Certified Test Report

GE Distribution Transformer *Hickory, NC* *Shreveport, LA*

TEST TITLE: GE PROTECTIVE COATING SYSTEM - NETWORK TRANSFORMER PRODUCTS

TEST RELEASE DATE: FEBRUARY 1993

TEST REPORT NUMBER: RP-PT-93054-1
NWTCERT.DOC

PURPOSE: EVALUATE THE PROTECTIVE COATING SYSTEM USED ON GE NETWORK TRANSFORMER PRODUCTS FOR CONFORMANCE TO ANSI C57.12.30 (ENCLOSURE INTEGRITY OF SUBMERSIBLE EQUIPMENT).

CONCLUSION: THE PROTECTIVE COATING SYSTEM USED ON GE NETWORK TRANSFORMERS MEETS OR EXCEEDS ALL PERFORMANCE CRITERIA AS REQUIRED BY ANSI C57.12.30 (ENCLOSURE INTEGRITY OF SUBMERSIBLE EQUIPMENT).

\S\ Michael Nolte

DATE: 02-20-93

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COATING SYSTEM OVERVIEW

All General Electric network transformers are fabricated from copper bearing steel (.2% copper content). Copper bearing steel is used because it exhibits a higher inherent resistance to corrosive attack than conventional carbon steel.
The protective coating system utilized by General Electric on all network transformers consists of a zinc rich epoxy primer followed by an epoxy topcoat. This protective coating system is considered a heavy duty protection system which is necessary in the severe operating environments in which network transformers operate. The zinc rich primer has greater than 85% zinc content (by weight) in the dry film and provides ***galvanic*** protection to the substrate material. In the event that the coating system is damaged, any exposed substrate material will be protected by the sacrificial corrosion of the adjacent zinc. The epoxy topcoat provides a protective barrier between the operating environment and the zinc primer. The General Electric network coating system consists of copper bearing steel, zinc rich primer and epoxy topcoat.

Satisfactory performance of the General Electric network coating system is dependent upon proper substrate pretreatment. Proper surface pretreatment consists of an abrasive blast to (1) thoroughly remove all oxides to assure the zinc metal in the primer is in direct contact with the substrate metal and (2) generate a surface profile for optimum adhesion of the coating and to maximize primer-to-substrate surface contact area.

The zinc rich primer is a two (2) part epoxy polyamide. Field experience with hot dip galvanized products has shown a direct relationship between zinc thickness and anticipated "useful sacrificial life". Based on this type of information, a minimum of .003" dry film thickness is specified for the zinc rich primer used on the network transformer.

The epoxy topcoat is also a two (2) part epoxy polyamide. A minimum .003" dry film thickness is specified for the topcoat. The epoxy topcoat is intended to protect the zinc primer from direct exposure to low pH environments or high pH environments that can be detrimental to the zinc. In addition the epoxy topcoat must provide a sufficient level of protection from ultraviolet degradation to insure long field life.

CROSSHATCH ADHESION

Proposed ANSI C57.12.30
Section **4.5.1 Cross Hatch Adhesion Test** - One (1) panel shall be scribed to bare metal in accordance with ASTM D3359-87. Method A shall be used for films thicker than 5 mils. Method B shall be used for films less than or equal to 5 mils. There shall be 100% adhesion to the substrate and between layers. A rating of 5A for method A and 5B for Method B per ASTM D3359-87 is required.

CROSSHATCH ADHESION TEST DATA

The General Electric network transformer protective coating system, when tested per ASTM D3359 exhibits 100% adhesion or a 5B rating with no coating removal.

CROSSHATCH ADHESION RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 CROSSHATCH ADHESION REQUIREMENTS.

IMPACT RESISTANCE

Proposed ANSI C57.12.30
Section **4.5.2 Impact Test** - One (1) panel at -7°C ± 2°C (20°F ± 4°F) panel temperature shall be impacted per ASTM D2794-84 at a value of 80 in-lb$_f$. Expose the panel to 96 hours of salt spray exposure per ASTM B117-85. There shall be no red rust visible in the impact (intrusion) area of the panel.

