MEMORANDUM TO: Thomas L. King, Director
Division of Risk Analysis and Applications
Office of Nuclear Regulatory Research

FROM: Michael E. Mayfield, Acting Director
Division of Engineering Technology
Office of Nuclear Regulatory Research

SUBJECT: DRAFT SNL LETTER REPORT, "CIRCUIT FAILURE MODE AND LIKELIHOOD ANALYSIS"

In your memorandum dated 12/29/99, you requested that DET comment on the subject SNL letter report. Since the electrical circuits evaluated in the study involve cable systems, our review and comments are focused on Cable Failure Modes, Circuit Failure Modes, and their likelihood from deterministic and engineering perspectives.

Our general and specific comments are provided in the attachment. If you or any member of your staff have any questions with regard to our comments, please contact Jit Vora (jpv) at 415-5833.

Attachment: As stated

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Attachment

CIRCUIT FAILURE MODE
AND LIKELIHOOD ANALYSIS

General Comments:

1. The report is silent on any discussion of self initiated internal electrical circuit failures and resultant fires. Experience indicates that many fires are attributable to faults and failures within the electrical components and their associated circuits. The components generally involve rotating machines (motors and generators), switchgear, transformers, circuit-breakers and electro-mechanical relays. These electrical components are especially vulnerable after degradation due to dust and contaminants, corroded contacts and embrittlements of insulating materials, and then subjected to partial discharges and arcing during normal operation and during electrical switching transients and faults.

2. In the draft SNL report significant emphasis is placed on “hot shorts.” While other types of electrical faults such as, single line to ground, multi-phase to ground and other types of degradation and faults have either been omitted or sparsely discussed. These types of electrical faults would be more prevalent and their likelihood of occurrence would be relatively higher than “hot shorts.”

3. Recommend adding the following documents in Chapter 7.0, References.
A) EPRI TR-103841, “Low-Voltage Environmentally-Qualified Cable. License Renewal Industry Report; Revision 1,” July 1994.

B) SAND96-0344, “ Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations,” September 1996.

These reports provide valuable insights on cables, cable aging, environmental qualification, diagnostics and condition monitoring, and applications of cables in operating nuclear power plants

4. While discussing Circuit Failure Modes it is desirable to include a single line diagram or two depicting major electrical components and their interfaces.

5. There is very little discussion on the cable circuit protection schemes against i) overvoltages, ii) overcurrents, and iii) abnormal temperatures. Electrical protection schemes truly influence failure modes and severity of electrical faults including “hot shorts.” Diversion of energy involved in electrical faults, fault duration and coordination of protection schemes will influence the likelihood of fires and their intensities and duration. For example, surge protection schemes within electrical circuits, when properly applied and coordinated, will divert fault currents to system grounds and clamp overvoltages from being applied to electrical equipment and circuits which they are intended to protect.

<u>Specific Comments</u>:

1. 1.1 Background. 1st Paragraph and Subsequent Bullets.

(A) A “cable conductor failure” normally means “open circuit.” It does not constitute “short to ground’ or “hot shorts.” A conductor failure may or may not involve a failure of insulating capability while a” short to ground” or “hot shorts” would involve some sort of insulation failure.

(B) An unacceptable damage to the integrity of an electrical cable system would be “degraded” insulating capability. In certain scenarios a cable system may not lose its intended function but it may experience anomalies which may result in erroneous signals and erratic actuations of equipment.

(C) “hot shorts” would generally involve “insulation failure” with or without “conductor failure.”

2. Page 5, 2.1, Description of Cables. 1st. Paragraph, Last Sentence.

From the perspective of design and application, the jacket serves as physical protection and it has no direct electrical function. However, experience shows that cracks develop in jackets over time due to environmental effects. These cracks provide a path for moisture/water intrusion in a cable system (e.g., splices, connectors and various interfaces) which may then result in partial or complete failure of the system.

3. Page 7, 2.2, Cable Failure Modes.

(A) It should be recognized that prior to open circuit, conductivity of the conductor will change due to temperature rise and may result in faulty signals and spurious actuations of equipment.

(B) For electrical circuits, partial shorts to ground are quite common and as such, these likely scenarios should be recognized and included in this section of the report.

(C) 4th Bullet. It should be recognized that the power scenario during a high impedance fault will depend upon the circuit design and the associated fault protection schemes.

4. Page 9, 2nd Paragraph.

Include “buried” cable systems (direct buried or buried in conduits) as prevalent cable routing schemes in operating nuclear power plants.

5. Page 16, Table 2-2, Cable Age, 2nd Paragraph, 1st Sentence.

From the point of view of complexity, cable configuration and construction is extremely simple and straight forward. It does not involve many interfaces, complex geometries and dissimilar materials. Aging effects and failure modes are well known and the information is generally available in environmental qualification (EQ) and research reports.

6. Page 18, Table 2-2: Conduits

It should be recognized that conduits could be metal, plastic or made up of some composites. Further, conduits could be laid on the surface or buried. Also, loading forces may increase at transitional points as cables leave conduits. Experience also indicates that moisture/water can accumulate in conduits and degrade cable's functional integrity.

7. Page 22, Table 2-2. Base ampacity for power circuits.

It is not the base current (amperes) but the ampacity (amperes/cm2), in conjunction with the heat transfer capability of the circuit design, that will influence its normal operating temperature, overheating and failure mode likelihoods.

Again, significant emphasis is placed on the integrity of the conductor itself and not on the conductor insulation. In most scenarios insulation will degrade and fail prior to the melting of the conductor itself.

8. Page 22, Table 2-2. Circuit Voltage.

In general, high voltages (above the rated voltage of a cable system) will impact the integrity of insulating materials prior to open circuit failures. Specified rated voltage of cables are normally based on the dielectric strengths of the polymers involved.

It is not the level of voltage (high, medium or low) that influences the electrical shorts. It is the voltage gradients and the withstand capability of the insulating materials and surrounding environments which influence the likelihood of electrical failures (shorts).

9. Page 27, 2nd Paragraph. 1st Sentence.

It is not clear as to why hot shorts in all three phases of an ac power source are required to energize a component such as motor-operated valve or a pump.

10. Page 31. 4.1, Circuit Analysis Process Description.

The circuit analysis process should include a feedback process between the screening steps. For example, feedback from step 4 to step 1 would be of interest for reassuring fire PRA critical scenarios based on the results of the Detailed Qualitative Circuit Analysis.