**Topical Issues on Performance Categorization
of Structures, Systems and Components for
Natural Phenomena Hazards Mitigation**

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December 1992

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EXECUTIVE SUMMARY

The proposed order DOE 5480.NPH for natural phenomena hazards (NPH) mitigation of DOE facilities requires classifying structures, systems, and components (SSCs) into five NPH performance categories, each with a different target performance goal based on their importance, mission, cost, failure consequence, and safety considerations. A DOE standard (DOE-STD-1021-92) has been developed for trial use that provides criteria and guidelines for the selection of these performance categories. The details of the topical issues that were considered in developing this proposed standard, as well as the issues that should be considered before finalizing this standard are discussed in this report.

The interrelationship among the various DOE documents that relate to the graded approach of SSC performance categorization has been discussed. The documents discussed include the proposed safety analysis rule (10CFR830), DOE's nuclear safety policy (SEN-35-91), DOE orders related to: general design criteria (DOE 6430.1A and B), safety design criteria (DOE 5480.RD & NNFDC), nuclear safety analysis reports (DOE 5480.23), NPH mitigation (DOE 5480.NPH), etc., and detailed guidelines and standards (DOE-STD-1027-92, DOE/TIC 11603, and UCRL-15910).

At present, DOE facilities and the SSCs comprising these facilities undergo several types of classification/categorization: (i) facility hazard categorization and classification per DOE 5480.23, DOE-STD-1027-92, and DOE 5481.1B, (ii) facility or SSC usage categorization per UCRL-15910 or proposed DOE-STD-1020-92, (iii) SSC safety classification per DOE 6430.1A (or B), DOE 5480.RD, and DOE 5480.NNFDC, and (iv) SSC NPH performance categorization per proposed DOE-STD-1021-92. The advantages and disadvantages of linking or consolidating some of these classification/categorization processes are briefly discussed. Specifically, the issue of linking facility hazard classification/categorization with SSC performance categorization has been examined and discussed in detail along with the issue of using dose-limit based criteria that can generally be made compatible with quantitative safety policy goals.

The issues of adverse system interaction and common-cause failure have been discussed and how these should be considered in the performance categorization process have been outlined. Similarly, the issue of considering environmental protection (in addition to worker, co-located worker and public life safety) as one of the parameters for performance categorization has been discussed briefly.

Based on the discussions of these topical issues, a set of criteria has been recommended for adoption in the proposed DOE standard on NPH performance categorization of SSCs.

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1.0 INTRODUCTION

Lawrence Livermore National Laboratory (LLNL), under contract to the United States Department of Energy (DOE), has been providing assistance in the development of criteria, standards, and guidelines for designing and evaluating DOE facilities subjected to natural phenomena hazards (NPHs). The NPH design/evaluation guideline document, UCRL-15910 (Reference 1) is one of the documents that resulted from this assistance. Even though UCRL-15910 is referred in the General Design Criteria DOE 6430.1A (Reference 2), it is not uniformly applied in the design/evaluation process of DOE facilities. To achieve uniform application of this document, and also to provide a comprehensive NPH mitigation program, an order, DOE 5480.NPH (Reference 3), has recently been developed that requires placing structures, systems, and components (SSCs) comprising DOE facilities into five performance categories (PC) based on importance, mission, cost, and safety considerations. DOE 5480.NPH refers to a standard, DOE-STD-1021-92 (under development, Reference 4) that will provide criteria and guidelines for the selection of SSC performance category. An interim version of this standard has been recently proposed for trial use. The details of the topical issues that were considered in developing this proposed standard, as well as the issues that should be considered before the standard is finalized, are discussed and presented in this report.

Facilities owned, operated or administered by DOE vary widely in mission, complexity, and hazard potential. NPH mitigation of these facilities involves an array of rules, policies, orders, and standards, which must be considered in the development of performance categorization criteria. The interrelationship among these documents, as these relate to SSC performance categorization, is discussed in Section 2.0 of this report. This discussion covers the existing documents as well as the documents that are presently being developed which may have some impact on NPH mitigation.

NPH performance categorization is an application of the "graded approach" in which the rigor, stringency, cost, and the level of effort in the design/evaluation process must commensurate with the importance, mission, and the safety hazard potential of the facility. Facility hazard categorization/classification is also performed applying this general principle of the "graded approach". Thus, a possibility exists that SSC performance category can be linked to the facility hazard category/class. This possibility is critically examined in Section 3.0.

Many DOE facilities maintain inventories of radioactive and other toxic materials potential release of which can adversely affect the life and safety of the workers, co-workers, and the general public. The performance goals, and hence the performance categories, of the SSCs comprising these facilities should thus be commensurating with the severity of such potential adverse effect. The toxic dose to workers, co-workers, or to the members of the public that may result from the non-performance or unacceptable behavior of an SSC is a commonly-used parameter to measure the adverse effects. The desirability of using such toxic dose limits as a basis for SSC performance categorization is discussed in Section 4.0 of this report.

There are many SSCs in DOE facilities whose behavior during NPH events may adversely affect the performance of other SSCs that are more important from mission, cost or safety considerations. Performance Categorization must consider such system interactions. Various methods of precluding adverse system interaction effects are presented in Section 5.0.

Very often the failure of a particular SSC during an NPH event may not have any adverse effect, but its failure in combination with the NPH-caused failure of other SSCs may adversely affect the mission, cost, or safety. Consideration of such common-cause failures in the performance categorization process is discussed in Section 6.0.

According to various DOE orders and General Design Criteria, specifically according to DOE 5480.NPH, NPH mitigation must include environmental protection in addition to the considerations for mission, cost, and life safety. How this can be considered in SSC performance categorization is discussed in Section 7.0.

A set of recommendations is presented in Section 8.0 that are based on the discussions in Sections 2.0 through 7.0. These recommendations can be adopted in the DOE standard on performance categorization (Reference 4) that has been presently proposed for trial use. However, the extent to which such adoption will be feasible will depend on the various provisions in several general and safety design criteria related orders that are presently being developed by DOE.

2.0 INTERRELATIONSHIP AMONG PERTINENT DOE DOCUMENTS

The documents that are pertinent to NPH design and evaluation of DOE facilities can be placed into the following three broad groups based on regulatory hierarchy:

Group I – Code of Federal Regulations (CFR), Executive Orders, and DOE Policy Statements.

Group II – DOE Orders

Group III – DOE Standards and Guidelines

2.1 Group I Documents

Group I documents that are pertinent to NPH performance categorization of SSCs are listed and briefly described in the following paragraphs:

a) 10CFR Part 830 (Proposed Rules, Reference 5)

10CFR Part 830.110, Safety analysis Report, proposes the rules of performing safety analyses of nuclear facilities, and requires the use of a "graded approach". It also requires that a hazard analysis be performed for each DOE nuclear facility to evaluate the consequences of unmitigated releases of radioactive materials. NPH performance categorization of SSCs can be considered a part of the overall process of implementing this rule.

b) Executive Order 12699 of January 5, 1990, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction (Reference 6)

This order provides the general requirements to reduce seismic risks to the lives of occupants of buildings owned or leased by the Federal Government, but exempts those federal agencies that require seismic safety levels higher than those imposed by this executive order. Since, existing DOE requirements (e.g. UCRL-15910) are more stringent, this executive order does not have any direct bearing on NPH performance categorization of SSCs.

c) SEN-35-91, DOE Nuclear Safety Policy (Reference 7)

This safety policy provides two quantitative safety goals to limit the risks of fatalities associated with DOE's nuclear operations (one for prompt fatality and the other for cancer fatality). These safety goals, even though general in nature, can be useful to develop design guidelines, and should be considered in NPH performance categorization of SSCs.

2.2 Group II Documents

There are a large number of DOE orders that covers various design and safety issues. Of these orders, those pertinent to NPH performance categorization of SSCs are listed and briefly described in the following paragraphs:

a) DOE 6430.1A, General Design Criteria (Reference 2)

This order provides design requirements for all DOE facilities, except nuclear reactor facilities. It has direct relationship with NPH performance categorization of SSCs because:

- (i) it requires that the facilities must be designed to withstand NPH effects,
- (ii) it provides some guidelines to select acceptable accident consequences (such as off-site radiation dose limits), and
- (iii) it defines the "Safety Class Items" whose failure could adversely affect the environment or the safety and health of the public.