IMPACT RESISTANCE TEST DATA

The General Electric network transformer protective coating system was tested for impact resistance using 60 in-lb$_f$, 80 in-lb$_f$, 120 in-lb$_f$ and 160 in-lb$_f$ at a panel/coating temperature of 20°F. A similiar series of impact resistance tests were performed at a panel/coating temperature of 77°F. At test panel temperatures of 20°F and 77°F the epoxy topcoat exhibited no cracking up to ≅ 80 in-lb$_f$ direct impact. It is believed that film cracking is primarily due to the thickness of the protective coalting system used on network transformers. When impacted above 80 in-lb$_f$ the topcoat exhibited cracking but when exposed to 96 hours salt spray no red rust was visible (see photographs). All high energy impact zones exhibit a "white rust" which is zinc carbonate. Zinc carbonate is the corrosion product formed when zinc provides sacrificial glavanic corrosion protection to the substrate, providing assurance that the zinc is providing sacrificial protection as designed.

IMPACT RESISTANCE RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 IMPACT RESISTANCE REQUIREMENTS.

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GRAVELOMETER (CHIP RESISTANCE)

Proposed ANSI C57.12.30
Section **4.5.3 Gravelometer Test** - Two (2) panels are to be tested per ASTM D3170-87 at room temperature using 60 psi air pressure. Expose the test panels for 96 hours in salt spray per ASTM B117-85. Remove from salt spray, rinse and dry panels. Evaluate panels per SAE (Society of Automotive Engineers) J400 for quantity and size of rusted chipped areas. Minimum rating shall be 7B per SAE J400. A reprint of SAE J400 rating standards can be found on the next page.

GRAVELOMETER TEST DATA

Panels were exposed to gravelometer testing per ASTM D3170 at panel temperatures of 20°F and 77°F. The 20°F test temperature was used to reflect a "worse case" field senario for potential chipping damage. Two (2) chip evaluations were performed on each test panel. The first chip evaluation was performed after gravelometer exposure. This evaluation is based only on *visible damage to the coating* and does not differentiate the type of coating damage, i.e, topcoat marring, topcoat puncture, primer marring or primer puncture to expose substrate. The second evaluation is performed after the panel has been exposed to 96 hours of salt spray. This evaluation looks only for the *presence of red rust* to identify any coating damage that has punctured the primer and exposed substrate the corrosive attack.

PANEL IDENTIFICATION	VISIBLE CHIP DAMAGE PRIOR TO SALT SPRAY	CORROSION CHIP RATING AFTER SALT SPRAY
20°F PANEL TEMPERATURE	3C	NO RED RUST >9B WHITE RUST 7C
77°F PANEL TEMPERATURE	3C	NO RED RUST >9B WHITE RUST 6C

GRAVELOMETER (CHIP RESISTANCE) RESULTS

The General Electric network transformer protective coating exhibits similiar physical damage when exposed to gravelometer testing at 20°F or 77°F. Upon completion of the salt spray exposure the test panels exhibit the characteristic "white rust" deposits where the primer has been exposed with a 7C rating at 20°F and a slightly lower 6C rating at 77°F. Neither panel exhibited any red rust deposits (>9B rating).

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 GRAVELOMETER (CHIP RESISTANCE) REQUIREMENTS.

ULTRAVIOLET ACCELERATED WEATHERING (QUV) AND SIMULATED CORROSIVE ATMOSPHERIC BREAKDOWN (SCAB)

Proposed ANSI C57.12.30

Section **4.5.4 Ultraviolet Accelerated Weathering (QUV) and Simulated Corrosive Atmospheric Breakdown (SCAB)** - Three (3) panels shall be prepared and tested in accordance with the procedure described in the ANSI C57.12.30 appendix. Upon completion of 20 cycles SCAB, loss of adhesion and under film corrosion from bare metal shall not extend more than 1/8 inch from the scribe. The scribe shall be evaluated per ASTM D1654-84, procedure A method 2 (Scrape Method) and rated according to Table 1 with a minimum rating of 6. The unscribed areas of the panels shall be evaluated per ASTM D1654-84, procedure B and rated according to Table 2. A minimum rating of 10 is required.

SCAB TEST DATA

Network transformer panels were coated and exposed to 500 hours ultraviolet (QUV) to represent storage conditions that the apparatus could see prior to installation. After completion of the ultraviolet exposure, the panels were then scribed and exposed to 20 cycles of SCAB. Additional panels were exposed to 30 cycles SCAB and 40 cycles SCAB.

