U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

8.3.2 D-C POWER SYSTEMS (ONSITE)

REVIEW RESPONSIBILITIES

Primary - Power Systems Branch (PSB)

Secondary - None

I. AREAS OF REVIEW

The descriptive information, analyses, and referenced documents, including electrical single line diagrams, electrical schematics, functional piping and instrument diagrams, logic diagrams, tables, and physical arrangement drawings for the d-c onsite power system, presented in the applicant's safety analysis report (SAR), are reviewed. The intent of the review is to determine that the d-c onsite power system satisfies the requirements of General Design Criteria 2, 4, 5, 17, 18 and 50 and will perform its intended functions during all plant operating and accident conditions.

The d-c power systems include those d-c power sources and their distribution systems and vital supporting systems provided to supply motive or control power to safety-related equipment. Batteries and battery chargers are used as the power sources for the d-c power system, and inverters are used to convert d-c from the d-c distribution system to a-c instrumentation and control power as required.

The PSB will pursue the following phases in the review of the d-c power systems during both the construction permit (CP) and operating license (OL) stages of the licensing process:

1. System Redundancy Requirements
   The system is reviewed to determine that the required redundancy of components and subsystems is provided. This requires an examination of the d-c power system configuration including power supplies, power supply feeders, load center arrangements, loads supplied from each bus, and power connections to the instrumentation and control devices of the system.

2. Conformance with the Single Failure Criterion

In determining the adequacy of this system to meet the single failure criterion, the electrical and physical separation of redundant power sources and associated distribution systems are examined to assess the independence between redundant portions of the system. This will include a review of the interconnections between redundant buses, buses and loads, and buses and power supplies; proposed sharing of the d-c power system between units at the same site; the design criteria and bases governing the installation of electrical cable for redundant portions of the systems; and physical arrangement of redundant switchgear and power supplies.

3. Power Supplies

Design information and analyses demonstrating the suitability of batteries and battery chargers as d-c power supplies and inverters that convert d-c to a-c for instrumentation and control power are reviewed to assure that they have sufficient capacity and capability to perform their intended functions. This will require an examination of the characteristics and design requirements of each load; the length of time each load is required; the combined load demand connected to each battery or battery charger during the "worst" operating condition; the voltage recovering characteristics of the battery and battery chargers; and the continuous and short-term ratings for the battery and battery chargers.

In addition, where the proposed design provides for the connection of nonsafety-related loads to the d-c power system and sharing of batteries and battery chargers between units at the same site, particular review emphasis is given to assuring against marginal capacity and degradation of reliability that may result from implementing such design provisions.

4. Identification

The means proposed for identifying the d-c power system components including cables and cable trays as safety-related equipment in the plant are reviewed. Also, the identification scheme used to distinguish between redundant cables and raceways of the power system is reviewed.

5. Vital Supporting Systems

The instrumentation, control circuits, and power connections of vital supporting systems are reviewed to determine that they are designed to the same criteria as those for the Class 1E loads and power systems that they support. This will include an examination of the vital supporting system component redundancy, power feed assignment to instrumentation, control of loads, initiating circuits, load characteristics, equipment identification scheme, and design criteria and bases for the installation of redundant cables.

6. Surveillance and Testing

The means proposed for monitoring the status of system operability are reviewed. Periodic onsite testing capability is reviewed.

7. Other Review Areas

The d-c system is reviewed to determine that:

(a) The system and its components have the appropriate seismic design classification.

(b) The system and its components are housed in a structure with seismic Category I classification.

(c) The system and its components are designed to withstand environmental conditions associated with normal operation, natural phenomena, and postulated accidents.

(d) The system and its components have a "Class 1E" quality assurance classification.

