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MCGAUGHY, R. W.	Iowa Electric Light & Power Co.
RECIP. NAME	**RECIPIENT AFFILIATION**
DAVIS, A. B.	Region 3, Office of Director

SUBJECT: Forwards addl info re environ qualification of electrical butt splices, per 870707 telcon request. No AMP nylon splices installed in drywell penetrations for environmentally qualified equipment.

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Iowa Electric Light and Power Company

July 22, 1987
NG-87-2752

Mr. A. Bert Davis
Regional Administrator
Region III
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, IL 60137

Subject: Duane Arnold Energy Center
Docket No.: 50-331
Op. License No.: DPR-49
Qualification of Electrical Splices
File: A-64, A-103, SpF-129

Dear Mr. Davis:

The purpose of this letter is to provide additional information regarding the environmental qualification of electrical butt splices at the Duane Arnold Energy Center (DAEC). This information was requested by your staff in a telephone conversation on July 7, 1987 with members of the DAEC staff.

Attachments 1 through 3 provide responses to your staff's specific questions. Should you have any additional concerns, please contact this office.

Very truly yours,

William [signature] for

Richard W. McGaughy
Vice-President, Production

RWM/NKP/gj*

Attachments: 1) Applications and Locations of Nylon Insulated Splices
2) Basis for Environmental Qualification of Splices at the Duane Arnold Energy Center
3) Corrective Actions

cc: N. Peterson
L. Liu
L. Root
Document Control Desk (Original)
A. Cappucci (NRC-NRR)
NRC Resident Office

8707280364

IE28

JUL 27 1987

Attachment 1 to
NG-87-2752

APPLICATIONS AND LOCATIONS OF NYLON INSULATED SPLICES

QUESTION:

What types of EQ related cable splices were used at the Duane Arnold Energy Center (DAEC) and what are the specific locations of the various types of splices?

RESPONSE:

Although we cannot identify the specific locations of AMP nylon splices, they had been in use in the drywell, steam tunnel and other High Energy Line Break (HELB) areas, as well as the EQ Harsh "Radiation Only" areas. AMP nylon splices were not used in drywell penetration assemblies for EQ related circuits.

The drywell penetrations purchased from General Electric (GE) were supplied with Thomas & Betts (T&B) nylon "Stakon" splices. For applications requiring splices in other areas, AMP nylon splices were used. A summary of the various types of splices used, their locations, and the approximate number of splices in each area is given in Table 1-1 of this Attachment.

AMP products were the preferred product used at the DAEC because of the reliability of their ratchet crimping tool and ease of verifying that the tool remained in calibration.

Application of butt splices at the DAEC outside of the drywell penetrations was limited to terminating field installed cables to equipment where space would not allow the use of terminal blocks and ring tongue lugs. Also, in limited applications where a field cable had to be spliced due to damage, splices were used to make cable repairs. In these applications, nylon splices were initially used.

Nylon splices were replaced in the warehouse stock in May, 1981 with AMP Nuclear PIDG Window Indent (nuclear grade) Butt Splices. The AMP nuclear grade splices are different from the AMP nylon splices which failed the qualification test performed by Commonwealth Edison in 1986. The primary difference is that the AMP nuclear grade splices are insulated with polyvinylidene fluoride (PVDF) rather than nylon. When preventative or corrective maintenance took place on EQ equipment after May, 1981 associated nylon splices were replaced with AMP nuclear grade splices. As discussed in Attachment 3, all splices (nylon or nuclear grade) used in EQ applications have been taped using a qualified taping procedure. Maintenance procedures are in place to assure that the practice of taping of splices is followed for each EQ related splice.

In conclusion, no AMP nylon splices were installed in the drywell penetrations for EQ equipment. In other HELB areas, the exact type of installed nylon or nuclear grade splice locations cannot be feasably determined because it would require removing the qualified moisture seal for inspection from hundreds electrical splices in areas that are currently inaccessible.

TABLE 1-1

LOCATIONS OF INSULATED BUTT SPLICES IN EQ CIRCUITS

LOCATION	NUMBER OF SPLICES [1]	THOMAS & BETTS NYLON	AMP NYLON [2]	AMP NUCLEAR GRADE
Drywell - In Penetrations	200	X	None	X
Drywell - Outside of Penetrations	40	X	X	X
HELB Areas - Outside Drywell	40	X	X	X
Radiation Only Areas	325	X	X	X

Notes: 1 Approximate total number of EQ related splices are given. The number of each specific type of splice is not available. After 1981, AMP nuclear grade splices were used exclusively when splice replacement was required.

2 Type of splices which failed the Commonwealth Edison testing.

3 Non-EQ splices consist of all three types in all locations.

Attachment 2 to
NG-87-2752

BASIS FOR ENVIRONMENTAL QUALIFICATION OF SPLICES AT THE DUANE ARNOLD ENERGY CENTER

QUESTION:

What was the basis for qualification of the butt splices used at the DAEC, specifically AMP nylon splices?

RESPONSE:

1.0 INTRODUCTION

This document provides a summary of the qualification performed by Iowa Electric (IE) for nylon splices and details the fact that qualification of these splices was in full compliance with all applicable regulations.

2.0 REGULATING BASIS

Qualification was regulated by 10CFR50.49(k). This allows qualification of the Duane Arnold Energy Center (DAEC) plant equipment installed prior to the issuance of 10CFR50.49 to DOR Guideline provisions.