PANEL IDENTIFICATION	PANEL EVALUATION
PANEL #C01022-1 20 CYCLE SCAB	PAINT FADE NO CREEPBACK OBSERVED CREEPBACK = 10 PANEL PASS
PANEL #C01022-5 30 CYCLE SCAB	PAINT FADE NO CREEPBACK OBSERVED CREEPBACK = 10 PANEL PASS
PANEL #C01022-7 40 CYCLE SCAB	PAINT FADE NO CREEPBACK OBSERVED CREEPBACK = 10 PANEL PASS

SCAB TEST RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 SCAB CORROSION RESISTANCE REQUIREMENTS.

OIL RESISTANCE

Proposed ANSI C57.12.39
Section **4.5.5 Oil Resistance Test** - Partially immerse one (1) panel in the liquid used as the insulating medium for 72 hours, at 100°C-105°C (212°F-221°F). On the immersed portion of the panel there shall be no blisters and no more than one (1) pencil hardness change when tested in accordance with ASTM D3363-89, using either method.

OIL RESISTANCE TEST DATA

Test panels with the General Electric network coating system were partially immersed in conventional 10C transformer oil and silicone fluid for 72 hours at a temperature of 105°C. Upon completion of the test period the panels were inspected for the presence of blistering, coating delamination or any other visible signs of potential coating-insulating fluid incompatibility. Pencil hardness was also measured. No test panel exhibited any deterioration.

OIL RESISTANCE RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 SCAB OIL RESISTANCE REQUIREMENTS.

IMMERSION (SOAK) TEST

Proposed ANSI C57.12.30
Section **4.5.6 Soak Test** - Partially immerse one (1) panel into Harrison's solution maintained at 65°C for 1000 hours. Allow the panel to cool to room temperature and dry off. On the immersed portion of the panel there shall be no blisters and no more than one (1) pencil harness change when tested in accordance with ASTM D3363-89, using either method.

IMMERSION (SOAK) TEST DATA

Test panels were partially immersed into Harrison's solution for 1000 hours. One panel was immersed at 50°C test temperature and a second test panel was immersed at 65°C test temperature. Upon completion of the test the immersed portion and vapor phase portion of the test panels were carefully inspected for any signs of coating deterioration. No blistering, cracking or crazing was visible on the coating nor was there any measureable change in pencil hardness.

IMMERSION (SOAK) TEST RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 SCAB IMMERSION (SOAK) RESISTANCE REQUIREMENTS.

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THERMAL CYCLE TEST

Proposed ANSI C57.12.30

4.5.7 Thermal Cycle Test - One (1) panel shall be exposed to thermal cycling for four (4) weeks. Place test panels into a 130°C (266°F) oven for 8 hours and followed by 16 hours at 25°C (77°F). This cycle is to be repeated each weekday (Monday - Friday). Maintain test panel temperature at 130°C (266°F) on weekends (Saturday and Sunday or Holiday/s). Upon completion of the test expose the panel to 96 hours of salt spray per ASTM B117-85. There shall be no blistering and no red rust visible on the panel.

THERMAL CYCLE TEST DATA

Coated test panels were placed into thermal cycling for four (4) weeks. Upon completion of the thermal cycling period the panels were carefully inspected for any signs of coating deterioration. No blistering, cracking, crazing or loss of adhesion was noted.

THERMAL CYCLE RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES ANSI C57.12.30 THERMAL CYCLE RESISTANCE REQUIREMENTS.

SALT SPRAY CORROSION RESISTANCE

Not an ANSI C57.12.30 test

Salt spray corrosion resistance testing is not addressed in proposed ANSI C57.12.30. However, salt spray corrosion testing is performed universally, accepted and continues to be used as a relative rating tool by many electrical manufacturers and utilities alike. For this reason General Electric performed salt spray corrosion testing on the network transformer coating. All salt spray corrosion testing was performed per ASTM B117. Scribeline creepback was evaluated per ASTM D1654, procedure A using method 2. The maximum allowable creepback is 1/8" (3.0 mm) or a *minimum* rating of "7". The unscribed area or field of the panel was evaluated by using ASTM D1654 procedure B. No blistering is allowed for a rating of "10".

