2.0 PRINCIPAL DESIGN CRITERIA

I. Review Objective

The purpose of evaluating the principal design criteria related to structures, systems, and components (SSC) important to safety is to ensure that they comply with the relevant general criteria established in 10 CFR Part 72[1], further guidance can be found in NUREG/CR-6407[2] "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety." Material provided in this chapter will form the basis for accepting the safety analysis report (SAR) for staff review.

The applicant should present details of the principal design criteria in either Section 2 or defer the details to the associated sections of the SAR. If the applicant chooses deferral, a general reference to these criteria must be presented. Regulatory Guide (RG) 3.61[3] provides general guidance concerning information that should be included in the principal design criteria for a dry cask storage system (DCSS). In general, these criteria include specifications regarding the fuel or other material to be stored in the DCSS, as well as the external conditions that may exist in the casks operating environment during normal and off-normal operations, accident conditions, and natural phenomena events. A detailed evaluation of how the DCSS design meets the principal design criteria should be presented in Sections 3 through 14 of the safety evaluation report (SER).

II. Areas of Review

The following areas of review have been adopted by the NRC staff, and include those areas noted in RG 3.61:

1. structures, systems, and components important to safety

2. design bases for structures, systems, and components important to safety
   a. spent fuel specifications
   b. external conditions

3. design criteria for safety protection systems

   a. general
   b. structural
   c. thermal
   d. shielding/confinement/radiation protection
   e. criticality
   f. operating procedures
   g. acceptance tests and maintenance
   h. decommissioning
   i. material compatibility[4]

III. Regulatory Requirements

1. Structures, Systems, and Components Important to Safety

The applicant must identify all SSC that are important to safety, and describe the relationships of non-important to safety SSC on overall DCSS performance. [10 CFR 72.24(c)(3) and 72.44(d)]

The applicant must specify the design bases and criteria all SSC that are important to safety. [10 CFR 72.24(c)(1), 72.24(c)(2), 72.120(a), and 72.236(b)]

2. Design Bases for Structures, Systems, and Components Important to Safety

a. Spent Fuel Specifications

The applicant must provide the range of specifications for the spent fuel to be stored in the DCSS. These specifications should include, but are not to be limited to: the type of spent fuel (i.e., boiling-water reactor (BWR), pressurized-water reactor (PWR), or both); content, weight, dimensions and configurations of the fuel; maximum allowable enrichment of the fuel before any irradiation; maximum fuel burnup (i.e., megawatt-days/mtu); minimum acceptable cooling time of the spent fuel before storage in the DCSS (aged at least 1 year); maximum heat load to be dissipated; maximum spent fuel elements to be loaded; spent fuel condition (i.e., intact assembly or consolidated fuel rods); and any inerting atmosphere requirements. [10 CFR 72.2(a)(1) and 72.236(a)]

b. External Conditions

The design bases for SSC important to safety must reflect an appropriate consideration of environmental conditions associated with normal operations, as well as design considerations for both normal and accident conditions and the effects of natural phenomena events. [10 CFR 72.122(b)]

3. Design Criteria for Safety Protection Systems

a. General

The DCSS must be designed to safely store the spent fuel for a minimum of 20 years and to permit maintenance as required. [10 CFR 72.236(g)]

SSC important to safety must be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety of the function to be performed. [10 CFR 72.122(a)]

The applicant must identify all codes and standards applicable to the SSC. [10 CFR 72.24(c)(4)]

b. Structural

SSC that are important to safety must be designed to accommodate the combined loads of normal operations, accidents, and natural phenomena events with an adequate margin of safety. [10 CFR 72.24(c)(3), 72.122(b), and 72.122(c)]

The design-basis earthquake must be equivalent to or exceed the safe shutdown earthquake of a nuclear plant at sites evaluated under 10 CFR Part 100[5]. [10 CFR 72.102(f)]

The DCSS must maintain confinement of radioactive material within the limits of 10 CFR Part 72 and Part 20, under normal, off-normal, and credible accident conditions. [10 CFR 72.236(l)]

The DCSS must be designed and fabricated so that the spent fuel is maintained in a subcritical condition all under all credible normal, off-normal, and accident conditions. [10 CFR 72.124(a) and 72.236(c)]

The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

Storage systems must be designed to allow ready retrieval of spent fuel waste for further processing or disposal. [10 CFR 72.122(l)]

c. Thermal

Each spent fuel storage or handling system must be designed with a heat removal capability having testability and reliability consistent with its importance to safety. [10 CFR 72.128(a)(4)]

The DCSS must be designed to provide adequate heat removal capacity without active cooling systems. [10 CFR 72.236(f)]

d. Shielding/Confinement/Radiation Protection

The proposed DCSS design must provide radiation shielding and confinement features that are sufficient to meet the requirements of 10 CFR 72.104 and 72.106. [10 CFR 72.126(a), 72.128(a)(2), 72.128(a)(3), and 72.236(d)]

