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SUBJECT: Part 21 rept re current transformer encapsulant matl.

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April 17, 1989

ASEA BROWN BOVERI

Albert F. Kaiser
President

Mr. Carl Berlinger, Branch Chief
Office of Generic Communications
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Part 21 Report
ABB Power Distribution, Inc.
Current Transformer (CT) Encapsulant Material

Gentlemen:

ABB switchgear equipment has for many years utilized current transformers and sensors encapsulated in an epoxy-anhydride compound. Epoxy-anhydride formulations are commonly used as encapsulants in a great many electrical components. Normally these materials form a durable protective casing with proper formulating and curing.

During the past few years a very small number of low voltage current transformers and ground sensors manufactured with this particular type of material have been found to be softening or reverting back to liquid.

In August 1988 some TKM CT's in two spare (deenergized) low voltage load centers at the St. Lucie Nuclear Plant of FP&L were found to be softening. This, as in a few previous cases, was attributed to a formulating or curing problem, however, a detailed evaluation was initiated to determine the cause of this material degradation.

This evaluation consisted primarily of a series of accelerated aging tests conducted at Piedmont Dielectrics Inc. and some special tests at Clemson University. A summary of these tests is included as Appendix "C" of this report.

It should be noted that these accelerated aging tests were unusual and very severe and are not considered a standard test for this material.

<u>Summary of Evaluation</u>

There are least 500,000 to 600,000 components made of this material in service today. The number of items that have shown signs of reversion are considerably less than .01% of those manufactured over the past 24 years.

Items which reverted to liquid after being in service for more than 10 years have been isolated cases. One CT was recovered from a commercial installation near Orlando, Florida; one CT from a factory in North Carolina; one ground sensor from a factory in Spartanburg, S.C. and one ground sensor from equipment installed in Taiwan.

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ABB Power Distribution Inc.

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The common factors in the reverted materials environment appear to be elevated air temperatures at high relative humidity, with little or no mitigating circumstances such as air conditioning, space heaters, or self heating. The CT's at St. Lucie were not energized.

It has been found that the effects of humidity on DDSA used in the hardener is what causes the depolymerization or reversion. It is also known that decreasing the amount of DDSA in the hardener can improve the materials resistance to reversion, however, it cannot prevent it altogether.

The results of these tests confirm that the epoxy will revert back to liquid, however, the prediction of when this will happen is not readily apparent. Whether this will happen in 10 years, 30 years, or 100 years in a particular environment remains to be determined.

The small number of field occurrences and the scattering of data from tests makes it difficult to do more than generalize about the causes of reversion and the factors affecting the rate of reversion at this time.

It should be noted that the CT's at St. Lucie that were found to be reverting had been inspected 18 months earlier and were found to be normal at that time. Approximately 15 CT's were changed out in each of two load centers.

Recommended Inspection

It is recommended that items encapsulated with the epoxy be inspected at approximately 18 month intervals. With the equipment deenergized, the item can be examined by pressing a thumb nail into the material. This should leave a small indentation if the material is still acceptable for use. If the material is tacky it has started to revert. The reversion process is slow but irreversible. Once it has started it will continue until the material liquifies. The item should be replaced when the encapsulant becomes tacky.

If the item shows no sign of reversion, it can continue to be used indefinitely. Some few items failed at approximately 10 years. The CT's that reverted at St. Lucie were 17 years old, however, the other CT's at St. Lucie show no signs of reversion at this time. Many CT's have been in service for over 20 years with no signs of reversion.

Once the process of reversion is detected, there is adequate time to order and install replacement parts. The process of degradation is very gradual as was evident by the 18 month inspection cycle at St. Lucie and from the tests performed by Clemson.

An inspection of CT's at Turkey Point shows no signs of reversion. Turkey Point was built approximately two to three years earlier than St. Lucie.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] as each of two [illegible]

[illegible]

[illegible]

[illegible] approximately 13 years [illegible]

[illegible]

[illegible]

Determination of material hardness by means of a durometer as it is done in the factory is not a practical means of inspecting CT's in field service. In fact, it could be misleading. The durometer can only be used if the item being tested is on a smooth flat surface.

Equipment Affected

Reversion has occurred in TKM type CT's used in low voltage switchgear. It also occurred in ground sensors used in medium and low voltage switchgear. The same material is used in medium voltage CT's and other sensors, however, there have been no reports of reversion in these items.

