U.S. NUCLEAR REGULATORY COMMISSION
STANDARD REVIEW PLAN
OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 8.3.2 D-C POWER SYSTEMS (ONSITE)

REVIEW RESPONSIBILITIES

Primary - Electrical, Instrumentation and Control Systems Branch (EICSB)

Secondary - Auxiliary and Power Conversion Systems Branch (APCSB)
Containment Systems Branch (CSB)
Mechanical Engineering Branch (MEB)
Reactor Systems Branch (RSB)
Quality Assurance Branch (QAB)

I. AREAS OF REVIEW

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 power as required. Information on the d-c power system presented in the applicant's safety analysis report (SAR) is reviewed by the staff to determine that the d-c power system required for safe operation during all operating and accident conditions meets the requirements of General Design Criteria (GDC) 17 and 18 and are consistent with Regulatory Guide 1.32, applicable industry standards, and staff positions as listed in Table 8-1. For construction permit (CP) applications, the descriptive information presented for the d-c power system should include commitments to meet the acceptance criteria listed below or adequate justification for exceptions taken, preliminary single line diagrams illustrating the redundancy of d-c power supplies, preliminary load assignments, and preliminary physical arrangement drawings illustrating the independence of redundant batteries and distribution circuits. For operating license (OL) applications, the descriptive information presented should include final single line diagrams, electrical schematics, final physical arrangement drawings, and complete load distribution diagrams, as are needed to determine that the d-c power system has sufficient capacity and capability to meet its functional requirements and otherwise satisfies the mandatory design criteria.

The EICSB will pursue the following phases in the review of the d-c power system:

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

2. 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; the physical arrangement of redundant load centers and power supplies; proposed sharing of the d-c power system between units at the same site; and the design criteria and bases governing the installation of electrical cable for redundant portions of the systems.

3. Design information and analyses demonstrating the suitability of batteries and battery chargers as d-c power supplies are reviewed to assure that they have sufficient capacity, capability, and reliability to perform their intended functions. This will require an examination of the characteristics 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 non-safety-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. The means proposed for identifying the d-c power system cables and cable trays as safety-related equipment in the plant are reviewed. Also, the identification scheme used to distinguish between redundant cables and cable trays of the power system is reviewed.

5. 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 IE 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. Preoperational and initial start-up test programs and periodic onsite testing capabilities are reviewed. The means proposed for automatically monitoring the status of system operability are reviewed.

7. Other areas of review associated with these systems which are covered elsewhere are as follows:

   a. Environmental design and qualification testing of electrical equipment are addressed in Standard Review Plan (SRP) 3.11.

   b. Technical specification requirements imposed upon the operation of the d-c power system are discussed in Chapter 16 of the SAR. Assistance and consultation on technical specifications for the d-c power system are provided in accordance with the procedures stated in SRP 8.1.

The APCSB will evaluate the adequacy of those auxiliary systems that are vital to the proper operation of the d-c power system. These include such systems as the heating and ventilation systems for load center, battery, and battery charger and inverter rooms, and fire detection and protection systems. In particular, the APCSB will determine that the piping, ducting, and valving arrangments of redundant vital auxiliary supporting systems meet the single failure criterion. In addition, the APCSB will examine the physical arrangment of components and structures associated with the d-c power system and its supporting auxiliary aystems and determine that single events and accidents will not disable redundant features.

The CSB will identify those containment ventilation systems provided for maintaining a controlled environment for safety-related instrumentation and electrical equipment located inside the containment.

The MEB reviews the criteria for seismic qualification analyses, and the test and analysis procedures and methods to assure the operability of instrumentation and electrical equipment in the event of a seismic occurrence.

The RSB will identify any differences or changes in the safety-related loads and systems from those stated in the SAR that are needed to assure sufficient capacity.

The QAB will verify the adequacy of the quality assurance program for this system.

II. ACCEPTANCE CRITERIA

The d-c power system is acceptable when it can be concluded that this system has the required redundancy, meets the single failure criterion, and has the capacity, capability, and reliability to supply d-c power to all safety-related loads required by the accident analyses. Table 8-1 lists the criteria that are utilized as the bases for arriving at this conclusion. In addition, the references include those evaluation guides used by the reviewer as aids in ascertaining that the criteria have been met. Section III of this plan discusses the application of these evaluation guides to the review. The application of most of the acceptance criteria to the areas of review described in Section I of this plan is detailed below. The applicability of other criteria listed in Table 8-1 but not specifically addressed above is considered to be self-evident, and their application in the review process is considered self-explanatory.

