PHASE I
FINAL REPORT

Proposal/Agreement No. 382-P-9955R

on

ANALYSIS OF MATERIALS: D. C. COOK SAFETY INJECTION MOTOR MATERIALS QUALIFICATION

to

AMERICAN ELECTRIC POWER
SERVICE CORPORATION

December 30, 1987

by

Tom Gruber and William Mirick

BATTELLE
Columbus Division
505 King Avenue
Columbus, Ohio 43201-2693

ATTACHMENT 2 TO AEP:NRC:0775AP

ANALYSIS OF MATERIALS: D. C. COOK SAFETY

INJECTION MOTOR MATERIALS QUALIFICATION

8907210090 890714
PDR ADOCK 05000316
P PDC

TABLE OF CONTENTS

PHASE I
FINAL REPORT

on

ANALYSIS OF MATERIALS
D. C. COOK SAFETY INJECTION
MOTOR MATERIALS QUALIFICATION

to

AMERICAN ELECTRIC POWER
SERVICE CORPORATION

from

BATTELLE
Columbus Division

by

Tom Gruber and William Merick

December 30, 1987

INTRODUCTION

A 400 horse power safety injection motor which was qualified for Class 1E service (equipment for nuclear power generating stations) was sent to a non-certified shop for balancing. The rotor was balanced and, as is normal practice, the stator was varnished and the end windings painted. There is concern about the status of the Class 1E qualification of this motor as a result of the use of non-certified materials used to varnish the stator. The chemical compatibility of the newly added varnish with the original materials is unknown.

A two phase program was proposed to American Electric Power (AEP) by Battelle to resolve these questions. Phase I, Analysis of Materials, involves a search for information and data to demonstrate that the newly added materials and the original materials are compatible, and that the motor remains qualified for Class 1E service. Phase II, Materials Qualification, involves the irradiation of a combination of the original stator materials

and the newly applied materials to demonstrate that there is no adverse reaction to radiation.

This is the Final Report for Phase I. The following sections contain a summary of the work performed, conclusions, and recommendations for further action by American Electric Power. The final section of this report, Materials Analysis Details, provides permanent documentation of the information located and highlights the information that substantiates the conclusions. The final section, Materials Analysis Details, is lengthy and is directed toward those persons with a detailed interest in the effects of radiation on organic materials.

SUMMARY

The objective of the Phase I analysis of the materials was to determine if the varnish and paint added to the motor have any adverse effect on the originally qualified materials and the qualification of the motor. The first step was to obtain information about the materials used by the motor manufacturer, Westinghouse, and the shop which balanced and varnished the motor.

The two materials used by Westinghouse were identified as:

Item #1 B-6-665, Air Dry Insulating Enamel-Epoxy, and

Item #2 B-172 Epoxy Varnish.

The information about the materials used by Westinghouse was proprietary and was obtained only after Battelle had entered a confidential information agreement with Westinghouse.

The shop that balanced the motor used material manufactured by Schenectady Chemical, Inc., with the registered trade marked name Aquanel 600, a water borne insulating varnish. This varnish is a modified alkyd solution containing dimethylaminoethanol and butyl cellosolve.

The search for pertinent data in published literature was conducted in two steps: (1) a search of published indexes of engineering and technical literature, and (2) a search of computerized databases. As it turned out, a

report on a significant survey was located which contained an extensive bibliography. Copies were obtained of pertinent reports and journal articles from this bibliography. The most recent information obtained was dated 1979. The computerized database search was then conducted to obtain the most recent information available, 1986. Abstracts contained in the computer search off-line output confirmed the conclusions which had been made from the pre-1980 information. Copies of several original reports located by the computer search were ordered to obtain information on the specific materials used on the motor in question.

No information was found on the specific materials used on the D. C. Cook Safety Injection Motor. However, all the information obtained from world-wide sources confirms that with few specific exceptions organic materials used for paints, varnishes, and insulating coatings may be expected to perform satisfactorily to radiation doses up to 10^8 rads. This information is summarized in the last section of this report and pertinent details have been highlighted by arrows in the lefthand margin (==>).

CONCLUSIONS

Review of the information obtained through the literature search supports the following conclusions:

(1) Radiation damage is not likely to occur until the varnishes and paints in question have received a dose of more than 10^8 rads.

(2) There is not likely to be any problem unless the original and over-laid varnish and paints are chemically incompatible.

(3) It is feasible to perform a relatively simple laboratory evaluation of the materials in question to determine chemical compatibility.

(4) If the materials are incompatible, there is no need to perform irradiation tests.

(5) Thermal aging of varnish and paint samples may be performed prior to irradiation of samples.

(6) If the materials are chemically compatible, and if electrical measurements after irradiation to 10^8 rads (gamma) show no degradation, continued use of the motor for its Class 1E application is acceptable.

RECOMMENDATIONS

The following recommendations are made on the basis of the above conclusions.

(1) The chemical compatibility of the original motor insulation materials with the newly applied insulation materials be determined experimentally. These experiments may be conducted using twisted pairs of copper wire and need not use stator windings. Small sample size analysis technique should be used with a sample size of 16.

(2) If the original and the newly added materials are chemically compatible, irradiation experiments should be conducted to verify the effects of radiation on this material combination. These experiments should be conducted to a total dose of 10^8 rads with insulation resistance and voltage breakdown measurements made before and after irradiation. It is not necessary to make these measurements during irradiation. The experimental samples may be twisted pairs of wire. Small sample size analysis techniques should be used with a sample size of 16.

MATERIALS ANALYSIS DETAILS

Literature Search

The literature search was conducted in three steps:

(1) Search of the Applied Research index to obtain specific references and also to determine which technical journals contained papers about radiation and Class 1E motors.

(2) Search of the yearly indexes of selected publications and journals.

(3) Interrogations of computerized databases.

Three extensive databases were searched through the services of Dialog Information Services, Inc.:

(1) DOE ENERGY, the database of the United State Department of Energy, is one the world's largest sources of literature references on all aspects of energy and related topics. DOE ENERGY provides coverage of journal articles, report literature, conference papers, books, patents, dissertations, and translations. The following energy topics are included: nuclear, wind, fossil, geothermal, tidal, and solar. Related topics such as environment, energy policy, and conservation are also included.