Appendix "A" lists all components that are manufactured with the epoxy resin and require the inspection mentioned above.

The fact that there have been no reversions reported in the medium voltage CT's may be because the epoxy is poured into a hard reinforced cylindrical case and the epoxy potting compound is only exposed to humidity on the top. This effectively reduces the surface area of the epoxy exposed to humidity by a factor of ten. Tests are being performed to evaluate these components.

Corrective Action

Only components showing actual signs of reversion need to be replaced.

Replacement parts can be obtained by following existing procedures for ordering spare parts.

Copies of this report are being forwarded to all Nuclear Power Generating Stations that have ABB Power Distribution, Inc. equipment being utilized in Nuclear Safety Related applications.

Appendix "B" contains a list of Nuclear Power Generating Stations with ABB Power Distribution, Inc. low voltage and/or medium voltage switchgear in Nuclear Safety Related applications.

Further Considerations

Alternate designs for CT's are being evaluated.

Changing the encapsulant to a polyurethane material is being evaluated. No change can be implemented quickly due to materials testing and design testing that must be accomplished. Three alternative materials are currently under evaluation.

As can be seen from this evaluation, the probability of encountering this type problem is very low, and if it is detected there is adequate time to initiate corrective action. The material degradation is a very slow process.

This report is being issued to advise the users of the potential for this problem and to initiate inspections recommended above.

A. F. Kaiser

A. F. Kaiser, President
ABB Power Distribution, Inc.

EWR/jm

Attachments

[illegible]

[illegible]

[illegible]

APPENDIX A

Components Used in NSR Installations

CATALOG NO.	C/T TYPE	WHERE USED
*	TKM followed by Suffix 1, 2, 3, 4 K-Line Neutral Sensor	K-Line Low Voltage Switchgear K-Line Low Voltage Switchgear
*	GS-5 & GS-200 & GSM & RCSG Round & Rectangular Sensors	K-Line Low Voltage Switchgear HK Medium Voltage Switchgear
401619 & 401621	LKM followed by Suffix 1, 2	LK Low Voltage Switchgear
401658, 401665, 401781 & 401786	LKM Neutral Sensor	LK Low Voltage Switchgear
401636	LK Sensor	LK Circuit Breaker
401644	LK Sensor	LK Circuit Breaker
*	MC, MCS, MCB, MCR followed by Suffix 5, 15, 20, 21, 25	HK Medium Voltage Switchgear
401717	LK Sensor (2500 thru 4200)	LK Circuit Breaker

* ALL CATALOG NUMBERS APPLICABLE TO THIS CT TYPE ARE INCLUDED IN APPENDIX A, SHEET 2.

Rev. [illegible]
Sheet 1 of 2

APPENDIX A

Components Used in NSR Installations

CATALOG NO.	[illegible]	WHERE USED
	LSM followed by Suffix 1, 2, 3, 4 K-Line Neutral Sensor	K-Line Low Voltage Switchgear K-Line Low Voltage Switchgear
	GS-[illegible]-2000 [illegible] 5 RG56 Round & Rectangular Sensors	K-Line Low Voltage Switchgear HK Medium Voltage Switchgear
401615 & 401621	LSM followed by Suffix 1, 2	LK Low Voltage Switchgear
401658, 401665, 401751 & 401[illegible]	LSM Neutral Sensor	LK Low Voltage Switchgear
401656	LK Sensor	LK Circuit Breaker
401[illegible]	LK Sensor	LK Circuit Breaker
	MC, MCA, MCB, MCR Followed by Suffix [illegible], 17, 20, 21, 25	HK Medium Voltage Switchgear
401617	LK Sensor (2500 thru 4200)	LK Circuit Breaker

* ALL CATALOG NUMBERS APPLICABLE TO THIS CT TYPE ARE INCLUDED IN APPENDIX A, SHEET 2.

