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Subject: Yellow Alert: High Voltage Electrical Shock

The following Lesson Learned is posted by Sandia National Laboratory:

Title: High Voltage Electrical Shock
Identifier: Formal Lessons Learned Report, 1999-KO-SNL-0002 Date: December 18, 1998

Lessons Learned Statement: Caution must be used when working with test circuits to avoid electrical shocks.

Discussion of Activities: On January 16, 1998, two employees were performing diagnosis of a tester circuit anomaly during developmental testing prior to production use when an employee received an electrical shock from a partially charged capacitor
bank in a high voltage pulse forming network. A test sequence was initiated and the circuit did not "fire" as anticipated. Power supplies to the test circuit were shut off and the voltage meter on the power supply front panel was observed as a means to verify that the capacitor bank was discharged. The buses on both sides of the capacitor bank were shorted to ground by sequentially touching each bus with a grounding wand. The test circuit chamber interlock switches were operated to activate a relay to connect the capacitor bank to ground through a discharge resistor. Both capacitor bank buses were again shorted to ground with the grounding wand. At this point, both employees acknowledged to each other that it was safe to proceed. One of the employees then reached into the oil-filled tank to begin removing banana-plug connections to the suspect module. When removing one of the banana plugs, the employee received a shock between his index finger and thumb and a point approximately ¾-inch beyond the back of his thumb toward the wrist. The procedure that was followed was the same as that used previously without incident.

An investigation of the cause of the event identified that both of two wires that provided connection from the circuit to ground had both opened-up. This caused the capacitor bank to lose its ground reference, thus causing the ground-referenced discharge wand to be ineffective due to an open circuit path. Further it was identified that with both wires open, the capacitor bank could not have charged. It was postulated that the break in one of the wire connections was of small enough distance to cause the high voltage to arc across the break and partially charge the capacitor bank. It was determined that the conductor for one of the cables did not have sufficient mechanical strength to withstand the weight of the cable and the movement of the cable as connections were made and removed during diagnostic tests.

Analysis: The following factors contributed to the occurrence:
1) Power supply meters did not indicate the true discharge condition of the capacitor bank due to the broken wires causing the path to the power supply to be opened-up,
2) Use of a single grounded discharge wand did not provide the capability to discharge the capacitor bank due to the loss of ground reference caused by the broken wires,

3) One of the cables connecting to ground had a conductor which was of insufficient diameter and mechanical strength to be able to withstand the mechanical stresses caused by cable movement and,
4) The module was not positioned in the tank such that it was easily accessible without having to move cables to gain clear access to the module.

Recommended Actions: Subsequent to the analysis of the event's contributing factors, the following lessons learned were identified:
1) Meters on power supplies should not be used as the only means of capacitor charge voltage indication.
2) Measurement of voltage across capacitor terminals with voltage probes and meter rated for the voltage should be made prior to work on circuit components.
3) Two grounding wands should be applied simultaneously across the capacitor bank for discharging purposes.
4) While the grounding wands are applied, a shorting jumper is connected across the capacitor bank to provide positive continuous shorting across the capacitor bank.
5) Shorting jumper continuity should be checked prior to use.
6) Connections to the circuit for applying the shorting jumper need to be readily accessible and allow ease of connection (e.g. banana jacks).
7) Cable conductors must be sized to withstand the weight of the cable/insulation and mechanical stresses caused by cable movement during diagnostic activities.
8) Modules that must be removed or adjusted during diagnostic testing should be positioned so that they are easily accessible without having to reach through cabling or other hardware for access.

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