(2) The EI ENGINEERING MEETINGS database covers significant published proceedings of engineering and technical conferences, symposia, meetings, and colloquia. The file is produced by Engineering Information, Inc. EI ENGINEERING database covers all disciplines of engineering including civil engineering, environmental engineering, geological

engineering, bioengineering, electrical engineering, electronics, control devices and principles, applied mathematics and physics, and more.

(3) The COMPENDEX database, produced by Engineering Information, Inc., provides coverage of the world's significant engineering and technological literature. The database corresponds with the printed Engineering Index. Publications from around the world are indexed, including approximately 4,500 journals, publications of engineering societies and organizations, technical reports, monographs, and publications from approximately 2,000 conferences each year.

Summaries and abstracts of pertinent articles and papers located are contained in the final section of this report, "Literature Survey Summary."

Literature Survey Summary

The information contained in this section substantiates the above conclusions and recommendations. Significant information contained in the material extracted from articles and reports, and from abstracts of articles and reports, is noted with an arrow (==>) in the left margin.

The initial information search was performed using the Applied Research index under the following topics:

1985 and later:
- Nuclear
  - Power Plants
    - Electrical Equipment

1984 and earlier:
- Atomic
  - Power Plants
    - Auxiliaries

<u>Publications Located:</u>

IEEE Trans Energy Convers

EPRI J

IEEE Trans Power Appar Syst

Eng N

Resinous Products

Insulating Materials

<u>Publications Located</u>:

Electr World

Wire J Int

IEEE Trans Power Appar Syst

Insulation, electric

<u>Publications Located</u>:

EPRI J

Power

J Appl Phys

IEEE Trans Energy Convers

IEEE Trans Power Deliv

Electric Motors

Maintenance and Repair

<u>Publications Located</u>:

IEEE Trans Ind Appl

Electr Constr Maint

Windings

Electric Motors, AC

<u>Publications Located</u>:

Electr Constr Maint

Paint

<u>Publications Located</u>:

Chem Ind

Chem Eng

J Coat Technol

The journals containing information specific to the Class 1E motor problem were:

IEEE Transactions on Power Apparatus and Systems

IEEE Transactions on Electrical Insulation

IEEE Transactions on Nuclear Science

Information from IEEE Transactions

The following articles from IEEE transactions were reviewed:

IEEE Transaction on Power Apparatus and Systems,
Vol. PAS-102, No. 8, August 1983

SOME CONSIDERATIONS AND METHODS WHICH MAY BE USED
TO QUALIFY EQUIPMENT IN A MILD ENVIRONMENT

Perry L. Kline and J. Haratyk
Bechtel Power Corporation
12400 E. Imperial Highway
Norwalk, CA 90650

Abstract - This paper presents a definition of a so called "mild or non-harsh environment", a method to qualify (Class 1E) equipment in this environment, and the reasons behind this approach.

Extracts

The mild environment area is define as any area where the environmental parameters which are present when an accident occurs (LOCA, MSLB, or HELBA) show no significant difference from the environment experienced during normal/abnormal plant operations.

... Class 1E mild environment qualification program should contain the follow considerations, criteria and constraints:

...

3- Supplier's documentation must clearly show that the equipment is capable of performing its Class 1E function in the postulated environmental and service conditions...

4- A surveillance and maintenance program should be initiated if item number three is not satisfactory. This program should be developed and implemented jointly by the owner and supplier . . .

> In addition to industry experience, considerable analytical data has been published concerning non-metallic materials and their susceptibility to time/temperature effects and radiation damage thresholds. A starting point in developing surveillance test intervals would be to list all non-metallic materials, their properties of interest, and identify the weak link materials that are likely to suffer loss of the important material characteristics due to environmental influences.
>
> ... The first step in performing a surveillance test is to conduct a thorough visual inspection... The second step is to perform the specific test to measure the physical and operational parameter selected... The last step is to examine the test results and verify that all acceptance criteria have been achieved.
>
> Emphasis should be directed toward the correct interpretation of any drift or change in the operating parameters or response time, together with the process and environmental conditions... measured during surveillance testing.

Industry standards may be used for guidance, but should not be considered to be acceptable as a total Class 1E equipment qualification program...

Reference

3. EPRI no. NP-2129-81 "Radiation Effects on Organic Materials in Nuclear Plants".

IEEE Transactions on Power Apparatus and Systems
Vol. PAS-100, No. 12, December 1981

IEEE 323 QUALIFICATION EXPERIENCE

B. M. Schutzbank and L. B. Tiscione
Ebasco Services Inc.
New York N.Y.

Abstract - The purpose of this paper is to discuss several topics of concern regarding the qualification of Class 1E equipment for use in Nuclear Power Plants and to present experience gained in establishing methodologies and/or guide-lines to streamline the qualification process.

Extracts

In the absence of approved specific equipment standards, numerous equipment suppliers have attempted to satisfy thermal aging criteria by utilizing the 10 degree C rule (specifically for insulating systems). The acceptance of this analysis depends on the available state of the art, activation energy factors (expressed in eV) of component materials have not progressed sufficiently to allow for accuracy. The 10 degree C rule is only an approximate method. A large error may results in obtaining a test temperature and duration if the activation energy is not constant throughout the temperature range. An extreme degree of conservatism may also be imposed during testing so that the results appear more pessimistic, thus projecting a reduced qualified life.

The following aging analysis, based on IEEE 323-1974 and IEEE 101-1971, offers a comparison between the 10 degree C rule and an Arrhenius calculation based on a component material's activation energy...

The qualified life of the... material using the 10 degree C rule would be 1.269 years. However, based on the Arrhenius calculation using activation energy, the qualified life is 40 years.

