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A GUIDE TO RADIOLOGICAL ACCIDENT CONSIDERATIONS FOR SITING AND DESIGN OF DOE NONREACTOR NUCLEAR FACILITIES

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ABSTRACT

DOE Office of Nuclear Safety has sponsored preparation of a guidance document to aid field offices and contractors in their analyses of consequences of postulated major accidents. A summary of needs for such guidance was presented at the 4th Environmental Protection Conference in 1982. A guide will soon be issued for trial use after extensive peer review. The guide addresses the requirements of DOE Orders 5480.1A, Chapter V, and 6430.1, including the general requirement that DOE nuclear facilities be sited, designed, and operated in accordance with standards, codes, and guides consistent with those applied to comparable licensed nuclear facilities.

The guide includes both philosophical and technical information in the areas of:

- siting guidelines doses applied to an offsite reference person;
- consideration also given to an onsite reference person;
- physical parameters, models, and assumptions to be applied when calculating doses for comparison to siting criteria; and
- potential accident consequences other than radiological dose to a reference person which might affect siting and major design features of the facility, such as environmental contamination, population dose, and associated public health effects.

Recommendations and/or clarifications are provided where this could be done without adding new requirements. In this regard, the guide is considered a valuable aid to the safety analyst, especially where requirements have been subject to inconsistent interpretation or where analysis methods are in transition, such as use of dose model (ICRP 2 or ICRP 30) or use of probabilistic methods of risk analysis in the siting and design of nuclear facilities.

INTRODUCTION

A paper presented by the authors at the 4th DOE Environmental Protection Information Meeting in 1982 described the need for a guide to postulated accident analysis for site evaluation and major design feature selection for DOE nuclear facilities. This paper describes the guide which has since been prepared to meet this need. The guide entitled "A Guide to Radiological Accident Considerations for Siting and Design of DOE Nonreactor Nuclear Facilities," has completed the peer-review and revision process and is being printed. Issue is expected near December 1, 1984.

The Guide will be routed through all field offices to the respective contractor health, safety, and environmental organizations. Many of these groups have reviewed and commented during the peer review of two earlier drafts. Fourteen peer reviewers plus a large number of other interested personnel at DOE sites have commented on the present guide. It is expected that the Guide will undergo a revision 1-2 years after issue to accommodate finalization of the DOE Order 6430.1, Chapter I, revision and any other changes which are found necessary.

The need for guidance for the safety analyst stems primarily from the disparities between diverse operations and siting situations found in DOE nuclear facilities and the light water reactor (LWR) operations for which existing siting criteria were written. The Nuclear Regulatory Commission (NRC) has supplemented existing siting guidance (10 CFR 100) in greater detail with Regulatory Guides, Technical Information Documents, and Safety Guides. Although DOE safety analysts use this NRC guidance where it can logically be applied, they desired a more generalized document, philosophical in principle, keyed to DOE Orders, and applicable to the diversity of DOE nuclear facilities. The Guide was written to provide guidance in greater detail than is possible in DOE Orders, without establishing new requirements not already stated in the DOE Orders. Flexibility is needed and is indeed allowed; however, some technical aspects of postulated accident analysis should be common. These aspects are pointed out in the Guide, generally with the proviso that methods or models other than those in the Guide may be used if justification can be provided. This applies especially to site-specific models and data developed for this purpose.

The scope of the Guide has been restricted to analysis of postulated radiological accidents for the purpose of siting and major design feature selection for DOE nonreactor nuclear facilities. The Guide does not deal with consequences involving workers inside the facility being evaluated. It should be considered only a guide, not a regulation. Although basically intended to apply only to future facilities, portions of the Guide apply to new processes in existing facilities. An example of the latter case is the postulated accident initiated by natural phenomena in a facility designed under old structural criteria. A new facility would be designed to withstand all credible natural phenomena, therefore no release would occur. This might not be the case for an existing facility which does not meet current criteria.

SITING GUIDELINES

Criteria or other substantive guidance related to siting and major design features of DOE nonreactor nuclear facilities are contained in DOE Orders 5480.1A and 6430.1. Specific radiological dose guidelines have been written for inclusion in Chapter I of Order 6430.1. These are presently in concurrence cycle. The authors of the Guide have followed the formulation of these guidelines and are presenting them in the Guide in their expected form.

