COMMONWEALTH EDISON COMPANY
QUAD CITIES - UNITS 1 AND 2/DRESDEN - UNITS 2 & 3

Engineering Procedure, Surveillance Program for Butyl Rubber Insulated Cables

Prepared by

Component Qualification Division
Sargent & Lundy Engineers

Project Nos.: 6896-00
6897-00

1.0 Purpose

The purpose of this engineering procedure, is to provide the necessary steps, methods and schedule to be used for implementing a surveillance program for the Butyl insulated 600V power and control cables installed in Quad Cities - Units 1 & 2/Dresden Station - Units 2 & 3.

2.0 References

1. Sargent & Lundy, File CQD-014975
   Environmental Qualification of Simplex Electrical Cables, Dresden 2 and 3.

2. S&L CQD File #015111, Environmental Qualification of GE Butyl Cables, Dresden Units 2 and 3.

3. S&L CQD File #014973, Environmental Qualification of Simplex Butyl Cables, Quad Cities - Units 1 and 2.

4. S&L CQD File #015110, Environmental Qualification of GE Butyl Cables, Quad Cities - Units 1 and 2.

5. NUREG/CR-2156
   Radiation-Thermal Degradation of PE and PVC: Mechanism of Synergism and Dose Rate Effects
   Sandia National Laboratory
   June 1981

6. I. Kuriyama, et al.
   Radiation Resistance of Cable Insulating Materials for Nuclear Power Generating Stations
   IEEE Trans Electr. Insulation, Vol EI-13, No. 3
   June 1978

7. R. Blodgett and R. Fisher
Insulations and Jacket for Control and Power Cables in Thermal Reactor Nuclear Generating Stations
IEEE Trans PAS, Vol 98, No. 5
May 1969

8. A. Kinetic Model for Predicting Oxidative Degradation Rates in Combined Radiation - Thermal Environments, Sandi National Laboratories, Albuquerque, New Mexico

9. ICEA/NEMA Standards Publication No. S-66-524 1982

10. Reference Item Mil. Std. 105D

3.0 Objective

The objective of this engineering procedure surveillance plan is to ensure that surveillance programs are being properly conducted on safety-related Butyl rubber 600V power and control cables. Of particular concern are the incorporation of specific environmental qualification aspects and methods used to identify and track (surveillance) degrading performance and/or reversion. This procedure and plan utilizes check-sheets to document observations, identify materials and configurations, and track or trend data associated with cable performance. In summary, this procedure and plan is part of the comprehensive Qualification Maintenance Program. The data obtained by field verification of component identity and condition, destructive analysis, chemical analysis, surveillance, routine maintenance, and maintenance history will be used to ensure continuing qualification and detect potential degradation of cable performance. This data will examine the state of Butyl Rubber's oxidation and reversion with age.

This engineering procedure and plan is considered a "living document" and as such it is anticipated that it will be refined and updated to reflect experience and technical information as it becomes available.

Visual Indication of Degradation -

A. General

Overall thermal and radiation degradation mechanisms in cable materials result from competing molecular cross-linking and scission phenomena. The cross-linking processes generally increase tensile strength while chain scissioning causes strength reductions. The competing effects are evident in many cable materials where an initial improvement in tensile strength is followed by long-term reduction; swelling in cable polymers is often an indication of this competing cross-linking and scissioning process. Moisture absorption effects are also evidenced by swelling. With respect to cable surveillance, visual indication of cable swelling in harsh areas where ambient temperatures, radiation or moisture levels are relatively high is probably indicative of a need for increased surveillance of the subject cable. Swelling does not imply serious degradation; however, additional surveillance activities of reduced time between surveillance activities may be required in order to resolve the problem.

B. Cable Specific Considerations

Surveillance personnel should be aware of the following property changes indicative of possible degradation, oxidation or reversion.

Material	Property Change
Butyl insulation	Decreased flexibility* Tensile strength decreased
PVC jacket	Embrittlement, decreased elasticity

*Softening or tackiness observed above 1 x 10^7 rad.

1. Cable Inspection Plan -

It is not the intent of this procedure to require 100% inspection of all installed cable. The sampling program established ensures that representative specimens are monitored throughout the life of the plant. Selection criteria included consideration of cable location and accessibility; normal environmental conditions such as temperature, radiation, (environmental extremes in particular were considered, such as location of cable in the steam tunnel); cable construction; ambient tray or conduit temperatures due to heat generation in surrounding cables; and relative footage of installed cable in the plant. It is recommended that inspection of the cables selected be integrated with EPMS actions for the associated plant equipment, and that they be inspected on a staggered basis. In this way, the cable EPMS program can be implemented easily and reasonable assurance can be provided that cable condition is being monitored.