In the review of other areas associated with the d-c onsite power system, the PSB will coordinate other branches' evaluations that interface with the overall review of the system as follows: The Auxiliary System Branch (ASB) evalutes the adequacy of those auxiliary systems that are vital to the proper operation and/or protection of the d-c power system as part of its primary review responsibility for SRP Section 9.4. This includes such systems as the heating and ventilation systems for load center, battery, battery charger, and inverter rooms. In particular, the ASB determines that the piping, ducting, and valving arrangements of redundant vital auxiliary supporting systems meet the single failure criterion. In addition, the ASB examines the physical arrangement of the d-c power system and its supporting auxiliary system components and associated structures to determine that single events and accidents will not disable redundant features as part of its primary review responsibility for SRP Section 3.4.1, 3.5.1.1, 3.5.2, and 3.6.1. The ASB determines those system components requiring electric power as a function of time for each mode of reactor operation and accident conditions as part of its primary review responsibility for SRP Sections 6.7, 9.1.3, 9.1.4, 9.2, 9.3, 9.4, 9.5.1, 10.4.7, and 10.4.9. The Containment Systems Branch (CSB) evaluates the adequacy of those containment ventilation systems provided for maintaining a controlled environment for safety-related electrical equipment located inside the containment as part of its primary review responsibility for SRP Section 6.2.2. The CSB determines those system components requiring electric power as a function of time for each mode of reactor operation and accident condition as part of its primary review responsibility for SRP Sections 6.2.2, 6.2.4, and 6.2.5. The Equipment Qualification Branch (EQB) determines the environmental qualification of safety-related electrical equipment as part of its primary review responsibility for SRP Section 3.11. In particular, the EQB determines the capability of safety-related electrical equipment to perform their designed safety function when subject to and following (1) the effects of accident environments such as loss-of-coolant and steamline break accidents, (2) the effects of normal environments that exceed the equipment's design parameters such as temperature and humidity, (3) the effects of environments caused by loss of non-Class 1E heating and ventilation systems, (4) the effects of seimsic shaking, and (5) the effects of normal design environments on redundant safety-related electrical equipment that do not have diversity of design such as redundant components manufactured and designed by the same supplier. The Reactor Systems Branch (RSB) determines those system components requiring electric power as a function of time for each mode of reactor operation and accident condition as part of its primary review responsibility for SRP Sections 5.4.6, 5.4.7, and 6.3. The Instrumentation and Control Systems Branch (ICSB) determines those system components requiring electric power as a function of time for each mode of reactor operation and accident condition as part of its primary review responsibility for SRP Sections 7.2 through 7.7. In addition, ICSB verifies the adequacy of safety-related display instrumentation and other instrumentation systems including bypass indication required for safety as part of its primary review responsibility for SRP Sections 7.5

and 7.6. The Effluent Treatment Systems Branch (ETSB) determines those system components requiring electric power as a function of time for each mode of reactor operation and accident condition as part of its primary review responsibility for SRP Section 6.5.1. The Procedures and Test Review Branch (PTRB) determines the acceptability of the preoperational and initial startup tests and programs as part of its primary review responsibility for SRP Section 14.0. The Mechanical Engineering Branch (MEB) reviews the criteria for seismic qualification and the test and analysis procedures and methods to ensure the mechanical survivability of Category I instrumentation and electrical equipment (including raceways, switchgear, control room boards, and instrument racks and panels) in the event of a seismic occurrence. Electrical operability is reviewed by EQB as described above. The Chemical Engineering Branch (CMEB) examines the fire protection and fire fighting systems for the d-c power system and its supporting auxiliary system components to assure that adverse effects of fire are minimized as part of its primary review responsibility for SRP Section 9.5.1. This includes the adequacy of protection provided redundant safe shutdown circuits to determine that a single design basis fire will not disable both redundant circuits. The reviews for technical specifications and quality assurance including periodic testing are coordinated and performed by the Licensing Guidance Branch and Quality Assurance Branch as part of their primary review responsibility for SRP Sections 16.0 and 17.0, respectively.

For those areas of review identified above as being reviewed as part of the primary review reponsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

In general the d-c power system is acceptable when it can be concluded that this system has the required redundancy, meets the single failure criterion, is protected from the effects of postulated accidents, is testable, and has the capacity and capability to supply d-c power to all safety loads and other required equipment in accordance with GDC 2, 4, 5, 17, 18, and 50.

SRP Section 8.1 Table 8-1 lists General Design Criteria, regulatory guides and staff technical positions, utilized as the bases for arriving at this conclusion.

The design of the d-c power system is acceptable if the integrated design is in accordance with the following criteria and guidelines:

1. General Design Criterion 2, as related to structures, systems, and components of the d-c power system being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods, as established in Chapter 3 of the SAR and reviewed by ASB, and SEB as part of their primary review responsibility.

2. General Design Criterion 4, as related to structures, systems, and components of the d-c power system being capable of withstanding the effects of missiles and environmental conditions associated with normal operation and postulated accidents as established in Chapter 3 of the SAR and reviews by ASB, RSB and EQB as part of their primary review responsibility.

