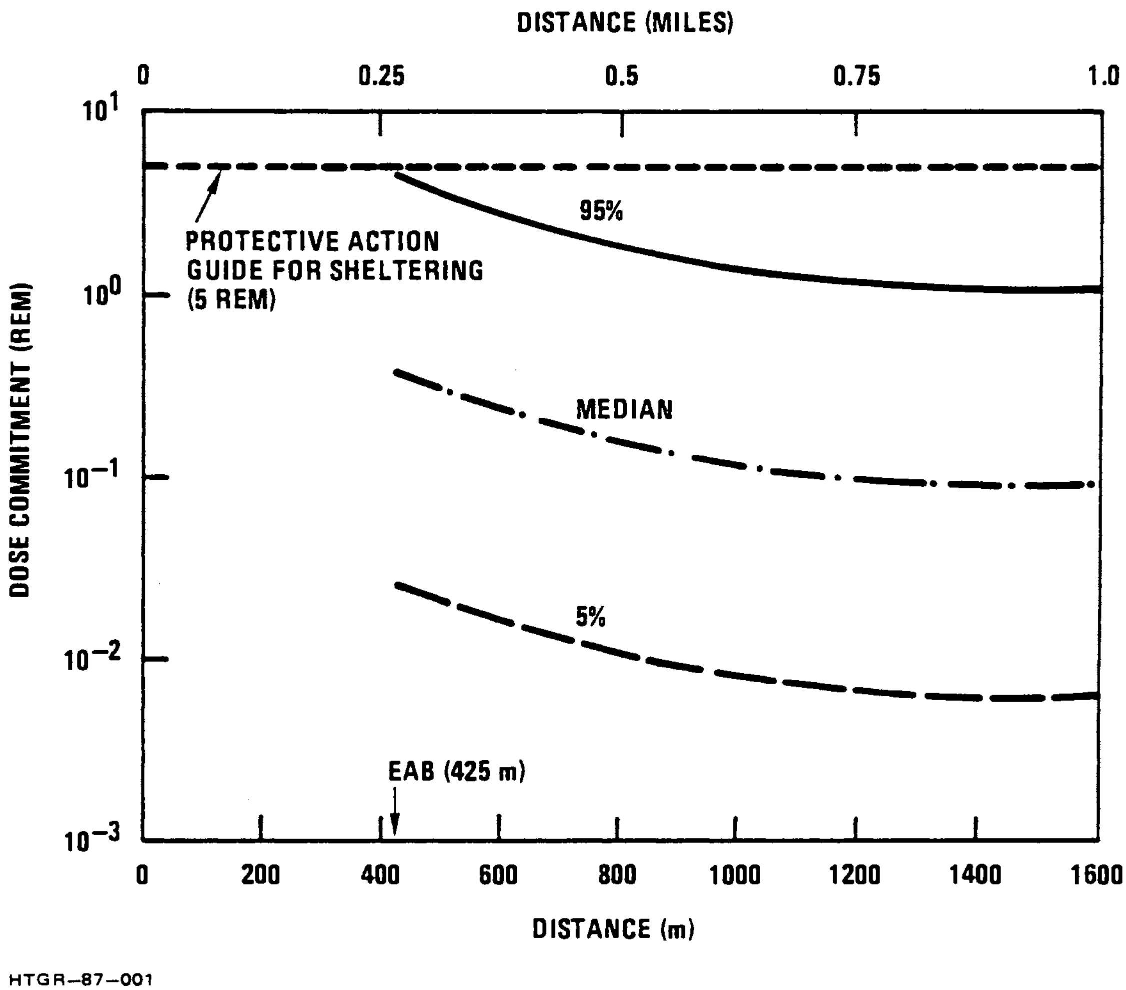

Fig. A-10. Thyroid inhalation dose commitment for EPBE-1 versus distance for an individual with no protective actions