IEEE Transactions on Power Apparatus and Systems
Vol. PAS-102, No. 6, June 1983

SPECIFICATION FOR ENVIRONMENT QUALIFICATION
OF CLASS 1E EQUIPMENT

Newell S. Porter
Washington Public Power Supply System
Richland, Washington

Abstract - One of the major challenges to obtain qualified Class 1E equipment is the adequacy of the specification. This paper presents the minimum requirements that must be considered in the preparation of specifications for Class 1E equipment.

Extract

In conclusion, a specification for Class 1E equipment should be written so that a supplier can provide qualified equipment...

IEEE Transactions on Power Apparatus Systems
Vol. PAS-102, No. 6, June 1983

R. Coupland
Wyle Laboratories
Huntsville, Alabama

A. Marion
Baltimore Gas & Electric Company
Baltimore, Maryland

Abstract - This paper describes the first phase in the development of a Maintenance Management System which will be used to assure that the maintenance necessary to ensure qualification of environmentally qualified, safety related equipment is performed. A review of the qualification documentation of a selected subset of the safety-related equipment was performed, and the information obtained was summarized.

Extract

... Incorporation of these recommendation into the maintenance system will ensure that the maintenance required for continued equipment qualification is identified.

IEEE Transactions on Nuclear Science,
Vol. NS-26, No. 4, August 1979

DESIGNER'S GUIDE TO RADIATION EFFECT ON MATERIALS FOR USE ON JUPITER FLY-BYS AND ORBITERS

Frank L. Bouquet and William E. Price
Jet Propulsion Laboratory
Pasadena, CA 91103

Donald M. Newell
Ford Aerospace
Palo Alto, CA 94303

Abstract - This paper summarizes the state-of-the-art of the complex field of radiation effects on spacecraft materials. It is intended as a guide for designers of systems exposed to damaging electrons and protons. The emphasis is on the relative damage levels for the more common materials that may be used. Information on the preliminary flux and fluence levels of the yet to be designed Jupiter orbiter, Galileo, is also presented.

Extracts

Organic Materials as a class are highly susceptible to radiation damage via ionization, bond breakage, free radical formation, and recombination. The class includes all plastics and elastomers in all function and forms such as adhesives, encapsulants, films, coatings, foams, and fabrics. These materials are most effected in their physical properties, usually becoming embrittled at relatively low dose.

Although the name of the material is unchanged, the actual chemical formulation could have been changed over the years. This is a particular danger with trade names.

[Structural and mechanical properties that change usually include thermal conductivity, which is closely related to electrical conductivity.]

General radiation sensitivity of Materials: Epoxies, silicones, phenolics,
==> polyimides, fiberglass-epoxy, carbon and alloy steels, polystyrene, polyimide -- 10^9 rads (Si).

Radiation stability of plastics, preferred class:

1- Phenolics, filled or reinforces, except paper filled

2- Epoxies, curing agents may be classified in the following order of decreasing tolerance: Anhydride > aromatic amine > aliphatic amine > diethanolamine.

Radiation stability of plastics (estimated from a graph):

		Approx Threshold	Appreciably Altered
	Epoxies		
==>	Polystyrene	9.9e9	1.2e10
	Diallyl Phthalate		
	Polyimide (Kapton)		9e9
	Polyurethanes	8e8	3e9
	Phenolics	1.5e7	4e8
	Polyimide (Vespel)	1e7	6e7
	Aramid (Kevlar)		
	Melamine Formaldehyde		
	Polyester glass laminate		
	PVC		

Coatings and Films: The phenolics, silicone alkyd enamels, the alkyd and epoxy formulations and styrenes are preferred.

Radiation stability of coatings and films:

		Appreciably Altered
==>	Phenolic alkyd enamels	1e9 - 1e10
	Silicone alkyd enamels	1e9 - 1e10
	Alkyds and epoxy formulations	1e9 - 1e10
	Polyurethane	1.5e8 - 1e9
	Styrene	1.5e8 - 1e9
	Acrylic	

IEEE Transaction on Electrical Insulation,
Vol. EI-15, No. 4, August 1980

THERMAL AGING PREDICTIONS FROM AN ARRHENIUS PLOT
WITH ONLY ONE DATA POINT

Robert R. Dixon
Westinghouse Electric Corporation
Research and Development Center
Pittsburgh, PA 15235

Abstract - Arrhenius plots are useful in predicting long-term use temperatures of organic materials and in choosing parameters for accelerated aging. For materials and components without established Arrhenius curves (which is also a measure of the activation energy of degradation) would allow longer-term prediction from a few short-term tests. Conversely, a required long-term temperature target can be extrapolated on the same slope to a range of short-time exposure temperatures suitable for accelerates tests. A review is made of available activation energies, from which values can be selected for conservative extrapolations on an Arrhenius plot.

Extracts

$$dR/dt = A \exp(-E/kT)$$

dR/dt is reduction in property with respect to time.

A is a constant.

k is the gas constant or, depending up the units, the Boltzmann constant.

T is the absolute temperature.

E is the activation energy of the aging reaction.

Integration of the rate equation followed by taking of the logarithms results in

$$\ln t = (E/k)\ 1/T + B$$

is a straight line known as an Arrhenius plot.

From an examination of a typical Arrhenius plot, it can be readily seen that if the slope is steep (high activation energy), long-life extrapolations reach relatively high temperatures. An undetected degradation mechanism with a lower activation energy would reduce the effective long-term temperature, with the conclusion that the prediction was optimistic. However, if the curve has a low slope, the chances of an even lower activation energy are minimal, and the projected life is a conservative value.

In place of establishing the Arrhenius line from a number of aging experiments, it has been proposed that the line could be established from one test point and an assumed slope. If the slope were selected to be very conservative (low activation energy), then the performance of the material or part would be expected to exceed longer life (lower temperature) predictions.

The key to these approaches is the development of a method of selecting an Arrhenius slope which can be considered to be a conservative value.

... activation energies were determined from Arrhenius curves provided in a series of Westinghouse unpublished R&D reports. Properties monitored for these materials included flexural strength, impact strength, dielectric strength, etc. The actual values calculated from 667 Arrhenius slopes are listed in Table 1.