APPENDIX A

CT & SENSOR CATALOG NUMBERS

TYPE	CAT. NO.	TYPE	CAT.NO.	TYPE	CAT.NO.
TKM	401181	MC-5	401437	MC-15	400977
TKM	401184	MC-5	400862		
TKM	401190			MC-15A	401026
TKM	401310	MC-5A	401309		
TKM	401344			MC-15A1	401160
TKM	401174	MC-5M	401043		
SENSORS		MC-5M	401434	MC-15AS	401042
GS	302L0721UL				
GS	302B0500UL	MC-5M1	401179	MC-15A1S	401601
GS	302B0800UL	MC-5A1	401343	MC-15A1S	401314
GS	302B1013UL			MC-15A1S	401191
GS	302B1017UL	MCB-5	401012	MC-15S	401197
GS	302B1024UL	MCB-5	401048	MC-15S	401086
GS	302L0725UL			MC-15S	401018
GS	302A0500	MCB-5A	401024		
GS	302A0800			MC-15M	401031
GS	401240	MCB-5AS	401048		
GS	401222			MC-15M1	401161
GS	401214	MCB-5M	401040		
GS	401215			MC-15M1S	401194
GS	401205	MCB-5MS	401744		
GS	401208	MCB-5MS	401040		
GS	401202			MCB-15	401012
		MCS-5	400990	MCB-15S	401036
GSM	401075			MCB-15A	401024
GSM	401259	MCS-5S	401056		
		MCS-5S	401339	MCB-15AS	401048
		MC-25A1	401574	MCB-15AS	401591
NEUTRAL	609301			MCB-15M	401040
		MC-25A1S	401683		
GS	614521	MC-25M	401577	MCR-15A	401480
GS	614605			MCR-15A1	401514
GS	614608	MCS-20	401034	MCR-15M	401479
GS	401257	MCS-21S	401193	MCR-15M1	401529
GS	401262	MCS-21S	401124		
GS	401263	MCS-21S	401338	MCS-15	400990
GS	401264	MCS-21	401153		
		MCS-21S	401538		
		MCS-25	401572		
		MCS-25S	401580		

APPENDIX A

TYPE - SENSOR CATALOG NUMBERS

CAT. NO.	TYPE	CAT. NO.	TYPE	CAT. NO.	TYPE
400977	MC-1	401131	MC-5	401181	TM
		400962	MC-5	401154	[illegible]
401026	MC-15A			401150	TYM
		401309	MC-5	401310	TRM
401139	MC-15AI			[illegible]	ISM
		401013	MC-5M	401174	[illegible]
401042	MC-15AS	401034	MC-5M		SENSORS
				301F072 [illegible]	GS
401601	MC-15AIS	401129	MC-5AI	302B05001	GS
[illegible]	MC-15AIS	[illegible]	MC-5AI	302B08001	GS
[illegible]	MC-15AIS			302B101 [illegible]	GS
[illegible]	MC-15S	401012	MCB-5	302P1017 [illegible]	GS
401036	MC-15S	401015	MCB-5	3022022 [illegible]	GS
401013	MC-15S			302L072 [illegible]	GS
		401024	MCB-5A	302A0500	GS
401041	MC-1 M			302A0800	GS
		[illegible]	MCB-5A	401240	GS
[illegible]	MC-1 MI			401222	GS
		401040	MCB-5M	401214	GS
401104	MC-1 MIS			401215	GS
		401174	MCB-5M	401204	GS
		01010	MCB-5M	401205	GS
401012	MCB-15			401202	GS
401036	MCB-15S	400990	MCS-5		
401024	MCB-15A			401075	GSM
		401056	MCS-5S	401159	GSM
401018	MCB-15AS	401339	MCS-5S		
401591	MCB-15AS	401574	M -25AI		
401040	MCB-15M			609301	FILTRAN
		401653	MC-25AI		
401450	MCR-1	401577	MC-25M	611521	GS
401514	MCR-1			611605	GS
401479	MCR-15M	401034	MCS-20	[illegible]605	GS
401529	MCR-15MI	401193	MCS-21S	401257	GS
		401124	MCS-21S	401262	GS
400990	MCS-1	[illegible]	MCS-21S	401263	GS
		[illegible]	MCS-21	401264	GS
		[illegible]	MCS-21S		
		[illegible]	MCS-25		
		40153 [illegible]	MCS-25S		

