February 22, 2002

MEMORANDUM TO: Gary M. Holahan, Director, DSSA:NRR
Jack R. Strosnider, Jr., Director, DE:NRR
John Zwolinksi, Director, DLPM:NRR
David B. Matthews, Director, DRIP:NRR
Scott Newberry, Director, DRAA:RES
Michael E. Mayfield, Director, DET:RES
A. Randolph Blough, Director, DRP:RGN-I
Loren R. Plisco, Director, DRP:RGN-II
Geoffrey E. Grant, Director, DRP:RGN-III
Kenneth E. Brockman, Director, DRP:RGN-IV

FROM: Farouk Eltawila, Director **/RA/**
Division of Systems Analysis and Regulatory Effectiveness
Office for Nuclear Regulatory Research

SUBJECT: FINAL REPORT: OPERATING EXPERIENCE ASSESSMENT – ENERGETIC FAULTS IN 4.16 kV TO 13.8 kV SWITCHGEAR AND BUS DUCTS THAT CAUSED FIRES IN NUCLEAR POWER PLANTS 1986–2001

Attached is the final report, "Operating Experience Assessment-Energetic Faults in 4.16 kV and 13.8 kV Switchgear and Bus Ducts That Caused Fires in Nuclear Power Plants 1986-2001." On March 18, 2001, Maanshan Unit 1, a nuclear plant in Taiwan, experienced a fire and a station blackout due to an electrical fault in a safety-related 4.16 kV switchgear. The Office of Nuclear Regulatory Research (RES) assessed the Maanshan and five similar U.S. fires from 1986 to June 2001. Specific objectives were to identify and assess U.S. fire incidents similar to Maanshan to: (1) better understand and characterize fire effects in fire risk modeling for evaluation under the RES Fire Risk Research Program, (2) identify potential lessons learned in the areas of inspection, plant design, maintenance, and operations, and (3) identify U.S. plants that may be vulnerable to a Maanshan-type event for evaluation under the RES Fire Risk Research Program.

As background, on September 26, 2001, a draft of this report was sent to internal peer reviewers who were requested to comment on the reasonableness of the approach and the appropriateness of the conclusions (ADAMS Accession Number ML01270058). The report was not issued for public comment because of its potential sensitivity. In response, comments were received from the Scott Newberry, Director, Division of Risk Analysis and Applications (DRAA), RES; and Michael Mayfield, Director, Division of Engineering Technology (DET), RES. John Zwolinski, Division of Licensing and Project Management, Nuclear Reactor Regulations (NRR),

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provided comments from several groups within NRR. Arthur Howell, Director, Division of Reactor Safety, Region IV provided comments from all of the regions. Each comment was restated verbatim, addressed, and the draft report revised as documented in memorandum to the file (ADAMS Accession Number ML020370002).

The comments also contained recommendations that require activities beyond the scope of the report. The RES staff recommended additional engineering research topics related to circuit breaker aging and the effectiveness of bus protection schemes. The RES staff also recommended that the subsequent use of water when other fire suppressants failed should be revisited as this was a major issue following the fire at Browns Ferry in 1975 that should have been resolved. NRR recommended that RES provide specific recommendations for further NRC staff or licensee actions to better address the potential vulnerabilities: a sensitivity study to show the generic implications and relative impacts of the major characteristics of these events in IPEEE fire risk analyses; and determination if the circuit breakers which may be susceptible to energetic fires are monitored under the Maintenance Rule Program.

As a result of this report, the RES Operating Plan has been revised to assess circuit breaker aging and bus protective schemes. In addition, the fire risk model implications as summarized below, sensitivity studies as suggested by NRR, and the plant electrical designs that may be vulnerable to a Maanshan-type event are planned to be addressed under the RES Fire Risk Research Program. Conclusion of this RES program may lead to better tools and procedures to address the potential of switchgear fire vulnerabilities.

In the interim, NRR recently issued “Information Notice (IN) 2002-01: Metalclad Switchgear Failures and Consequent Losses of Offsite Power,” January 8, 2002 to inform addressees of electrical equipment failure modes and design vulnerabilities identified following the two switchgear fire events in 2001 (two of the six events discussed and assessed in this report).