3. General Design Criterion 5, as related to the sharing of structures, systems, and components of the d-c power system, and the following guidelines:

   a. Regulatory Guide 1.32 (see also IEEE 308), as related to the sharing of structures, systems, and components of the d-c power system, position C.2.a.

   b. Regulatory Guide 1.81, as related to the sharing of structures, systems, and components of the d-c power system, position C.1.

4. General Design Criteron 17, as related to the onsite d-c power system's (a) capacity and capability to permit functioning of structures, systems, and components important to safety, (b) the independence and redundancy to perform its safety function assuming a single failure, and (c) provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit or the loss of power from the transmission network. Acceptance is based on meeting the following specific guidelines:

   a. Regulatory Guide 1.6, as related to the onsite d-c power system, positions D.1, D.3, and D.4.

   b. Regulatory Guide 1.32 (see also IEEE 308), as related to the onsite d-c power system.

   c. Regulatory Guide 1.75 (see also IEEE 384), as related to the onsite d-c power system.

5. General Design Criterion 18, as related to the testability of the onsite d-c power system, and the following guidelines:

   a. Regulatory Guide 1.32 (see also IEEE 308), as related to test capability of the onsite d-c power system.

   b. Regulatory Guide 1.118 (see also IEEE 378), as related to the capability for testing the onsite d-c power system.

6. The design requirements for an onsite d-c power supply for systems covered by General Design Criteria 33, 34, 38, 41 and 44 are encompassed in General Design Criterion 17.

7. General Design Criterion 50, as related to the design of containment electrical penetrations containing circuits of safety-related and nonsafety-related d-c power systems and guidelines of Regulatory Guide 1.63 (see also IEEE 317), as related to the capability of the electric penetration assemblies to withstand, without loss of mechanical integrity, the maximum possible fault current versus time condition that could occur given single random failure of circuit overload protective devices located in circuits of the onsite Class 1E and non-Class 1E d-c power systems.

Branch Technical Positions and Regulatory Guides that provide information, recommendations and guidance and in general describe a basis acceptable to the staff that may be used to implement the requirements of General Design

Criteria 2, 4, 5, 17, 18, and 50 are identified in SRP Section 8.1, Table 8.1 and Appendix 8-A.

III. REVIEW PROCEDURES

The primary objective in the review of the d-c power system is to determine that this system satisfies the acceptance criteria stated in subsection II and will perform its design functions during plant normal operation, anticipated operational occurrences, and accident conditions. In the CP review, the descriptive information, including the design bases and their relation to the acceptance criteria, preliminary analyses, electrical single line diagrams, functional logic diagrams, preliminary functional piping and instrumentation diagrams (P&IDs), and preliminary physical arrangement drawings are examined to determine that there is reasonable assurance that the final design will meet these objectives. At the OL stage, these objectives are verified during the review of final electrical schematics, functional P&IDs, and physical arrangement drawings and are confirmed during a visit to the site. To assure that acceptance criteria stated in subsection II are satisfied, the review is performed as detailed below.

The primary reviewer will coordinate this review with the other branch areas of review as stated in subsection I. The primary reviewer obtains and uses such input as required to assure that this review procedure is complete.

1. System Redundancy Requirements

   GDC 33, 34, 35, 38, 41, and 44 set forth requirements with regard to safety-related systems that must be supplied by the onsite (a-c and d-c) power systems. Also, these criteria state that safety-related system redundancy shall be such that for onsite power system operation (assuming offsite power is not available) the system safety function can be accomplished assuming a single failure. The acceptability of the onsite d-c power system with regard to redundancy is based on conformance to the same degree of redundancy required of safety-related components and systems required by these GDC. The descriptive information including electrical single line diagrams (CP and OL stages), functional P&IDs (CP and OL stages), and electrical schematics (OL stage) is reviewed to verify that this redundancy is reflected in the d-c power system with regard to both power sources and associated distribution systems. Also, it is verified in coordination with other branches that redundant safety-related loads are distributed between redundant distribution systems, and that the instrumentation and control devices for the safety-related loads and power system are supplied from the related redundant distribution systems.

2. Conformance with the Single Failure Criterion

   As required by GDC 17, the d-c power system must be capable of performing its safety function assuming a single failure. In evaluating the adequacy of this system to meet the single failure criterion, both electrical and physical separation of redundant power sources and distribution systems, including their connected loads, are reviewed to assess the independence between redundant portions of the system.