The specific requirement exists in Order 5480.1A that DOE nuclear facilities are sited, designed, constructed, etc., in accordance with generally uniform standards, guides, and codes that are consistent with those applied to comparable licensed nuclear facilities. This carries on the generally accepted use of siting dose limits in 10 CFR 100 of 25 rem whole body or 300 rem thyroid to a person located at the site boundary for two hours following the accident. Radiological dose guidelines in 6430.1 as proposed are consistent with 10 CFR 100 whole body dose but considers other organ doses as shown in Table I.

TABLE 1. Radiological Guidelines (6430.1 proposed)[a]

Organ	Dose (rem)
Whole body	25
Thyroid	300
Bone surfaces	300
Lung	75
Effective dose equivalent	25

[a] These guidelines apply to the offsite person receiving the highest dose, assuming dose is accumulated over 50 yr from a single exposure.

Proposed guidance in 6430.1, Chapter I, initiates consideration of consequences other than dose to the offsite person. Although specific numerical guidance is not provided in any of these cases, the following should receive consideration:

- a reference onsite person (not in the facility under evaluation),
- environmental contamination (primarily a cleanup cost impact),
- population dose, and
- public health effects.

Any of the latter three impacts would aid decision making when several sites are being compared for suitability. Information on deriving each of these impacts is provided in the Guide.

The onsite person receives consideration because many adjacent facilities on DOE reservations may be totally unrelated to the facility under evaluation, that is, administrative or support buildings with very few features in common with the nuclear facility. In some cases, the only large populations near a DOE nuclear facility is an onsite population which, up to now, has received no direct consideration in the siting of nuclear facilities. The Guide attempts to aid the analyst in specifying the location and dose of the maximally exposed onsite person. Although economic and other ramifications of the onsite dose guideline have not been analyzed, a generally favorable consensus was reached among reviewers of the Guide.

ACCIDENT DESCRIPTIONS

The Guide recommends that postulated design basis accidents (DBAs) be described in the general form shown in Figure 1, Accident Release Steps, and Figure 2, Accident Consequences Steps. Operational accidents caused by internal initiators such as explosion, fire, nuclear criticality, or leaks (equipment failure or operator error) were discussed in terms of major features, publications containing historical data, and other information useful to the analyst in describing potential DBAs. Several event or incident summaries are available which contribute to available postulated accident descriptions, particularly in chemical processing activities. However, such summaries are not available for all nuclear operations with radiological accident potential. The Guide cites available references under each of the four accident categories listed above.

Treatment of natural phenomena as accident initiators is also discussed. Recent compilation by Lawrence Livermore National Laboratory of earthquake and tornado hazard models for a large number of DOE sites has provided significantly improved site-specific guidance for the analyst. Information remains limited when a damage estimate and a release fraction are to be selected.

Offsite sources of accident initiation are discussed in less detail. These might include aircraft, explosions, and upstream dams. If a site might be threatened by a credible event offsite, the analyst is expected to consider its effect. Similar guidance included in the NRC Standard Review Plan is considered generally applicable.

PARAMETERS, ASSUMPTIONS, DEFINITIONS, AND MODELS

Variation among analysts in the accident-related parameters they select, assumptions they make, definitions they use, and dispersion and dose models they select allows broad variation in results, sometimes several orders of magnitude. Also this variation might permit choices that lead to a preconceived or desired result rather than a result which is conservatively overestimated. The Guide has attempted to identify areas of major uncertainty and recommend values which have achieved a level of acceptability through use in past analyses. Where new data are available but perhaps not yet reviewed sufficiently to have gained general acceptance, the Guide has cited the source as background information without recommending its use.