4.0 Tools Required

1. Insulated Rubber Gloves
2. Face Shield
3. 500VDC Megger
4. Instron Model 1130 (Tensile test)
5. Microscope (Destructive Analysis)
6. Solvent (Chemical Analysis)

5.0 Precautions

1. Inspections may be done on energized cables. However, personnel must wear insulated rubber gloves and face shield.

2. Observe all applicable safety procedures.

3. Notify shift supervisor prior to performing checklist in Attachment A.

6.0 Notes:

1. If the outer jacket and/or the insulation indicated swelling, softening, visible embrittlement, cracking and discoloration in certain areas the EQ coordinator should be notified immediately and shall evaluate the cable for possible degradation.

2. The sampling program established should ensure that representative specimens are monitored throughout the life of the plant.

3. Selection criteria should include consideration of cable location and accessibility, cable construction, ambient tray or conduit temperatures due to heat generation in surrounding cables, and relative footage of the type of cable installed.

4. Inspection of the cables selected should be integrated with other surveillance for the associated equipment and should be performed on a staggered basis (one half of the samples during alternate outages). Group I and Group II samples should be surveiled at alternate outages.

7.0 Cable Selection Criteria

The sample size was determined per MIL Std 105D and is based on the total number of pieces of equipment serviced at each station via Butyl Rubber 600V power and control cable. The total number of equipment serviced by Butyl rubber cables for each unit is between 98 and 111. Per the selection criteria given in the MIL standards 105D, when the number of components is between 91 and 150, for a confidence level of 95%, Cables associated with 20 components must be sampled. The selection was made with an emphasis in selecting the cables located in harsh zones of the plant. The sample shall be selected using Attachment C.

8.0 Maintenance and Surveillance

The cables specified in Attachment C shall be reviewed for visual and electrical degradation and have an inspection rate of once every other fuel cycle. If the cables to be examined cannot be identified in the area visual checking should be performed of all the cables in that vicinity. Any indication of aging, oxidation or reversion related degradation such as cracks, discoloration, and softening or hardening of the insulation material must be investigated. Any indication of oxidation or reversion from the results of the inspection shall be investigated.

Should degradation be indicated a sample of the cable should be removed to monitor for reversion and oxidation via Chemical and Destructive Analysis. The cable ends which are removed shall be identified as such (i.e., MCC end, equipment end, pull box location, etc.). Destructive Analysis shall investigate changes in tensile strength, elongation, reversion and oxidation. The results of the Destructive Analysis shall be reported to the station EQ co-ordinator for evaluation. Arrangements should be made to replace the affected cables as required.

Surveillance and inspection for Butyl insulated 600V power and control cable installed at Dresden Station should be performed using Attachments A and C.

Destructive and chemical analysis should be performed using Attachment B.

Signature:____________________

Date:____________________

BUTYL INSULATED CABLE
SURVEILLANCE

Signature:____________________

Date:_________________________

1. Cable Tag No:________, Cable Jacket Identification __________

   Location:________, Approximate length __________
2. Are jacket markings legible? (Yes/No) __________
3. Inspect exposed cable for external physical damage or abnormal conditions. (Yes/No) __________

________ Check for cracks or puncture marks in jacket

________ Check for discoloration of cable jacket

________ Check for softening of cable jacket

________ Check for hardening or brittleness of cable jacket

________ Check for deformation of cable (i.e., kinks, twists, sharp bends, etc.)

________ Check for evidence of water, moisture, or oil on cable

________ Check for evidence of cable jacket swelling

________ Check for dirt or high dust concentration on cable (Cables with heavy layers of dust or dirt should be cleaned off and inspected for all of the above listed items.)

________ Remarks____

1. Jacket splitting is more likely in areas of high mechanical stress, especially near bends and penetrations. The inspection should include a representative sample of these sections of exposed cable.

Signature:____________________
Date:________________________

2. Jacket indentation or surface abrasion may have occurred during cable pulling. Evidence of these conditions should be recorded above in the "Remarks" area to eliminate possible misinterpretation as a degradation-related effect. The location, extent of damage and amount of damage (ex. 2 ft. of cable) shall be recorded.

4. Wherever there is no cable jacket, perform inspections of cable conductor insulation. In general, this can be performed concurrently with inspections of electrical terminations on other equipment (e.g., motors, transmitters).