This document refers to DOE/TIC 11603, Rev. 1 (Reference 8) for examples of safety classification of SSCs, and to UCRL-15910 (Reference 1) for NPH design and evaluation methodology. The scope and provisions of DOE 6430.1A will be significantly different when it is revised as DOE 6430.1B (Reference 29).

b) DOE 5480.23. Nuclear Safety Analysis Reports (Reference 9)

This order specifies the requirements for safety analyses that establish the adequacy of the safety bases of DOE nuclear facilities. Provisions of this order are similar to those in the proposed 10CFR830.110 (see 2.1 (a) above). This order requires accident analyses, hazard classification and the use of a graded approach, and as such, is pertinent to NPH Performance Categorization of SSCs.

DOE 5480.23 cancels certain parts of DOE 5480.5 (Reference 10), DOE 5480.6 (Reference 11), and DOE 5481.1B (Reference 12).

c) DOE 5481.1B. Safety Analysis and Review system (Reference 12)

This order establishes the requirements for the preparation and review of safety analyses of DOE facilities. After the issuance of DOE 5480.23, this order no longer applies to nuclear facilities, but applies to all other facilities. It is pertinent to NPH performance categorization of SSCs because it requires evaluating potential accidents including those resulting from natural phenomena, and uses a hazard classification method that is somewhat similar to the graded approach described in DOE 5480.23 and proposed 10CFR830.

d) DOE 5480.NPH. Natural Phenomena Hazards Mitigation (Proposed Order, Reference 3)

This proposed order will establish DOE policy and requirements for NPH mitigation of all DOE facilities except those licensed by the Nuclear Regulatory Commission and part of Naval Nuclear Propulsion Program that are excluded by Executive Order 12344 and Public Law 98-525. DOE 5480.NPH requires NPH performance categorization of SSCs using a graded approach, and provides NPH performance goals for five SSC categories in terms of annual probability of unacceptable behavior limits.

e) DOE 5480.NNFDC. Non-reactor Nuclear Facility Safety Design Criteria (Proposed Order, Reference 13)

This proposed order will establish the safety design criteria for DOE's non-reactor nuclear facilities (presently provided in DOE 6430.1A), and will define the "safety" systems for

these facilities, As such, this document will have some bearing on NPH performance categorization of SSCs.

- f) DOE 5480.RD, Safety Design Criteria for Nuclear Reactors (Proposed Order, Reference 14)

This proposed order will establish the safety design criteria for DOE's nuclear reactor facilities, and will define the "safety" systems for these facilities. As such, this document is pertinent to NPH performance categorization of SSCs.

2.3 Group III Documents

There are three Group III DOE documents that are pertinent to NPH performance categorization of SSCs. These are briefly described below:

- a) DOE-STD-1027-92, Guidance on Hazard Classification (Proposed Standard, Reference 15)

This proposed standard provides detailed guidelines for hazard classification of nuclear facilities for complying with the requirements given in DOE 5480.23. The hazard class of a facility can be used in a graded approach for categorizing the SSCs in that facility; as such, this document is pertinent to SSC performance categorization.

- b) DOE/TIC 11603, Nonreactor Nuclear Facilities: Standards & Criteria Guide (Reference 8)

This document, referred in DOE 6430.1A, describes various DOE facilities, and provides guidelines for general safety classification of SSCs in these facilities. Thus, this document provides information on the safety significance of SSCs that are of primary importance for NPH performance categorization.

- c) UCRL-15910, NPH Design and Evaluation Guidelines (Reference 1)

This document, referred to in DOE 6430.1A, presents NPH design and evaluation requirements that are performance-goal based. To ensure that the level of conservatism in NPH mitigation is appropriate for facility characteristics such as importance, mission, replacement/repair cost, and safety hazards (that may result from adverse facility

behavior during an NPH), UCRL-15910 sets target "performance goals" and groups DOE facilities into four usage categories, each with a different target performance goal.

UCRL-15910 is being revised and is being divided into several new documents. The basic NPH mitigation requirements have been included into DOE 5480.NPH (Reference 3) which will replace the UCRL-15910 "usage categories" by SSC "performance categories". The criteria and methodology for determining performance categories is being provided in a separate standard, DOE-STD-1021-92 (Reference 4), and the NPH design/evaluation methodology will be provided in a new standard, DOE-STD-1020-92 (Reference 21).

3.0 LINKAGE BETWEEN SSC PERFORMANCE CATEGORY AND FACILITY HAZARD CATEGORY/CLASS

At present, the design and safety adequacy of an SSC subjected to NPH is ensured through compliance with UCRL-15910 (Reference 1). The use of UCRL-15910 requires selection of "usage category" for the facility to which the SSC belongs. Usage categories are to be based on facility or SSC characteristics such as mission dependence, occupancy, amount and type of hazardous materials involved, and distance to population centers. Four usage categories were suggested for NPH design/evaluation of DOE facilities, and each usage category was assigned a "performance goal" (defined as annual probability of exceeding acceptable behavior limit, or simply, annual probability of failure), as tabulated below:

UCRL-15910 Usage Category	Performance Goal
General Use Facilities	$10^{-3}/\text{yr}$
Important or Low Hazard Facilities	$5 \times 10^{-4}/\text{yr}$
Moderate Hazard Facilities	$10^{-4}/\text{yr}$
High Hazard Facilities	$10^{-5}/\text{yr}$

Facilities or SSCs that process, handle, or store radioactive and other hazardous materials are to be placed into High, Moderate, or Low Hazard usage categories. Other facilities or SSCs are to be assigned to Important or General Use usage categories.

Before DOE 5480.23 (Reference 9) was issued, a separate document, DOE 5481.1B (Reference 12) required that the facilities associated with radioactive/hazardous materials be placed into one of the following three hazard classes:

- a) **Low:** Those which present minor on-site and negligible off-site impacts to people or the environment;

- b) **Moderate:** Those which present considerable potential on-site impacts to people or the environment, but at most only minor off-site impacts;
- c) **High:** Those with the potential for on-site or off-site impacts to large number of persons or for major impacts to the environment.

Since the bases for these three hazard classes are very similar to those for the UCRL-15910 Low, Moderate, and High usage categories, several DOE contractors have linked DOE 5481.1B hazard classes with UCRL-15910 usage categories for NPH design/evaluation of their facilities/SSCs. However, no generic DOE standard provides guidance to establish such a linkage.

For nuclear facilities, recently issued DOE 5480.23 also requires similar classification of facilities based on the consequences of unmitigated release of radioactive and/or hazardous materials:

- a) **Category 1 :** Those with a potential for significant off-site consequences.
- b) **Category 2 :** Those with a potential for significant on-site consequences.
- c) **Category 3 :** Those with a potential for only significant localized consequences.

The proposed standard DOE-STD-1027-92 (Reference 15) provides additional clarification to the above hazard categorization criteria for nuclear facilities, as summarized below.

- (i) **General Use Facilities:** Facilities that contain such quantities of radioactive materials, which if released, would not have to be reported to the Environmental Protection Agency (EPA), i.e., quantities less than those specified in Appendix B of 40CFR302.4 (Reference 16) (These quantities of radionuclides, if released, represent levels that would produce less than 1 millirem at several hundred meters).
- (ii) **Hazard Category 3 Facilities:** Facilities with sufficient quantities of radioactive materials to be reportable to the Environmental Protection Agency, i.e., quantities equal to or more than those specified in Appendix B of 40CFR302.4 (Reference 16).

- (iii) **Hazard Category 2 Facilities:** Facilities with sufficient quantities of radioactive/hazardous materials and energy that require on-site emergency planning. This is equivalent to quantities of radioactive materials whose unmitigated release could produce a total dose of 1 rem in the range of 100 to 300 meters from the facility (this is based on 10CFR30, Reference 17).

Also, this category includes facilities containing special nuclear materials in quantities equal to or more than the theoretical mass limits for criticality emergencies as specified in ANSI 16.1 (Reference 18) [These quantities for U_{233} , U_{235} , and Pu_{239} are 500, 700, and 450 grams, respectively], and facilities containing (non-radioactive) hazardous materials in quantities equal to or more than the threshold quantities specified in 29CFR1910.119 (Reference 19), or if not included in 29CFR1910.119 (Reference 35), in 40CFR355.

- (iv) **Hazard Category 1 Facilities:** Facilities with sufficient quantities of radioactive/hazardous materials and energy that, if released, would possibly result in off-site prompt fatalities. The dose criteria for prompt fatality have been specified as follows:

- Radiological Criteria: 100 rem Effective Dose Equivalent (EDE) received over seven days at the site boundary.
- Hazardous Chemical Criteria: American Hygiene Association's ERPG-3 concentration limits (Reference 20) at the site boundary.