3.0 APPLICATION

This summary is applicable to all EQ harsh area nylon splices that interface with the DAEC environmentally qualified equipment. Qualification was based on the worst case environmental parameters which are defined by a direct exposure to an in containment loss of coolant accident (LOCA). This worst case basis allows the subject splices to be installed in all areas of the DAEC.

4.0 METHOD

4.1 Accident Qualification

Environmental qualification for a post accident, pressure, temperature and steam environment was based on type testing. The type test performed, titled "Qualification Test for F-01 Electrical Penetration Assembly", dated April 30, 1971, tested an entire General Electric (GE) penetration assembly including nylon insulated splices. The penetration was subjected to a simulated LOCA environment which enveloped the DAEC worst case conditions. The splices functioned throughout the test and the integrity of the splices was proven by acceptable insulation resistance readings taken both during and after the LOCA simulation. No anomalies were listed that affected the nylon splices.

4.2 Radiation and Aging Qualification

The LOCA type test of the penetration did not include thermal aging and irradiation. Sections 5.1 and 5.3 of the DOR Guidelines require qualification of environmentally qualified equipment exposed to severe temperature, pressure and steam service conditions be based on type testing as detailed above. However, these sections allow an analytical qualification of other service conditions. Aging and radiation qualification of DAEC nylon splices is proven by analysis and supportive test data, as described below.

The IE analysis concluded that the worst case radiation dose effects (normal plus accident) on the nylon splices would be negligible. Conclusions were based on radiation data detailed in the EPRI Final Report No. NP-4172SP, "Radiation Data for Design and Qualification of Nuclear Plant Equipment". The EPRI report contained data on several types of nylon (polyamide) materials. Test data provided for the polyamide most susceptable to radiation degradation was used in the analysis. The DAEC nylon splices are insulated with unmodified 6,6 nylon which has a higher radiation degradation threshold than the polyamide used for the analysis. Therefore, the analysis was conservative.

Because of the passive function of electrical splices, the only environmental parameters that would age the nylon insulation are normal radiation dose and normal ambient temperatures. Degradation caused by the normal radiation doses that occur at the DAEC were considered negligible as discussed above.

Thermal aging of the nylon splices was considered in the determination of thermal aging effects on the entire penetration assembly. This determination, as allowed by the DOR Guidelines, was done by analysis and supported by test data. The analytical approach of the DAEC Environmental Qualificaton Record File used both manufacturer prototype testing and Arrhenius Calculations to show that the penetration assemblies, including the nylon splices, are qualified for in excess of 40 years when installed in normal, DAEC ambient temperatures. Therefore, thermal aging is not a major contributor to nylon splice degradation.

4.3 Similarity of Nylon Insulations

Because of the inherent similarity of the nylon insulation used at the DAEC, the above qualification method is applied to all nylon splices regardless of manufacturer. The nylon-insulated splices used at the DAEC or type tested by GE were AMP, Hollingsworth, or T&B products. This has been determined through design document review and contacts with GE. The catalog numbers for the different nylon splices are relatively insignificant because they serve only to identify the various sizes corresponding to wire gauges for which they can be used. The type of nylon used for the insulation is essentially the same in all cases.

AMP and Hollingsworth have used two similar nylons to insulate the splices. The two types are Zytel-42 and Celanese-1200, and both materials are unmodified 6,6 nylons. T&B uses Zytel-42 to produce the insulating sleeve on their splices. Through contacts with T&B it was determined that this is the only nylon they would have used to insulate the splices.

Zytel-42 is a Du Pont product and is formulated from unmodified 6,6 nylon with no additives. Celanese-1200 is produced by Celanese Plastics and is one of its products for high temperature applications. Celanese-1200 is also an unmodified 6,6 nylon.

Table 2-1 of this Attachment lists specific properties of the two nylons for comparison.

6,6 nylon is a thermoplastic polyamide that is produced by the reaction of adipic acid (a 6-carbon dibasic acid) and hexamethylene diamine (a 6-carbon aliphatic diamine). Properties such as melting point, and modulus of elasticity are determined primarily by the type of nylon. Impact resistance is affected by the type of modifier used (if any) and molecular weight. Melt viscosity is determined mainly by molecular weight. Though some nylons use various additives to enhance specific properties, such as heat resistance, or to improve processing (molding, extrusion, or injections), the nylons used in the DAEC splices are unmodified.

Because the splice insulation is an extruded tubing, the nylons used are similar because the production of nylon tubing requires a nylon with specific properties. Those properties are found in unmodified 6,6 nylons. Table 2-1 of this Attachment shows the properties for the two nylons in question, also the range of properties for the 6,6 nylons used for extrusion of tubing. Various 6,6 nylons are used to produce extruded parts such as rods, slabs, and tubing. An important property to the extrusion of tubing, film, or complex shapes is the melt viscosity. A high viscosity is required for the product of the kind of tubing used for splice insulation. The unmodified 6,6 nylon possesses the high viscosity necessary for tubing extrusion. A review of the Plastics

Desk Top Data Bank, Book A and B, Edition 6, 1983, indicates that 6,6 nylons used for extrusion are unmodified or only slightly modified for impact resistance and have nearly identical properties.