________ Check for cracking, embrittlement, or surface crazing.
________ Check for surface contamination of conductor insulation.
________ Check for insulation discoloration, including evidence of surface tracking.
________ Check for evidence of cable extrusion-aid dried weepage at 600V power and control cable jacket ends.
________ Others

Note: Oils or other lubricants are used by some manufacturers during fabrication of the cable. Weepage does not imply cable degradation, but requires corrective actions to eliminate residues. Cable pulling compound may have been used during installation of the cable. This does not imply cable degradation, but requires corrective actions to eliminate residues.

Signature:____________________
Date:_________________________

5. Wherever visible inspect copper conductor terminations.

________ Check for evidence of oxidation/corrosion at the termination interface.

________ Check tightness of connection for loose connections with handpull test.

________ Remarks____

6. Megger cables. Use a 500 Vdc for control and power cables. Record the following insulation resistance (IR) at 1 minute:

Wire No.	IR at 1 Minute	
____________	________________	meg-ohms
____________	________________	meg-ohms
____________	________________	meg-ohms
____________	________________	meg-ohms
____________	________________	meg-ohms

Record ambient temperature ____ ^{o}F.

Caution: Before meggering make sure that the whole run is available for the test to avoid injury to personnel and damage to equipment.

Notes:

1. Measure insulation resistance from conductors to ground.
2. Conductors previously meggered in these cables should be selected in order that data trending analyses can be performed.

Signature:____________________

Date:________________________

3. One-minute insulation resistance readings should be greater than 1.5 meg-ohms for all conductors at $60^{o}F$. If this criteria cannot be met, further evaluation should be performed to determine the cause (e.g., terminations and connectors). If insulation degradation is suspected, it shall be reported to the station EQ coordinator for further evaluation.

(This test should be performed only if visual degradation is noted)

Signature: ____________________

Date: ____________________

1.0 Perform Destructive Analysis

Cable #	Wire No.	Point on Cable
______	______	______
______	______	______
______	______	______

Metallographic polishing. Mount samples in an epoxy, polished by standard metallographic techniques and examine using a microscope. Oxidized and unoxidized regions are visible as bands of different optical reflectivity.

Remarks ____

Tensile tests. Use an Instron Model 1130 testing machine equipped with pneumatic grips and having an extensometer clamped to the sample.

Remarks ____

Voltage Withstand Test. Subject to 5,000 VAC test for 5 minutes immerse in tap water and apply voltage between each measure leakage current conductor and all other conductors and also to ground.

Remarks: ____

Signature: ____________________

Date: ____________________

2.0 Chemical Analysis (If degradation is present)

Cable #	Wire No.	Point on Cable	# of Cross Linked Polymers

Enlarge cable samples (swelling) by soaking in a solvent. Via spectroscopy measure the number of cross-linked polymers.

CABLE SAMPLES

Dresden Unit 2

Equipment	Cable #	Zone	Group
M02-1402-25A	22603	9/31	I
S0-2-203-3D	23906	9/31	II
	25055	9/31	
M02-1501-11A	22680	5	
	22681	5/9/31	I
	22682	5	
	22679	5	
M02-1501-27B	22902	30/31	II
[illegible]2-1501-32A	22658	5	
	22659	5/9/31	I
	22660	5	
	22657	5	
S02-203-2A	26349	9/31	II
	26350	9	
S02-203-1C	26370	9/31	I
M02-2301-35	23930	6/31	
	26211	6	II
	26212	6	
TS261-15C	24001	9	I
M02150111B	22961	4	II
	22962	4/31	
	22963	4	
	22960	4	
M02150128B	23965	30/31	I
S022032B	26362	9/31	II
	26363	9	
	26364	9	

Equipment	Cable #	Zone	Group
M0210011A	22483	18	I
	22485	18	
	22487	18	
SWGR 23-1	20627	9/31	
	20628	9/31	
	20629	9/31	
M02-1402 38A	22638	2/5	
	22639	2/9/31	
	22637	2/5	
	23061	2/5	I
	22812	2/5/9/31	
M02-1401A	22782	4/5/9/31	
	20877	5/9/31	II
	20878	5/9/31	
	20879	5	
	20881	5	
M021402 24B	22837	26	I
M0213011	22559	9/31	II
M0220257A	22515	9/31	I
S022031A	26342	18	II