Thus, it is observed that the facility hazard category, if determined using DOE-STD-1027-92 or equivalent methods, will be a good indicator of the consequences of unmitigated release. Even though the assessment of the risk associated with a facility should be performed considering its engineered safety features, the unmitigated release consequence is also a valid measure of the risk associated with it. (It may be considered as an indicator of the upperbound risk). Thus, the linkage between NPH facility usage categories of UCRL-15910 and facility hazard categories of DOE 5481.1B, DOE 5480.23, and DOE-STD-1027-92 has some rationale basis. Such a linkage, however, should be supplemented by some consideration of the engineered design features of a facility.

In the proposed performance categorization standard (Reference 4), SSC performance categories have been linked with the facility hazard categories/classes from the rationale discussed above. This has been done with some recognition of the engineered design features of the SSCs: an SSC belonging to a particular hazard category facility is placed into a performance category based on its safety classification according to the general design and safety design criteria DOE 6430.1A, 6430.1B, 5480.RD, or 5480.NNFDC. But, since the present safety classification method in these general and safety design criteria documents classifies SSCs into only two grades, safety and non-safety, the proposed categorization method in Reference 4 would place all safety SSCs of a facility in one performance category irrespective of their failure consequences. Thus, if the failure of an SSC in a Hazard Category 1 facility causes an off-site dose greater than 0.5 rem, it will be classified as a safety SSC, and placed in Performance Category 4 irrespective of whether the dose is 1 rem or 100 rem. Thus, this method does not truly meet the intent of graded approach, and has the potential to add unnecessary conservatism in the design and evaluation process.

As a remedy, it is recommended that an option be given to lower the performance category of an SSC, if its failure results in a dose level that is lower than a certain preset value. This option can be exercised if the cost associated with the dose calculation can be justified against the reduction in unnecessary design conservatism. This option of using dose limits as a categorization parameter is discussed in the next section.

An alternative remedy to lack of proper gradation in the Reference 4 performance categorization method would be to make SSC safety classification similar or identical to performance categorization, thereby classifying SSCs based on a single set of criteria and eliminating the need to correlate with the facility hazard category. This would result in a uniform treatment of all internal and external events including NPH-related events. Such a method would simplify the design and evaluation process enormously, and should be the near term goal of DOE.

4.0 DOSE LIMITS AS A CATEGORIZATION PARAMETER

In accordance with the graded approach of DOE 5480.23 (Reference 9) and the requirements of DOE 5480.NPH (Reference 3), NPH design and evaluation of SSCs in DOE facilities will be performed using SSC performance goals as targets. Performance goals vary with the SSC performance category, and have been specified in DOE 5480.NPH in terms of annual probability of exceeding acceptable behavior limits. To ensure that these performance goals meet the intent of the DOE safety policy SEN-35-91 (Reference 7), it will be necessary to select SSC performance categories such that the associated performance goals are generally compatible with the risk goals set in the safety policy. Presently, no DOE document provides guidance to establish any explicit or approximate correlation between SSC categorization and DOE's overall safety goals or risks.

The fact that SSC categorization is not explicitly or approximately correlated with the overall safety goals or permissible risk values is not unique for DOE facilities. In the commercial nuclear power industry also, which has identical safety goals, any correlation that may exist between, say, SSC safety classification and safety goals are not explicitly established. However, the need and rationale for some linkage between quantitative safety goals and SSC design rules have been recognized both in the commercial nuclear power industry as well as in the DOE community. For example, ANSI/ANS 51.1 (Reference 22) provides off-site radiological dose criteria for various plant events that may occur within the frequency range of 10^{-1} to 10^{-6} per year (See Table 4-1). Dose limits in this table have been specified as percentages of 10CFR50, Appendix I (Reference 23) and 10CFR100 (Reference 24) limits. In a somewhat similar way, DOE/TIC-11603 (Reference 8) provides, for DOE facilities, radiological consequence guidelines for various plant events that may occur within the frequency range of 1 (normal operation) and 10^{-6} per year (See Table 4-2 and Figure 4-1). DOE 6430.1A (Reference 2) also specifies, as part of siting criteria, radiological dose limits for low probability accidental events that are very similar to 10CFR100 limits. Similar guidelines should be developed to correlate SSC performance category and the maximum radiological or toxic doses that may result from an SSC failure, while meeting the intent of the safety policy,

The use of dose limits as a performance categorization parameter has several advantages. The primary advantage is that it provides a rational basis for grading safety-related SSCs in proportion to the relative severity of SSC failure consequences. If dose limits or some other measures of SSC failure consequence are not used as criteria for performance categorization,

all SSCs in a given facility, whose failure may result in a loss of confinement/containment, would have to be placed in the same category irrespective of the size and the consequence of the release. This will not be an appropriate use of the "Graded Approach".

It is recognized that dose calculation may sometimes lead to a sizable and expensive effort. But, in certain cases, the use of dose limits as categorization criteria can be cost-effective. For example, consider a facility with a large inventory of radioactive materials for which the facility has been assigned a Hazard Category 1 status. Assume that the design of the facility is such that the HVAC system of the facility may leak when subjected to the design level hazard loads, but the potential release at the site boundary would be a very small fraction of 10CFR100 limits. If dose limits are not used as categorization criteria, the HVAC system must be assigned to PC-4, even though its failure is essentially inconsequential from exposure considerations. This may unnecessarily lead to a very expensive design upgrade. On the other hand, if dose limits are used as categorization criteria, the HVAC system would be assigned to a lower performance category, the design hazard level for which may be such that no design upgrade would be necessary.

The need for some standardized guidelines linking performance categorization and dose limits can also be recognized when one compares the dose limits that are presently being used at various DOE sites. A quick review of sample categorization criteria documents of three DOE facilities shows a wide variation of dose limits used (see Table 4-3). Such a wide variation in criteria among various facilities can be eliminated if safety-policy based dose limits are specified in the SSC performance categorization standard.

As was indicated in the last paragraph of Section 3.0, the use of dose limits, as measures of SSC failure consequence, can alternatively be used in the SSC safety classification process. This may serve the same purpose of gradation, and may even be more desirable if classification rules require adherence to performance goals and groupings similar to those recommended in DOE 5480.NPH. However, presently SSCs are simply classified into two groups: safety SSCs (whose failure may result in more than 0.5 rem off-site dose) and non-safety SSCs. Until these safety classification rules are modified to be compatible with the performance goals and groupings of DOE 5480.NPH, it is recommended that the dose limits recommended in this report be used for SSC performance categorization.

DOE nuclear safety policy, SEN-35-91 (Reference 7) sets the following two quantitative safety goals:

- a) *The risk to an average individual in the vicinity of a DOE nuclear facility for prompt fatalities that might result from accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatalities resulting from other accidents to which members of the population are generally exposed. For evaluation purposes, individuals are assumed to be located within one mile of the site boundary.*
- b) *The risk to the population in the area of a DOE nuclear facility for cancer fatalities that might result from operations should not exceed one-tenth of one percent (0.1%) of the sum of all cancer fatality risks resulting from all other causes. For evaluation purposes, individuals are assumed to be located within 10 miles of the site boundary.*

In addition to setting these two goals, SEN-35-91 also provides the following guidance:

- *DOE shall pursue the evolution of additional potential safety goals for plant and co-located workers to support enhanced safe operations of its facilities.*
- *DOE recognizes there are large uncertainties in the data and available methods for assessing risk levels especially with respect to potential health effects from nuclear facility operations. Therefore, reasonable analyses based on available data using standardized approaches may be employed while more rigorous approaches and better data are developed.*
- *DOE safety goals are aiming points and are not substitutes for compliance with DOE directives and nuclear safety-related rules.*
- *The adoption of safety goals should not be construed as a requirement to conduct probabilistic risk assessments.*

John Ahearne, Chairman of the Advisory Committee on Nuclear Facility Safety (ACNFS), in his January 1992 letter (Reference 30), was very critical of DOE's nuclear safety policy SEN-35-91. He found the policy "fundamentally flawed" on several grounds. Some of his comments, which can be used to justify dose-limit based SSC categorization, are reproduced below.