During normal operations and other anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to (1) planned discharges to the general environment of radioactive materials except radon and its decay products, (2) direct radiation from operations of the ISFSI or monitored retrievable storage (MRS), and (3) any other radiation from uranium fuel cycle operations within the region. [10 CFR 72.24(d), 72.104(a), and 72.236(d)]

Any individual located at or beyond the nearest boundary of the controlled area shall not receive a dose greater than 5 rem to the whole body or any organ from any design-basis accident. The minimum distance from the spent fuel handling and storage facilities to the nearest boundary of the controlled area shall be 100 meters. [10 CFR 72.24(d), 72.24(m), 72.106(b), and 36(d)]

The DCSS must be designed to provide redundant sealing of confinement systems. [10 CFR 72.236(e)]

Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. [10 CFR 72.122(h)(4) and 72.128(a)(1)]

The DCSS design must include inspections, instrumentation and/or control (I&C) systems to monitor the SSC that are important to safety over anticipated ranges for normal and off-normal operation. In addition, the applicant must identify those control systems that must remain operational under accident conditions. [10 CFR 72.122(i)]

e. Criticality

Spent fuel transfer and storage systems must be designed to remain subcritical under all credible conditions. [10 CFR 72.124(a) and 72.236(c)]

When practicable, the DCSS must be designed on the basis of favorable geometry, permanently fixed neutron-absorbing materials (poisons), or both. Where solid neutron-absorbing materials are used, the design shall allow for positive means to verify their continued efficacy. [10 CFR 72.124(b)]

f. Operating Procedures

The DCSS must be compatible with wet or dry spent fuel loading and unloading procedures. [10 CFR 72.236(h)]

Storage systems must be designed to allow ready retrieval of spent fuel for further processing or disposal. [10 CFR 72.122(l)]

The DCSS must be designed to minimize the quantity of radioactive waste generated. [10 CFR 72.24(f) and 72.128(a)(5)]

The applicant must describe equipment and processes proposed to maintain control of radioactive effluents. [10 CFR 72.24(l)(2)]

To the extent practicable, the DCSS must be designed to facilitate decontamination. [10 CFR 72.236(I)]

The applicant must establish operational restrictions to meet the limits defined in 10 CFR Part 20 and to ensure that radioactive materials in effluents and direct radiation levels associated with ISFSI operations will remain as low as is reasonably achievable (ALARA). [10 CFR 72.24(e) and 72.104(b)]

g. Acceptance Tests and Maintenance

The DCSS design must permit testing and maintenance as required. [10 CFR 72.236(g)]

SSC that are important to safety must be designed, fabricated, erected, tested, and maintained to quality standards commensurate with the importance to safety of the function to be performed. [10 CFR 72.24(c), 72.122(a), 72.122(f), and 72.128(a)(1)]

h. Decommissioning

The DCSS must be compatible with wet or dry unloading facilities. [10 CFR 72.236(h)]

The DCSS must be designed for decommissioning. Provisions must be made to facilitate decontamination of structures and equipment and to minimize the quantity of radioactive wastes, contaminated equipment, and contaminated materials at the time the ISFSI is permanently decommissioned. [10 CFR 72.24(f), 72.130, and 72.236(I)]

The applicant must provide information concerning the proposed practices and procedures for decontaminating the site and facilities and for disposing of residual radioactive materials after all spent fuel has been removed. Such information must provide reasonable assurance that decontamination and decommissioning will adequately protect the health and safety of the public. [10 CFR 72.24(q) and 72.30(a)]

IV. Acceptance Criteria

The reviewer should verify that the applicant has provided either general or summary discussions of the SSC's design features, and both operational and accident conditions in a sufficiently clear manner that the applicant demonstrates a clear and defensible case that they have met the design criteria. In evaluating the principal design criteria related to DCSS SSC that are important to safety, reviewers should seek to ensure that the given design fulfills the following acceptance criteria:

1. Structures, Systems, and Components Important to Safety

The applicant should discuss the general configuration of the DCSS, and should provide an overview of specific components and their intended functions. In addition, the applicant should identify those components deemed to be important to safety, and should address the safety functions of those components in terms of how they meet the general design criteria and regulatory requirements discussed above. Additional information concerning specific functional requirements for individual DCSS components are addressed in the subsequent chapters of this SRP.

