DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

April 13, 2012

Mr. David Huizenga
Senior Advisor for Environmental Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0113

Dear Mr. Huizenga:

The staff of the Defense Nuclear Facilities Safety Board (Board) reviewed the ongoing design and construction of the electrical distribution system for the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site. The review included discussions with representatives from the Department of Energy (DOE), as well as its contractor, Bechtel National, Incorporated (BNI), on December 13–15, 2011. The Board believes that the electrical distribution system design has a substantial number of specific safety issues that require action. The enclosed report provides details on these issues.

Although the WTP electrical distribution system meets many of the requirements of DOE orders and consensus industry standards, the review by the Board's staff raised concerns about the operability and safety of the overall electrical distribution system. Safety-related electrical equipment for the Low Activity Waste Facility is being procured without invoking requirements for equipment qualification. During a walk-down of the WTP construction site, the staff found evidence that 13.8 kV electrical cables had been submerged under water in a manhole. The staff identified numerous pieces of installed electrical equipment that have open gratings and are placed under the sprinklers of the fire protection system, resulting in hazardous conditions. The staff also found that the safety strategy for valve-regulated lead-acid batteries failed to address the credible hazards of battery fires and explosions, resulting from thermal runaway and hydrogen release scenarios.

During the review, the staff discussed the project's recent decision to employ combustion turbine driven generators combined with uninterruptable power supply systems in lieu of the normally used reciprocating diesel engine driven generators as the WTP emergency power source. This design change introduces new safety requirements, which are not yet included in the WTP safety basis. As combustion turbine generators are not currently used at any defense nuclear facilities, the project's plans for qualifying this equipment for safety-class use are still under development. Therefore, the Board's staff did not attempt to evaluate the adequacy of this subsystem.

Pursuant to 42 U.S.C. § 2286b(d), the Board requests a report within 120 days of receipt of this letter outlining actions DOE has taken or plans to take to address the issues related to the design and construction of the WTP electrical distribution system summarized above and discussed in the enclosed report.

Sincerely,

Peter S. Winokur, Ph.D.
Chairman

Enclosure

c: Mr. Matthew S. McCormick
Mr. Scott L. Samuelson
Mrs. Mari-Jo Campagnone

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

February 8, 2012

MEMORANDUM FOR: T. J. Dwyer, Technical Director

COPIES: Board Members

FROM: P. Fox, A. Gwal, and M. Horr

SUBJECT: Review of the Electrical Distribution System for the Waste Treatment and Immobilization Plant, Hanford Site

This report documents the results of a review conducted by the staff of the Defense Nuclear Facilities Safety Board (Board) of the electrical distribution system for the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site. Staff members P. Fox, A. Gwal, M. Horr, W. Linzau, and R. Quirk met with representatives from the Department of Energy's (DOE) Offices of River Protection (ORP) and Richland Operations (RL), as well as DOE's contractor, Bechtel National, Incorporated (BNI), on December 13–15, 2011. The staff reviewed the design of the medium- and low-voltage electrical distribution system (including the class 1E emergency power system) and supporting uninterruptible power supply (UPS) systems. The review also included discussion of the WTP project team's plan to replace the typically used reciprocating diesel driven generators with combustion turbine generators for the safety-class (SC) emergency power system. The staff also completed a walk-down of construction site areas where significant electrical installations are complete or in progress.

Background. The WTP project's electrical design is nearing completion. BNI reports that the electrical designs for all five WTP facilities are more than 80 percent complete with the exception of the Pretreatment Facility (PTF), which is 69 percent complete. The class 1E emergency power system comprises the majority of the remaining design work. This is due to the project team's decision to replace the SC reciprocating diesel driven generators with SC emergency turbine generators and large SC UPS systems. Additionally, the project team has selected valve-regulated lead-acid (VRLA) batteries for use in UPS systems and for electrical distribution of direct current (DC) power. This design decision requires a reevaluation of the hazards and controls associated with the batteries and their chargers.

Electrical Distribution System. The staff determined that the requirements of Institute of Electrical and Electronics Engineers (IEEE) standards are generally incorporated into the overall design. The staff concluded that the existing design meets the single-failure criterion and redundancy requirements specified in IEEE Standard 308, *IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations,* and IEEE Standard 384, *IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits*, as tailored in the WTP Safety

Requirements Document (SRD). Specific issues identified with the design of the WTP electrical distribution system and its construction are detailed below.