- *As a standard for the protection of the public, the document adopts the quantitative safety goals previously formulated by the Nuclear Regulatory Commission, but makes no mention of any such standards for the plant workers or for protection of the environment. Yet the DOE has an entirely different risk profile from NRC, with worker safety and environmental protection dominating, and chemical risk often more important than radiation.*
- *The document speaks of shared responsibility between DOE and its contractors, but never addresses the question of just how the responsibility is to be shared. For example, it states in one place that the contractor management is responsible to "maintain a proper balance of safety, production goals, and cost considerations." However, the Department certainly should have the major role in setting the appropriate balance. The division of responsibility is an extremely important question, ..."*
- *The draft describes the safety goals as "aiming points," without explaining the term. That diminishes their stature, and seems to send the message they should not be taken seriously. Perhaps not, but then why promulgate them? ... the fundamental problem of how to use quantitative safety goals, once promulgated, is as important as their statement.*
- *There is much stress on the development of a "culture that is dedicated to continuously striving to enhance nuclear safety." ... a policy of continuous enhancement has no visible end point, can become an end in itself long past the point of diminishing returns, and can ultimately waste resources without commensurate safety benefit. The purpose of safety goals is to establish a reasonable standard for judging when enough is enough. To not confront this point is to miss the purpose of safety goals.*
- *The central question of all risk management is how to balance the inevitable residual level of risk against both the costs of further reduction and the requirement to do the assigned job with the available resources. The document states too simplistically that "assurance of adequate safety will not be compromised," without any effort to clarify what is meant by the words "adequate," "assurance," and "compromised". Does the Department intend to leave the definition of "adequate" to each individual, or even each facility? The document states that safety and production goals are "mutually compatible," but provides no guidance on how the real conflicts between them are to be resolved.*

4.1 Offsite Radiation Dose Limits

The most widely-quoted offsite dose limit is the one given in 10 CFR 100 (Reference 24) that essentially specifies the limits for accidental or emergency dose as 25 rem whole body and 300 rem to the thyroid. For easy reference, the complete text of subpart 100.11 that sets these limits are reproduced in Appendix A of this report. The general design criteria, DOE 6430.1A, uses similar dose limits, even though it does not refer to 10 CFR 100. Again, for easy reference, the pertinent paragraphs from sections 0200-1.2 and 0200-1.3 of DOE 6430.1A are reproduced in Appendix B of this report.

A different accidental offsite dose limit (5 rem to the whole body or to any organ) has been specified in 10 CFR 72 (Reference 31) for Independent Spent Fuel Storage Installations. Yet another offsite dose criteria (0.5 rem or more) was used to define "Important-to-safety" SSC in 10 CFR 60 (Reference 32) for the design of High Level Radioactive Waste Repositories.

Since the above dose limits were specified without any reference to NRC's safety policy (numerical safety goals are identical to DOE's SEN-35-91, see Reference 33), an attempt is made here to determine/estimate off-site dose limits that are compatible with the numerical safety goals. It is recognized here that there are large uncertainties in the data and the methods for assessing health/life risks. As such, the compatible dose limits estimated here will be approximate. However, such approximations are unavoidable, but for categorization purposes, can provide a rational way of determining the relative safety importance of SSCs.

To estimate compatible dose limits, only prompt fatality risk goals will be considered here because it will provide more conservative dose limits (concluded from Reference 33 discussion, partly reproduced below):

... the prompt fatality objective for protecting individuals generally provides even greater protection to the population as a whole. That is, if the quantitative objective for prompt fatality is met for individuals in the immediate vicinity of the plant, the estimated risk of delayed cancer fatality to persons within 10 miles of the plant and beyond would generally be much lower than the quantitative objective for cancer fatality.

The annual prompt fatalities from all accidents in the United States is approximately 93,500 (Reference 34). If the total population of the United States is assumed to be 250 million, and if it is assumed that all individuals within one mile of the site boundary are at equal risk, then the safety policy compatible risk is about $(.001 \text{ times } 93,500 + 250 \times 10^6 =) 3.7 \times 10^{-7}$ per year. However, the intent of the policy is to compute this number on an average basis (both

biologically as well as locationally) as evident from the following discussion in Reference 33:

The average individual in the vicinity of the plant is defined as the average individual biologically (in terms of age and other risk factors) and locationally who resides within a mile from the plant site boundary. This means that the average individual is found by accumulating the estimated individual risks and dividing by the number of individuals residing in the vicinity of the plant (defined as the area within 1 mile of the nuclear power plant site boundary).

Thus, if locational distribution (due to wind, dispersion, and distance from the site boundary) is considered, it is very likely that the maximum permissible risk to a biologically-average individual would be several times higher than the 3.7×10^{-7} per year value. A factor of 2 is assumed conservatively, which sets the risk level to 7.4×10^{-7} per year.

This value, when divided by the performance goal values for various SSC performance categories, will provide the prompt fatality risk (probability) values for selecting dose limits. These risk values are shown in Table 4-4 (3rd column). Thus, for example, the dose limit for a PC-4 SSC should correspond to a 7.4 percent prompt-fatality risk and for a PC-2 SSC should correspond to a 0.15 percent prompt-fatality risk.

Too few data are available that correlate dose received versus probability of prompt fatality (PPF). Those that are available are often inconclusive. The relationship between dose and PPF is very complex, and is influenced by many parameters. However, for the present purpose of selecting dose limits as criteria for performance categorization, an approximate range of values is considered adequate.

After reviewing recent study and research results, Reference 25 recommends that the radiation dose corresponding to a 50% PPF be taken as 430 rem. Reference 26 shows that the 50% PPF dose is between 400 - 500 rem. Reference 25 also indicates that between 100 to 200 rem exposure, the prompt fatality rate is below 10 percent. Reference 27 indicates that the whole body exposure in the range of 100 - 200 rem is "rarely" fatal. Considering these recommendations and observations, the dose corresponding to 7.4% PPF is taken as 250 rem, as shown in the 4th column of Table 4-4.

Reference 25 shows that below 50 to 100 rem exposure, PPF is almost negligible. Reference 26 indicates that at low dose regions for which direct observational data are not available, the relationship between dose and PPF can be conservatively assumed to be linear.

The interim DOE standard STD-1027-92 (Reference 15), using WASH-1400 as the basis, has set 100 rem as a conservative dose corresponding to a PPF of 0.01 or 1 percent. Using this as one node point (i.e., dose = 100 rem, PPF = 0.01), and the zero node point (i.e., dose = 0 rem, PPF = 0.0), and linearly interpolating in-between, the radiation dose limits for other performance categories are set as shown in the 4th column of Table 4-4.

Thus, the dose limit for Performance Category 4 SSCs that is compatible with the safety goal is approximately 250 rem, if it is assumed that the particular SSC failure is the only contributor. But, in general, many SSCs from more than one facility in the site can potentially contribute, and SSC failure may be caused by more than one internal and external design basis events. If these are considered, the dose limits should be much smaller than those shown in the 4th column of Table 4-4. These considerations are very complex, and are possible only while performing a probabilistic risk assessment (PRA) of the facility, and not while setting a dose limit for design evaluation or categorization purposes. A practical and conservative way would be to lower the dose limits shown in the 4th column of Table 4-4 by an order of magnitude. Accordingly, the radiation dose limits in Column 5 of Table 4-4 are set by dividing column 4 dose limits by 10. These values are recommended for use in the performance categorization of SSCs in DOE's nuclear facilities. These values, even though not rigorously derived, provide a rational method of gradation that would meet the intent of the graded approach and would be generally compatible with the safety policy.

4.2 Radiation Dose Limits for Workers and Co-located Workers

Workers and co-located workers are protected against excessive radiation exposures during normal operations by complying with the requirements given in DOE 5480.11 (Reference 28), DOE 6430.1A, and other applicable documents. But potential exposures of workers and co-located workers that may result from NPH-related or other accidental events are not covered in any of these documents or in any design guideline documents. Emergency planning and evacuation procedures are generally assumed to provide the necessary level of worker and co-located worker protection. DOE nuclear safety policy, SEN-35-91, also does not provide any specific policy guidance on this issue, except that it states:

DOE shall pursue the evolution of additional potential safety goals for plant and co-located workers to support enhanced safe operations of its facilities.

One rational way of setting dose limits for workers and co-located workers would be to permit doses in proportion to the level of voluntary involvement of the worker to plant operation processes, the level of training that the worker has undergone to

protect himself/herself from the adverse effects of accidental releases, and the number and effectiveness of barriers between the worker and the accidental release location. Thus, the dose limit for a worker, who is directly involved with the operation or the process and is located within the confinement/barrier structure, can rationally be higher than that for a co-located worker, who has entered the secured area of the site/facility, has only general knowledge of the associated hazards, but is outside the confinement/barrier and does not have direct involvement with the operation or the process from which accidental release may occur.