1. System Redundancy Requirements

GDC 22, 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 preferred 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 by these GDC.

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. To meet this requirement, electrical independence between redundant portions of this system must be maintained. An acceptable design in this regard must meet the requirements of IEEE Std 308 and satisfy the positions of Regulatory Guide 1.6. Should the proposed design provide for sharing of the d-c power system between units at the same site, the governing criteria stated in IEEE Std 308 are not explicit enough to be used as the basis for acceptance. Therefore, the acceptability of such a design to meet the single failure criterion is based on the design satisfying the recommendations of Regulatory Guide 1.81. This position sets forth acceptable bases for implementing the requirements of GDC 5, "Sharing of Structures, Systems, and Components." To assure that physical independence of redundant equipment, including cables and cable trays, is maintained in accordance with the requirements of GDC 2, 3, and 4, an acceptable design arrangement should satisfy the positions of Regulatory Guide 1.75.

3. Power Supplies

a. The capacity, capability, and reliability of the d-c power supplies is acceptable if the basis for selection of the batteries and battery chargers satisfies the requirements of IEEE Std 308.

b. The Regulatory position in Regulatory Guide 1.81 states that the sharing of d-c power systems between generating units will not be permitted.

c. Should the proposed design provide for the connection and disconnection of non-safety-related loads to and from the standby d-c power supplies, it should conform to Regulatory Guide 1.75 with respect to the role isolation devices play in this regard. The design must be such as to assure that the interconnections and the added non-safety-related loads will not result in any degradation of the safety-related system.

d. Regarding the design of thermal overload protection for motors of motor-operated safety-related valves, the acceptability of the design is based on Branch Technical Position EICSB 27.

4. Identification of Cables and Cable Trays

The method used for identifying d-c power system cables and cable trays as safety-related equipment in the plant, and the identification scheme used to distinguish

between redundant cables and cable trays are acceptable if in accordance with Regulatory Guide 1.75.

5. Vital Supporting Systems

The instrumentation, controls, and electrical equipment for those supporting systems identified as vital to the proper functioning of the safety-related systems are acceptable if the design conforms to the same criteria as for the safety-related systems supported.

6. System Testing and Surveillance

To assure that the preoperational and initial start-up test programs for the d-c power system meet the requirements of GDC 1, they must be in accordance with Regulatory Guides 1.68 and 1.41. To assure that the periodic onsite testing capabilities satisfy the requirements of GDC 18 and 21, an acceptable testing program should include the battery capacity tests described in Section 5 of IEEE Std 450 and the positions of Regulatory Guide 1.22. With regard to surveillance of the d-c power system operability status, an acceptable design should satisfy the positions of Regulatory Guide 1.47, as augmented by Branch Technical Position EICSB 21.

7. Other Review Areas

For those areas of review identified as being the responsibility of other branches, the acceptance criteria and their application to the areas of review are included in the appropriate standard review plans. However, there are some acceptance criteria that are commonly used by both primary and secondary review branches as the basis for determining that a design is acceptable. For the d-c power system, these criteria and their application to the areas of review are as follows:

a. Seismic Design Requirements

In determining the adequacy of the seismic design of Category I instrumentation and electrical equipment, both the MEB and EICSB will perform reviews in this regard to ascertain that the proposed design satisfies such standards as IEEE Std 344, "Guide for Seismic Qualification of Class I Electric Equipment for Nuclear Power Generating Stations," as supplemented by Branch Technical Position EICSB 10, "Electrical and Mechanical Equipment Seismic Qualification Program."

b. Quality Assurance

To assure that the requirements of GDC 1 are met in the d-c power system, the quality assurance program for the safety-related instrumentation and electrical equipment must satisfy the requirements of IEEE Std 336, "Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations," as augmented by Regulatory Guide 1.30, "Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment." Both the QAB and EICSB will perform reviews in this regard to ascertain that the proposed quality assurance program is consistent with the acceptance criteria.

III. REVIEW PROCEDURES

The main objectives in the review of the d-c power system are to determine that this system has the required redundancy, meets the single failure criterion, and has the capacity, capability, and reliability to supply d-c power to all required safety-related loads. 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 these objectives have been met in accordance with the requirements of the criteria, the review is performed as detailed below.

In certain instances, it will be the reviewer's judgement that for a specific case under review, emphasis should be placed on specific aspects of the design, while other aspects of the design need not receive the same emphasis and in-depth review. Typical reasons for such placement of emphasis are the introduction of new design features or the utilization in the design of design features previously reviewed and found acceptable.

