UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

November 21, 1988

NRC INFORMATION NOTICE NO. 88-89: DEGRADATION OF KAPTON ELECTRICAL INSULATION

Addressees:

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose:

This information notice is being provided to alert addressees to a potentially generic safety problem involving Kapton aromatic polyimide electrical insulation. Kapton is used extensively in nuclear power plants as wire insulation in containment penetrations and cable entrance seals manufactured by Conax Buffalo Corporation, and in various insulation systems in products supplied by other vendors. Kapton is a registered trademark of E. I. du Pont de Nemours and Company.

It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

Problems involving Kapton insulation have been reported at nuclear power plants and elsewhere as described below. The most significant event identified in the nuclear industry occurred at San Onofre Unit 1.

San Onofre Nuclear Generating Station Unit 1

On June 15, 1987 Southern California Edison Company advised the NRC of a problem involving damaged Kapton insulation on containment electrical penetration assemblies at San Onofre Unit 1. During electrical testing of control rod drive equipment circuits to determine if previous cooling fan malfunctions had caused any damage, unacceptably low insulation resistances were found on 35 circuits. In one penetration assembly alone, 11 circuits tested below one megohm and 11 others below 100 megohms. The licensee then visually inspected the approximately 5000 penetration leads in the plant, and discovered nicked insulation in 52 cables covering close to 200 circuits. Most of the defects were outside containment; 15 nicked leads were inside containment.

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Laboratory analysis of two damaged leads showed no signs of electrically induced damage, and the insulation edges at the breaks were smooth (suggesting moderate chemical attack). The damage sites were highly localized; adjacent insulation showed no degradation. The copper conductor was oxidized considerably.

As a short-term corrective action, the licensee replaced all safety-related wires showing any signs of degradation or damage. Longer-term corrective action, now partially completed, includes provision of cable tray covers; replacement of nicked non-safety-related cables; and administrative and procedural measures such as personnel training and written precautions concerning unprotected Kapton-insulated wires. This event is described in Licensee Event Report 05000205 87-008-00, dated July 10, 1987.

The licensee attributed the damage primarily to physical damage (cuts, punctures, abrasions) to exposed Kapton insulation, mainly during installation of the replacement penetration assemblies in 1985-86. Some damage was attributed to subsequent stepping on the wires and placing or dropping objects on them. Once the Kapton insulation was penetrated, condensation of marine air on the outside containment pigtails provided a conductive path that lowered insulation resistances. The extensive replacement of containment electrical penetration assemblies such as occurred at San Onofre Unit 1 is uncommon, and it contributed to the exposure of unprotected Kapton leads to mechanical damage. Exposure of the Kapton leads to an outside marine atmosphere is also unusual.

Other Kapton Concerns

(1) Information Notice 87-08 (reference 1) describes 1986 failures of motorized valve operators because wires insulated with Kapton/Teflon and Nomex short-circuited. The Kapton/Teflon was a 0.0012-inch tape overlapped 50-percent. These wires were subjected to abrasion damage during wiring of the valve operators.

(2) Information Notice 87-16 (reference 2) describes 1987 degradation of Kapton diaphragms in pressure switches caused by chemical attack by ammonia contained in the process fluid.

(3) In 1984 Gulf States Utilities filed a 10 CFR 50.55(e) report concerning a short circuit between two Kapton-insulated wires from Conax penetration assemblies at River Bend Station Unit 1. The condition occurred during plant construction, and inspection showed 15 of 201 conductors to have nicked or otherwise damaged insulation. Investigation showed that degradation was generally attributable to scuffs, gashes, and related damage aggravated by the presence of water.

(4) In several instances anomalies have occurred during qualification type testing of Kapton-insulated pigtail wires on Conax products or on other equipment such as transmitters that had cable entrances sealed by Conax seals. The anomalies have been attributed to handling and stresses not typical of plant installations; e.g., shipment from a radiation test facility to a steam test facility. Only a few wires showed degradation in each instance, whereas multiple wires not subject to abnormal handling have successfully completed type test sequences.

(5) In response to Information Notices 87-08 and 87-16, du Pont wrote to the NRC to caution that when Kapton is used in nuclear power plants where environmental qualification is required, engineered designs which protect Kapton from direct exposure to loss of coolant accident sprays are required. This is because Kapton tends to degrade when exposed to high temperature steam or to certain volatile chemicals such as sodium hydroxide.