Additional design constraints may be imposed by way of limiting the number of workers and co-located workers who can receive certain specified doses from accidental events (including NPH-related events). However, selection of such limits on the number of personnel as well as on the permissible dose should depend on the facility and site layout, facility mission, personnel distribution within the facility/site, and the proximity of the facility to population centers. Specifying these limits generically for various performance categories of SSCs may impose severe restrictions on the design, operation, and maintenance of the facility that may be incompatible with its mission. Specifying generic dose limits for accidental exposures of workers located in the immediate vicinity of the release location within the confinement/barrier will be especially difficult and should be selected and approved on a case-by-case basis. However, for consistency of application between various facilities and sites, some simple non-mandatory guidelines can be established through a consensus process. One such simple guideline is proposed in Table 4-5, in which the dose limits for workers and co-located workers are selected as multiples of off-site accidental dose values (5 for the workers within the confinement/barrier, 2 for co-located workers outside the confinement/barrier, but within the site).

4.3 Accidental Toxicity Dose Limits

Compatible prompt fatality risk values shown in the third column of Table 4-4 are also applicable for the determination/selection of toxicity dose limits. To set toxicity dose limits that are compatible with these risk values, guidance can be taken from DOE Standard 1027-92 (Reference 15) and American Industrial Hygiene Association's Emergency Response Planning Guidelines (ERPG)(Reference 20). Standard 1027-92 basically defined Hazard Category 1 facility as the one with significant potential for off-site prompt fatality, and ERPG-3 doses are defined as those below which the potential for prompt fatality is considered insignificant. Then,

the off-site toxicity dose limits for various SSC performance categories can be set as shown in Table 4-6. Even though dose and risk relationship are likely to be different for different toxic materials, for simplicity, Table 4-6 off-site values are selected assuming a linear relationship. However, to qualitatively compensate for the uncertainty in the dose-risk relationship, the other two ERPG dose limits (i.e. ERPG-2, and ERPG-1) have also been considered in selecting dose limits as shown in Table 4-6. This will ensure that the dose limits are not excessively conservative.

The discussion on the selection of radiation dose limits for workers and co-located workers in Section 4.2 above are also applicable for toxicity dose limits. However, since data on dose-risk relationship for toxic materials are more complex and scarce than that for radiation, smaller factors over off-site limits are proposed (i.e. 3 and 1.5 instead of 5 and 2).

It is recognized that the dose limits proposed in Table 4-6 are qualitatively derived. However, in the absence of more rigorously-derived data, the use of Table 4-6 values as optional criteria for a performance categorization of SSCs will provide a convenient way of meeting the intent of the safety goal and graded approach.

Table 4-1

**Offsite Radiological Dose Criteria for Plant Conditions
(From Reference 22)**

Best-Estimate Frequency of Occurrence (F) Per Reactor Year	Plant Condition	Offsite Radiological Dose Criterion
Normal Operations	1	10 CFR 50, App I
$F \geq 10^{-1}$	2	10 CFR 50, App I
$10^{-1} > F \geq 10^{-2}$	3	10% 10 CFR 100
$10^{-2} > F \geq 10^{-4}$	4	25% 10 CFR 100
$10^{-4} > F \geq 10^{-6}$	5	100% 10 CFR 100

Table 4-2

**Safety Guidelines in Terms of Probability of Occurrence and Consequence
(From Reference 8)**

Plant Operating Condition	Estimated Annual Probability of Occurrence, P	Radiological Consequence Guidelines
I. <u>Normal Events:</u> Events that are planned to occur regularly in the course of normal facility operation	$P \leq 1$	DOE 5480.1A, Chapter XI
II. <u>Anticipated Events:</u> Events of moderate frequency which may occur once or more during the life of a facility	$1 \geq P \geq 10^{-2}$	DOE 5480.1A, Chapter XI
III. <u>Unlikely Events:</u> Events which are not expected, but which may occur during the lifetime of a facility	$10^{-2} > P \geq 10^{-4}$	DOE 5480.1A, Chapter XI up to a "small fraction." (i.e., 10%) of the Condition IV dose guidelines
IV. <u>Extremely Unlikely Events:</u> Events which are not expected to occur during the life of a facility but are postulated because their consequences would include the potential for the release of significant amounts of radioactive material and because they represent upper bounds on failures or accidents with a probability of occurrence sufficiently high to require consideration in design.	$10^{-4} > P \geq 10^{-6}$	"Well within," (i.e., 25%) of the Condition IV dose guidelines up to a maximum of ≤ 25 rem whole body, ≤ 300 rem thyroid, ≤ 300 rem bone surface, ≤ 75 rem lung, and ≤ 75 rem any other organ as prescribed in DOE 6430.1, Chapter I. In some cases, DOE 5480.1A, Chapter XI emergency exposure guidelines may be applied.
V. <u>Incredible Events:</u> Events of extremely low probability of occurrence or non-mechanistic hypothetical events	$P < 10^{-6}$	Accidents in this class may have the potential for exceeding the consequence guidelines for Operating Condition IV.

Table 4-3

Sample of Dose Limits Used for SSC Categorization at 3 DOE Sites

Site	DOSE LIMIT					
	High Hazard Facility		Moderate Hazard Facility		Low Hazard Facility	
	Off-Site Max.	On-Site Max	Off-Site Max	On-Site Max	Off-Site Max	On-Site Max
A	20 rem to any person	20 rem to 100 persons or more	5 rem to any person	20 rem to 5 persons or more	—	—
B	20 rem to any person	400 rem to any person	10 millirem to any person	5 rem to any person	—	Measurable Radiation
C*	≥ 100 rem to any person	≥ 100 rem to any person	Less than 100 rem to any person	≥ 100 rem to any person	Less than 3 rem to any person	Less than 100 rem to any person or ≥ 100 rem to more than two workers

* Also permits the following doses for No-Hazard Facilities:

Offsite Max = Incidental dose

On-site Max < 100 rem to any person

Table 4-4

**SEN-35-91 and DOE 5480.NPH Compatible Prompt Fatality Risk Values
and Dose Limits at Site Boundary**

Performance Category	Performance Goal ⁽¹⁾	Compatible Prompt Fatality Risk (%)	Total Radiation Dose Limits (rem, EDE)	Recommended Radiation Dose Limit (rem, EDE) ⁽³⁾
4	10 ⁻⁵	7.4	250	25(100) ⁽²⁾
3	10 ⁻⁴	0.74	50	5(20)
2	5x10 ⁻⁴	0.15	10	1(4)
1	10 ⁻³	0.07	5	0.5(2)
0	N/A	N/A	N/A	N/A

Note 1: From DOE 5480.NPH (Reference 3)

Note 2: Values in the parenthesis are percentages of 10CFR100 dose limit, which are basically as follows:

- Total radiation dose to the whole body 25 rem
- Total radiation dose to the thyroid from Iodine exposure 300 rem

Note 3: For sites surrounded by large sparsely-populated areas higher dose may be permitted upon justification and DOE's approval on a case-by-case basis.

Table 4-5**Radiological Dose Limits for Performance Categorization (1)**

Type of Exposure/Dose	SSC Category			
	PC-4	PC-3	PC-2	PC-1
a. Dose at the site boundary to any person. (2)	100%	20%	4%	2%
b. Dose to workers located within the confinement/barrier (3)	500%	100%	20%	10%
c. Dose to co-located workers outside the confinement/barrier, but within the site. (3)	200%	40%	8%	4%

Note 1: Limits are expressed as percent of 10CFR100 Offsite Radiation Dose Limits, which are basically as follows:

- Total Radiation Dose to the Whole Body 25 rem
- Total Radiation Dose to the Thyroid from Iodine Exposure 300 rem

Note 2: For sites surrounded by large sparsely-populated areas higher dose may be permitted upon justification and DOE's approval on a case-by-case basis.

Note 3: These limits should be used as non-mandatory design guidelines, and not as mandatory requirements.