The number of materials in each increment of 0.1 eV was plotted against activation energy...; the peak occurs about the same energy value [1.1 eV, 23000 cal), but the number of materials below 0.5 eV is only 3 percent. ... this distribution on log-normal, and 95 percent of the values exceed 0.61 eV. The conservative slope selected was 0.5 eV.

==> TABLE 1. ACTIVATION ENERGIES FROM ARRHENIUS PLOTS

Materials	Measured Property	Activation Energy K Cal/Mole	Activation Energy eV
Melamine-Glass (G-5)	Dielect Strgth	6.7	0.29
Epoxy Varnish	Dielect Strgth	10.9	0.48
Ester-Glass (GPO-3)	Flex Strgth	13.1	0.57
RTV Silicone	Elongation	13.8	0.60
Phenolic-Asbestos	Dielect Strgth	13.9	0.61
Nylon, GF	Tensil Strgth	16.1	0.70
Acetal	Tensil Strgth	16.8	0.74
Mineral Phenolic	Flex Strgth	17.0	0.74
Silicone Varnish	Dielect Strgth	17.0	0.74
Polypropylene	Oxidation	18.7	0.81
Phenolic-Cotton	Dielect Strgth	19.4	0.84
Phenolic-Alkyd Varnish	Dielect Strgth	19.6	0.85
Epoxy	Weight Loss	20.3	0.88
Epoxy Adhesive	Shear Strgth	20.5	0.39
Nylon	Impact Strgth	20.7	0.90
Pressboard	Tensil Strgth	20.9	0.93
Imide Film	Dielect Strgth	21.4	0.93
Silicone	Dielect Strgth	21.6	0.94
Phenolic-Asbestos (A)	Flex Strgth	21.7	0.94
Cast Epoxy	Flex Strgth	22.6	0.98
Urethane-Nylon wire ins	Dielect Strgth	22.9	0.99
Phenolic-Glass (G-3)	Dielect Strgth	23.3	1.01
Polycarbonate	Tens Imp	23.3	1.01
Phenolic-Paper	Flex Strgth	23.6	1.02
Epoxy Wire Insulation	Dielect Strgth	24.2	1.05
Epoxy-Glass (FR-4)	Dielect Strgth	24.2	1.05
Varnish Cotton	Dielect Strgth	24.4	1.08
PVC	Elongation	24.9	1.08
Ester-Glass (GPO-1)	Flex Strgth	25.0	1.09
Phenolic-Cellulose	Flex Strgth	25.4	1.10
Polyethylene, crs-lnkd	Dielect Strgth	25.6	1.11
Urethane	Dielect Strgth	25.8	1.12
Ester-Glass (GPO-2)	Dielect Strgth	26.0	1.13
Ester + Nylon wire ins	Dielect Strgth	26.1	1.14
Ester-Glass (GPO-1)	Dielect Strgth	26.6	1.16
Phen-Alkyd Varnish	Dielect Strgth	26.6	1.16
Vulc Fiber	Dielect Strgth	26.8	1.16
Phenolic-Cell + Min	Impact Strgth	26.9	1.17
Polyester Film	Dielect Strgth	27.1	1.18
Cast Epoxy	Impact Strgth	27.2	1.18
Alkyd Varnish	Dielect Strgth	27.2	1.18

==> TABLE 1. ACTIVATION ENERGIES FROM ARRHENIUS PLOTS (Continued)

Materials	Measured Property	Activation Energy K Cal/Mole	Activation Energy eV
Epoxy	Weight Loss	27.2	1.18
Silicone	Dielect Strgth	27.2	1.18
Phenolic Paper (XX)	Flex Strgth	27.5	1.20
Vulc Fiber	Flex Strgth	27.7	1.21
Phenolic-Cellulose	Impact Strgth	28.5	1.24
Phenolic-Glass (G-3)	Flex Strgth	28.5	1.24
Phenolic-Kraft	Flex Strgth	28.8	1.25
Neoprene	Elongation	29.0	1.26
Amide-Imide Varnish	Dielect Strgth	30.0	1.31
Ester Anaerobic	Shear Strgth	31.7	1.38
Acetylated Cotton	Tensil Strgth	32.0	1.39
Silicone-Asbestos	Dielect Strgth	32.5	1.41
Epoxy-Glass (FR-4)	Flex Strgth	34.4	1.50
Polyester Film	Brittle	36.3	1.58
Nylon Paper	Dielect Strgth	36.6	1.59
Ester-Amide-Imide Varn	Dielect Strgth	36.6	1.59
Epoxy-Glass (G-11)	Flex Strgth	37.6	1.64
Polyester Wire Insula	Dielect Strgth	37.7	1.64
Kraft Paper	Burst Strgth	38.5	1.67
Polyester, TP	Tensil Strgth	40.3	1.75
Varnished Kraft	Dielect Strgth	42.7	1.86
Nylon Paper	Elongation	43.9	1.19
Ester-Glass (GPO-3)	Dielect Strgth	46.7	2.03
Phenolic-Cotton	Flex Strgth	48.8	2.12
Melamine-Glass	Flex Strgth	50.1	2.18

IEEE Transactions on Electrical Insulation,
Vol. EI-16, No. 1, February 1981

THEORY OF EQUALIZATION OF THERMAL AGEING PROCESSES OF ELECTRICAL INSULATING MATERIALS IN THERMAL ENDURANCE TEST

III. TEST RESULTS ON AN ENAMELLED WIRE, A POLYESTER GLASS LAMINATE AND AN EPOXY CASTING RESIN

Paavo Paloniemi
Oy Stromberg Ab
Helsinki, Finland

Paul Linstrom
Technical Research Center
Espoo, Finland

Abstract - Comparative test results are presented on polyester-imide coated copper wires, a polyester glass mat laminate, and a heterocyclic epoxy resin. Tests have been performed according to the application principles of the EAP theory, described in Paper II of this series. Results of test show that the ageing behavior of these materials is well predictable on the basis of EAP tests, and in every case better than the prediction based on conventional test results, whenever a reliable comparison could be made. With the exception of one insignificant deviation, all the material behaved according to the EAP principles developed in the theoretical Paper II of this series. The results described here and those published earlier can be taken as the proof of reliability of the EAP method for thermal endurance testing of electrical insulating materials.