SALT SPRAY CORROSION TEST DATA

PANEL IDENTIFICATION	SALT SPRAY TEST EVALUATION
PANEL #S11289-B2 6000 HOURS SALT SPRAY	NO BLISTERING B=10 NO MEASUREABLE CREEPBACK C=10 PANEL PASS
PANEL #S11289-B3 8000 HOURS SALT SPRAY	NO BLISTERING B=10 NO MEASUREABLE CREEPBACK C=10 PANEL PASS
PANEL #S11289-B5 10000 HOURS SALT SPRAY	NO BLISTERING B=10 NO MEASUREABLE CREEPBACK[1] C=10 PANEL PASS[1]

1 one scribeline exibited a localized creepback region whereas no creepback was found on any other scribeline/panel. Close examination of the creepback revealed a coating application defect.

SALT SPRAY CORROSION RESULTS

THE PROTECTIVE COATING SYSTEM USED BY GENERAL ELECTRIC ON NETWORK TRANSFORMERS PASSES 10000 HOURS SALT SPRAY RESISTANCE USING *ANSI C57.12.28* TESTING METHODOLOGY. *ANSI C57.12.28* (PADMOUNTED ENCLOSURE INTEGRITY) REQUIRES 1500 HOURS SALT SPRAY RESISTANCE.

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ENVIRONMENTAL DATA

The General Electric network transformer protective coating system was tested by an independant laboratory for conformance to Federal Resister Vol. 55, No. 66, 03/29/90. This particular test procedure, known as the TCLP test, is a means to evaluate if a coating system could contaminate ground water in event that the network tank were to be landfilled at end-of-useful-life. The independant laboratory evaluated the network primer and the network topcoat as separate systems. The laboratory tested for possible "leaching" of arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver. All reported values are below the present treatment standard (see below).

The network transformer protective coating system is certified, by the manufacturer, to contain less than .06% lead (wt/wt) and less than .06% chromium (wt/wt).

Lab ID: 108098 Client ID: 8 Matrix: SOLID
Other ID: Description: ZN RICH EPOXY PRIMER

Arsenic-TCLP	< 0.20 mg/l
Barium-TCLP	0.44 mg/l
Cadmium-TCLP	0.018 mg/l
Chromium-TCLP	< 0.010 mg/l
Lead-TCLP	< 0.10 mg/l
Mercury-TCLP	< 0.0002 mg/l
Selenium-TCLP	< 0.20 mg/l
Silver-TCLP	< 0.010 mg/l

Lab ID: 108099 Client ID: 9 Matrix: SOLID
Other ID: Description: BLK POLYAMIDE EPOXY TOPCOAT

Arsenic-TCLP	< 0.20 mg/l
Barium-TCLP	0.21 mg/l
Cadmium-TCLP	< 0.005 mg/l
Chromium-TCLP	< 0.010 mg/l
Lead-TCLP	< 0.10 mg/l
Mercury-TCLP	< 0.0002 mg/l
Selenium-TCLP	< 0.20 mg/l
Silver-TCLP	< 0.010 mg/l

Waste Code	Hazardous Property/Constituent	Treatment Standard or Technology
D001	Ignitability	Fuel substitution, recovery, or incineration
D002	Corrosives	Deactivation, 2 < pH < 12.5
D003	Reactive Cyanides	Non-Wastewaters Cyanide, (T): 590 mg/kg Cyanide, (A): 30 mg/kg Wastewaters Cyanide, (A): 0.86 mg/liter
D003	Reactives	Deactivation to remove the characteristic of reactivity
D004	TC*-Arsenic	5.0 mg/liter-EP Toxicity Procedure
D005	TC*-Barium	100 mg/liter-TCLP**
D006	TC*-Cadmium	1.0 mg/liter-TCLP**
D007	TC*-Chromium	5.0 mg/liter-TCLP**
D008	TC*-Lead	5.0 mg/liter-TCLP**
D009	TC*-Mercury (@ < 260 mg/kg)	0.20 mg/liter-TCLP**
D010	TC*-Selenium	5.7 mg/liter-TCLP**
D011	TC* Silver	5.0 mg/liter-TCLP**