Properties that show a wide range of values or which do not change significantly from one nylon to another are poor indicators of chemical composition. The following properties are included in this group:

a. Melting point
b. Elongation
c. Flexural modulus
d. Thermal conductivity
e. Specific heat
f. Continuous service
g. Volume resistivity
h. Water absorption

Properties with narrow ranges or which change rapidly with modification are good indicators for identification of chemical composition. These properties for 6,6 nylon are as follows:

a.	Density	71.25 lb./cu. ft.
b.	Izod notched RT	1-2 ft.-lb./in.
c.	Dielectric strength	600 V/10^{-3} in.
d.	Tensile strength yield	11-12 kpsi

Density value gives a good indication of the identity of a material. A review of modified nylons indicate significant variations in the density depending on the particular modifier type and amount.

Tensile strength is another indicator for material identification. The 6,6 nylons that have been modified with glass minerals or molybdenum disulfide tend to have higher tensile strength and much lower values of percentage elongation at break than the unmodified 6,6 nylons. 6,6 nylons modified for high impact have a similar value for elongation at break and a much lower tensile strength than unmodified 6,6 nylons.

The dielectric strength as measured per unit thickness varies greatly with material composition. The dielectric strength is a measure of the electrical strength of a material as an insulator. The dielectric strength is the voltage gradient at which electric failure as a breakdown occurs as a continuous arc (analogous to tensile strength in mechanical properties).

The Izod Impact Test indicates the energy required to break a notched specimen under standard conditions. The Izod value is generally useful in comparing different types of material for specific applications. For 6,6 nylon, the value increases significantly for modified materials.

When nylons are subjected to elevated temperatures for prolonged periods of time in the presence of air, oxidative degradation will occur. The rate will depend on the time and temperature but the effect is to reduce tensile strength and toughness and can eventually lend to surface cracking and embrittlement. The continuous service temperature for 6,6 nylons is listed between 200 and 300F.

Comparing narrow range properties of the 6,6 nylons specified in Table 2-1 show that the 6,6 nylons used for the DAEC nylon splices are almost identical. Therefore, the extent to which environmental stresses effect the nylon splices would not differ and the qualification method applies to all DAEC installed nylon splices.

5.0 AMP NUCLEAR GRADE SPLICES

As described in Section 4.1 and 4.2, IE qualified nylon splices by a combination of testing and analysis. However, butt splices using insulating materials superior to nylon became available around 1980. The AMP nuclear grade butt splice uses polyvinylidene fluoride (PVDF) insulation instead of nylon. The PVDF material has better resistance to temperature and radiation degradation than nylon. Therefore, IE began routinely replacing butt splices with the AMP nuclear grade splices whenever a splice needed replacing.

The AMP qualification test report (110-11004) for its nuclear grade splices (PIDG) concluded that, based on the test results, the splices are capable of performing their required functions throughout their 40-year qualified life and during the subsequent design basis events of seismic, radiation exposure, steam line break, LOCA and post-LOCA conditions. According the the AMP test report, the test complied with the guidelines set forth in IEEE Standards 323-1974, and 383-1974, and NUREG-0588, Rev. 1, Category 1 for Class 1E inside containment service. IE initially based the qualification of AMP nuclear grade splices on this test report.

Although the AMP LOCA test configuration for the nuclear grade butt splices did not exactly duplicate the configuration at the DAEC, the nuclear grade splices were clearly superior to the "qualified" nylon butt splices they replaced, specifically for their increased radiation and thermal aging resistance properties.

During discussions with the NRC in December, 1986, the NRC informed IE that the AMP test report was not valid for qualification of nuclear grade splices. When this information was made known to IE, the decision had already been made to tape all EQ butt splices in HELB areas. This decision was based on moisture intrusion concerns described in Attachment 3. However, the AMP nuclear grade splices were qualifiable through similarity analysis to the GE F-01 penetration test report, and EPRI report NP-47172SP.

6.0 CONCLUSIONS

The qualification of the nylon splices used at the DAEC was in accordance with regulations and guidance documents including the DOR Guidelines. These regulations and documents provided clear guidance to allow a sound and reasonable method of qualification to the DAEC worst case environments. Both type testing and analysis supported by test data were used for the basis of all qualification conclusions.

Additional assurance of nylon splice qualification was provided through the approval of the qualification method. This method was found acceptable through two third-party audits (conducted by contractors for IE) and by the fact that all comments identified in NRC Technical Evaluation Reports (TERs) and Safety Evaluation Reports (SERs) were satisfactorily resolved.

Therefore, until the present type testing of Amp nylon splices identified functional problems, the Iowa Electric qualification was sound, reasonable and acceptable per NRC guidance.

TABLE 2-1

PROPERTIES OF UNMODIFIED 6,6 NYLON
(from Plastics, 6th Edition)

Property	ASTM Method	Unit	Du Pont Zytel 42	Celanese Celanese 1200	General Ranga for Tubular Extended 6,6 Nylons
Mechanical					
Tensile strength	D638	kpsi	12.4	12.4	7.82 - 12.8
Elongation at break	D638	%	90	100 - 150	40 - 150
Yield strength	D638	kpsi	12.4	12.4	11 - 12
Elengation of yield	D638	%	5		5 - 28
Flexural modulus	D790	kpsi	410	420	175 - 494
Compressive stress 1% deformation	D695	kpsi	4.9		4.9 - 6.7
Izod impact	D256	ft-lb/in.	1.2	1.3	0.5 - 2.5
Thermal					
Melting point	D789	°F	491	495	482 - 495
Heat deflection temperature	D648	°F			
264 psi			194	167	167 - 207
66 psi		455	374	260 - 455	
Coefficient of linear thermal expansion	D696	in./in.	4E-05	5E-05	3.33 - 6.11E-05
Specific heat	-	-	0.4	0.4	0.4
Thermal conductivity	-	Btu-in./hr-ft^2-°F	1.7		1.65 - 1.74
Electrical					
Volume resistivity	D257	ohm/cm	1E15	1E14	1E14 - 6E15
Dielectric strength	D149	V/10^{-3} in.		600	570 - 600
Dielectric constant	D150	10^3 Hz	3.9	5.3	3.6 - 5.3
Dissipation factor	D150	10^3 Hz	0.03	0.035	0.02 - 0.06
Other					
Density	D792	lb/ft^3	71.25	71.20	71.2 - 71.56
Water absorption	D570	%/24 hr	1.2	1.5	1.1 - 1.5