Electrical Equipment Qualification—The WTP SRD requires that safety-related electrical equipment meet the service and environmental qualification requirements of IEEE Standard 323, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*. However, per BNI's letter to ORP dated March 29, 2010, (CCN 214065) and ORP's response to BNI dated March 30, 2010, (CCN 216355), the project team is procuring safety-significant (SS) electrical equipment for the Low Activity Waste (LAW) Facility that has been exempted from these requirements. BNI cited and DOE agreed with three reasons for this exemption: (1) the SS classification is due to chemical toxicity hazards, (2) the equipment will be procured from chemical industry vendors that lack experience with some IEEE nuclear industry specific standards, and (3) the LAW Facility has minimal radiological hazards. BNI's request and DOE's approval of this exemption were predicated on BNI adopting equivalent chemical industry codes and standards for the design, specification, and fabrication of electrical components to ensure that the equipment can perform its intended safety function in the anticipated environment. However, the project team has not identified any chemical industry codes and standards or developed a process to compare the requirements of these standards to nuclear industry IEEE standards.

While the Board's staff concurs that the harsh environment and radiation safety requirements of IEEE Standard 323 may not be applicable to equipment in the LAW Facility, the remaining service and environmental qualification requirements of IEEE Standard 323 and the seismic qualification requirements of IEEE Standard 344, *IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*, are applicable. The WTP project team needs to select and justify a suitable equivalent set of chemical industry codes and standards to replace the requirements of these IEEE nuclear standards or clearly state and justify which portions of IEEE Standard 323 and IEEE Standard 344 remain applicable to qualification of SS electrical equipment in the LAW facility. Qualification to environmental and seismic conditions is necessary to ensure that the electrical equipment will perform its credited safety functions under expected operating and accident conditions.

Cable Ampacity Derating—BNI representatives stated that current cable sizing criteria are based only on planned electrical loading and environmental conditions and do not take the effects of penetration seals or fire-protected cable trays and conduits into consideration. Cable sizing and ampacity derating is especially important when electrical cable is installed through penetration seals in fire stops or in fire-protected trays and conduits, as is expected in the final design of some WTP facilities. These fire protection features cause a reduction in the heat transfer characteristics of electrical cables and result in localized hot spots where the cable's thermal limits may be exceeded at current levels below the cable's original ampacity rating. By derating the maximum current a cable can carry, these localized hot spots can be prevented. Cables that are sized without considering this can fail and become unable to perform their safety function. The design is approaching the maturity level where cable routes will soon be finalized. Once cable routing has been finalized in the design, the project team can calculate appropriate derating factors from testing in accordance with IEEE Standard 848, *IEEE Standard Procedure for the Determination of the Ampacity Derating of Fire-Protected Cables,* or an equivalent methodology. However, the Board's staff found that neither IEEE Standard 848 nor equivalent requirements are included in either the WTP SRD or the Basis of Design (BOD). This could lead to procurement of inadequately sized cables.

Adjustable Speed Drives Fed from Uninterruptible Power Supplies—The design of the WTP facilities relies on adjustable speed drives (ASD) fed from UPS systems to control many of the large (above 150 hp) motors. These large SS and SC motors, such as those of the SC 250 hp C5V exhaust fans in PTF, require electrical power during a loss of off-site power event. UPS systems will provide emergency power for these safety-related ASDs until either the emergency generators are ready for SC loads or the loads are no longer required due to a process shutdown for SS loads. Typically, an engine-driven electrical generator, which has a purely sinusoidal output voltage waveform, is used to provide emergency power to ASDs and motors of this size. However, the output waveforms of UPS systems are not pure sinusoids and may contain high frequency harmonics. The effects of these harmonics and other voltage fluctuations on the ASDs' power conversion electronics are difficult to predict and control. Without proper analysis and testing, this design approach may jeopardize the operability of safety-related systems.

The use of UPS systems to power ASDs has not been previously attempted in DOE defense nuclear facilities, but similar power electronics applications in other industries have often resulted in overheating of electrical components as well as vibration and mechanical failure of mechanical components. In these circumstances, the solutions required to address the problem were often expensive, labor intensive, and proprietary.

If an electrical generator is required because UPS system cannot reliably supply electrical power to ASDs that drive safety-related equipment, significant design changes would be necessary. For example, the LAW Facility currently has no connection to a safety-related generator, and such a connection would have to be added.