2. Design Bases for Structures, Systems, and Components Important to Safety

Detailed descriptions of each of the items listed below are generally found in specific sections of the SAR; however, a brief description of these areas, including a summary of the analytical techniques used in the design process, should also be captured in Section 2 of the SAR. This description gives reviewers a perspective on how specific DCSS components interact to meet the regulatory requirements of 10 CFR Part 72. This discussion should be non-proprietary since it may be used to familiarize interested persons with the design features and bounding conditions of operation of a given DCSS.

a. Spent Fuel Specifications

The applicant should define the range and types of spent fuel or other radioactive materials that the DCSS is designed to store. In addition, these specifications should include, but are not to be limited to, the type of spent fuel (i.e., boiling-water reactor (BWR), pressurized-water reactor (PWR), or both), weights of the stored materials, dimensions & configurations of the fuel, maximum allowable enrichment of the fuel before any irradiation, burnup (i.e., megawatt-days/mtu), minimum acceptable cooling time of the spent fuel before storage in the DCSS (aged at least 1 year), maximum heat designed to be dissipated, maximum number of spent fuel elements, condition of the spent fuel (i.e., intact assembly or consolidated fuel rods), inerting atmosphere requirements, and the maximum amount of fuel permitted for storage in the DCSS. For DCSSs that will be used to store radioactive materials other than spent fuel, that is, activated components associated with a spent fuel assembly (e.g., control rods, BWR fuel channels), the applicant should specify the types and amounts of radionuclides, heat generation and the relevant source strengths and radiation energy spectra permitted for storage in the DCSS.

b. External Conditions

The SAR should define the bounding conditions under which the DCSS is expected to operate. Such conditions include both normal and off-normal environmental conditions, as well as accident conditions. In addition, the applicant should consider the effects of natural events, such as tornadoes, earthquakes, floods, and lightning strikes. The effects of such events are addressed in individual chapters of the SRP (e.g., the effects of an earthquake on the DCSS structural components are addressed in Chapter 3, "Structural Analysis").

3. Design Criteria for Safety Protection Systems

a. General

The SAR should define an expected lifetime for the cask design. The staff has accepted a minimum of 20 years as consistent with the licensing period. The applicant should also briefly describe the proposed quality assurance (QA) program, and applicable industry codes and standards, that will be applied to the design, fabrication, construction, and operation of the DCSS.

In establishing normal and off-normal conditions applicable to the design criteria for DCSS designs, applicants should account for actual facility operating conditions. Design considerations should therefore reflect normal operational ranges, including any seasonal variations or effects.

b. Structural

The SAR should define how the DCSS structural components are designed to accommodate combined normal, off-normal, and accident loads, while protecting the DCSS contents from significant structural degradation, criticality, and loss of confinement, while preserving retrievability. This discussion is generally a summary of the analytical techniques and calculational results from the detailed analysis discussed in SAR Section 3 and should be presented in a non-proprietary forum.

c. Thermal

The applicant should provide a general discussion of the proposed heat removal mechanisms, including the reliability and verifiability of such mechanisms and any associated limitations. All heat removal mechanisms should be passive and independent of intervening actions under normal and off-normal conditions.

d. Shielding/Confinement/Radiation Protection

The applicant should describe those features of the cask that protect occupational workers and members of the public against direct radiation dosages and releases of radioactive material, and minimize the dose after any off-normal or accident conditions.

e. Criticality

The SAR should address the mechanisms and design features that enable the DCSS to maintain spent fuel in a subcritical condition under normal, off-normal, and accident conditions.

f. Operating Procedures

The applicant should provide potential licensees with guidance regarding the content of normal, off-normal, and accident response procedures. Cautions regarding both loading, unloading, and other important procedures should be mentioned here. Applicants may choose to provide model procedures to be used as an aid for preparing detailed site-specific procedures.

g. Acceptance Tests and Maintenance

The applicant should identify the general commitments and industry codes and standards used to derive acceptance, maintenance, and periodic surveillance tests used to verify the capability of DCSS components to perform their designated functions. In addition, the applicant should discuss the methods used to assess the need for such tests with regard to specific components.

h. Decommissioning

Casks should be designed for ease of decontamination and eventual decommissioning. The applicant should describe the features of the design that support these two activities.

V. Review Procedures

All members of the review team should review Section 2 of the SAR. Although RG 3.61 defines the standard format and content of an SAR, it does not address the different levels of detail expected in introducing component design criteria in SAR Section 2 and as compared with latter sections of the SAR. Consequently, reviewers for each section of the SAR should consider Section 2 in combination with additional details presented later in the SAR. In this SRP, evaluation of design criteria applicable to each of the relevant chapters of the SAR are discussed in detail in those chapters.

Inclusion of a separate section for design criteria in both the SAR and SER supports the staff's procedure of deliberately reviewing these criteria for acceptability apart from the proposed design and infrastructure of the system. This approach forms a "two-step" review process in which the acceptability of the detailed design criteria is separately stated. In-depth evaluation to assess satisfaction of these or other criteria is addressed in other sections of this SRP.