CORRECTIVE ACTIONS

QUESTION:

What were the corrective actions taken by Iowa Electric to ensure compliance with 10CFR50.49 and why were the actions taken?

RESPONSE:

On December 5, 1986, the Duane Arnold Energy Center (DAEC) was informed by telephone of a potential problem stemming from the environmental qualification of nylon insulated electrical butt splices in drywell penetration assemblies at another utility. This equipment was within the scope of the DAEC Equipment Qualification (EQ) program and was considered by Iowa Electric (IE) to be environmentally qualified based on type test data, analysis, and similarity.

IE immediately began an evaluation of this information and learned that failures of nylon insulated butt splices (specifically AMP nylon or Premium Grade Splices) had occurred recently during qualification testing, by a testing laboratory, for another utility. Based on additional telephone conversations, IE concluded that the qualification test conditions were more severe than the DAEC environmental envelope and therefore, the test failures did not necessarily invalidate the DAEC qualification of the splices (which was based on the DOR guidelines). Specifically, IE was told initially that the test splices had been exposed to 200 MRad while the DAEC's worst predicted radiation exposure to the splices is 21 MRad. IE's evaluation using the DOR Guidelines predicted that the nylon splices would experience degradation at approximately 40 MRad.

On December 9, 1986, IE received further verbal information which indicated that due to an error at the testing facility, the irradiation of the test specimens was less conservative than the environmental envelope for the DAEC EQ program. IE reviewed this information and an immediate plant shutdown was initiated on December 9, 1986. It was the intention of IE that the plant was to remain in a cold shutdown condition until the electrical splices in question could be adequately qualified by repair, replacement, modification or further analysis.

The drywell penetrations at the DAEC are of F-01 series design and were supplied by GE. Each penetration assembly was procured as a unit and included nylon insulated butt splices. Thomas and Betts (T&B) nylon insulated splices were supplied with the penetrations. Since construction, maintenance activities and/or design changes have also installed AMP Nuclear Grade butt splices in the penetrations. No AMP Premium Grade (Nylon) splices were installed in the drywell penetration assemblies in EQ applications.

At that point in time, it was felt that the failures of the tested splices were due to radiation/temperature induced aging. Based on this information, IE made the decision to replace all T&B nylon splices in EQ applications located in the drywell penetrations with AMP nuclear grade insulated butt splices. No moisture seal was to be installed over the splices. This decision was based on the fact that the AMP nuclear grade splices had radiation and thermal aging resistance properties (because of material differences) that were superior to the existing nylon splices, as evidenced by the AMP test report for the nuclear grade splices. ("AMP Insulated Terminals and Splices for Class 1E, Inside Containment Service In Nuclear Power Generating Stations", 110-11004, Revision A, dated February 2, 1982.)

On December 12, 1986, the NRC Region III staff verbally informed IE that the failure of the test specimens may have been due to moisture intrusion caused by prolonged exposure of the specimens to a steam or spray environment. With this new information, IE concluded that not only the AMP nylon insulated butt splices, but all (T&B and AMP nuclear grade) insulated butt splices located in penetrations or junction boxes in High Energy Line Break (HELB) areas may have needed to have a moisture seal installed to upgrade the environmental qualification. This conclusion was based on the similarity of construction of all types of insulated butt splices at the DAEC.

The moisture seal was accomplished by taping the insulated butt splices with a qualified tape and taping procedure. Qualification is documented in IE file QUAL-M-345-00. As mentioned earlier, the T&B nylon insulated butt splices, for EQ applications in the drywell penetrations, were replaced with AMP nuclear grade butt splices following the December 9, 1986 shutdown. By December 12, replacement of the T&B nylon splices with AMP nuclear grade splices in the drywell penetrations was well underway. With the newly expanded work scope described above, the decision was made to complete the replacement of the nylon splices in the penetrations and install a moisture seal. In junction boxes located in HELB areas, the insulated butt splices were not replaced, but a tape seal was applied to these splices regardless of the insulation jacket design.

As noted in NRC Information Notice 86-104, the concerns related to the use of the AMP butt splices are related to moisture intrusion, which is not a concern for splices located in non-HELB areas. However, there is some question as to whether the AMP splices meet the criteria of IEEE-323-1974. IE committed to applying the tape seal to all EQ related butt splices located in non-HELB areas prior to startup from the Cycle 8/9 refueling outage. This commitment was met by IE. A justification for not taping these splices during the December, 1986 outage was submitted to the NRC as Attachment 3 to Reference 1.

A summary of the corrective actions taken is given in Table 3-1 of this attachment.