A thorough knowledge of each UPS and ASD combination is fundamental to ensuring that the system can perform its safety function reliably. The WTP project will need to determine the potential voltage fluctuations and harmonics inflicted on ASDs due to switching to and operating on power from UPS systems, and the effects on the ASDs and the driven motor's performance. The project team will have to evaluate the potential for these phenomena to impact system reliability and develop and implement requirements for filtering equipment for each UPS, ASD, and motor combination that performs a SS or SC function.

Fast Reclosing of Power Supply Breakers—The staff reviewed the project's strategy for preventing damage to large induction motors as a result of fast reclosing of electrical breakers and operation of automatic bus transfer switches. As detailed in National Electrical Manufacturers Association (NEMA) MG-1-1993, Revision 2, Motors and Generators section 20.85; initially upon a loss of power, induction motors continue to rotate and retain residual magnetism; therefore, they develop generator action and induced voltages. When the motors are exposed to an automatic bus transfer or a fast reclosing of the power supply breaker, there is a potential for the incoming voltage to be out of phase with that induced in the rotating machine. This can result in the development of a transient current and torque, the magnitude of which may range from 2 to 20 times the value rated for the machine, potentially causing damage to the motor. The severity of this damage is a function of the machine's construction, system inertia, operating conditions, and switching times. The project team will have to perform an evaluation of the magnitude and effects transient torque has on large induction motors during a rapid restoration of power in order to provide suitable protective devices for the protection of the connected motors, as required by NEMA MG-1.

NEMA MG-1 is not directly included in either the WTP SRD or BOD. Various standards that are included in the project's SRD and BOD cite differing versions of NEMA MG-1. NEMA MG-1 is also listed as a requirement in several procurement specifications for electrical equipment for WTP. The project team should select an appropriate version of the NEMA MG-1 standard for inclusion in both the WTP SRD and BOD to ensure that protective measures are implemented to prevent a loss or challenge to a safety function due to rapid restoration of power.

Valve-Regulated Lead-Acid Battery Charging System Safety Control Set—Chemical reactions in lead-acid batteries produce hydrogen and introduce explosion and fire hazards. To minimize this hazard, the project team selected VRLA batteries for use in the safety-related and non-safety-related portions of the UPS and DC electrical (DCE) systems. The design of VRLA batteries limits the release of hydrogen during normal operation and reduces the hazard by containing and recombining hydrogen and oxygen in the battery. However, high ambient temperatures or high battery temperature caused by overcharging can increase pressure within the battery and cause significant hydrogen gas releases. To limit this hazard, most VRLA batteries use a temperature compensated charging system that helps limit battery temperatures and reduces the likelihood of battery overpressure. Additionally, to mitigate the hydrogen hazard, IEEE Standard 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications*, requires that areas containing VRLA batteries have dedicated ventilation systems to remove the heat generated by the battery charging process and to remove any hydrogen gas generated by the batteries.

The WTP project team recently modified the strategy used to control the hydrogen hazard associated with charging lead acid batteries. The control strategy now credits the temperature compensated charging system with preventing the generation of hydrogen gas as long as the safety-related cooling ventilation system maintains ambient temperature within an expected range. Using this control, the project team determined that battery fires and explosions are no longer credible events and thus eliminated a previous safety-related control requirement for ventilation flow across the batteries to prevent hydrogen gas accumulation while maintaining safety-related ventilation for battery cooling.

However, the staff notes that IEEE Standard 1187 considers battery fires and explosions to be credible events for systems that use temperature compensated charging. Consequently, the standard requires direct ventilation and recommends temperature compensated charging for mitigation of hydrogen hazards in addition to requiring ventilation for prevention of battery overheating. Thus there is a conflict between the standard and the current WTP safety strategy. The staff reviewed the justification provided for elimination of the requirement to provide ventilation to prevent hydrogen accumulation but determined it did not provide a compelling argument for failing to comply with IEEE Standard 1187.

The WTP project team has purchased the Alcad AT-30 series battery charger for use in the non-safety-related UPS and DCE installations in the WTP facilities. The staff's review of the Alcad AT-30 operating and service instructions revealed that the Alcad charger will allow battery charging to continue in a non-temperature compensated mode if the temperature compensating circuit fails. If the project team selected the same model of battery charger for the safety-related portions of the UPS and DCE systems, this mode of operation would represent a dangerous failure of an active safety control. The presence of a dangerous failure mode indicates that battery explosions and fires are a credible hazard. The relevant standards for the design of safety instrumented systems require methods to prevent or mitigate dangerous failure modes.