   To assure electrical independence, the design criteria, analyses, description, and implementation as depicted on functional logic diagrams, electrical single line diagrams, and electrical schematics are reviewed to determine that the design meets the requirements set forth in IEEE

Std 308 and satisfies the positions of Regulatory Guide 1.6. Additional guidance in evaluating this aspect of the design is derived from IEEE Std 379, "Guide for the Application of the Single Failure Criterion to Nuclear Power Generating Station Protection Systems," as augmented by Regulatory Guide 1.53. Other aspects of the design where special review attention is given to ascertain that the electrical independence and physical separation has not been compromised are as follows:

a. The interconnections between redundant load centers through bus tie breakers and multi-feeder breakers used to connect extra redundant loads to either of the redundant distribution systems are examined to assure that no single failure in the interconnections will cause the paralleling of the d-c power supplies. To assure this, the control circuits of the bus tie breakers or multi-feeder breakers must preclude automatic transferring of load centers or loads from the designated supply to the redundant counterpart upon loss of the designated supply (Position 4 of Regulatory Guide 1.6). Regarding the interconnections through bus tie breakers, an acceptable design will provide for two tie breakers connected in series and physically separated from each other in accordance with the acceptance criteria for separation of safety-related systems which is discussed below. Further, the interconnection of redundant load centers must be accomplished only manually.

b. To assure physical independence, the criteria governing the physical separation of redundant equipment including cables and cable trays, and their implementation as depicted on preliminary (CP stage) or final (OL stage) physical arrangement drawings are reviewed to determine that the design arrangement satisfies the requirements of IEEE Std 384 and positions of Regulatory Guide 1.75. These guides and standards set forth acceptance criteria for the separation of circuits and electrical equipment contained in or associated with the safety-related power system. To determine that the independence of the redundant cable installation is consistent with the requirements set forth in IEEE Std 384 and the positions set forth in Regulatory Guide 1.75, the proposed design criteria governing the separation of safety-related cables and raceways are reviewed including such criteria as those for cable derating; raceway filling; cable routing in containment penetration areas, cable spreading rooms, control rooms, and other congested areas; sharing of raceways with nonsafety-related cables or with cables of the same system or other systems; prohibiting cable splices in raceways; spacing of power and control wiring and components associated with safety-related electric systems in control boards, panels, and relay racks; and fire barriers and separation between redundant raceways.

3. D-C Power Supplies and Distribution Systems

In assuring that the requirements of GDC 17 and IEEE Std 308 have been met with regard to the d-c power system having sufficient capacity and capability to supply the required distribution system loads, the design bases, design criteria, analyses, description, and implementation as depicted on electrical drawings and performance characteristic curves are reviewed. To establish that the capacity of the d-c supply is adequate to power the prescribed loads, the nameplate capacity claimed in the design bases is checked against the loads identified in electrical distribution diagrams. The capability of the system is reviewed by evaluating

the performance characteristic curves that illustrate the response of the supplies to the most severe loading conditions at the plant. The performance characteristic curves would include voltage profile curves, discharge rate curves, and temperature effect curves. The capacity of the d-c supplies should be assured by periodic discharge tests of the batteries as described in IEEE Std 450 and Regulatory Guide 1.129.

The reviewer incoordination with other branches becomes familiar with the purpose and the operation of each safety system, including system component arrangements as depicted on functional P&IDs, expected system performance as established in the accident analyses, modes of system operation and interactions during normal and accident conditions, and interactions between systems. Following this, it is verified that the tabulation of all safety-related loads to be connected to each d-c supply is consistent with the information obtained incoordination with other branches.

The characteristics of each load (such as motor horsepower and volt-amp ratings, inrush current, starting volt-amps and torque), the length of time each load is required, and the basis used to establish the power required for each safety-related load (such as motor name plate rating, pump run out condition, or estimated load under expected flow and pressure) are utilized to verify the calculations establishing the combined load demand to be connected to each d-c supply during the "worst" operating conditions. In reviewing the design of the thermal overload protection for motors of motor operated safety-related valves, the reviewer is guided by Regulatory Guide 1.106.

Where the proposed design provides for the sharing of d-c supplies between units at the same site, and connection and disconnection of nonsafety-related loads to and from the safety-related distribution buses, particular attention is given in the review to assure that the implementation of such design provisions does not compromise the capacity, capability, or reliability of these supplies.