Although the design criteria presented in the SAR may be acceptable to the staff, the actual design may not meet either these criteria or the applicable regulatory requirements. It is also possible that the design criteria themselves, as presented in the SAR, may be unacceptable for application to a given DCSS design. As a result, the design may be unacceptable in that it does not meet the regulatory requirements, or the design may satisfy alternative criteria that are not described in the SAR, but are acceptable to the NRC staff. Reviewers should bring any of these situations to the immediate attention of NRC management.

1. Structures, Systems, and Components Important to Safety

Verify that the applicant has clearly identified all SSC important to safety (as defined by 10 CFR Part 72.3) and documented the rationale for this designation. Such information may be provided in tabular form. Review the general DCSS description presented in SAR Section 1. Ensure that the applicant has provided adequate justification for excluded SSC.

Pay particular attention to instrumentation and other equipment (e.g., lifting devices and transport vehicles). In general, the NRC staff accepts that monitoring systems need not be classified as being important to safety. For example, a failure in the functioning of the pressure monitoring system does not directly result in a release of radionuclides. Additional justification for not considering such systems as being important to safety may be presented in later sections of the SAR and summarized in Section 2.

SSC designated as being important to safety should be included or referenced in the discussion of Design Features within the Technical Specifications provided in SAR Section 12.

2. Design Bases for Structures, Systems, and Components Important to Safety

Verify that the applicant's design bases for DCSS approval accurately identify the range of spent fuel configurations and characteristics, the enveloping conditions of use, and identify the bounding site characteristics. These determine the bounds within which an ISFSI owner may use the SAR, rather than providing additional proof regarding suitability of the covered topics.

a. Spent Fuel Specifications

Review the detailed specifications for the spent fuel to be stored in the DCSS as they are presented in SAR Section 2, and ensure that they are consistent with those discussed in Section 1.The description of the range of spent fuel to be stored should include the type (PWR, BWR, or both), configuration (e.g., 17x17, 15x15, or 8x8), fuel vendor, number of assemblies per cask, enrichment, burnup, minimum cooling time, decay heat generation rate, type of cladding, physical dimensions, total weight per assembly, and uranium weight per assembly. In addition, if control assemblies will be stored with the fuel, ensure that combined weight, dimensions, heat load, and other appropriate information (e.g., number per cask) are specified.

Examine any limitations regarding the condition of the spent fuel. If damage that could be classified as a "Gross Cladding Defect" is allowed, the effects of such damage should be assessed in later sections of the SAR. If damaged rods have been removed from a fuel assembly, determine whether a need exists to replace them with dummy rods before loading into the cask. Note, the presence of an additional moderator will need to be addressed in the criticality analysis in SAR Section 6.

The release of fill and fission product gases from failed fuel rods increases the pressure in the cask cavity, as well as increasing the potential source-term in the event of confinement failure. Consequently, the applicant should provide information regarding the fill/fission product gas present in the fuel as well as the free volume in the cask cavity to enable reviewers to evaluate the pressure in the cask cavity resulting from cladding failure during storage. For the purpose of calculating internal cask pressures, the NRC staff has accepted the following bounding assumptions regarding the minimum percentages of fuel rods to have failed (and released their gases):

- 1% for normal conditions
- 10% for off-normal conditions
- 100% for design-basis (accident and extreme natural phenomena) conditions

Pay particular attention to the specification of burnup, cooling time, and decay heat generation rate. These parameters are generally not independent, and the manner in which they are specified and combined can significantly affect the maximum allowed cladding temperature, as discussed in Chapter 4 of the SRP.

Note the specification of enrichment limits. As discussed in Chapter 5 of the SRP, the criticality evaluation is based on the highest enrichment (for a given fuel assembly), while the shielding source term, especially for neutrons, should be based on the lowest enrichment (for a given burnup).

The SAR will typically list various fuel assemblies that can be stored in the DCSS. In general, no one type of fuel assembly will be bounding for all analyses. Ensure that the applicant has justified which specifications are bounding for each of the evaluations presented in subsequent sections of the SAR. Specifications used in these analyses should also be clearly identified or referenced in Section 12 of both the SAR and SER.

If the applicant requests permission for the storage of non-fuel core components in the cask, review the relevant detailed specifications, conditions, and constraints presented in the SAR. These specifications should be at least as detailed as the applicable information presented for the fuel designs, to provide the reviewer with a basis for a determination that the relevant safety functions of the DCSS will be maintained.

b. External Conditions

The SAR should identify those external conditions that significantly affect, or could potentially affect, the performance of the DCSS. These design-basis conditions will generally restrict either the sites at which the DCSS can be used for spent fuel storage or the manner in which the DCSS can be handled. For example, by selecting the design-basis earthquake (DBE), the SAR limits the use of the cask being reviewed to sites for which the safe shutdown earthquake (SSE) does not exceed the DCSS system DBE. By establishing a design-basis drop, the SAR defines the maximum height to which a cask can be lifted without additional safety analysis or design changes (e.g. impact limiters) by the licensee. Reviewers should note that movement of cask system components within a reactor building may not meet the NRC's criteria for movement of heavy loads within the reactor building[6]. As such, if a potential user (licensee) has been identified, coordination with the appropriate project manager or technical lead from the NRC's Office of Nuclear Reactor Regulation (NRR) should occur during the early stages of DCSS design review.