Table 4-6
Toxicity Dose Limits for Performance Categorization (1)

Type of Exposure/Dose	SSC Category			
	PC-4	PC-3	PC-2	PC-1
a. Dose at the site boundary to any person ⁽²⁾	ERPG-3	Larger of ERPG-2 or 20% of ERPG-3	Larger of ERPG-1 or 4% of ERPG-3	Larger of ERPG-1 or 2% of ERPG-3
b. Dose to workers located within the confinement/barrier ⁽³⁾	300% of ERPG-3	Larger of ERPG-2 or 60 % of ERPG-3	Larger of ERPG-1 or 12% of ERPG-3	Larger of ERPG-1 or 6% of ERPG-3
c. Dose to co-located workers outside the confinement/barrier, but within the site. ⁽³⁾	150% of ERPG-3	Larger of ERPG-2 or 30% of ERPG-3	Larger of ERPG-1 or 6% of ERPG-3	Larger of ERPG-1 or 3% of ERPG-3

Note 1: Emergency Response Planning Guidelines (ERPG) are used to define dose limits. These are defined by the American Industrial Hygiene Association (Reference 20) as follows:

- The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.
- The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

Note 2: For sites surrounded by large sparsely-populated areas higher dose may be permitted upon justification and DOE's approval on a case-by-case basis.

Note 3: These limits should be used as non-mandatory design guidelines, and not as mandatory requirements

Figure 4-1

Simplified Illustration of the Intent of the Radiological Consequence Guidelines (from Reference 8)

5.0 CONSIDERATION OF SYSTEM INTERACTION

An SSC that has been designed to remain within its acceptable behavior limits during and after its design basis NPH event (hereafter designated as the "target" SSC) can still be adversely affected by the behavior of other SSCs (hereafter designated as "source" SSC). This phenomenon is commonly referred as system interaction. In determining the performance category of SSCs such adverse interaction between the source and the target must be considered.

Adverse system interaction effects can be of several types depending on the system configuration and functions. Typical adverse interactions can be grouped into one of the following types:

- (i) Structural Failure: Inadequately designed, inadequately anchored, and unanchored components may fail, slide, and/or topple and fall on or bump into other components that are not designed to withstand such interaction effects.
- (ii) Proximity and Impact: Adjacent components may impact each other causing damage if the clearance between them is inadequate for NPH - induced deflections. Such adverse interaction may occur even if the deflection of the source is within its design limits.
- (iii) Differential Displacement: A target SSC (e.g. vital cable trays, pipes, ventilation ducts) may span between different structural systems (source). Differential displacements between the structural systems may be within acceptable behavior limits for the various components of the structural system, but may still affect the target SSC adversely.
- (iv) Mechanical or Electrical Failure: The failure of a source mechanical or electrical component may impair the safety function of another target component or system (e.g. the failure of a valve in a non-safety water distribution system causing flooding that short-circuits a safety class electrical motor).

The source SSC may adversely interact with the target SSC even if it is within its acceptable behavior limits. Adequate measures must be taken to prevent or preclude such interactions. Changing the performance category of the source SSC may mitigate such an adverse system

interaction, but it is not generally the most cost-effective way. Instead, a better mitigation method may consist of creating sufficient separation between the source and the target, building barriers between the source and the target, stiffening the source or its support system, installing new components, modifying existing components, or any combination of these measures.

If the source SSC can adversely interact with the target only after it exceeds its acceptable behavior limits (i.e. after its failure), any of the measures listed in the paragraph above may be taken, or the source SSC may be required to satisfy additional NPH requirements such that the performance goal of the target SSC is not compromised.

Specific recommendations have been made in Section 8 to mitigate adverse system interaction effects discussed in the preceding paragraphs.

6.0 CONSIDERATION OF COMMON-CAUSE FAILURE

Very often, the failure of an SSC by itself during an NPH event may not result in any adverse effect, but its failure with other SSCs may. This phenomenon, usually referred to as common-cause or common-mode failure, must be recognized while determining the performance category of SSCs. Consideration of common-cause failure effects is best done during the systematic evaluation of plant accident conditions when safety classification of SSCs is performed. However, it is also important to consider these during SSC performance categorization, because NPH events, especially earthquake, usually affect many or all SSCs in a facility, thereby increasing the potential for multiple SSC failure.

The criteria recommended in Section 8 explicitly takes into account the possibility of common-cause failure of SSCs.

7.0 Environmental Protection as a Categorization Parameter

Both DOE 5480.23 and 5480.NPH requires environmental protection from NPH effects. As such, it is essential that environmental protection gets considered, either directly or indirectly in the SSC performance categorization process (note also ACNFS Chairman, John Ahearne's comment in Section 4.0). One way to achieve this would be to provide environmental protection related clauses in performance categorization criteria. Alternatively, similar clauses can be included in the general design criteria (DOE 6430.1A) or safety design criteria (DOE 5480.NNFDC and DOE 5480.RD) documents.

Criteria should be provided to protect the environment not only from the adverse effects of radioactive and toxic materials that are harmful to human, but also from materials that are harmful to the environment (even if these may be benign to human). For example, if a large tank containing oil fails and spills oil during a seismic event, no worker or public life may be directly endangered, but the quantity of release may be such that it is unacceptably harmful to the environment (e.g., groundwater, wild life or vegetation). The design of such a tank should be based on criteria that are relatively more stringent than for the tank whose failure does not adversely affect the environment from NPH considerations. This can be best achieved by placing the tank in a higher performance category.

To appropriately consider environmental protection in the SSC performance categorization process, it will be necessary to establish the permissible limits of radioactive/toxic and non-toxic materials that can be released to the environment following the NPH-related failure of various performance category SSCs. Ideally, these permissible limits should be based on some kind of policy goals on environmental risks similar to those established for prompt fatality and cancer death risks in SEN-35-91 (Reference 7). No such environmental protection policy goals have yet evolved which can be used to correlate frequency of NPH-related accidental events and the permissible limits of releases. However, till any such policy evolves, release limits given in the facility hazard classification standard, DOE-STD-1027-92 (Reference 15) can be used for SSC Performance Categories 2 and 3. Since these release limits are based on the assumption of unmitigated release and does not explicitly take into account the engineered safety design features in a facility, the use of these limits in SSC performance categorization will be conservative.

For PC-4 SSCs, limits on quantities of radioactive/ hazardous materials that can be released to the environment have not been explicitly established, but can be specified as quantities equivalent to that can cause prompt fatality at the site boundary.

The criteria recommended in Section 8 considers environmental protection as a performance categorization parameter as discussed above. However, additional research and discussions will be necessary for rational development of release quantity limits that will be consistent with other existing rules and orders related to environmental protection.

8.0 RECOMMENDATIONS

In this section, a set of criteria has been recommended for SSC performance categorization. These criteria were developed based on the topical discussions presented in the previous sections.

8.1 General Recommendations

- (a) Data and information necessary for SSC performance categorization should be obtained from the design basis system studies, accident analyses, and calculations performed for the following purposes:
 - (i) Hazard classification of all facilities, except nuclear facilities, in accordance with DOE 5481.1B (Reference 12) which results in facility hazard classes: High Hazard (HH), Moderate Hazard (MH), and Low Hazard (LH).
 - (ii) Hazard categorization of nuclear facilities in accordance with DOE 5480.23 (Reference 9) and DOE-STD-1027-92 (Reference 15) which results in facility hazard categories HC1 (highest), HC2, and HC3 (lowest).
 - (iii) Safety classification of SSCs in accordance with DOE 5480.RD (for nuclear reactor facilities, Reference 14), DOE 5480.NNFDC (for non-reactor nuclear facilities, Reference 13), and 6430.1B (other facilities, Reference 29) which results in the identification of safety and non-safety systems.

For facilities not covered by the above numbered DOE orders, available data and information from appropriately-verified design basis documents should be used.

- (b) If additional data or information are needed, these should be obtained by studies, analyses, and/or walkdowns. Any such studies, analyses, or walkdowns should be performed by methods that satisfy applicable technical and quality assurance requirements of national, federal, or industry consensus standards.