Until the test results of the AMP nylon splice testing were made known in December 1986, IE had no reason to know that the qualification of installed splices may have been inadequate. Furthermore, upon receipt of substantial verbal information, IE promptly took corrective actions to upgrade the questionable qualification of all splices in EQ harsh areas, prior to the issuance of NRC Information Notice 86-104. NRC Information Notice 86-104 was issued on December 16, 1986 and was the first written information received by IE indicating problems with qualification with AMP splices.

The corrective actions taken have been reviewed by NRC Region III inspectors and have been found to be acceptable per References 2 and 3.

REFERENCES:

1) Letter from R. McGaughy (IELP) to J. Keppler (NRC) dated December 19, 1986 (NG-86-4544)

2) Letter from W. Guldemond (NRC) to L. Liu (IELP) dated February 11, 1987 (NRC IR No. 50-331/87002)

3) Letter from J. Harrison (NRC) to L. Liu (IELP) dated May 18, 1987 (NRC IR No. 50-331/87009)

TABLE 3-1

CORRECTIVE ACTIONS COMPLETED FOR EQ CIRCUITS

LOCATION	THOMAS & BETTS NYLON	AMP NYLON	AMP NUCLEAR GRADE
Drywell - Penetrations	R,T [1]	None	T [1]
Drywell - Outside of Penetrations	T [1]	T [1]	T [1]
HELB Areas - Outsdie of Drywell	T [1]	T [1]	T [1]
Radiation Only	T [2]	T [2]	T [2]

Key: R = Replaced with AMP Nuclear Grade Splices

T = Taped using qualified tape and taping procedures

Notes: 1 Corrective action completed December 9-21, 1986 after initial notification which prompted plant shutdown.

2 JCO written during December, 1986 shutdown. Corrective action completed during Cycle 8/9 refueling outage (March - July, 1987).

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AUTH. NAME	AUTHOR AFFILIATION
MCGAUGHY, R. W.	Iowa Electric Light & Power Co.

RECIP. NAME	RECIPIENT AFFILIATION
DAVIS, A. B.	Region 3, Office of Director

SUBJECT: Forwards addl info re environ qualification of electrical butt splices, per 870707 telcon request. No AMP nylon splices installed in drywell penetrations for environmentally qualified equipment.

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Iowa Electric Light and Power Company

July 22, 1987
NG-87-2752

Mr. A. Bert Davis
Regional Administrator
Region III
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, IL 60137

Subject: Duane Arnold Energy Center
Docket No.: 50-331
Op. License No.: DPR-49
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File: A-64, A-103, SpF-129

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Attachments 1 through 3 provide responses to your staff's specific questions. Should you have any additional concerns, please contact this office.

Very truly yours,

William Rothert for

Richard W. McGaughy
Vice-President, Production

RWM/NKP/gj*

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2) Basis for Environmental Qualification of Splices at the Duane Arnold Energy Center
3) Corrective Actions

cc: N. Peterson
L. Liu
L. Root
Document Control Desk (Original)
A. Cappucci (NRC-NRR)
NRC Resident Office

A048 1/1

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BASIS FOR ENVIRONMENTAL QUALIFICATION OF SPLICES AT THE DUANE ARNOLD ENERGY CENTER

QUESTION:

What was the basis for qualification of the butt splices used at the DAEC, specifically AMP nylon splices?

RESPONSE:

1.0 INTRODUCTION

This document provides a summary of the qualification performed by Iowa Electric (IE) for nylon splices and details the fact that qualification of these splices was in full compliance with all applicable regulations.

2.0 REGULATING BASIS

Qualification was regulated by 10CFR50.49(k). This allows qualification of the Duane Arnold Energy Center (DAEC) plant equipment installed prior to the issuance of 10CFR50.49 to DOR Guideline provisions.

3.0 APPLICATION

This summary is applicable to all EQ harsh area nylon splices that interface with the DAEC environmentally qualified equipment. Qualification was based on the worst case environmental parameters which are defined by a direct exposure to an in containment loss of coolant accident (LOCA). This worst case basis allows the subject splices to be installed in all areas of the DAEC.

4.0 METHOD

4.1 Accident Qualification

Environmental qualification for a post accident, pressure, temperature and steam environment was based on type testing. The type test performed, titled "Qualification Test for F-01 Electrical Penetration Assembly", dated April 30, 1971, tested an entire General Electric (GE) penetration assembly including nylon insulated splices. The penetration was subjected to a simulated LOCA environment which enveloped the DAEC worst case conditions. The splices functioned throughout the test and the integrity of the splices was proven by acceptable insulation resistance readings taken both during and after the LOCA simulation. No anomalies were listed that affected the nylon splices.

4.2 Radiation and Aging Qualification

The LOCA type test of the penetration did not include thermal aging and irradiation. Sections 5.1 and 5.3 of the DOR Guidelines require qualification of environmentally qualified equipment exposed to severe temperature, pressure and steam service conditions be based on type testing as detailed above. However, these sections allow an analytical qualification of other service conditions. Aging and radiation qualification of DAEC nylon splices is proven by analysis and supportive test data, as described below.

The IE analysis concluded that the worst case radiation dose effects (normal plus accident) on the nylon splices would be negligible. Conclusions were based on radiation data detailed in the EPRI Final Report No. NP-4172SP, "Radiation Data for Design and Qualification of Nuclear Plant Equipment". The EPRI report contained data on several types of nylon (polyamide) materials. Test data provided for the polyamide most susceptable to radiation degradation was used in the analysis. The DAEC nylon splices are insulated with unmodified 6,6 nylon which has a higher radiation degradation threshold than the polyamide used for the analysis. Therefore, the analysis was conservative.