At a minimum the NRC staff has generally addressed the conditions discussed below; however, other conditions may be relevant depending on specific details of the DCSS design. Reviewers should pay particular attention to special design features and how these might be affected both by other external conditions and other DCSS components.

"Normal" conditions (including conditions involving handling and transfer) and the extreme ranges of normal conditions are presumed to exist during design-basis accidents or design-basis natural phenomena, with the exception of irrational or readily avoidable combinations. For example, an earthquake or tornado may occur at any time and in combination with any "normal" condition. By contrast, it can be presumed that transfer, loading, and unloading operations would not be conducted during a flood.

“Off-normal” conditions and events are presumed to occur in combination with normal conditions that are not mutually exclusive. Nonetheless, it is not required that the SAR analyze or the system be designed for the simultaneous occurrence of independent off-normal conditions or events, design-basis accidents, or design-basis natural phenomena.

Conditions involving a “latent” equipment or instrument failure or malfunction (that is, one that occurs and remains undetected) should be presumed to exist concurrently with other off-normal or design-basis conditions and events.Typical latent malfunctions include a misreading instrument that is not detected as part of routine procedures; an undetected ventilation blockage; or undetected damage from an earlier design-basis event or condition if no provisions exist for detection, recovery, or remediation of such conditions.

For normal , off-normal and accident conditions, reviewers should verify that the applicant has defined appropriate operating and accident scenarios. For these scenarios the applicant should include in the SAR a comprehensive evaluation of the effects of such scenarios on the SSC important to safety. Applicant’s evaluations should demonstrate that the requirements of 10 CFR Part 72 .106 as well as 10 CFR Part 20 have been met.

If appropriate, the following design bases should be included as operating controls and limits in Section 12 of both the SAR and SER:

(1) Normal Conditions

For a given spent fuel specification, the primary external conditions that affect DCSS performance are, the ambient temperatures, insolence, and the operational environment experienced by the DCSS.

The NRC accepts as the maximum and minimum “normal” temperatures the highest and lowest ambient temperatures recorded in each year, averaged over the years of record. For the SAR, the applicant may select any design-basis temperatures as long as the restrictions they impose are acceptable to both the applicant and the NRC. If the cask is also designed for transportation, the temperature requirements of 10 CFR Part 71[7] could determine the design basis temperatures for storage.

For storage casks, the NRC staff accepts a treatment of insolence similar to that prescribed in 10 CFR Part 71.71 for transportation casks. If the applicant selects another design approach, it must be justified in the SAR.

The operational environment experienced by the DCSS under normal conditions includes the manner in which the cask is loaded, unloaded, and lifted. Occupational dose rates will in part, depend on whether the cask is sealed in a wet or a dry environment. Fuel cladding temperatures may also be affected. The manner in which the cask is lifted will determine the load on the trunnions and/or lifting yoke. The orientation of the cask (vertical or horizontal) and its height above ground during transport to the ISFSI will establish initial conditions for the drop accidents discussed below.

(2) Off-Normal Conditions

SARs generally address several off-normal conditions. These should include variations in temperatures beyond normal, failure of 10 percent of the fuel rods combined with off-normal temperatures, failure of one of the confinement boundaries, partial blockage of air vents, human error, out-of-tolerance equipment performance, equipment failure, and instrumentation failure or faulty calibration.

(3) Accident Conditions

The staff has generally considered that the following accidents should be evaluated in the SAR. Because of the NRC’s defense-in-depth approach, each should be evaluated regardless of whether it is highly unlikely or highly improbable. These do not constitute the only accidents that should be addressed if the SAR is to serve as a reference for accidents for the site-specific application. Others that may be derived from a hazard analysis could include accidents resulting from operational error, instrument failure, lightning, and other occurrences. Accident situations that are not credible because of design features or other reasons should be identified and justified in the SAR.

(a) Cask Drop

The SAR should identify the operating environment experienced by the cask, as well as the drop events (i.e., end, side, corner) that could result. Generally the design basis is established either in terms of the maximum height to which the cask may be lifted when handled outside the reactor site spent fuel building or in terms of the maximum acceleration that the cask could experience in a drop.

(b) Cask Tipover

Although cask system supporting structures may be identified and constructed as being important to safety (i.e. designed to preclude cask tipovers), the NRC considers that cask tipover events should be analyzed. In some cases, cask tipover may be determined to be a credible hazard, and the associated analysis should reflect the conditions (e.g., heights and accelerations) associated with that hazard.