IEEE Transactions on Electrical Insulation,
Vol. EI-17, No. 4, August 1982

RADIATION-INDUCED CONDUCTIVITY IN POLYMERIC INSULATING MATERIALS DEGRADED UNDER SPECIFIED CONDITIONS

Yoshiaki Nakase and Isamu Kuriyama
Japan Atomic Energy Research Institute

Tohru Takahashi and Setsuya Isshiki
The Fujikura Cable Works Ltd.

Abstract - Various polymeric insulating materials for cables were degraded by simulated irradiation and environmental conditions for normal operating and under accident at a nuclear power reactor. Thermally stimulated currents were observed only in the crystalline samples, and the higher the crystal-

linity, the large the amounts of detrapped carriers. The change of fine structure of the degraded sample was investigated by the change of X-ray crystallinity, melting behavior, and glass transition temperature. The radiation induced conductivity was studied during irradiation and a decay curve was measured after the irradiation. Analysis of the conductivity decay
==> curve enables us to detect at most four kinds of carriers with different time
==> constants. Long-lived carriers were hardly observed in the non-crystalline samples, while many were seen in the crystalline samples. With the decrease of crystallinity by degradation, only short-lived carriers were observed, indicating the existence of trapping sites for the long-lived carriers in or around the polymer crystallites. Treatment of samples with high temperature steam and chemicals showed no special effect on the samples except for polyimide which dissolved in alkaline solution.

Other Reports

EPRI NP-2129 Project 1707-3
Final Reports, November 1981

RADIATION EFFECTS ON ORGANIC
MATERIALS IN NUCLEAR PLANTS

M.B. Bruce and M.V. Davis
Georgia Institute of Technology
Nuclear Engineering Department
Atlanta, Georgia 30332

Project Description - Equipment in nuclear plants must be qualified to perform safety-related functions after long periods of exposure to low-level radiation during operation and after short periods of high-level radiation during accidents postulated for design... This report by the Georgia Institute of Technology presents the results of a literature search for data concerning the radiation resistance of organic materials.

Project Results - The report includes an overview of radiation effects and an extensive list of organic materials in order of increasing resistance to
==> radiation damage. An important finding is that a total dose of less the 1e5 rads produces no significant degradation of mechanical or electrical proper-
==> ties. (Notable exceptions are equipment that contain Teflon or semiconductor
==> devices). Also, at this level, no significant synergistic effects of radiation combined with other environmental stresses, such as elevated temperatures, were identified. The results of this work will be of interest to utility engineers, architect-engineers, equipment manufacturers, and regulatory staff involved in the qualification of equipment for radiation effects.

Abstract - A literature search was conducted to identify information useful in determining the lowest level at which radiation causes damage to nuclear

plant equipment. Information was sought concerning synergistic effects of radiation and other environmental stresses.

Organic polymers are often identified as the weak elements in equipment. Data on radiation effects are summarized for 50 generic name plastics and 16 elastomers. Coating, lubricants, and adhesives are treated separately.

Inorganic and metallic are considered briefly. With a few noted exceptions, these are more radiation resistant than organic materials.

Some semiconductor devices and electronic assemblies are extremely sensitive to radiation. Any damage threshold including these would be too low to be of practical value. With that exception, equipment exposed to less than 1e4
==> rads should not be significantly affected. Equipment containing no Teflon should not be significantly affects by 1e5 rads.

Data concerning synergistic effects and radiation sensitization are discussed. The authors suggest correlations between the two effects.

Extracts

Specifically, little threshold information is available for complete component/equipment items. . . many equipment items function acceptably with degraded materials.

Organic polymers are most often identified as the weak element(s) in operating equipment and so as a group were selected for detail study.

Inorganics and metallic are generally little affected by radiation environments that cause considerable degradation in organic materials. Important exceptions are identified in Section 2 . . .

Reference 44 presents the following generalized statements drawn from a number of sources:

==> 1. Pigmented coatings are more resistant to radiation than those containing little or no pigments. Carbon black inhibits damage, while some grades of titanium dioxide accelerate damage. Extender pigments appear to contribute to color change.

2. Realistic comparisons of different coating systems can be made only if the same pigment compositions are used in all vehicles.

==> 3. The choice of primer is important when a costing to be subjected to radiation is applied to metal substrates.

==> 4. The degree of cure for any specific system can influence apparent radiation resistance.

5. Residual solvents can influence radiation resistance.

6. To a point, gamma radiation (and Heat) initially improves the physical properties of many organic coatings. Exposure to radiation beyond a given point tends to excessively crosslink and/or degrade organic coatings. This leads to coating embrittlement which develops into failure. For epoxies applied to steel, failure usually occurs at the metal-coating interface.

==> ... many coating systems are not greatly affected by radiation exposures below 1e8 rads.

Privileged Communications (N8472N0928)

Extracts

Since some confusion appears to exist in the nomenclature used in the insulation field, the following definitions are used ...

Enamel is the coating applied directly to a bare copper wire to yield magnet wire.

Varnish is the material used for wet-winding or dipping coils, to hold the individual turns of the coil in place.

Impregnant is the compound used in conjunction with fabric tapes to form a protective coat over the entire coil.

Cement is an adhesive compound used to hold the completed coil in proper position in the motor.

Resin is the organic polymer solid used in enamels, varnishes, impregnants, and cements.

It is accepted by the insulation industry that not all varnishes are "com-
==> patible" with any given magnet wire, or with each other. Insulation is therefore best evaluated as a complete system. Solvents from varnishes may react to soften or craze enamels.

A burn-out testing device was utilized to determine compatibility of materials in the potting compound formulation. This burn-out testing device is similar to that described by W. G. Stiffler in his paper "A Motor

Manufacturer Evaluation of Electrical Insulating Materials", given at the 6th Electrical Insulation Conference in 1965...