Because of the passive function of electrical splices, the only environmental parameters that would age the nylon insulation are normal radiation dose and normal ambient temperatures. Degradation caused by the normal radiation doses that occur at the DAEC were considered negligible as discussed above.

Thermal aging of the nylon splices was considered in the determination of thermal aging effects on the entire penetration assembly. This determination, as allowed by the DOR Guidelines, was done by analysis and supported by test data. The analytical approach of the DAEC Environmental Qualificaton Record File used both manufacturer prototype testing and Arrhenius Calculations to show that the penetration assemblies, including the nylon splices, are qualified for in excess of 40 years when installed in normal, DAEC ambient temperatures. Therefore, thermal aging is not a major contributor to nylon splice degradation.

4.3 Similarity of Nylon Insulations

Because of the inherent similarity of the nylon insulation used at the DAEC, the above qualification method is applied to all nylon splices regardless of manufacturer. The nylon-insulated splices used at the DAEC or type tested by GE were AMP, Hollingsworth, or T&B products. This has been determined through design document review and contacts with GE. The catalog numbers for the different nylon splices are relatively insignificant because they serve only to identify the various sizes corresponding to wire gauges for which they can be used. The type of nylon used for the insulation is essentially the same in all cases.

AMP and Hollingsworth have used two similar nylons to insulate the splices. The two types are Zytel-42 and Celanese-1200, and both materials are unmodified 6,6 nylons. T&B uses Zytel-42 to produce the insulating sleeve on their splices. Through contacts with T&B it was determined that this is the only nylon they would have used to insulate the splices.

Zytel-42 is a Du Pont product and is formulated from unmodified 6,6 nylon with no additives. Celanese-1200 is produced by Celanese Plastics and is one of its products for high temperature applications. Celanese-1200 is also an unmodified 6,6 nylon.

Table 2-1 of this Attachment lists specific properties of the two nylons for comparison.

6,6 nylon is a thermoplastic polyamide that is produced by the reaction of adipic acid (a 6-carbon dibasic acid) and hexamethylene diamine (a 6-carbon aliphatic diamine). Properties such as melting point, and modulus of elasticity are determined primarily by the type of nylon. Impact resistance is affected by the type of modifier used (if any) and molecular weight. Melt viscosity is determined mainly by molecular weight. Though some nylons use various additives to enhance specific properties, such as heat resistance, or to improve processing (molding, extrusion, or injections), the nylons used in the DAEC splices are unmodified.

Because the splice insulation is an extruded tubing, the nylons used are similar because the production of nylon tubing requires a nylon with specific properties. Those properties are found in unmodified 6,6 nylons. Table 2-1 of this Attachment shows the properties for the two nylons in question, also the range of properties for the 6,6 nylons used for extrusion of tubing. Various 6,6 nylons are used to produce extruded parts such as rods, slabs, and tubing. An important property to the extrusion of tubing, film, or complex shapes is the melt viscosity. A high viscosity is required for the product of the kind of tubing used for splice insulation. The unmodified 6,6 nylon possesses the high viscosity necessary for tubing extrusion. A review of the Plastics

Desk Top Data Bank, Book A and B, Edition 6, 1983, indicates that 6,6 nylons used for extrusion are unmodified or only slightly modified for impact resistance and have nearly identical properties.

Properties that show a wide range of values or which do not change significantly from one nylon to another are poor indicators of chemical composition. The following properties are included in this group:

a. Melting point
b. Elongation
c. Flexural modulus
d. Thermal conductivity
e. Specific heat
f. Continuous service
g. Volume resistivity
h. Water absorption

Properties with narrow ranges or which change rapidly with modification are good indicators for identification of chemical composition. These properties for 6,6 nylon are as follows:

a.	Density	71.25 lb./cu. ft.
b.	Izod notched RT	1-2 ft.-lb./in.
c.	Dielectric strength	600 V/10^{-3} in.
d.	Tensile strength yield	11-12 kpsi

Density value gives a good indication of the identity of a material. A review of modified nylons indicate significant variations in the density depending on the particular modifier type and amount.

Tensile strength is another indicator for material identification. The 6,6 nylons that have been modified with glass minerals or molybdenum disulfide tend to have higher tensile strength and much lower values of percentage elongation at break than the unmodified 6,6 nylons. 6,6 nylons modified for high impact have a similar value for elongation at break and a much lower tensile strength than unmodified 6,6 nylons.

The dielectric strength as measured per unit thickness varies greatly with material composition. The dielectric strength is a measure of the electrical strength of a material as an insulator. The dielectric strength is the voltage gradient at which electric failure as a breakdown occurs as a continuous arc (analogous to tensile strength in mechanical properties).

The Izod Impact Test indicates the energy required to break a notched specimen under standard conditions. The Izod value is generally useful in comparing different types of material for specific applications. For 6,6 nylon, the value increases significantly for modified materials.

When nylons are subjected to elevated temperatures for prolonged periods of time in the presence of air, oxidative degradation will occur. The rate will depend on the time and temperature but the effect is to reduce tensile strength and toughness and can eventually lend to surface cracking and embrittlement. The continuous service temperature for 6,6 nylons is listed between 200 and 300F.