- (c) For SSC performance categorization, the definition of "safety-related", "important-to-safety", or "safety class" SSCs (hereafter all referred to as "Safety") should be the same as those in the general design criteria and safety design criteria documents (DOE 6430.1B, DOE 5480.RD, and DOE 5480.NNFDC), except as follows:
- (i) A list of such SSCs should only include those SSCs that are required for preventing, mitigating, or monitoring the effects of an NPH or the effects of accidents that may result from an NPH. SSCs required for maintaining operating parameters within the safety limits during normal operations and anticipated operational occurrences need not be included in the list of safety items for NPH mitigation purposes.
 - (ii) An SSC, whose failure may impair or adversely affect an operator action that is required for safety during and following an NPH event, should also be treated as a safety SSC for the purpose of selecting performance category.
 - (iii) Even if an SSC is not classified as "safety" according to the above definition, it should be treated as "safety" if its failure by itself or its common-cause failure with one or more SSCs result in the non-performance of a safety function.
- (d) Performance categorization should be initially performed considering the basic categorization criteria (see Subsection 8.2 below) that will establish the preliminary performance category. The preliminary performance category should then be modified by considering applicable system interaction effects (see Subsection 8.3 below). However, if convenient, system interaction effects can be considered along with the basic categorization process, in which case the preliminary performance category need not be established.
- (e) For safety SSCs, the performance category determined by considering the basic categorization criteria (Subsection 8.2 below) and the system interaction effects (Subsection 8.3 below) should be modified by considering optional dose limits given in subsection 8.4 below, if such modification is necessary and justifiable from cost-benefit considerations.

8.2 Recommended Basic Categorization Criteria

- (a) The recommended basic categorization criteria are summarized in the flow-chart shown in Figure 8-1, and described in the following paragraphs category-by-category. The criteria recommended and presented here assume that the hazard categorization/classification, accident analyses, and identification of "safety" systems for facilities that store, handle or process radioactive and toxic materials have been performed and documented in accordance with the recommendations given in Subsection 8.1 above. It is also assumed that the mission and functional/performance requirements of SSCs being categorized are known, or have been determined.

The application of the basic categorization criteria presented here will establish the preliminary performance category of SSCs. The preliminary performance category may not account for system interactions, if any, that are described in Subsection 8.3 below, but will account for common-cause failure effects as discussed in Paragraph 8.1(c)(iii) above.

- (b) Performance Category 4: An SSC shall be placed in Preliminary Performance Category 4 (PC-4) if any of the following two conditions apply:

- (i) The SSC is part of a "safety" system in a Hazard Category 1 (HC1) or a High Hazard (HH) Facility, and performs a safety function by itself, or in combination with one or more SSC's.
- (ii) The SSC's failure causes release of radioactive or toxic materials to the environment outside the site boundary or to ground water, and the quantity, rate, and concentration of the release are greater than or equivalent to that can cause prompt human fatality.

An SSC that does not satisfy the above criteria may also be placed in PC-4 for improved performance if justified from cost-benefit or environmental considerations.

(c) Performance Category 3: An SSC shall be placed in Preliminary Performance Category 3 (PC-3) if any of the following two conditions apply:

- (i) The SSC is part of a "safety" system in a Hazard Category 2 (HC2) or a Moderate Hazard (MH) Facility, and performs a safety function by itself, or in combination with one or more SSC's.
- (ii) SSC's failure causes release of radioactive or toxic materials to the environment outside the site boundary or to ground water, and the quantity of the release is equal to or more than the "threshold quantities" specified in 29CFR1910119 and 40CFR355, or is equivalent to the quantity that can produce a dose of 1 rem or more in the range of 100 to 300 meters from the facility.

An SSC that does not satisfy the above criteria may also be placed in PC-3 for improved performance if justified from cost-benefit considerations.

(d) Performance Category 2: An SSC shall be placed in Preliminary Performance Category 2 (PC-2) if it is not covered in Paragraphs (b) and (c) above, and if any of the following conditions apply:

- (i) The SSC is part of a "safety" system in a Hazard Category 3 (HC3) or a Low Hazard (LH) Facility, and performs a safety function by itself, or in combination with one or more SSCs.
- (ii) The SSC's failure by itself or in combination with one or more SSCs may result in loss of function of any emergency handling, hazard recovery, fire suppression, emergency preparedness, communication, or emergency power system that may be needed to preserve the health and safety of the facility workers and co-located workers.
- (iii) The SSC is part of a building which is primarily used for assembly of more than 300 persons (in one room), and the SSC failure may adversely affect the life safety of the occupants.

- (iv) The SSC's failure causes release of radioactive materials to the environment outside the site boundary or to ground water, and the quantity of the release is equal to or more than the "reportable quantities" specified in 40CFR302.4.

An SSC that does not satisfy the above criteria may also be placed in PC-2 from cost and mission considerations, e.g., when SSC failure causes excessive downtime, SSC is very difficult to replace, or SSC replacement/repair is very costly.

- (e) Performance Category 1: An SSC that is not covered in Paragraphs (b), (c), and (d) above shall be placed in Preliminary Performance Category 1 (PC-1) if any of the following conditions apply:
 - (i) It is a building structure with potential human occupancy.
 - (ii) The SSC's failure may cause a life threatening situation to facility workers or co-located workers.
 - (iii) The SSC's failure may cause damage that can be prevented or reduced cost-effectively by designing it to withstand NPH effects.
 - (iv) The SSC's failure causes release of chemicals to the environment or to ground water and the quantity, rate, and concentration of the release is harmful to the environment.
- (f) Performance Category 0: An SSC that is not covered in Paragraphs (b) through (e) above may be placed in Preliminary Performance Category 0 (PC-0), if it is not important because of safety, mission, or cost considerations, and if it is more cost-effective to replace or repair than to design it to withstand NPH effects, except that, an SSC whose failure may have any adverse effect on the performance of a PC-1, PC-2, PC-3, or PC-4 SSC shall not be placed in PC-0.

8.3 System Interaction Effects

- (a) An SSC that has been preliminarily categorized in accordance with the basic categorization criteria of Subsection 8.2 (designate it as "source"), shall have appropriate additional NPH mitigation requirements as provided in paragraphs (b), (c) and (d) below, if its behavior by itself, or the multiple common-cause behavior of it with other SSCs may adversely affect the performance of another SSC (designate it as "target"). These additional requirements will depend on the type of source behavior that causes adverse interaction with the target during or following an NPH event.
- (b) If the source behavior that causes adverse interaction is within the acceptable behavior limits of the source, i.e. if the adverse interaction occurs before source failure, adequate measures shall be taken to preclude such interaction and to ensure that the performance goal for the target is preserved. For example, assume that the postulated seismic deflection of a PC-1 cabinet (source) is within its own acceptable behavior limits, but the cabinet can potentially impact and fail a PC-2 fire-suppression component (target). To prevent this adverse interaction, the cabinet support system or the cabinet itself can be stiffened/strengthened in such a way that the calculated deflection of the cabinet towards the target, when subjected to a seismic level corresponding to the performance category of the target, is less than the available clearance by a factor equal to the applicable design margin for the target. Alternatively, a barrier can be provided to preclude the adverse interaction and to protect the target. Such a barrier shall be designed to withstand NPH effects combined with the interaction effects from the source (in this case the impact from the PC-1 cabinet). To ensure that the target performance goal is preserved, the barrier shall be placed in the same performance category as the target (in this case PC-2).
- (c) If the adverse interaction is possible only after the source fails or exceeds its acceptable behavior limits, either of the following two requirements shall be met to preclude adverse interaction:
 - (i) The source shall have additional NPH requirements corresponding to the performance category of the target in accordance with Table 8-1. These

additional requirements can be restricted to the source failure mode related to the adverse interaction effects.

- (ii) Adequate measures shall be taken to preclude adverse interaction and to ensure that the performance goal for the target is preserved. Examples of acceptable measures are: stiffening/strengthening of the source structure or support system, relocating the source and/or the target, installing barriers, installing new components, modifying existing components, or any combination of these measures.
- (d) If the behavior or failure of a source can adversely affect the performance of more than one target, the source shall have additional NPH requirements corresponding to the highest performance category that is determined by applying the rules provided in Paragraph (a), (b) and (c) above separately for each target.

8.4 Optional Use of Dose Limits for Categorization

An SSC, that has been placed in PC-4, PC-3, or PC-2 in accordance with the criteria given in Subsections 8.2 and 8.3 above, may be placed in a lower performance category by using dose limits given in Tables 8-2 and 8-3, if the performance category of the SSC was established on the basis of confinement or containment function. Thus, for example, if an SSC was placed in PC-4 because it is part of a Hazard Category 1 safety system, and because its failure may result in an offsite release of 4 rem (i.e. less than 20% of 25 rem), the SSC can be placed in PC-3.

Figure 8-1. Basic Criteria for Preliminary NPH Performance Categorization of Structures, Systems, and Components

[Use this Figure only in the context of Section 8 of this document ; also see Subsections 8.3 and 8.4 for system interaction effects and optional use of dose limits.]