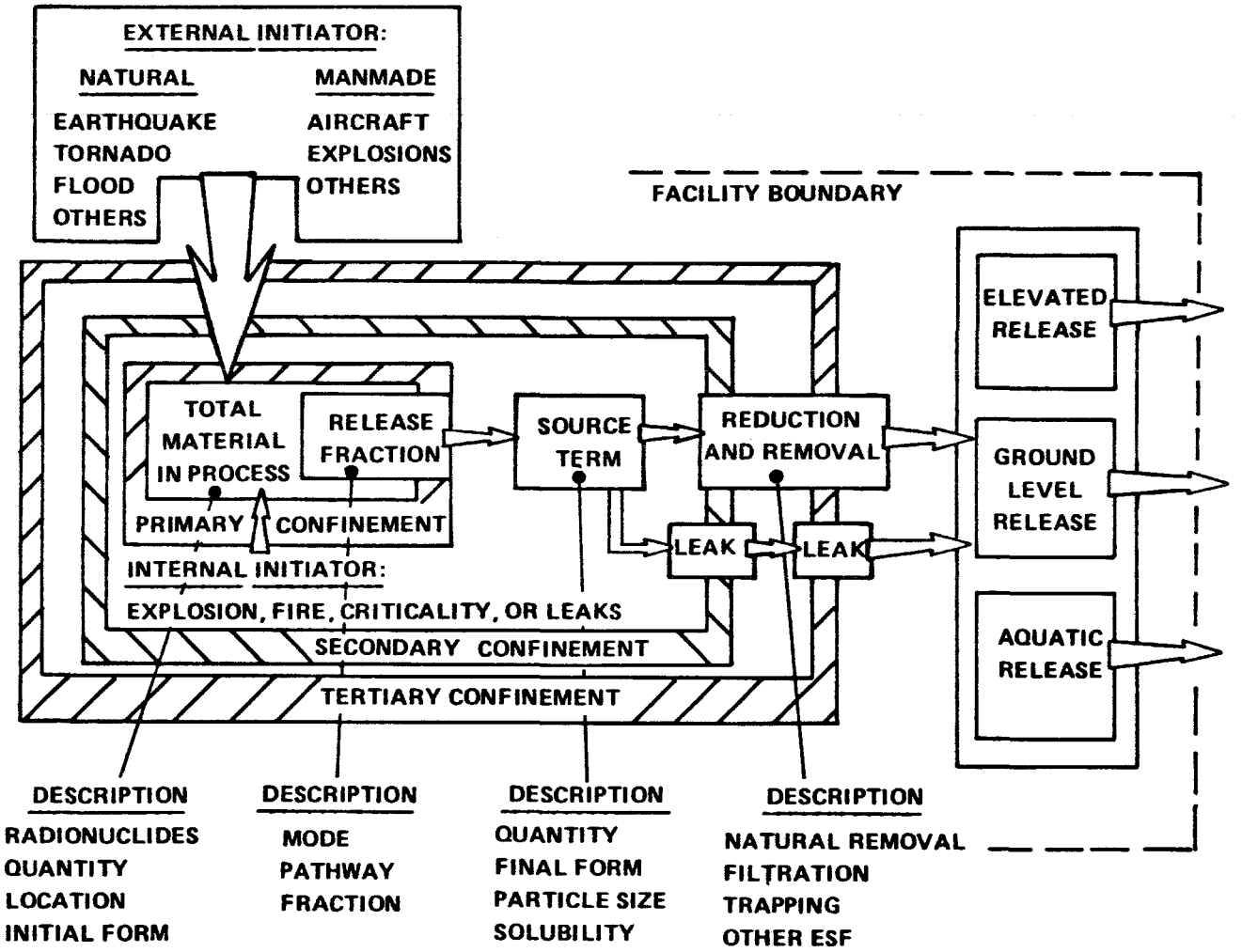

Figure 1. Postulated Accident Release Steps

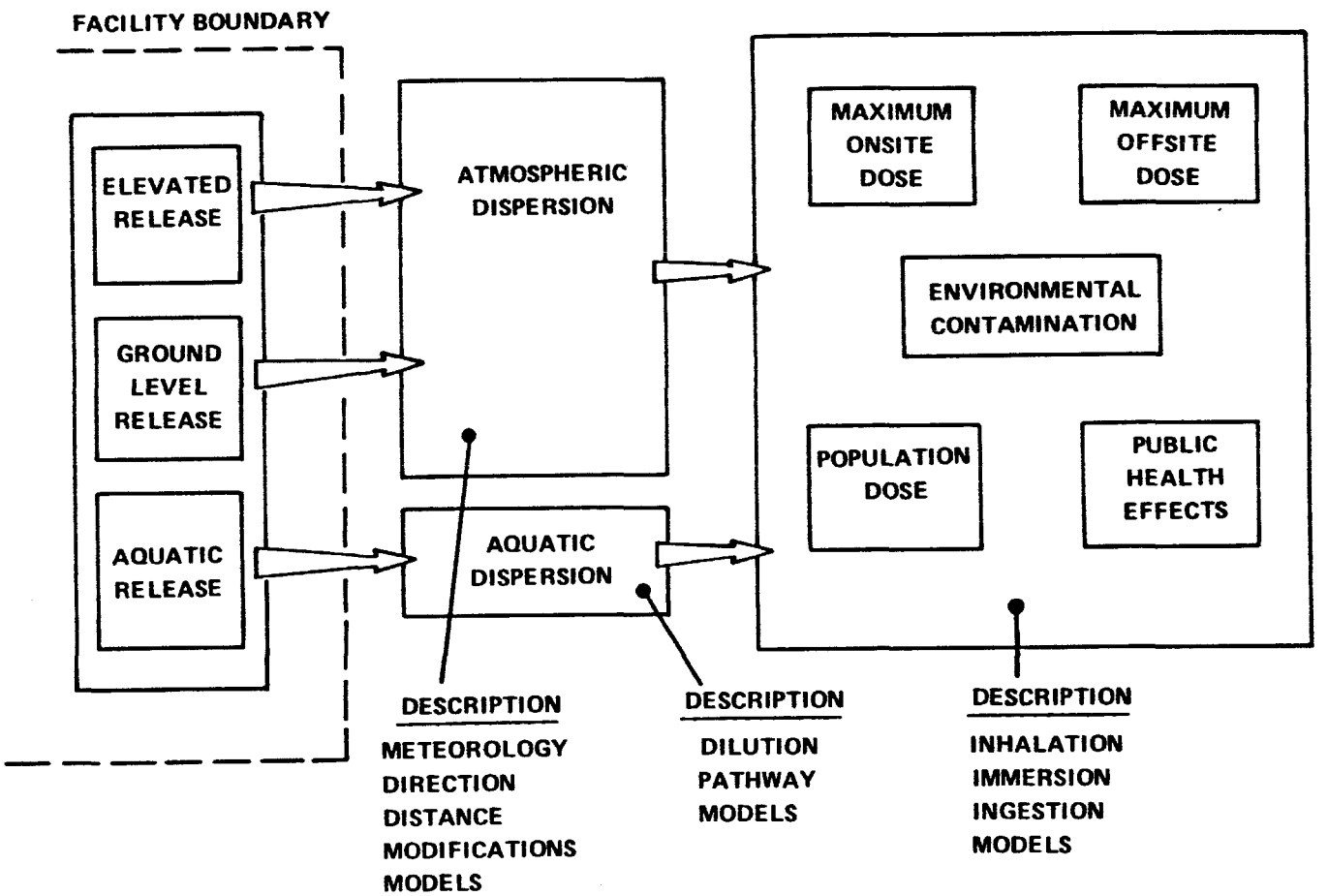

Figure 2. Postulated Accident Consequence Steps

The Guide addresses parameters, assumptions, definitions, and models in each of the following steps of the dose calculation:

- o source term,
- o release fraction,
- o reduction and removal factors,
- o release duration,
- o meteorological analysis and dispersion, and
- o radiological dose.

These major topics are discussed briefly in the following sections.

Source Term

The radionuclides released from primary confinement in readily dispersible form can be identified for spent fuel reprocessing, plutonium or reactor fuel processing, and nuclear criticality accidents. Computer codes are available which provide the amounts of fission products available for release after known periods of reactor operation and decay time. Other releases such as tritium or unmixed radioisotopes are straightforward. However, less information is available for the source term of large accelerators. The Guide provides available information for source terms of nonreactor nuclear facilities by reference.

Release Fraction

Values of the fraction of total radioactive material released from primary confinement in readily dispersible form are tabulated by several authors for a number of accident types. These values are discussed in the Guide with the acknowledgement that the use of other values may be justified. Particularly in question is the 50% halogen fraction assumed released from spent fuel; TMI-2 experience may lead to a reduced fraction in the near future.

Reduction and Removal Factors

This section deals with the reduction (natural means) and removal (engineered means) factors applied to the source term to determine estimated amounts of radioactivity released from the facility. Performance of engineered safety features (ESFs) is of primary interest and is discussed under three possible conditions accompanying an accident: 1) the ESF is unprotected from the effects of the accident and is destroyed or severely degraded, 2) the ESF is protected to an indefinite degree from the effects of the accident and some degradation of performance should be assumed, and 3) the ESF is fully protected from all effects of the accident and may be assumed to perform in accordance with test results. The analyst must decide which case best fits the postulated accident and assume credit (or lack of credit) appropriate to the accident. This approach is presented in the Guide as a reasonable approach to ESF credit which has not been uniformly applied in the past.

Release Duration

Postulated accidents at a DOE nonreactor nuclear facility are usually of short duration, which affects evacuation and dispersion assumptions. An effort should be made to describe the timing of the release, since peak concentrations, although shortlived, may be relatively high at some points of exposure.