Comparing narrow range properties of the 6,6 nylons specified in Table 2-1 show that the 6,6 nylons used for the DAEC nylon splices are almost identical. Therefore, the extent to which environmental stresses effect the nylon splices would not differ and the qualification method applies to all DAEC installed nylon splices.

5.0 AMP NUCLEAR GRADE SPLICES

As described in Section 4.1 and 4.2, IE qualified nylon splices by a combination of testing and analysis. However, butt splices using insulating materials superior to nylon became available around 1980. The AMP nuclear grade butt splice uses polyvinylidene fluoride (PVDF) insulation instead of nylon. The PVDF material has better resistance to temperature and radiation degradation than nylon. Therefore, IE began routinely replacing butt splices with the AMP nuclear grade splices whenever a splice needed replacing.

The AMP qualification test report (110-11004) for its nuclear grade splices (PIDG) concluded that, based on the test results, the splices are capable of performing their required functions throughout their 40-year qualified life and during the subsequent design basis events of seismic, radiation exposure, steam line break, LOCA and post-LOCA conditions. According the the AMP test report, the test complied with the guidelines set forth in IEEE Standards 323-1974, and 383-1974, and NUREG-0588, Rev. 1, Category 1 for Class 1E inside containment service. IE initially based the qualification of AMP nuclear grade splices on this test report.

Although the AMP LOCA test configuration for the nuclear grade butt splices did not exactly duplicate the configuration at the DAEC, the nuclear grade splices were clearly superior to the "qualified" nylon butt splices they replaced, specifically for their increased radiation and thermal aging resistance properties.

During discussions with the NRC in December, 1986, the NRC informed IE that the AMP test report was not valid for qualification of nuclear grade splices. When this information was made known to IE, the decision had already been made to tape all EQ butt splices in HELB areas. This decision was based on moisture intrusion concerns described in Attachment 3. However, the AMP nuclear grade splices were qualifiable through similarity analysis to the GE F-01 penetration test report, and EPRI report NP-47172SP.

6.0 CONCLUSIONS

The qualification of the nylon splices used at the DAEC was in accordance with regulations and guidance documents including the DOR Guidelines. These regulations and documents provided clear guidance to allow a sound and reasonable method of qualification to the DAEC worst case environments. Both type testing and analysis supported by test data were used for the basis of all qualification conclusions.

Additional assurance of nylon splice qualification was provided through the approval of the qualification method. This method was found acceptable through two third-party audits (conducted by contractors for IE) and by the fact that all comments identified in NRC Technical Evaluation Reports (TERs) and Safety Evaluation Reports (SERs) were satisfactorily resolved.

Therefore, until the present type testing of Amp nylon splices identified functional problems, the Iowa Electric qualification was sound, reasonable and acceptable per NRC guidance.

TABLE 2-1

PROPERTIES OF UNMODIFIED 6,6 NYLON
(from Plastics, 6th Edition)

Property	ASTM Method	Unit	Du Pont Zytel 42	Calanese Calanese 1200	General Ranga for Tubular Extended 6,6 Nylons
Mechanical					
Tensile strength	D638	kpsi	12.4	12.4	7.82 - 12.8
Elongation at break	D638	%	90	100 - 150	40 - 150
Yield strength	D638	kpsi	12.4	12.4	11 - 12
Elongation of yield	D638	%	5		5 - 28
Flexural modulus	D790	kpsi	410	420	175 - 494
Compressive stress 1% deformation	D695	kpsi	4.9		4.9 - 6.7
Izod impact	D256	ft-lb/in.	1.2	1.3	0.5 - 2.5
Thermal					
Melting point	D789	°F	491	495	482 - 495
Heat deflection temperature	D648	°F			
264 psi			194	167	167 - 207
66 psi		455	374	260 - 455	
Coefficient of linear thermal expansion	D696	in./in.	4E-05	5E-05	3.33 - 6.11E-05
Specific heat	-	-	0.4	0.4	0.4
Thermal conductivity	-	Btu-in./hr-ft^2-°F	1.7		1.65 - 1.74
Electrical					
Volume resistivity	D257	ohm/cm	1E15	1E14	1E14 - 6E15
Dielectric strength	D149	V/10^{-3} in.		600	570 - 600
Dielectric constant	D150	10^3 Hz	3.9	5.3	3.6 - 5.3
Dissipation factor	D150	10^3 Hz	0.03	0.035	0.02 - 0.06
Other					
Density	D792	lb/ft^3	71.25	71.20	71.2 - 71.56
Water absorption	D570	%/24 hr	1.2	1.5	1.1 - 1.5

CORRECTIVE ACTIONS

QUESTION:

What were the corrective actions taken by Iowa Electric to ensure compliance with 10CFR50.49 and why were the actions taken?

RESPONSE:

On December 5, 1986, the Duane Arnold Energy Center (DAEC) was informed by telephone of a potential problem stemming from the environmental qualification of nylon insulated electrical butt splices in drywell penetration assemblies at another utility. This equipment was within the scope of the DAEC Equipment Qualification (EQ) program and was considered by Iowa Electric (IE) to be environmentally qualified based on type test data, analysis, and similarity.

IE immediately began an evaluation of this information and learned that failures of nylon insulated butt splices (specifically AMP nylon or Premium Grade Splices) had occurred recently during qualification testing, by a testing laboratory, for another utility. Based on additional telephone conversations, IE concluded that the qualification test conditions were more severe than the DAEC environmental envelope and therefore, the test failures did not necessarily invalidate the DAEC qualification of the splices (which was based on the DOR guidelines). Specifically, IE was told initially that the test splices had been exposed to 200 MRad while the DAEC's worst predicted radiation exposure to the splices is 21 MRad. IE's evaluation using the DOR Guidelines predicted that the nylon splices would experience degradation at approximately 40 MRad.