In the absence of an identified hazard, the NRC has accepted a non-mechanistic cask tipover about a lower corner onto a receiving surface from a position of balance with no initial velocity. The receiving surface for a horizontal or vertical drop may be either an unyielding hard surface; or, the receiving surface may be modeled as a reinforced concrete pad on an engineered fill[8,9]. The NRC has also accepted analysis involving the dropping of a cask with its longitudinal axis in the horizontal position that, with analysis of a vertical axis drop, could bound a non-mechanistic tipover case.

(c) Fire

The fire conditions postulated in the SAR should provide an “envelope” for subsequent comparison with site-specific conditions. The NRC accepts the methods discussed in 10 CFR Part 71.73. The NRC staff also accepts that the applicant may consider a fire based upon the limited availability of flammable material at an ISFSI (e.g., only that associated with vehicles transporting or lifting the cask or possibly nearby foliage). Regardless of which approach the applicant takes, the SAR should specify and justify the bounding conditions for a “design basis” fire

(d) Fuel Rod Rupture

The regulations require that the cask be designed to withstand the effects of accident conditions and natural phenomena events without impairing its capability to perform safety functions. Consequently, the NRC has asserted and the applicant should assume, during the cask analysis for conditions resulting from design-basis accidents and natural phenomena, a release of 100 percent of the initial rod fill gases and a release of 30 percent of the fission product gases from the fuel rods into the cask interior. The remaining 70 percent of the fission product gases are presumed to be retained within the fuel pellet.

(e) Leakage of the Confinement Boundary

Casks are designed to provide the confinement safety function under all credible conditions. Nevertheless, the NRC staff considers that, for assessment purposes and to demonstrate the overall safety of the storage cask system, the DCSS should be evaluated for the effects of a confinement boundary failure. The SAR should identify this failure as a bounding release caused by a non-mechanistic event and the effects should be evaluated as described in the Sandia National Laboratories Report 80-2124[10].

(f) Explosive Overpressure

The conditions under which an ISFSI may be exposed to the effects of an explosion vary greatly among individual sites. Generally, explosive overpressure is postulated to originate from an industrial accident. The effects of various sabotage methods on cask systems were evaluated separately by the Division of Fuel Cycle Safety and Safeguards in developing appropriate regulations in 10 CFR Part 73[11]. Therefore, explosive overpressures from sabotage events are not be considered in this SRP.

The extent to which explosive overpressure is addressed in the SAR directly affects the degree of site-specific review required. The principal concern in the SAR should be the effects of explosive overpressure on the storage system, rather than descriptions of hypothesized causes. Design parameters for blast or explosive overpressures should identify pressure levels as reflected (“side-on”) overpressure, and should provide an assumed pulse length and shape. This discussion should provide sufficient information for licensees to determine if the effects of their site-specific hazards are bounded by the cask system design bases.

(g) Air Flow Blockage

For storage systems with internal air flow passages, the applicant should consider blockage of air inlets and outlets in an accident condition. The NRC staff considers that the effects of such an assumption should be utilized in determining the appropriate inspection intervals, and/or monitoring systems, for the DCSS.

(4) Natural Phenomena Events

The staff has generally considered that the following events should be evaluated in the SAR.

(a) Flood

The SAR should establish a design-basis flood condition. This condition may be determined on the basis of the presumption that the cask cannot tip over and the yield strength of the cask will not be exceeded. Alternatively, the SAR can show that credible flooding conditions have negligible impact on the cask design.

If the SAR establishes parameters for a design-basis flood, all of the potential effects of flood water and ravine flood byproducts should be recognized. Serious flood consequences can involve effects such as blockage of ventilation ports by water and silting of air passages. Other potential effects include scouring below foundations and severe temperature gradients resulting from rapid cooling from immersion.

(b) Tornado

The NRC staff accepts design-basis tornado wind loading as defined by RG 1.76 (Region 1)[12] and tornado missile impacts defined by NUREG-0800, Section 3.5.1.4[13]. Design criteria should be established for the cask on the basis of these wind loading and missile impact definitions. The cask should not tip over and that the capability to perform the confinement safety function should not be impaired. The NRC considers that tornados and tornado missiles may occur without warning. The review should note that in general, the effects of a tornado missile bound those of a light general aviation aircraft directly impacting a DCSS.

(c) Earthquake

The SAR should state the parameters of the DBE. For ISFSIs at reactor sites, this is equivalent to the SSE used for analysis of nuclear facilities, under 10 CFR Part 50. An analysis for an "Operating-Basis Earthquake" (OBE) is not required for an DCSS SAR prepared in accordance with 10 CFR Part 72. Cask tipover accidents are analyzed, but tipover caused by an earthquake may not be a credible event.

(d) Burial under Debris

Debris resulting from natural phenomena or accidents that may affect cask system performance may be addressed in the SAR or may be left to the site-specific application. Such debris can result from floods, wind storms, or land slides. The principal effect is typically on thermal performance.