In addition to the review procedures of the EICSB, this section identifies those aspects of the review that will be accomplished by the secondary review branches.

1. System Redundancy Requirements

Based on the information provided by the RSB with regard to the required redundancy of safety-related components and systems (GDC 33, 34, 35, 38, 41, and 44), 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 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

In evaluating the adequacy of this system to meet the single failure criterion (GDC 17), 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. Since IEEE Std 308 does not set forth specific criteria governing the design of the circuits that initiate and control d-c power, the reviewer utilizes IEEE Std 279, "Criteria for Protection Systems for Nuclear Power Generating Stations," as an evaluation guide to ascertain that the designs of these circuits satisfy the basic single failure requirements of protection systems. Other aspects of the design where special review attention is given to ascertain that the electrical independence has not been compromised are as follows:

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.

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 positions of Regulatory Guide 1.75, "Physical Independence of Electric Systems." This guide sets forth acceptance criteria for the separation of circuits and electrical equipment contained in or associated with the safety-related power system. In essence, the review objective is to determine that the design provides for redundant portions of this system to be located in physically separated seismic Category I structures (GDC 2). It is verified that each structure has independent heating and ventilation (H&V) systems (including supply and exhaust pipes or ducts) to assure against single events and accidents from disabling redundant features (GDC 3, 4). The APSCB has primary responsibility in the review of the design arrangement of the Class IE systems and their vital supporting systems, except for the cable design which is the responsibility of the EICSB. The APCSB will also verify the adequacy of physical barriers such as doors separating redundant portions of this system to assure that events such as fire and flooding in one structure will not be propagated to other redundant equipment structures (GDC 3, 4). To determine that the independence of the redundant cable installation is consistent with the position 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; cable tray filling; cable routing in containment, penetration.

areas, cable spreading rooms, control rooms, and other congested areas; sharing of cable trays with non-safety-related cables or with cables of the same system or other systems; prohibiting cable splices in conduits and trays; fire detection and protection in the areas where cables are installed; 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 trays. With regard to determining the adequacy of the physical independence of redundant cables through penetration areas, the reviewer utilizes, in addition to Regulatory Guide 1.75, IEEE Std 317 as augmented by Regulatory Guide 1.63 as evaluation guides to ascertain that the electric penetration assemblies are designed in accordance with the requirements for safety-related equipment.

3. D-C Power Supplies

In assuring that the requirements of GDC 17 and IEEE Std 308 have been met with regard to the d-c power system (batteries and battery chargers) having sufficient capacity, capability, and reliability to supply the required distribution system loads, the design bases, design cirteria, 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 reliability of the d-c supplies should be assured by periodic discharge tests of the batteries as described in IEEE Std 450, and amplified by Branch Technical Position EICSB 6.

The reviewer first 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 provided by the RSB.

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 Branch Technical Position EICSB 27.

Where the proposed design provides for the sharing of d-c supplies between units at the same site, and connection and disconnection of non-safety-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 non-safety-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 non-safety-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 non-safety-related load, including control circuits and connections to the safety-related bus, must be designed to meet safety Class IE requirements. Should the d-c power supplies not have been sized to accommodate the added non-safety-related loads during emergency conditions, the design must provide for the automatic disconnection of those non-safety-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.

The description of the qualification test program (CP stage) and the results of such tests (OL stage) for demonstrating the suitability of the batteries and battery charger as d-c power supplies are judged to be acceptable if they satisfy the acceptance criteria listed in Section II.3 of this SRP or Table 8-1.

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 the batteries, battery chargers, and distribution centers used to supply power to d-c operated safety-related equipment. The scope of review of the d-c power system included single line diagrams (CP and OL), schematic diagrams (OL), and descriptive information for the d-c power system and for those auxiliary supporting systems that are essential to the operation of the d-c power system. The review has included the applicant's proposed design criteria and his analyses of the adequacy of those criteria and bases. The review also has included the applicant's analyses of the manner in which the design of the d-c power system conforms to the proposed design criteria. The basis for acceptance in the staff review has been conformance of the applicant's design, design criteria, and design bases for the d-c power system to the Commission's regulations as set forth in the general design criteria, and to applicable regulatory guides, branch technical positions, and industry standards. These are listed in Table 8-1.

"The staff concludes that the design of the d-c power system conforms to applicable regulations, guides, technical positions, and industry standards and is acceptable."

V. REFERENCES

1. Standard Review Plan Table 8-1, "Acceptance Criteria for Electric Power."

11/24/75

SRP 9.1.1