Table 8-1

System Interaction Effects on Performance Categorization

Performance Category of Target SSC ⁽¹⁾	Preliminary Performance Category of Source SSC ⁽²⁾	Range or Limit of Target Failure Probability Due to Interaction ⁽³⁾ (p)	Revised NPH Requirements of Source SSC ⁽⁴⁾
PC-4	PC-3	$p > 10\%$	PC-4
		$p \leq 10\%$	PC-3 ⁽⁵⁾
	PC-2	$p > 10\%$	PC-4
		$1\% < p \leq 10\%$	PC-3
		$p \leq 1\%$	PC-2 ⁽⁵⁾
	PC-1	$p > 10\%$	PC-4
		$1\% < p \leq 10\%$	PC-3
		$p \leq 1\%$	PC-1 ⁽⁵⁾
PC-3	PC-2	$p > 20\%$	PC-3
		$p \leq 20\%$	PC-2 ⁽⁵⁾
	PC-1	$p > 20\%$	PC-3
		$10\% < p \leq 20\%$	PC-2
		$p \leq 10\%$	PC-1 ⁽⁵⁾
PC-2	PC-1	$p > 50\%$	PC-2
		$p \leq 50\%$	PC-1 ⁽⁵⁾

Notes: (1) If the target consists of more than one SSC, the highest performance category of the group shall be considered here.

(2) This is the preliminary performance category of the source SSC before considering system interaction effects. Note that PC-0 is not considered here because, per Section 8.2(f), a PC-0 SSC cannot have any adverse effect on the performance of PC-1 through PC-4 SSCs. (cont'd)

Notes for Table 8-1 (cont'd)

- (3) This is the approximate probability of exceedance of acceptable behavior limit for the target SSC given that the source SSC will fail and interact with target SSC due to NPH effects.

Thus, if the target is a PC-4 SSC that may be adversely affected by the failure of a PC-2 SSC (source), and if the target failure probability due to this interaction is greater than 10%, then one of the methods of precluding the interaction will be to subject the source to additional NPH requirements corresponding to PC-4 (see also note 4 below).

- (4) The source SSC shall be designed/evaluated to those requirements of the revised performance category that are essential for precluding adverse interaction with the target (in other words, it is not necessary to satisfy the functional requirements of the source SSC when subjected to these additional NPH requirements unless essential for precluding adverse interaction).

The basis for determining the revised NPH requirements for the source SSC is that the performance goal of the target SSC shall not be compromised because of system interaction effects, i.e. the product of the performance goal for the revised source performance category (last column in Table 8-1) and the target failure probability (3rd column in Table 8-1) must not be more than the performance goal of the target SSC (1st column of Table 8-1). However, to account for uncertainties in determining target failure probabilities, the limiting values in the 3rd column of the table have been selected conservatively (i.e. equal to or lower than the values computed on the above basis).

- (5) For these cases, consideration of interaction effects does not require additional NPH requirements for the source SSC.

Table 8-2

Radiological Dose Limits for Performance Categorization (1)

Type of Exposure/Dose	SSC Category		
	PC-4	PC-3	PC-2
Dose at the site boundary to any person. (2)	100%	20%	2%

Note 1: Limits are expressed as percent of 10CFR100 Offsite Radiation Dose Limits, which are basically as follows:

- Total Radiation Dose to the Whole Body 25 rem
- Total Radiation Dose to the Thyroid from Iodine Exposure 300 rem

Note 2: For sites surrounded by large sparsely-populated areas higher dose may be permitted in accordance with applicable exemptions/deviations procedures (see Section 9 of DOE order 5480.NPH)

Table 8-3
Toxic Dose Limits for Performance Categorization (1)

Type of Exposure/Dose	SSC Category		
	PC-4	PC-3	PC-2
Dose at the site boundary to any person (2)	100% of ERPG-3	Larger of ERPG-2 or 20% of ERPG-3	Larger of ERPG-1 or 2% of ERPG-3

Note 1: Emergency Response Planning Guidelines (ERPG) (reference 20) are used to define dose limits. These are defined by the American Industrial Hygiene Association as follows:

- The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.
- The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

Note 2: For sites surrounded by large sparsely-populated areas higher dose may be permitted in accordance with applicable exemptions/deviations procedures (see Section 9 of DOE order 5480.NPH)

9.0 REFERENCES

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APPENDIX A

ACCIDENTAL RADIATION DOSE REFERENCE VALUES

[Extracts from 10CFR100, Reference 24]

- (a) As an aid in evaluating a proposed site, an applicant should assume a fission product release¹ from the core, the expected demonstrable leak rate from the containment and the meteorological conditions pertinent to his site to derive an exclusion area, a low population zone and population center distance. For the purpose of this analysis, which shall set forth the basis for the numerical values used, the applicant should determine the following:
- (1) An exclusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem² or a total radiation dose in excess of 300 rem² to the thyroid from iodine exposure.
 - (2) A low population zone of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure.
 - (3) A population center distance of at least one and one-third times the distance from the reactor to the outer boundary of the low population zone. In applying this guide, the boundary of the population center shall be determined upon consideration of population distribution. Political boundaries are not controlling in the application of this guide.

¹The fission product release assumed for these calculations should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events, that would result in potential hazards not exceeded by those from any accident considered credible. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products.

²The whole body dose of 25 rem referred to above corresponds numerically to the once in a lifetime accidental or emergency dose for radiation workers which, according to NCRP recommendations may be disregarded in the determination of their radiation exposure status (see NBS Handbook 69 dated June 5, 1959). However, neither its use nor that of the 300 rem value for thyroid exposure as set forth in these site criteria guides are intended to imply that these numbers constitute acceptable limits for emergency doses to the public under accident conditions. Rather, this 25 rem whole body value and the 300 rem thyroid value have been set forth in these guides as reference values, which can be used in the evaluation of reactor sites with respect to potential reactor accidents of exceedingly low probability of occurrence, and low risk of public exposure to radiation.

Where very large cities are involved, a greater distance may be necessary because of total integrated population dose consideration.

(b) For sites for multiple reactor facilities consideration should be given to the following:

- (1) If the reactors are independent to the extent that an accident in one reactor would not initiate an accident in another, the size of the exclusion area, low population zone and population center distance shall be fulfilled with respect to each reactor individually. The envelopes of the plan overlay of the areas so calculated shall then be taken as their respective boundaries.
- (2) If the reactors are interconnected to the extent that an accident in one reactor could affect the safety of operation of any other, the size of the exclusion area, low population zone and population center distance shall be based upon the assumption that all interconnected reactors emit their postulated fission product releases simultaneously. This requirement may be reduced in relation to the degree of coupling between reactors, the probability of concomitant accidents and the probability that an individual would not be exposed to the radiation effects from simultaneous releases. The applicant would be expected to justify to the satisfaction of the Commission the basis for such a reduction in the source term.
- (3) The applicant is expected to show that the simultaneous operation of multiple reactors at a site will not result in total radioactive effluent releases beyond the allowable limits of applicable regulations.

APPENDIX B

ACCIDENTAL RADIATION DOSE CRITERIA

[Extracts from DOE 6430.1A, Reference 2]

The following siting guidelines apply to off-site individuals receiving maximum dose from exposure to internally-deposited radioactive materials and/or to radiation from external sources. Guidelines are based on a 50-year committed dose equivalent.

The maximum calculated dose shall not exceed 25 rem to the whole body, 300 rem to the thyroid, 300 rem to the bone surface, 75 rem to the lung, or 150 rem to any other organ. If multiple organs receive doses from the same exposure, the effective dose equivalent from all sources shall not exceed 25 rem when calculated by using the ICRP Report No. 26 weighting factors.

These siting guidelines apply to nonreactor nuclear facilities. Siting and design criteria for nuclear reactors appear in DO 5480.6.

The use of doses as set forth in these guides is not intended to imply that these doses constitute acceptable limits for emergency doses to the public under accident conditions. Rather, these are reference values that can be used in the evaluation of facility design in combination with the suitability of the site with respect to accidents having a low probability of occurrence and low risk of public exposure to radiation.

NOTE: For a deterministic analysis, events to be analyzed are those judged to have maximum consequences based on technical review of the specific facility design and related radiological processes. For a probabilistic analysis, events to be considered are those events whose annual probability of occurrence exceeds 10^{-6} . These analyses provide the basis of judgment for selection of one site over alternative sites and for overall risk of operation of the facility.

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