APPENDIX B

Epoxy Encapsulated Items in NSR Locations

Arizona Public Service	Palo Verde
Arkansas Power & Light	Arkansas Nuclear One
Baltimore Gas & Electric	Calvert Cliffs
Boston Edison (CT's Only)	Pilgrim
Carolina Power & Light	Brunswick
Carolina Power & Light	Shearon Harris
Cincinnatti Gas & Electric	Zimmer
C.E.I.	Perry
Commonwealth Edison	Zion
Commonwealth Edison	LaSalle County
Connecticut Yankee	Connecticut Yankee
Consumers Power	Palisades
Consumers Power	Midland
Detroit Edison	Fermi
Duke Power	Oconee
Duke Power	McGuire
Duke Power	Catawba
Duquesne Light	Beaver Valley
Florida Power Corporation	Crystal River
Florida Power & Light	St. Lucie
Florida Power & Light	Turkey Point
Georgia Power	Vogtle
Gulf States Utilities	River Bend
Houston Lighting & Power	South Texas
Illinois Power	Clinton
Indiana & Michigan	Cook
Iowa Electric Light & Power	Arnold
Long Island Light	Shoreham
Systems Energy Resources (Formerly Mississippi Power & Light)	Grand Gulf
Niagara Mohawk	Nine Mile Point 2
Northeast Utilities	Millstone 3
Northern States Power	Prairie Island

[illegible] 9.2.B

Upon Unregulated Sites in NSR Stations

Arizona Public Service	Palo Verde
Arkansas Power & Light	Arkansas Nuclear One
Baltimore Gas & Electric	Calvert Cliffs
Boston Edison (CP's Unit)	Pilgrim
Carolina Power & Light	Brunswick
Carolina Power & Light	Shearon Harris
Cincinnati Gas & Electric	Zimmer
C.E.I.	Perry
Commonwealth Edison	Zion
Commonwealth Edison	LaSalle County
Connecticut Yankee	Connecticut Yankee
Consumers Power	Palisades
Consumers Power	Midland
Detroit Edison	Fermi
Duke Power	Oconee
Duke Power	McGuire
Duke Power	Catawba
Duquesne Light	Beaver Valley
Florida Power Corporation	Crystal River
Florida Power & Light	St. Lucie
Florida Power & Light	Turkey Point
Georgia Power	Vogtle
Gulf States Utilities	River Bend
Houston Lighting & Power	South Texas
Illinois Power	Clinton
Indiana & Michigan	Cook
Iowa Electric Light & Power	Arnold
Long Island Light	Shoreham
System Energy Resources (formerly Mississippi Power & Light)	Grand Gulf
Niagara Mohawk	Nine Mile Point 2
Northeast Utilities	Millstone 3
Northern States Power	Prairie Island

APPENDIX B

Epoxy Encapsulated Items in NSR Locations

Pennsylvania Power & Light	Susquehanna
Philadelphia Electric Company	Peach Bottom
Philadelphia Electric Company	Limerick
Portland General Electric	Trojan
Public Service Colorado	Ft. St. Vrain
Public Service Indiana	Marble Hill
Public Service New Hampshire	Seabrook
Public Service Electric & Gas	Salem
Public Service Electric & Gas	Hope Creek
SMUD	Rancho Seco
South Carolina Electric & Gas	Summer
Southern California Edison	San Onofre
TVA	Sequoyah
TVA	Watts Bar
TVA	Bellefonte
TVA	Hartsville
TVA	Phipps-Bend
TVA	Yellow Creek
Texas Utilities	Comanche Peak
Union Electric (Non 1E)	Calloway
Virginia Electric Power Company	Surry
Virginia Electric Power Company	North Anna
WPPSS	WNP
CFE (Mexico)	Laguna Verde
Taiwan Power	Kuosheng

APPENDIX B

Pipe Encapsulation [illegible] Applications

Pennsylvania Power & Light	Susquehanna
Philadelphia Electric Company	Peach Bottom
Philadelphia Electric Company	Limerick
Portland General Electric	Trojan
Public Service Colorado	Ft. St. Vrain
Public Service Indiana	Marble Hill
Public Service New Hampshire	Seabrook
Public Service Electric & Gas	Salem
Public Service Electric & Gas	Hope Creek
SMUD	Rancho Seco
South Carolina Electric & Gas	Summer
Southern California Edison	San Onofre
TVA	Sequoyah
TVA	Watts Bar
TVA	Bellefonte
TVA	Hartsville
TVA	Phipps-Bend
TVA	Yellow Creek
Texas Utilities	Comanche Peak
Union Electric (Mo.)	Callaway
Virginia Electric Power Company	Surry
Virginia Electric Power Company	North Anna
WPPSS	WNP
CFE (Mexico)	Laguna Verde
Taiwan Power	Kuosheng

APPENDIX C

Epoxy Encapsulant Materials Testing

During the past three years a few incidents have been reported of low voltage current transformers and ground sensors reverting back to liquid. This condition wherein the thermoset epoxy resin encapsulant material depolymerizes has occurred in switchgear units that have been in service for ten or more years. These failures had been attributed to incorrect mixing or formulating of the encapsulant material and the units were replaced.