CABLE SAMPLES

Dresden Unit 3

Equipment	Cable #	Zone	Group
MO-140224A	32613	30	I
SO-2033B	34840	30	II
	33673	30	
SO-2033D	33674	30	
SO-2033D	34845	30	I
MO-150111A	32679	5	
	32680	5	II
	32681	5/30	
	32682	5	
MO-15013A	30814	5/30	
	32716	5/30	I
	32742	5	
	32502	5	
	30231	5	
MO-23018	33908	9/31/36/37	
	33909	9/31/36/37	
	33910	9/31/36/37	II
	33912	9/31/36/37	
	33903	9	
MO-130111	32559	30/36	I
SO-22044	36316	30	II
MO-140238A	33061	2	
	32637	2/5	I
	32639	2/30	
	32812	2/5/30	
	32751	5	
MO 130114	32576	30	II

Equipment	Cable #	Zone	Group
TS2370D	33853	6	I
	33854	6	
	33855	6	
MO-7506A	22270	30	II
	22271	30	
	22272		
SWGR34-1	30739	26	I
	30740	26	
	30741	26	
MO-1502B	30906	5	II
MO-220-2	33752	9	I
	33753	9	
MO 150121A	32665	16	II
MO-150121B	32947	9	I
MO-12012	33820	22/36/37	
	33821	22/36/87	II
	33822	9/22/31/36/37	
	33842	22/36/37	
MO-23015	33879	2/4/36/37	
	33880	2/4/36/37	I
	33881	2/9/31/36/37	
	33882	2/4/36/37	
	34173	2/4/36/37	
	34619	2	
MO-10011A	32487	30	II

CABLE SAMPLES

Quad Cities Unit 1

Equipment	Cable #	Zone	Group
M0100128A	10271	23/25	
	12662	2	I
	12665	2	
	12667	23/25	
	12668	2	
M0100128B	10279	10	
	12942	2	
	12945	2	II
	12947	10	
	12948	2	
M0100116B	12960	5	
	12961	5	I
	12962	10/23	
	12963	5	
M0100147	12450	10	
	12464	10/23	II
	12465	10	
	12466	10	
	12467	10	
	12574	23	
M010014B	10228	10	I
	10229	5	
M01001185B	10246	5	
	10245	10	II
M0100160	12469	10/23	
	12472	10	I
	12477	10/23/25	
	12481	10/23/25	
M0100136	12535	23/25	
	12536	2	II
M010019B	12937	5	
	12938	5	I
	12939	10	
	12940	5	

Equipment	Cable #	Zone	Group
M014024B	12922	10/23	II
	13060	2	
S02031A	16342	23/25	I
S02032A	16348	10/23	
	16349	10/23	
	16350	10/23	
	16375	10/23	II
	16380	10/23	
M023015	13879	2	
	13880	2	I
	13881	10/23	
	13882	2	
M023018	13907	10/23/25	
	13908	10/23/25	
	13909	10/23/25	II
	13910	10/23	
	13912	10	
M010015B	12503	5	
	12732	10/23	
	12744	5	I
	12954	10/23	
M010017C	12890	5	
	12891	5	II
	12892	5	
	12893	10	
	12950	5	
M01001185A	10242	12/25	I
M0100123B	12901	10/23	II
M0140225B	12826	10/23	I
M0130117	10048	10/23/25	
	10049	10/23/25	
	10050	10	II
	10051	10	
	100136	10	
	100138	10	

CABLE SAMPLES

Quad Cities Unit 2

Equipment	Cable #	Zone	Group	Equipment	Cable #	Zone	Group
M0100137B	22972	2					
	22973	2	I	TS2370B	23995	4	I
	22974	2					
M0100128A	20271	10		M07507B	12265	37	
	22662	2			12266	37	
	22665	2	II		12267	37	II
	22666	2			12268	10/23	
	22667	10					
	22668	2					
M023015	23879	2		MCC281A	21355	22	
	23880	2	I		21356	22	I
					21357	22	
	23882	2					
S02033A	24839	10/23	II				
S022044	26316	10	I	M010017B	20292	10/23	
					20293	5	
M07503B	12275	37			22523	5	
	12276	10/23			22524	5	II
	12277	37	I		22525	5	
	12287	37			22526	10/23	
	12288	37			22527	10/23	
M07506A	22271	10/23	I	M0140238A	22637	2	
	22272	37			22638	2	I
	22274	37			22639	10/23	
					23061	2	
M010014A	20204	10		M0230136	23970	2/4	II
	20212	5	II		23971	2/4	
	20227	5					
					26210	2/4	
				M02025A	22508	10	
M0100136A	22533	2			25798	23	I
	22534	2	I				
	22535	10/23					
	22536	2		S02033D	24845	10/23	II
				M07505B	12254	37	
					12255	37	I
					12256	10/23	
M0100134A	22692	2		M07504A	22250	37	
	22693	2	II		22251	37	II
	22694	10/23			22253	10/23	