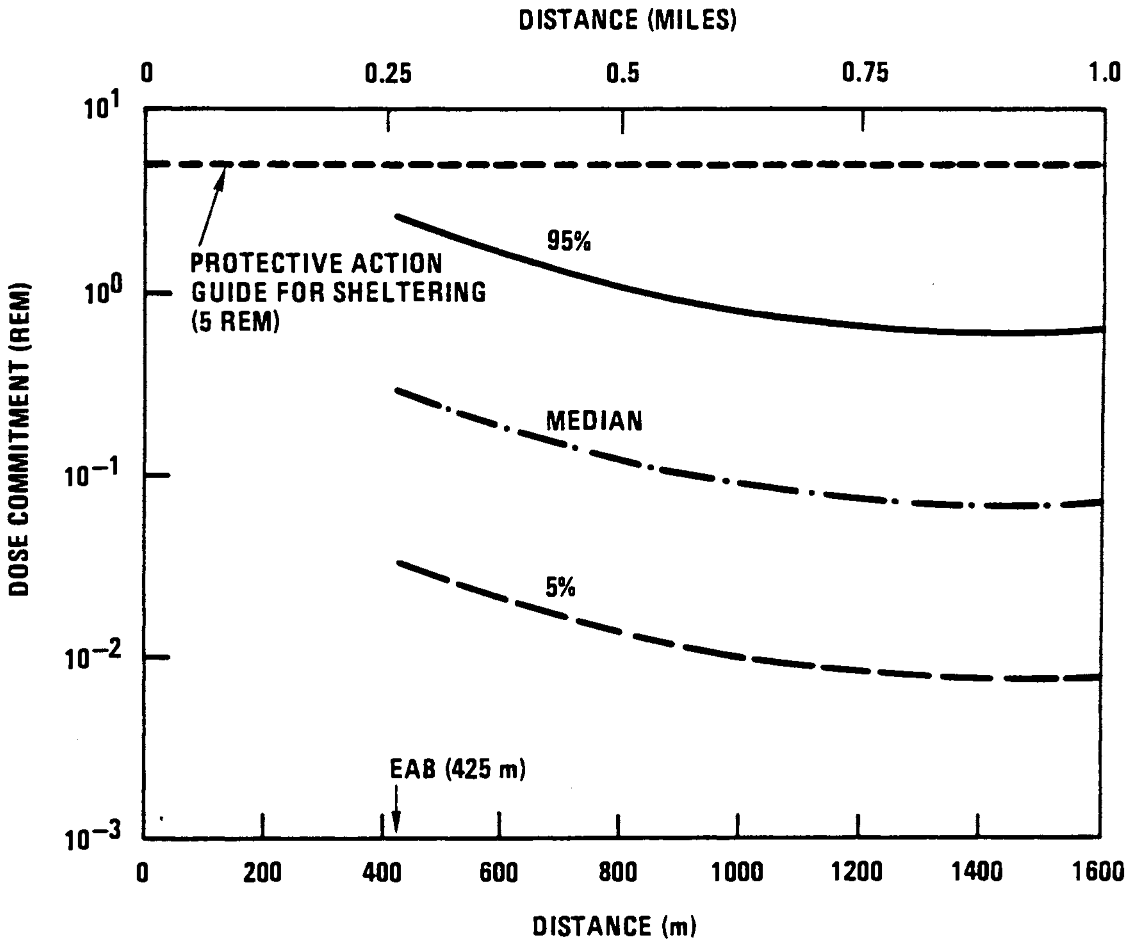

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Fig. A-11. Thyroid inhalation dose commitment for EPBE-2 versus distance for an individual with no protective actions