Assessment of the six events found fire risk model implications and potential lessons learned in the areas of plant design, maintenance, and operations as summarized below:

Fire Risk Modeling Implications

The events described in this report add further evidence to the finding in NUREG/CR-6738, “Risk Methods Insights From Fire Incidents,” August 2001, that current fire risk modeling of energetic electrical faults in 4.16 kV to 13.8 kV switchgear does not address the following characteristics of energetic fires: (1) the fire bypasses the typical fire initiation and growth stages; (2) a fire inside an electrical panel can propagate outside the panel; (3) the fire may result in failed initial fire suppression attempts; (4) smoke propagation outside the fire area affects operator response; (5) the fire may be longer than the 10 to 30 minutes typically analyzed; and (6) the plant material condition and independent failures may influence the chain of events.

These events demonstrate that fires from energetic electrical faults contain more energy than assumed in fire risk models as evidenced by explosions, arcing, smoke, ionized gases, and melting and vaporizing of equipment. The energy release exceeds heat release rates (HRRs)

assumed in fire risk models, possibly by a factor of 1000. Lower HHR values currently used may explain why current fire risk models have not identified the potential larger effects of fires from energetic electrical faults which may include the following: bypass of the fire initiation and growth stages, propagation of the fire to other equipment and across vertical fire barriers, ac power system designs that may be vulnerable to an SBO, failed fire suppression attempts with dry chemicals and the need to use water, longer restoration time to recover, and unexpected challenges and distractions to the operator from fire-induced failures.

Fire risk models may underestimate the risks from fires due to energetic faults in 4.16 kV to 13.8 kV switchgear and bus ducts by not considering: (1) development of HRR values corresponding to energetic electrical energy levels; (2) the effects of propagation from the fault location to other switchgear compartments, bus ducts, or overhead cables; (3) plant ac safety bus and circuit breaker configuration; (4) failed fire suppression attempts; (5) additional recovery actions; and (6) multiple accident sequences from fire induced equipment failures or operator error.

It appears that plant designs with two safety buses connected in parallel (similar to Maanshan) and connected to the auxiliary transformer (AT) through a single circuit breaker may be the most likely to experience an SBO from a fire due to an energetic fault.

Maintenance Considerations

The circuit breaker failures of the type which caused these events are maintenance preventable by periodic inspection and tests for degraded electrical insulation, dirt, moisture, and sluggish circuit breakers. Correctly timed operation of start-up transformer (ST) and AT supply circuit breaker mechanisms is critical to preventing fires in switchgear following bus transfers.

Design and Operating Considerations

Plant electrical fires have resulted in unrecoverable damage to portions of the circuits that route offsite power through the plant. Offsite power was available in the switchyard but could not be connected to the undamaged safety bus because the damage could not be isolated.

After extinguishing a fire with dry chemical, experience shows that water may be needed to reduce the likelihood of reflash. Prior to using water, it is common practice to de-energize the affected and nearby equipment to eliminate the potential personnel shock hazard. All these activities contribute to the duration of and recovery from the event.

U.S. switchgear fires also involved additional unexpected challenges to the control room and auxiliary operators. Typically, some control room and auxiliary operators participate as members of the fire brigade. Also, pre-existing latent failures (i.e., valve failure not related to the fire) that manifest during a fire have contributed to operator burden. Rapid response to augment the staff following an energetic fire could compensate for many of these concerns.

The report is consistent with the NRC strategic performance goals in the areas of maintaining safety, increasing public confidence, and making NRC activities more effective, efficient, and realistic as follows:

**Maintaining safety** – The report was based on operating experience and the results of licensee, NRC, and foreign plant risk assessments that evaluated the safety implications, used risk information to identify areas warranting continued attention, and independent technical review to ensure that safety is maintained.

**Public confidence** – The recommendations in this letter are consistent with assuring public health and safety will remain adequately protected from hazards resulting from the use of nuclear reactors.

**Making NRC activities more effective, efficient, and realistic** – The report provides a basis to make NRC activities more effective, efficient, and realistic from the assessment of technically sound and realistic information such as domestic and international operating experience, and past RES studies of fire risks.

Attachment:
Final Report, “Operating Experience Assessment-Energetic Faults in 4.16 kV and 13.8 kV Switchgear and Bus Ducts That Caused Fires in Nuclear Power Plants 1986-2001.”
**(ADAMS Assession No. ML021290358)**

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