(6) The Naval Research Laboratory (NRL) has published or presented several papers (references 3, 4) describing failures of Kapton-insulated wires during laboratory testing. The Navy has carefully examined potential problems with Naval aircraft service. As a result, The Navy intends to stop buying aircraft using Kapton-insulated wire, and the other military services are studying possible implementation of restrictions.

The NRL work, in conjunction with other available information, shows that Kapton wire insulation is subject to damage by four mechanisms:

- Mechanical nicking or gouging can expose a wire conductor. Low insulation resistance can occur if an electrical path to an adjacent metallic conductor is formed by either a conductive solution or direct metal-to-metal contact. The San Onofre Unit 1 event is of this type.

- Direct chemical attack by strong alkaline solution can dissolve Kapton. This process would be of concern only if Kapton were installed contrary to Conax installation instructions in plants with sodium hydroxide spray, so that the Kapton was either exposed to prolonged direct spray impingement or prolonged soaking in spray solution.

- Bullets or projectiles can damage energized wire bundles. This is not likely in commercial power plants, and related safety concerns are minimal because of the redundancy and separation used for safety-related equipment.

- A complex hydrolytic Kapton degradation process has been identified with synergistic, non-linear dependence on temperature, moisture, and mechanical strain. Test data from 60 degrees Celsius upward show a reciprocal logarithmic temperature dependence. du Pont (reference 5) has suggested a fifth-power humidity dependence. Wolf (reference 6) reported a strong dependence on strain and postulated a minimum strain of 3 to 4 percent below which degradation does not occur. The process is almost fully reversible provided that actual cracking has not occurred. Review of commercial nuclear power plant applications indicates that this mechanism is not significant for either normal or accident conditions; operating experience and type test results support this conclusion. However, violation of minimum bend radius requirements specified by Conax and Rosemount for their wires, combined with significant moisture exposure and elevated temperatures, could produce this type of damage.

du Pont has several publications describing Kapton and its use. These may be obtained by contacting:

Mr. Paul Wyche
E. I. du Pont Nemours and Company, Inc.
External Affairs Department N-2526
Wilmington, Delaware 19898
Phone: (302) 774-1942

Conax Seals

The major safety-related use of Kapton in commercial nuclear power plants is in Conax products: containment electrical penetration assemblies, penetration replacement adapter module assemblies, electrical conductor seal assemblies (ECSAs), PL-type gland seals, and resistance temperature detector assemblies. Conax uses Kapton-insulated wire constructed of two wraps of type FN Kapton film, spiral wrapped in opposite directions. Since the film consists of 0.001 inch of Kapton sandwiched between two 0.0005-inch layers of Teflon (a du Pont trademark for FEP fluorocarbon), and each wrap is overlapped 50-percent, the total insulation thickness is 0.008 inch. The MIL-W-81381/11 wire used by the Navy is similar except that it has a 0.002-inch dispersed Kapton topcoat.

For seal assemblies, Conax supplies a heat-shrinkable polyolefin jacket to mechanically protect Kapton insulation. In addition, installation manuals caution against mechanical damage and protective conduit is also specified. Penetration assemblies are supplied with a junction box which encloses Kapton leads. Most other vendors using Kapton-insulated leads in safety-related applications provide covers or enclosures (for example, Rosemount seals and Target Rock and Valcor solenoid valves).

Discussion:

Despite the plant-specific aspects of the San Onofre Unit 1 event, the generic lesson is that the performance of numerous Kapton-insulated wires degraded considerably after only one year in a quite mild environment. Mechanical damage to Kapton insulation combined with exposure to condensation of moist salty air produced unacceptable degradation of the electrical insulation properties.

Although Kapton-insulated pigtails have successfully completed several accident qualification type tests, the test specimens are believed to have been free from nicks in the insulation; further, test anomalies occurred in some cases in which the pigtails were subjected to abnormal handling. The lesson is that preaccident damage can lead to failure of Kapton-insulated wires during or after accidents.

Addressees are alerted that the following conditions may breach the integrity of Kapton insulation, leading to possible failures under either normal or accident conditions:

(1) Mechanical damage such as nicks, cuts, abrasion, or sharp bending combined with exposure to moisture.

(2) Prolonged contact with alkaline solutions.