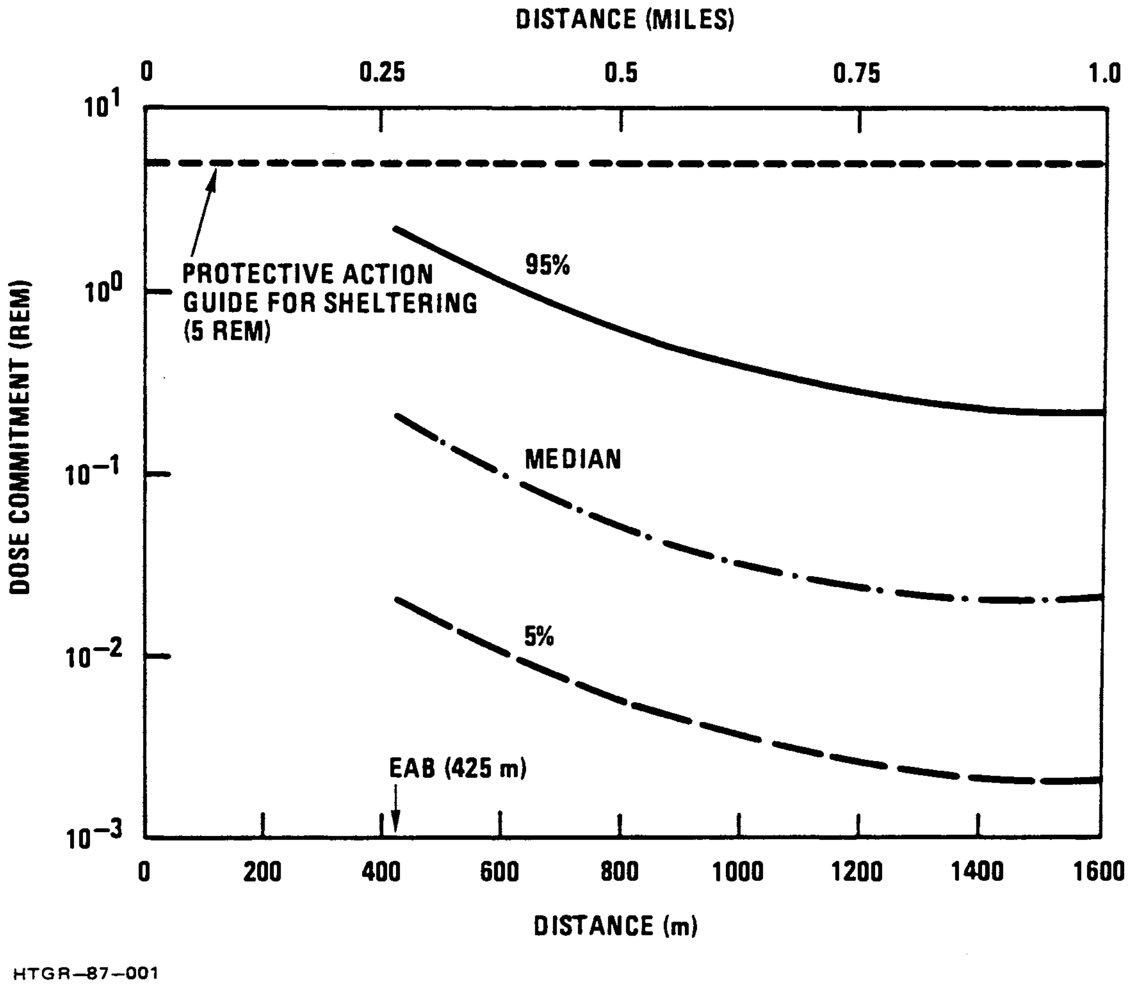

Fig. A-12. Thyroid inhalation dose commitment for EPBE-3 versus distance for an individual with no protective actions