(e) Lightning

Lightning typically has a negligible effect on cask systems; however, the requirements of the Lightning Protection Code and National Electric Code should be applied to the design of the cask system structures. These codes should be cited as part of the general design criteria for the cask system (see Section II.3.a, above). Lightning should also be addressed as a natural phenomenon in the SAR if cask system performance may be affected if lightning affects a component that is important to safety.

(f) Other

10 CFR Part 72 identifies several other natural phenomena events (including seiche, tsunami, and hurricane) that should be addressed for spent fuel storage. The SAR may include these as design-basis events or show that their effects are bounded by other events. If they are not addressed in the SAR and they prove to be applicable to a specific site, a safety analysis is required prior to approval for use of the DCSS under either a site specific, or general license.

3. Design Criteria for Safety Protection Systems

Because RG 3.61 does not distinguish between the principal design criteria that should be presented in Section 2 of the SAR and those that should be deferred to subsequent sections, the applicant may take one of several approaches. SAR Section 2 may discuss these criteria in general terms (similar to the wording in Section II.3 above), with details provided in later sections. Alternatively, SAR Section 2 may present detailed discussions of selected (or all) criteria. Past applicants have generally selected the latter approach. Subsequent chapters of this SRP provide detailed discussions of the design criteria applicable to each functional area (e.g. structural, thermal) without regard to those that may have been presented in SAR Section 2.

Cask system components that are to be used in facility areas subject to review under 10 CFR Part 50 should satisfy both the requirements in 10 CFR Part 72 (with review guided by this SRP) and 10 CFR Part 50 (with review guided by NUREG-0800 and applicable portions of RG 3.53[14]). Acceptance of the cask system in areas covered by 10 CFR Part 50 license requirements is not addressed in this SRP for approval under 10 CFR Part 72. If a reviewer knows that the cask system will be used at a specific reactor site, the NRR project manager for that site should be so informed. The reviewer is reminded that a likely matter of interest to NRR is heavy loads.

Regardless of where the descriptions and associated criteria are located in the SAR, reviewers should include a summary description and evaluation of the safety protection systems in the “Design Criteria” section of the SER. The system descriptions should address the functions of the various system components in providing confinement, cooling, subcriticality, radiation protection of the public and workers, and spent fuel retrieval. Summary criteria for the performance of the system as a whole in providing for these capabilities or functions should also be described and evaluated. Reviewers should verify that the design-basis assumptions presented are consistent with and reasonable for actual site or facility conditions.

Criteria relating to redundancy, and allowable levels of response by the DCSS under normal, off-normal, and design-basis conditions and events should be described and evaluated. In general, no unacceptable degradation in physical condition or functional performance should result from normal or off-normal conditions. The design criteria regarding limits of permissible system response and degradation resulting from a DBE should be evaluated against the SSC capabilities to perform the principal safety functions. Considerations of permissible responses should include detectability and corrective actions that may be proposed as conditions of system use.

Table 2-1 summarizes design criteria (and design bases) that should generally be identified during the initial stages of the review. This listing may vary depending on the details of the cask design.

(a) Continuous Monitoring

The Office of the General Counsel (OGC) has developed an opinion as to what constitutes "continuous monitoring" as required in 10 CFR Part 72.122(h)(4). The staff, in accordance with that opinion has concluded that both routine surveillance programs and active instrumentation meets the intent of "continuous monitoring". Cask vendors may propose, as part of the SAR, either active instrumentation or surveillance to show compliance with 10 CFR Part 72.122(h)(4).

The reviewer should note that some DCSS designs may contain a component or feature whose continued performance over the licensing period has not been demonstrated to staff with a sufficient level of confidence (e.g. rubber "O" rings). Therefore, staff may require the use of that active instrumentation, if the failure of that system or component causes an immediate threat to the public health and safety, and if that failure would not be detected by any other means. In some cases the vendor or staff in order to demonstrate compliance with 10 CFR Part 72.122(h)(4), may propose a technical specification requiring such instrumentation as part of the first use of a cask system. After first use and if warranted and approved by staff such instrumentation may be discontinued or modified.

The staff should verify that the applicant has met the intent of continuous monitoring so that they are able to determine when corrective action needs to be taken to maintain safe storage conditions.

VI. Evaluation Findings

Provide a summary statement similar to the following:

> The staff concludes that the principal design criteria for the [cask designation] are acceptable with regard to meeting the regulatory requirements of 10 CFR Part 72. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices. A more detailed evaluation of design criteria and an assessment of compliance with those criteria as presented in Sections 3 through 14 of the SER.