On December 9, 1986, IE received further verbal information which indicated that due to an error at the testing facility, the irradiation of the test specimens was less conservative than the environmental envelope for the DAEC EQ program. IE reviewed this information and an immediate plant shutdown was initiated on December 9, 1986. It was the intention of IE that the plant was to remain in a cold shutdown condition until the electrical splices in question could be adequately qualified by repair, replacement, modification or further analysis.

The drywell penetrations at the DAEC are of F-01 series design and were supplied by GE. Each penetration assembly was procured as a unit and included nylon insulated butt splices. Thomas and Betts (T&B) nylon insulated splices were supplied with the penetrations. Since construction, maintenance activities and/or design changes have also installed AMP Nuclear Grade butt splices in the penetrations. No AMP Premium Grade (Nylon) splices were installed in the drywell penetration assemblies in EQ applications.

At that point in time, it was felt that the failures of the tested splices were due to radiation/temperature induced aging. Based on this information, IE made the decision to replace all T&B nylon splices in EQ applications located in the drywell penetrations with AMP nuclear grade insulated butt splices. No moisture seal was to be installed over the splices. This decision was based on the fact that the AMP nuclear grade splices had radiation and thermal aging resistance properties (because of material differences) that were superior to the existing nylon splices, as evidenced by the AMP test report for the nuclear grade splices. ("AMP Insulated Terminals and Splices for Class 1E, Inside Containment Service In Nuclear Power Generating Stations", 110-11004, Revision A, dated February 2, 1982.)

On December 12, 1986, the NRC Region III staff verbally informed IE that the failure of the test specimens may have been due to moisture intrusion caused by prolonged exposure of the specimens to a steam or spray environment. With this new information, IE concluded that not only the AMP nylon insulated butt splices, but all (T&B and AMP nuclear grade) insulated butt splices located in penetrations or junction boxes in High Energy Line Break (HELB) areas may have needed to have a moisture seal installed to upgrade the environmental qualification. This conclusion was based on the similarity of construction of all types of insulated butt splices at the DAEC.

The moisture seal was accomplished by taping the insulated butt splices with a qualified tape and taping procedure. Qualification is documented in IE file QUAL-M-345-00. As mentioned earlier, the T&B nylon insulated butt splices, for EQ applications in the drywell penetrations, were replaced with AMP nuclear grade butt splices following the December 9, 1986 shutdown. By December 12, replacement of the T&B nylon splices with AMP nuclear grade splices in the drywell penetrations was well underway. With the newly expanded work scope described above, the decision was made to complete the replacement of the nylon splices in the penetrations and install a moisture seal. In junction boxes located in HELB areas, the insulated butt splices were not replaced, but a tape seal was applied to these splices regardless of the insulation jacket design.

As noted in NRC Information Notice 86-104, the concerns related to the use of the AMP butt splices are related to moisture intrusion, which is not a concern for splices located in non-HELB areas. However, there is some question as to whether the AMP splices meet the criteria of IEEE-323-1974. IE committed to applying the tape seal to all EQ related butt splices located in non-HELB areas prior to startup from the Cycle 8/9 refueling outage. This commitment was met by IE. A justification for not taping these splices during the December, 1986 outage was submitted to the NRC as Attachment 3 to Reference 1.

A summary of the corrective actions taken is given in Table 3-1 of this attachment.

Until the test results of the AMP nylon splice testing were made known in December 1986, IE had no reason to know that the qualification of installed splices may have been inadequate. Furthermore, upon receipt of substantial verbal information, IE promptly took corrective actions to upgrade the questionable qualification of all splices in EQ harsh areas, prior to the issuance of NRC Information Notice 86-104. NRC Information Notice 86-104 was issued on December 16, 1986 and was the first written information received by IE indicating problems with qualification with AMP splices.

The corrective actions taken have been reviewed by NRC Region III inspectors and have been found to be acceptable per References 2 and 3.

REFERENCES:

1) Letter from R. McGaughy (IELP) to J. Keppler (NRC) dated December 19, 1986 (NG-86-4544)

2) Letter from W. Guldemond (NRC) to L. Liu (IELP) dated February 11, 1987 (NRC IR No. 50-331/87002)

3) Letter from J. Harrison (NRC) to L. Liu (IELP) dated May 18, 1987 (NRC IR No. 50-331/87009)

TABLE 3-1

CORRECTIVE ACTIONS COMPLETED FOR EQ CIRCUITS

LOCATION	THOMAS & BETTS NYLON	AMP NYLON	AMP NUCLEAR GRADE
Drywell - Penetrations	R,T [1]	None	T [1]
Drywell - Outside of Penetrations	T [1]	T [1]	T [1]
HELB Areas - Outsdie of Drywell	T [1]	T [1]	T [1]
Radiation Only	T [2]	T [2]	T [2]

Key: R = Replaced with AMP Nuclear Grade Splices

T = Taped using qualified tape and taping procedures

Notes: [1] Corrective action completed December 9-21, 1986 after initial notification which prompted plant shutdown.

[2] JCO written during December, 1986 shutdown. Corrective action completed during Cycle 8/9 refueling outage (March - July, 1987).