The test comprises preparing a twisted pair of 20 gage polyester-polyamide-imide round enamels wire (producing 10 twists per 5 inches as outlined in the standard test methods - ASTM-3251) while applying a 1000 gram tension load on the wire during twisting. The twisted pairs are then dip coated in the selected pottant formulation or brush coated to give a completely and evenly coated wire finish. The pairs are cured at the recommended schedule after which the coated wire ends are stripped and the pairs evaluated to failure in the burn-out apparatus... An apparatus was designed and built at Battelle that applied independently controlled a-c current of 40 amperes to each wire of a twisted pair. A potential of 120 volts (a-c) is applied across the twisted pair to indicate failure. The twisted pair is enclosed in a Plexiglass cover to remove the influence of air currents and maintain temperature uniformity. Measurements of the surface temperature of the twisted pair carrying 40 amperes in each wire showed that 400 C was being obtained with this apparatus.

It is felt that the test simulates better than any other method available the
==> conditions that might be expected from serious overloads. It also appears in light of the data being obtained on varnished and unvarnished twisted pairs, that the method is of value in determining system compatibility of insulation components.

RADIATION EFFECTS ON ORGANIC MATERIALS

Edited by Robert O. Bolt and James G. Carroll
California Research Corporation
Richmond, California

Academic Press, 1963

CHAPTER 12 -- COATINGS AND FILMS
By James G. Carroll and Robert O. Bolt

The data presented in this chapter (summarized in the following tables) indicate that significant damage occurs to materials of interest at least one order of magnitude of radiation dose above the generally accepted qualification level of 1e7 rads.

TABLE 12.2. RELATIVE STABILITY OF ORGANIC COATING

Coating	Approx Max Gamma radiation resistance
==> Phenolic (phenol-formaldehyde)	44×10^8
Silicone-alkyd enamel	9 to 44×10^8
Alkyd enamels:	
40% phthalic anhydride	9 to 44×10^8
32% phthalic anhydride	6 to 9×10^8
Epoxy	4 to 9×10^8
Fluorinated vinyl	4 to 9×10^8
Nitrocellulose (white lacquer)	4 to 6×10^8

(page 450)

==>"After 9×10^8 rads and 50 hours at 500 F, the phenolic coatings retained their properties better than any of the other coatings tested. They had good abrasion resistance and adhesion and were little affected by exposure to 100 percent relative humidity for 28 days at 120 F. Silicone-alkyd enamel
==> actually showed improved properties at 9×10^8 rads but became powdery and brittle at 44×10^8 rads." (page 451)

"Similar paint films with and without various pigments were exposed on aluminum panels to 1.5×10^7 rads of gamma radiation... Regardless of the pigmentation the paints all behaved as expect from the stability of the bass coatings; i.e. pigments exerted little effect at this low dose." (page 451)

TABLE 12.3. THE RADIOLYSIS OF MOUNTED PROTECTIVE COATINGS[a]

Polymer base	Trade name	Surface	Gamma dose (air) 10^8 rads	Appearance[a]
Furan	Alkaloy-550[b]	Concrete	9.4	No failure
		Steel rod	8.4	No failure
Modified phenolic	Amphesive-801[b]	Concrete	9.4	No failure
		Steel rod	8.7	Drastically embrittled
Silicone alkyd	Solar Silicone[c]	Concrete	6.7	No failure
		Steel	6.7	No failure
Epoxy	Epon-395[d]	Steel	6.7	No failure
Vinyl chloride	Amercoat-33[e]	Aluminum	2.1	Failed, blistered
		Concrete	10.5	Failed, blistered
		Steel	8.7	Failed, blistered
Styrene	Prufcoat[f]	Concrete	8.7	Failed, brittle
		Steel	8.7	Failed, cracked
		Steel (wet)	0.8	Failed, cracked
Vinyl	Corrosite-22[g]	Aluminum	2.1	Failed, blistered
		Concrete	11.0	Borderline failure

a Examined for blisters, cracking, hardening, tackiness, etc. (page 452)
b Atlas Mineral Products Co.
c Solar Division, Gamble Skogmo, Inc.
d The Glidden Co.
e Amercoat Corp.
f Prufcoat Laboratories, Inc.
g Corrosite Corp.

RADIATION EFFECTS ON ORGANIC MATERIALS

Edited by Robert O. Bolt and James G. Carroll
California Research Corporation
Richmond, California

Academic Press, 1963

Chapter 13 DIELECTRIC FLUIDS
By Raymond S. Alger

Approximate tolerance of dielectric materials to static irradiation (25 percent change). The following data were taken from Figure 13.1, page 462.

==>	Teflon	1×10^5 rads
	Lucite	9×10^5 rads
	Water	9×10^6 rads
	Trichlorobenzene	7×10^6 rads
	Silicone oil	2×10^7 rads
	Natural rubber	3×10^6 rads
	Polyethylene	2×10^7 rads
	Transformer oil	6×10^7 rads
	Polystyrene	9×10^8 rads
	Caster oil	1×10^8 rads
	Ceramics	8×10^{10} rads

RADIATION EFFECTS ON ORGANIC MATERIALS

James G. Carroll and Robert O. Bolt
California Research Corporation
Richmond, California

Nucleonics, Vol. 18, No. 9, September 1960, pp. 78-83

"Radiation does not change all properties of an organic material to the same
==> degree. Thus, the critical property must be specified in considering useful
==> life of a materials."