Valve-Regulated Lead-Acid Battery Installation Location—During a walk-down of the WTP facilities, the Board's staff observed that many of the installed battery racks and associated charging systems are located in open areas near switchgear. In some cases, equipment located near the UPS systems and batteries is classified SS or SC. NESC C2-2012, *National Electrical Safety Code*, requires that storage batteries be located "within a protective enclosure or area accessible only to qualified persons." This requirement exists to protect equipment and personnel from the hazards and effects associated with battery fires and explosions. Additionally, DOE Standard 1027, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, requires that hazard controls to protect facility workers from the effects of operational accidents be considered. Based on applicable standards, the failure modes associated with VRLA batteries and the potential hazards to facility workers and safety equipment, the WTP battery units require enclosed and protected spaces away from normal personnel traffic and away from other safety related equipment.

Unprotected Electrical Equipment—During a walk-down of the WTP facilities, the staff identified numerous pieces of installed safety-related and non-safety-related electrical equipment with open gratings on the top of the equipment. Examples include switchgear, UPS systems, battery chargers, and power panels. These openings are located under the sprinkler heads of the fire protection system. Spray from activation of the sprinkler system or leakage from co-located fluid systems would likely penetrate this equipment and generate a short circuit that could damage the equipment and create hazardous conditions. The staff found this identical condition in the A-6 substation at Hanford during a 2004 review, as documented in the Board's letter to DOE dated August 26, 2004. The staff believes that if DOE had adopted an appropriate design standard such as IEEE Standard 833, *IEEE Recommended Practice for the Protection of Electric Equipment in Nuclear Power Generating Stations from Water Hazards*, this deficiency would have been prevented. IEEE Standard 833 addresses these issues and provides guidance for the protection of electrical equipment. Neither BNI personnel nor the Board's staff could readily determine the extent to which procured electrical equipment is affected by this problem. The

Board's staff continues to believe that the WTP project should include IEEE Standard 833 or an equivalent standard in the WTP SRD and BOD and implement its requirements for the protection of electrical equipment from water hazards.

High Voltage Cables in Manholes—The staff requested that two underground manholes housing electrical cables be opened for inspection. These cables supply power to nuclear facilities in the area. BNI personnel found several feet of water in manhole number 45, which houses several 13.8 kV cables, indicating that the current drainage system is not functional and that the design is inadequate to prevent wetting electrical cables. BNI had the water removed prior to the staff's arrival; however, the cables still showed signs of being submerged, and the staff questioned how long they had been submerged, the impact to their durability after being submerged, and their long-term ability to function underwater. The insulation material of submerged electrical cables will gradually lose its dielectric strength, which can lead to electrical faults, potentially resulting in explosions. This phenomenon was observed in manholes at the Y-12 site in the 1990s. Protecting the cables will require that the WTP project team develop a program to routinely survey manholes containing power cables for water and make modifications as necessary to keep electrical cables dry. These modifications could include installation of cable supports such as those detailed in the American Electricians' Handbook, which provides guidance on meeting the requirements of the National Electric Code. These modifications should ensure that cables are kept above the expected waterline in the event of manhole flooding.

Past Due Calibration of Protective Devices—During a walk-down of the switchgear room in the A6 substation, the Board's staff observed that the posted calibration date for many of the protective devices was more than 10 years ago (August 2001). DOE-RL personnel stated that these postings may be from the original programming and installation of the switchgear and that the switchgear is not calibrated on site, but sent back to the manufacturer in the event that it fails a calibration check. DOE-RL personnel could not provide the calibration check requirements or any records to support meeting these requirements. The A6 substation is currently not supplying any loads on the WTP site, but the equipment in the switchgear building is energized. The substation is scheduled to enter service in 2012 when some WTP buildings begin commissioning. It is not clear why DOE-RL is not requiring the contractor to maintain and calibrate electrical protective devices at the manufacturer's recommended intervals, or formally remove the equipment from service.

Emergency Turbine Generator Design Change—The project team's recent decision to replace the SC reciprocating diesel driven generators with SC emergency turbine generators (ETGs) and large SC UPS systems affects the WTP safety basis. Since the startup time requirements for ETGs exceed those of reciprocating diesels, the WTP project team is adding large SC UPS units to the design to power safety equipment during ETG startup. This emerging issue introduces new safety requirements and it is unclear how they will be incorporated into the safety basis. Additional staff reviews will be necessary after this portion of the design matures to determine the adequacy of the design changes and the selected safety requirements.