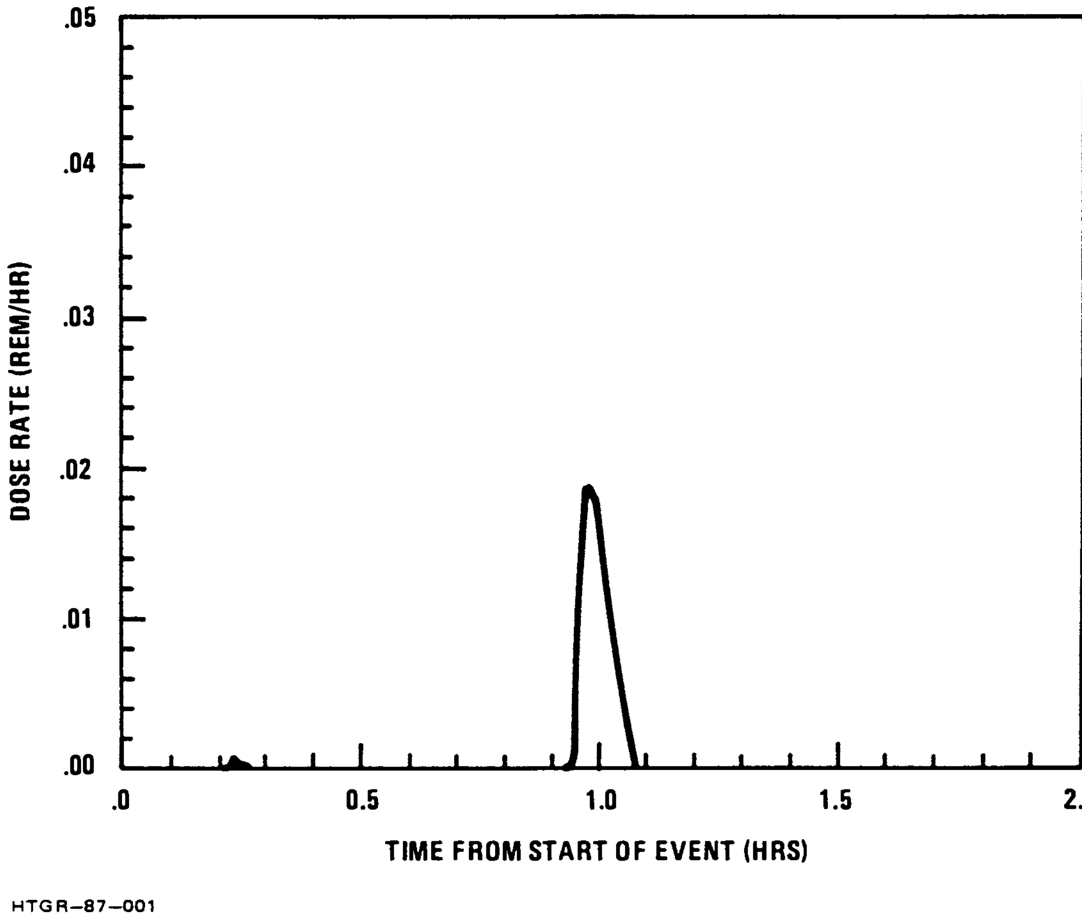

Fig. A-13. Whole body gamma dose rate at the EAB for EPBE-1 for an individual with no protective actions