Addressees are also reminded that excessive handling of wiring is undesirable. In view of the industry's generally good operating experience with Kapton, addressees may elect to take actions in response to the information in this notice by beginning with review of procedures and designs to determine whether the conditions cited above may exist. Caution with any future maintenance or installation activity involving Kapton is important.

Virtually all commercial nuclear power plants contain Kapton-insulated wires in safety and non-safety-related applications, with Conax products used most extensively. Such components as containment electrical penetration assemblies and cable entrance seals are commonly used in Class 1E circuits and in applications requiring qualification to 10 CFR 50.49. Failure of Kapton insulation during either normal plant operation or accident conditions could render associated equipment inoperable.

No specific action or written response is required by this information notice. If you have any questions about this matter, please contact the technical contact listed below or the Regional Administrator of the appropriate regional office.

Charles E. Rossi

Charles E. Rossi, Director
Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical Contact: Richard C. Wilson, NRR
(301) 492-0997

Attachments:
1. References
2. List of Recently Issued NRC Information Notices

REFERENCES

1. IE Information Notice No. 87-08: "Degraded Motor Leads in Limitorque dc Motor Operators," February 4, 1987.

2. IE Information Notice No. 87-16: "Degradation of Static "O" Ring Pressure Switches," April 2, 1987.

3. F. J. Campbell, "Temperature Dependence of Hydrolysis of Polyimide Wire Insulation," IEEE Transactions on Electrical Insulation, Vol. EI-20 No. 1, February 1985.

4. A. M. Bruning, "Predictive Life Measurements of Naval Aircraft Wiring," Proceedings: Workshop on Power Plant Cable Condition Monitoring, EPRI EL/NP/CS-5914SR, July 1988.

5. J. O. Punderson and J. F. Heacock, "Polyimide Film Insulation for Aerospace Wire and Cable: Why Long-Term Performance Exceeds Some Limited Laboratory Projections, " presented at the 34th International Wire and Cable Symposium, Cherry Hill, NJ, November 19-21, 1985 (available from du Pont).

6. C. J. Wolf, D. L. Fanter, and R. S. Soloman, "Environmental Degradation of Aromatic Polyimide-Insulated Electrical Wire," IEEE Transactions on Electrical Insulation, Vol. EI-19 No. 4, August 1984.

LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
88-88	Degradation of Westinghouse ARD Relays	11/16/88	All holders of OLs or CPs for nuclear power reactors.
88-87	Pump Wear and Foreign Objects in Plant Piping Systems	11/16/88	All holders of OLs or CPs for nuclear power reactors.
86-106, Supp. 3	Feedwater Line Break	11/10/88	All holders of OLs or CPs for nuclear power reactors.
88-86	Operating with Multiple Grounds in Direct Current Distribution Systems	10/21/88	All holders of OLs or CPs for nuclear power reactors.
88-85	Broken Retaining Block Studs on Anchor Darling Check Valves	10/14/88	All holders of OLs or CPs for nuclear power reactors.
88-84	Defective Motor Shaft Keys in Limitorque Motor Actuators	10/20/88	All holders of OLs or CPs for nuclear power reactors.
88-83	Inadequate Testing of Relay Contacts in Safety-Related Logic Systems	10/19/88	All holders of OLs or CPs for nuclear power reactors.
88-82	Torus Shells with Corrosion and Degraded Coatings in BWR Containments	10/14/88	All holders of OLs or CPs for BWRs.
88-81	Failure of Amp Window Indent Kynar Splices and Thomas and Betts Nylon Wire Caps During Environmental Qualification Testing	10/7/88	All holders of OLs or CPs for nuclear power, test, and research reactors.
88-80	Unexpected Piping Movement Attributed to Thermal Stratification	10/7/88	All holders of OLs or CPs for PWRs.

OL = Operating License
CP = Construction Permit

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*SEE PREVIOUS CONCURRENCE PAGE.

Final changes were discussed with R. Wilson and V. Potapovs on 11/15/88. CERossi

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10/25/88

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NAME	:RCWilson:mgc*	:UPotapovs*	:EWBrach*	:BKGrimes*	:CHBerlinger*	:CERossi
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With minor changes CHB

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DATE	:11/2/88	:11/2/88	:11/2/88	:11/5/88	: /88	: /88

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