In August 1988 some TKM current transformers in two spare (deenergized) low voltage load centers at the St. Lucie Nuclear Plant of Florida Power and Light were found to be in the reverted condition. The CT's at St. Lucie with this condition were manufactured in October 1971. This again appeared to be a mixing or curing problem, however, a detailed evaluation was initiated to determine the cause of the degradation of the epoxy resin material.

Experimental Testing

Several samples of the material were subjected to 95% relative humidity at 90°C (194°F). These environmental conditions were adapted from a standard Navy avionics test for the reversion of polyurethanes.

It should be noted that this accelerated aging test is unusual and very severe and is not a standard test for this material.

Five of the seven samples, including the control sample, reverted in 6 to 10 days. The rate of reversion was different and dependent upon the makeup of the samples. Test results indicated that one of the hardeners (DDSA) used in the epoxy formulation is the most likely cause of failure known as chain scission. Two samples which did not revert (liquify) in the 6 to 10 day period had been modified to contain less hardener. Altering the environmental conditions also affects the rate of reversion. A standard sample tested at 95% relative humidity and 80°C (176°F) took 23 days for reversion to occur.

Two TKM transformers manufactured at an earlier date were placed in the humidity chamber at 95% R.H. and 90°C. Both of these units reverted (liquified). One unit, manufactured between 2/74 and 5/79, was very soft when received, with a durometer hardness of 20D which is half the normal hardness. This indicated that this transformer had already started to revert. After 23 hours, the epoxy was very tacky and after 144 hours, the epoxy had liquified. The other transformer, manufactured between 1965 and 1972, had a normal hardness and did not revert until 480 hours into the test.

Finally, a new TKM transformer manufactured at Piedmont Dielectrics Inc. was subjected to the humidity/temperature test 95% R.H./90°C. Although this unit had a very high initial hardness of 58D, the material reverted after 288 hours.

APPENDIX C

Epoxy Encapsulant Materials Testing

During the past three years a few incidents have been reported of low voltage current transformers and ground sensors reverting back to liquid. This condition wherein the thermoset epoxy resin encapsulant material depolymerizes has occurred in switchgear units that have been in service for ten or more years. These failures had been attributed to incorrect mixing or formulating of the encapsulant material and the units were replaced.

In August 1983 some TRM current transformers in two spare (deenergized) low voltage load centers at the St. Lucie Nuclear Plant of Florida Power and Light were found to be in the reverted condition. The CT's at St. Lucie with this condition were manufactured in October 1971. This again appeared to be a mixing or curing problem, however, a detailed evaluation was initiated to determine the cause of the degradation of the epoxy resin material.

Experimental Testing

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Two TRM transformers manufactured at an earlier date were placed in the humidity chamber at 95% R.H. and 90°C. Both of these units reverted (liquified). One unit, manufactured between 2/74 and 5/79, was very soft when received, with a durometer hardness of 20D which is half the normal hardness. This indicated that this transformer had already started to revert. After 23 hours, the epoxy was very tacky and after 144 hours, the epoxy had liquified. The other transformer, manufactured between 1965 and 1972 had a normal hardness and did not revert until 480 hours into the test.

Finally a new TRM transformer manufactured at Midwest Electric Inc. was subjected to the humidity/temperature test 95% R.H. 90°C. Although this unit had a very high initial hardness of 75D, the material reverted after 298 hours.

APPENDIX C
(Continued)

The Chemical Engineering Department at Clemson University was contacted about other types of testing that could be done on the epoxy resin. Their suggestion was to run second order glass transition temperature (Tg) determinations.

Tg numbers are an indication of cross linking density. However, Tg determinations were not feasible, though the modulus of elasticity was determined. This physical property is also a function of cross linking density. By obtaining these values for a controlled specimen and for specimens exposed for 2 and 5 days at 95% R.H., 90°C, it was thought that it may be possible to determine a more accurate rate of degradation.

The results of these tests confirm that the epoxy will revert back to liquid, however, the prediction of when this will happen is not readily apparent. Whether this will happen in 10 years, 30 years, or 100 years in a particular environment remains to be determined.

APPENDIX
(Continued)

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