Dispersion

The Guide discusses dispersion models applicable to the accident case, primarily the Gaussian plume model adjusted to simulate puff or short term plume dispersion. Ranges of applicability and expected accuracy are discussed, along with appropriate adjustments for special effects such as plume rise and building wake effects. Credit for such refinements has not commonly been taken in dose calculations for these dispersion effects; however, they become more important when relative concentrations at onsite points are calculated.

Two meteorological categories, median and unfavorable, are defined to cover the range of dispersion conditions. Offsite dose calculations should be based on unfavorable dispersion conditions; that is an unfavorable sector dispersion factor is the X/Q exceeded by 0.5% of the total hourly observations at the site. Median conditions, those in which the sector X/Q is based on the X/Q exceeded by 50% of the hourly dispersion factors in that one sector, are suggested for use when the onsite dose is calculated. This method applies expected meteorology to the controlled conditions onsite rather than the extreme conditions associated with the unfavorable case. This approach has not yet received formal approval by issuance in DOE Order 6430.1 but is recommended as reasonable in the Guide.

Dose Calculations

The Guide discusses the several models used for dose calculation, makes suggestions toward achieving greater consistency of results, and generally supports the apparent movement toward adoption of dose models similar to ICRP 30 models. Individual organ models are either described or presented by reference. Inhalation dose, direct dose by immersion in a radionuclide cloud, or dose by ingestion of material leaked to the aquatic environment receive emphasis as the most likely pathways of dose. Two of the major variables going into inhalation dose calculation, particle size and solubility, are discussed for their role in the calculation of organ dose using the ICRP Task Group on Lung Dynamics (TGLD) model.

The maximally exposed person may be assumed to be the ICRP reference man unless the accident causes special conditions, for example, conditions under which dose to the thyroid of an infant by the cow-milk-infant pathway might predominate. Other variables such as breathing rate, quality factor of the radiation, organ mass, and the like are recommended to add greater uniformity to dose calculations.

RISK ESTIMATION

Risk estimation as a method of site evaluation and design feature selection is a fairly recent development and is still in limited use. Treatment of this subject in the Guide is limited to discussion of risk assessment methods presently in use by a few DOE contractors. Both qualitative (informal) methods and probabilistic (formal) methods have seen some use in accident analysis at several DOE sites. However, because the DOE has not formally adopted a risk assessment method or requirement, the Guide acts only to encourage continued activity in this area, urges refinement of available risk assessment methods, and suggests that the DOE further investigate probabilistic criteria similar to the safety goals proposed by NRC.

Accidents with higher probability but lower consequences than the accident likely to be chosen as a DBA are also considered in the Guide, based on present practice at several DOE sites. If an accident is expected to occur with higher frequency than a DBA and to produce consequences outside the facility under evaluation, it should be evaluated against guideline doses lower than the guidelines presented in Table I.

SUMMARY

This paper describes a soon-to-be-issued guide prepared to aid safety analysts in selecting suitable sites and major design features for DOE nonreactor nuclear facilities. Siting of a proposed nuclear facility has been based on radiological dose guidelines. New guidelines proposed for inclusion in DOE Order 6430.1, Chapter I, and consideration of other potential consequences (environmental contamination, population dose and public health effects) of a major radiological accident receive special attention in the Guide. In addition to the offsite person who might receive dose, the Guide discusses the requirement proposed for inclusion in DOE Order 6430.1 that onsite personnel also be considered when site and major design features of the nuclear facility are selected.

The types of information and available sources needed to describe DBAs initiated by operational events, natural phenomena, or offsite manmade events are presented in the Guide. The discussion of natural phenomena applies primarily to existing facilities not designed to withstand the design basis events currently considered appropriate in DOE Orders.

Evaluation of consequences requires selection of assumptions, definitions, parameters, and models in each of the following areas: source term, release fraction, reduction and removal factors, release duration, meteorological dispersion, and radiological dose. The Guide provides information in each of these areas in addition to the consideration of environmental contamination, population dose, and public health effects. Of particular interest to the analyst will be the discussions of preferred dose model, credit for ESF under emergency conditions, credit for evacuation capability, and reporting of public health effects.

Use of risk estimation methods within the DOE complex has enhanced the accident analysis process at several sites, although preferred method or risk criteria have not been established. Increased effort in this area is encouraged although not specifically recommended in the Guide.