Table 2-1 Outline of Design Criteria and Bases[a]

Design Criteria (Specify normal/off-normal/accident, if applicable)	
Design Life (License restricted to 20 years)	
Structural	
Design Code	
Containment (e.g., ASME[b], AISC[c])	
Non-containment	
Basket	
Trunnions	
Storage radiation and protective shielding and enclosure	
Transfer radiation and protective shielding and enclosure	
Cooling structure or system	
Design Weight	
Design Cavity Pressure	Normal/Off-Normal/Accident
Response and Degradation Limits	Normal/Off-Normal/Accident
Thermal	
Maximum Design Temperatures	
Cladding	5-yr Cooled Fuel (As Applicable) 10-yr Cooled Fuel
Other Components	
Insolation	
Side/Top/Bottom	
Fill Gas	
Confinement	
Method of Sealing	
Maximum Leak Rates	
Primary Seals	
Redundant Seals	
Cask Body	
Monitoring System Specifications	
Retrievability	
Normal and Off-Normal	
After DBE and Conditions	
Criticality	
Method of Control	

[a] This table should be filled out by reviewer for inclusion in the SER

[b] American Society of Mechanical Engineers

[c] American Institute of Steel Construction

(Geometry, Fixed Poison, Borated Pool Water)

Minimum Boron Concentration
Fixed
Pool Water

Maximum k_{eff}

Burnup Credit (None currently permitted)

Radiation Protection/Shielding

Confinement Cask	
Surface	Normal/Off-Normal/Accident
Position	
Exterior of Shielding	Normal/Off-Normal/Accident
Transfer Mode Position	
Storage Mode Position	

ISFSI Controlled Area Boundary
Normal/Off-Normal/Accident Dose Rate
Annual Dose

Design Bases

Spent Fuel Specifications
Type
Configuration/Vendor
Enrichment
Weight or range of weights
Burnup
Type of Cladding
Assemblies/Cask
Dimensions

Decay Heat/Assembly
5-yr Cooled Fuel
10-yr Cooled Fuel, etc.

Gas Volume (@ Temperature)
Fuel Condition/Damage Allowed
Control Components

Normal Design Event Conditions

Ambient Temperature
Maximum
Minimum

Loading
(Wet/Dry)

Storage Handling Orientation
(Vertical/Horizontal)

Max lift height
Other Conditions Considered in V.2.b.(1)

Off-Normal Design Event Conditions

Summarize Events Considered in V.2.b.(2)

Design-Basis Accident Design Events and Conditions

End Drop	Lift Height (or Maximum Acceleration)
Side Drop	Lift Height (or Maximum Acceleration)
Tip-Over	Acceleration (if applicable)

Fire
Duration
Temperature

Other Events Considered in V.2.b.(3)
(As Applicable)

Design-Basis Natural Phenomena Design Events and Conditions

Flood
Earthquake
Tornado

Other Events Considered in V.2.b.(4)
(As Applicable)

VII. References

1. *U.S. Code of Federal Regulations*, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-level Radioactive Waste," Part 72, Title 10, "Energy."

2. NUREG/CR-6407 INEL-95/0051 "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," February 1996.

3. U.S. Nuclear Regulatory Commission, "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask," Regulatory Guide 3.61, February 1989.

4. NRC Bulletin 96-04: Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks, July 1996.

5. *U.S. Code of Federal Regulations*, "Reactor Site Criteria," Part 100, Title 10, "Energy".

6. NRC Bulletin 96-02: "Movement of Heavy Loads Over Spent Fuel, Over Fuel in the Reactor Core, or Over Safety Related Equipment", April, 1996

7. *U.S. Code of Federal Regulations*, "Packaging and Transportation of Radioactive Material," Part 71, Title 10, "Energy."

8. Drop Tests onto Concrete Pads for Benchmarking Response of Interim Spent Fuel Storage Installation, "Sandia National Laboratories, Albuquerque, New Mexico, September 1993.

9. "Low-Velocity Impact Testing of Solid Steel Billet onto Concrete Pads," Draft Summary of Twelve Drop Tests, Lawrence Livermore National Laboratory, Livermore, California, March 1, 1996.

10. E. L. Wilmot, Sandia National Laboratories Report "Transportation Accident Scenarios for Commercial Spent Fuel", SAND80-2124, TTC-0158, February 1981

11. *U.S. Code of Federal Regulations*, "Physical Protection of Plants and Materials," Part 73, Title 10, "Energy."

12. U.S. Nuclear Regulatory Commission, "Design Basis Tornado for Nuclear Power Plants," Regulatory Guide 1.76, April 1974.

13. U.S. Nuclear Regulatory Commission, "Standard Review Plan, Missiles Generated by Natural Phenomena," NUREG-0800, Section 3.5.1.4, July 1981.

14. U.S. Nuclear Regulatory Commission, "Applicability of Existing Regulatory Guides to the Design and Operation of an Independent Spent Fuel Storage Installation " Regulatory Guide 3.53, July 1982.