TABLE 2. RADIATION STABILITY OF PLASTICS

Materials	Threshold dose for 25% change[a] (10^8 rads)
Polystyrene[1]	40
Phenol formaldehyde (asbestos filler)[1]	40
Polyester (mineral filler)[1]	4
Polyvinyl chloride[2]	1
Polyethylene[1]	0.9
Urea formaldehyde[1]	0.5
Monochlorotrifluorethylene[2]	0.2
Cellulose acetate[2]	0.2
Phenol formaldehyde (unfilled)[1]	0.1
Methyl methacrylate[2]	0.01
Polyester (unfilled)[1]	0.01
Polytetrafluoroethylene (Teflon)[2]	0.01

a Based on most sensitive property, usually tensile strength
1 Crosslinks
2 Scissions

SIMULATED AND SIMULTANEOUS LOSS-OF-COOLANT ACCIDENT TESTING OF PROTECTIVE COATINGS FOR THE NUCLEAR INDUSTRY

W. F. Oberbeck, Jr., K. G. Mayhan, and D. R. Edwards
University of Missouri-Rolla
Graduate Center for Materials Research, Rolla, Missouri 65401

J. R. Lopata, J. F. Montle, and D. R. Leritz
Carboline Company
350 Hanley Industry Court
St. Louis, Missouri 63144

"Results from the simultaneous exposure of coatings to high-pressure steam and radiation are compared to results obtained from the conventional simulated test procedures... Included zinc-based, epoxy, and phenolic primers with phenolic and modified phenolic topcoats. Coatings were exposed to ^{60}Co radiation dose in the range of 10^8 to 10^9 rad. The study showed that the conventional simulated LOCA conditions were more severe on the coatings than those tested under simultaneous exposure to high pressure steam and ^{60}Co

==> radiation. It was concluded that coatings that satisfactorily passed the simulated LOCA tests will also pass the simultaneous LOCA tests."

"The following general statements, which are based on reported data and results concerning radiation resistance, can be used as reference points:

1- Pigmented coatings are more resistant to radiation than those containing little or no pigments. Carbon black inhibits damage while some grades of titanium dioxide accelerate damage. Extender pigments appear to contribute to color change.

2- Realistic comparisons of different coating systems can be made only if the same pigment compositions are used for all vehicles.

3- The choice of primer is important when a coating to be subjected to radiation is applied to metal substrates.

4- The degree of cure for any specific system can influence radiation resistance.

5- Residual solvents can influence radiation resistance.

6- To a point, gamma radiation (and heat) initially improves the physical properties of many organic coatings. Exposure to radiation beyond a given point tends to excessively crosslink and/or degrade organic coatings. This leads to containing embrittlement which develops into failure. For epoxies applied to steel, failure usually occurs at the metal-coating interface."

==> "In general, the onset of coating deterioration was noted at radiation dose of 10^8 to 10^9 rads in water."

TABLE III. APPROXIMATE RADIATION LIMITS OF POLYMER VEHICLES

Vehicle	In Air (rad)	In Water (rad)
Phenolic	3×10^9 to 1×10^{10}	2×10^9 to 8×10^9
Epoxy	3×10^9 to 1×10^{10}	8×10^8 to 2×10^9
Alkyl-alkali silicates	10^{10}	10^9

==>

THE EFFECT OF NUCLEAR RADIATION ON THE ELECTRICAL PROPERTIES OF EPOXY RESINS

Marcel Van de Voorde
Organisation Europeane Pour La Recherche Nucleaire, CERN European Organization for Nuclear Research, CERN 68-13, Intersecting Storage Rings Division, April 17, 1968.

"The electrical properties which determine an insulator's behavior and which are studied in this paper include:

a) The dielectric strength, which determines the maximum electric field which can be supported without failure;

b) the electrical conductivity, which indicates the ease of charge transport;

c) the dielectric constant, which shows the degree of polarization;

d) the loss tangent, which indicates the rate of energy lost to energy stored in the dielectric.

All these properties depend on:

1) the chemical structure, crystallinity, crosslinks density;

2) the number of free charge carriers, their mobility and their ability to transfer energy to the surrounding molecules;

3) the polarizable species i.e. molecules with a permanent dipole moment and the orientation of the polar groups;

4) the number and energy distribution of electron-trapping sites."

"Transient phenomena can materially alter the electrical properties of a polymer during irradiation. One of the most striking transient changes is the enhancement of the electrical conductivity of the polymer. The conduc-
==> tivity of epoxy resins, for example, increases as much as four orders of magnitude in a strong nuclear field."

"Irradiation conditions

The irradiations were performed in the water reflector of the ASTRA-reactor at Seibersdorf (Austria). This radiation facility produces mainly gammas. The dose rate corresponds to approximately 7 rad/hr with a reactor power of 5 M. Watt and an ionization chamber is used as dosimeter.

In all cases, test samples were irradiated in demineralized water at about 30 C. The absorption of water during irradiation is between 0.5 and 2.5 per cent for samples with dimensions 150 x 150 x 2 mm^3. Before measuring the electrical properties the unirradiated and irradiated samples were dried under vacuum (10^{-2} torr) at 40 C during 20 hours."

"Dielectric Strength

...

==> 2) All the new epoxy resin systems... still give 90 percent of their initial value at 1×10^9 rad.

...

Surface resistivity

1) The surface resistivity of the epoxy resins studied is approximately 1×10^{13} ohm for hot cured and 1×10^{12} ohm for the system cured at room temperature.

==> 2) Small changes are noted up to 1×10^9 rad for the four studied systems.

...

Volume resistivity

...

2) The volume resistivity at room temperature of unirradiated epoxy resins is of the order of 10^{16} ohm cm.

3) ...

==> Practically no changes are noted at 1 x 10^{9} rad and room temperature.

...

Dielectric constant and dissipation factor

...

3) The dielectric constant and dissipation factor measured at room temperature and at 50 Hz are relatively insensitive to radiation over a wide range of doses for most of the systems studied.

...

General conclusions

...

==> 4) All resins, containing a high aromatic content and cured with an aromatic amine or anhydride gave good radiation resistant materials."

RADIATION EFFECTS IN ORGANIC MATERIALS

A. Charlesby
Royal Military College of Science
Shrivenham - Swindon, Wiltshire

C. DuPuy, Editor
Noordhoff-Leyton (1975)

"Conductivity

During irradiation the current is approximately proportional to the applied field and varies with the radiation intensity I, usually following an $I^{0.8}$ power dependence. This is difficult to explain in simple terms...

The post radiation current decreases approximately as $(t+a)^{-1}$ (t is time after cessation of radiation). This time dependence is likewise difficult to account for on any simple theory."