In the absence of specific criteria in IEEE Std 308 governing the connection and disconnection of nonsafety-related loads to and from the safety-related distribution buses, the review of the interconnections will consider isolation devices as defined in Regulatory Guide 1.75 and engineering judgement to determine the adequacy of the design. In assuring that the interconnections between nonsafety-related loads and safety-related buses will not result in the degradation of the safety-related system, the isolation device through which d-c power is supplied to the nonsafety-related load, including control circuits and connections to the safety-related bus, must be designed to meet safety Class 1E requirements. Should the d-c power supplies not have been sized to accommodate the added nonsafety-related loads during emergency conditions, the design must provide for the automatic disconnection of those nonsafety-related loads upon detection of the emergency condition. This action must be accomplished whether or not the load was already connected to the power supply.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and that the review supports conclusions of the following type, to be included in the staff's Safety Evaluation Report.

The d-c power system includes power supplies, distribution systems, and load groups arranged to provide d-c electric power to safety-related d-c loads and for control and switching of the safety-related power systems. The d-c power system also provides d-c electric power to inverters. The inverter convert the d-c to a-c and are arranged to provide a dependable power supply for safety-related instrumentation and control loads. The review of the d-c power system for the _____ plant covered the single line diagrams (CP and OL), station layout drawings (CP and OL), schematic diagrams (OL), and descriptive information. The basis for acceptance of the d-c power system in our review was conformance of the design criteria and bases to the Commission's regulations as set forth in the General Design Criteria (GDC) of Appendix A to 10 CFR Part 50. The staff concludes that the plant design is acceptable and meets the requirements of GDC 2, 4, 5, 17, 18, and 50. This conclusion is based on the following:

1. The applicant has met the requirements of GDC 2, "Design Basis for Protection Against Natural Phenomena," with respect to structures, systems, and components of the d-c power systems being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods as the d-c power system and components are located in seismic Category I structures which provides protection from the effects of tornadoes, tornado missiles, and floods. In addition, the d-c power system and components have a quality assurance designation "Class 1E."

2. The applicant has met the requirements of GDC 4, "Environmental and Missile Design Bases," with respect to structures, systems, and components of the d-c power system being capable of withstanding the effects of missiles and environmental conditions associated with normal operation and postulated accidents by adequate plant design and equipment qualification program.

3. The applicant has met the requirements of GDC 5, "Sharing of Structures, Systems, and Components," with respect to structures, systems, and components of the d-c power system. The d-c power system and components associated with the multi-unit design are housed in physically separate seismic Category I structures, and are not shared between units. Acceptability was based on the applicant meeting Regulatory Guide 1.32, position C.2.a, and guidelines of Regulatory Guide 1.81, position C.1.

4. The applicant has met the requirements of GDC 17, "Electric Power Systems," with respect to the onsite d-c power system's (a) capacity and capability to permit functioning of structures, systems, and components important to safety, (b) the independence and redundancy to perform their safety function assuming a single failure, and (c) provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit or the loss of power from the transmission network. Acceptability was based on the applicant's design of the d-c power systems meeting the guidelines of Regulaory Guide 1.6, positions D.1, D.2 and D.4, the guidelines of Regulatory Guide 1.32 and the guidelines of Regulatory Guide 1.75.

5. The applicant has met the requirements of GDC 18, "Inspection and Testing of Electric Power Systems," with respect to the onsite d-c power system. The d-c power system is designed to be testable during operation of the nuclear power generating station as well as during those intervals when the station is shutdown. Acceptability was based on the applicant meeting test capability guidelines of Regulatory Guide 1.32 and the guidelines of Regulatory Guide 1.118.

6. The applicant has met the requirements of GDC 50, "Containment Design Bases," with respect to penetrations containing circuits of the safety and nonsafety related d-c power system. Containment electric penetrations have been designed to accommodate, without exceeding their design leakage rate, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident concurrent with the maximum short-circuit current versus time condition that could occur given single random failures of circuit overload protective devices. This meets the positions of Regulatory Guide 1.63,

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. Standard Rview Plan Section 8.1, Table 8-1, "Acceptance Criteria and Guidelines for Electric Power Systems."

2. Standard Review Plan Appendix 8-A, "Branch Technical Positions (PSB)."

3. Standard Review Plan Appendix 8-B, "General Agenda, Station Site Visits."