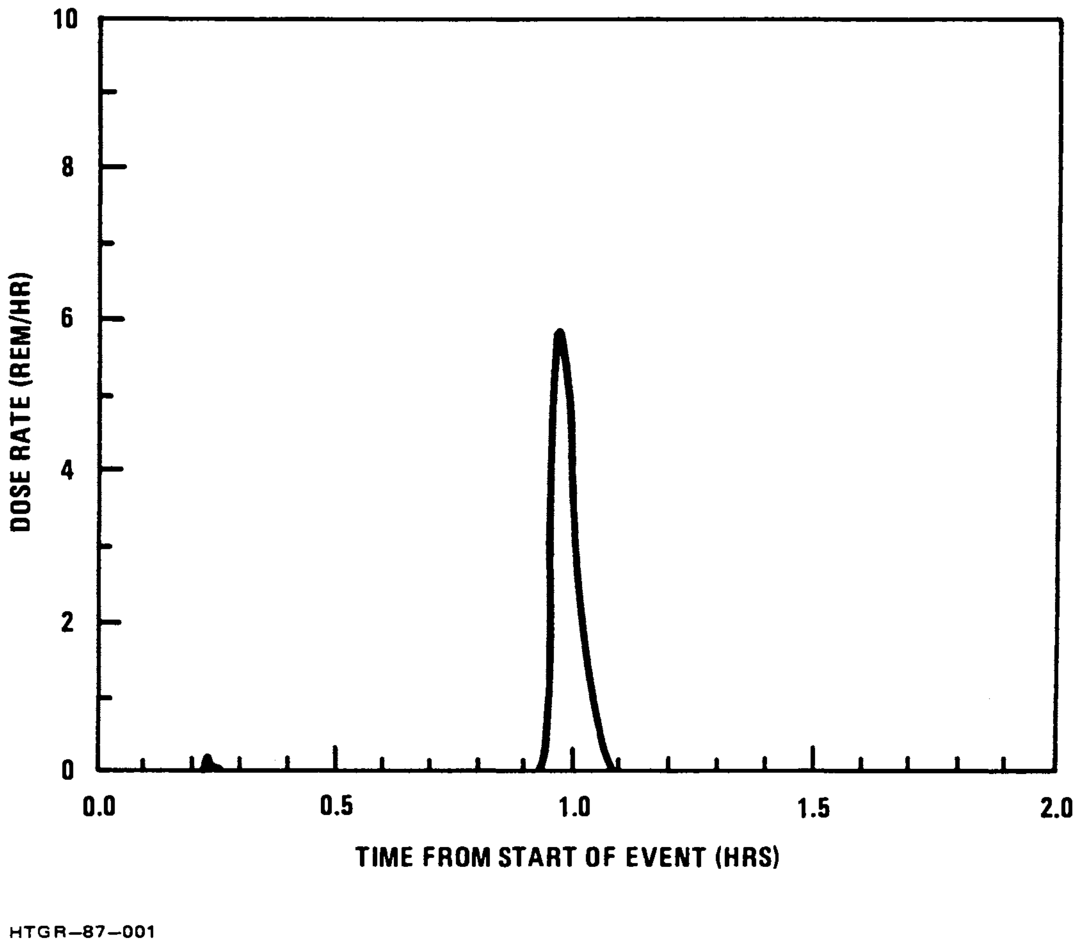

Fig. A-14. Thyroid inhalation dose rate at the EAB for EPBE-1 for an individual with no protective actions

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Department of Energy
Washington, DC 20545

NRC PROJECT NO. 672

March 2, 1987

Dr. Themis P. Speis, Deputy Director
Office of Nuclear Reactor Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Speis:

Consistent with the Advanced Reactor Policy (51FR2463, July 8, 1986), we provided our plans to you for early interaction on the Standard Modular High-Temperature Gas-Cooled Reactor (MHTGR) in the Licensing Plan (HTGR-85-001, February 1986). One of the documents in the Licensing Plan was the submittal of a Document on Emergency Planning Bases for the Standard Modular High-Temperature Gas-Cooled Reactor. In this report bases for establishing radiological emergency response plans are developed for the Standard Modular High-Temperature Gas-Cooled Reactor (MHTGR).

The approach for determining emergency planning bases for the Standard MHTGR is consistent with and in some instances more conservative than the approach used for light-water reactors. The scope of this report includes the application of this approach. Potential radiological doses as a function of distance from the plant are presented for design basis events and events beyond the design basis. The area over which planning for predetermined actions should be carried out for the Standard MHTGR is identified. Based on this data NRC's agreement is requested that the emergency planning zone for the dominant exposure pathway is encompassed by the plant exclusion area boundary. Therefore, no offsite plans for sheltering, evacuation, or rapid notification of the public are required for the Standard MHTGR.

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