HANDBOOK ON EPOXY RESINS

Henry Lee and Kris Neville
McGraw-Hill Book Company

Radiation Resistance, pp. 6-42 to 6-44

"Tests conducted to determine the effects of the various types of irradiation indicate:

1. Thermal neutrons ...

2. Fast neutrons ...

3. If the environment may react with the irradiated sample, the dosage rate becomes important. For example, electron radiation may produce free radicals at a greater rate than oxygen can diffuse into sample thereby causing cross-linking reactions to predominate. In the case of gamma and pile irradiations, free-radical production is sufficiently low to allow the diffusion of oxygen to influence the degradative process, causing shortening and inhibition of cross-linking.

==> Because of the interdependency of dosage rate and environment, aging studies in atmosphere under high dosage to obtain accelerated data may not adequately define the performance under actual service conditions.
==> ... In general, the more heat-resistance the epoxy compound, the more irradiation-resistant it will be.

With regard to chemical resistance after radiation, it has been found that the number of decontaminations an epoxy-resin coating can withstand without degradation is not
==> effected by doses below 10^7 rads. Above this dosage the useful life is reduced to two cycles.

RADIATION EFFECTS DESIGN HANDBOOK
SECTION 3. ELECTRICAL INSULATING MATERIALS AND CAPACITORS

C. L. Hanks and D. J. Hamman
Radiation Effects Information Center
Battelle Memorial Institute
July 1971

The follow gamma doses produce incipient to mild damage with the materials. nearly always usable (from Figure 3, page 9).

	Materials	Dose
==>	Phenolic, glass laminate	4×10^9
	Phenolic, asbestos filled	1.5×10^9
	Phenolic, unfilled	2×10^6
	Epoxy, aromatic-type curing agent	1.2×10^9
	Polyurethane	9×10^8
	Polyester, glass filled	9×10^8
	Olyester, mineral filled	8×10^7
	Diallyl Ohthalate, mineral filled	9×10^7
	Polyester, unfilled	3×10^5
	Mylar	3×10^6
	Silicone, glass filled	8×10^8
	Silicone, mineral filled	8×10^8
	Silicone, unfilled	1×10^8
	Melamine-formaldehyde	7×10^6
	Urea-formaldehyde	2×10^6
	Aniline-formaldehyde	6×10^5
	Polystyrene	7×10^5
	Acrylonitrile/butadiene/styrene (ABS)	1×10^8
	Polyimde	2×10^8
	Polyvinyl chloride	1.5×10^7
	Polyehylene	1.5×10^7
	Polyvinyl formal	1×10^7
	Polyvinylidene chloride	2×10^6
	Polycarbonate	2×10^6
	Kel-F Polytrifluorochlorethylene	1×10^6
	Polyvinyl butral	3×10^6
	Cellulose acetate	1.2×10^6
	Polymethyl methacrylate	8×10^5
	Polyamide	7×10^5
	Vinyl chloride-acetate	1×10^6
	Teflon (TFE)	1×10^4
	Teflon (FEP)	1×10^5
	Natural rubber	1.2×10^6
	Styrene-butadiene	1.2×10^6
	Neoprene rubber	1.2×10^6
	Silicone rubber	1×10^6
	Polypropylene	2×10^6
	Polyvinylidene fluoride (Kynar 400)	8×10^6

Degradation of the electrical properties of polyethyleneterephthalate [at]
==> 10^6 to 10^7 rads, is insignificant (p 20).

Polyamide (nylon) film changes in both physical and electrical properties ...
==> [with] threshold damage at a dose of 8.6 x 10^5 rads and 25 percent damage at 4.7 x 10^6 rads (p 21).

The permanent degradation or change in electrical properties ... [of]
==> polypropylene to the above doses [2.6 and 8.7 x 10^8 rads] is of little or no practical significance (p 22).

Information concerning the effect of radiation on the electrical properties of polyurethane is limited to two studies... [1.75 x 10^8 rads]. Insig
==> nificant permanent changes in the insulating properties, volume resistivity, or insulation resistance of less than one order of magnitude change were observed (p 23).

Changes in the electrical properties of polyvinylidene fluoride [Kynar 400] included decreases of between two and three orders of magnitude in volume
==> resistivity during irradiation to doses up to 2.1 x 10^7 and 6.6 x 10^7 rads.

Polyimide (Kapton) has shown little or no change in either physical or electrical properties to gamma doses (Co 60) of up to 10^9 rads.

Table 2, page 27 indicates the following bulk, sheet, and/or film materials as unsatisfactory at the indicated radiation exposure:

	Material	Total Electron Fluence, rads
==>	Acetal resin	3.8 x 10^8
	Acrylic plastics	1.8 x 10^9
	Ally carbonate, cast	1.3 x 10^9
	Cellulose acetate	1.8 x 10^9
	Cellulose butyrate	1.3 x 10^9
	Cellulose propionate	1.3 x 10^9
	Chlorinated polyether	9 x 10^9
	Polycarbonate	1.8 x 10^9
	Polyfluoroethyleneproplylene, Teflon FEP	1.1 x 10^9
	Polymethyl methacrylate, cast	3.8 x 10^8
	Polymethyl methacrylate, molding grade	1.3 x 10^9
	Styrene acrylic copolymer	9 x 10^8
	Polyvinyl chloride, DOP plasticize	1.1 x 10^9
	Polyvinyl chloride, rigid	1.3 x 10^9

Table 6, page 39 indicated the following epoxies exhibit satisfactory radiation tolerance at the indicated exposures:

	Epoxy Identification	Exposure, rads gamma
==>	Bisphenol A	8.8×10^7
	Eccobond 182	1×10^8
	Epocast 17B	8.8×10^7
	Epon 828	4.4×10^6
	Maraset 622-E	1×10^9
	Novalak	8.8×10^7
	Scotchcast 5	1×10^9
	Scotchcast 212	1×10^9
	Stycast 1095	1×10^8
	Stycast 2651 MM	4.4×10^6
	12-007	1.8×10^6
	412-M	1×10^9
	420-A	1×10^9
	1125A/B	1.8×10^6
	CF-8793	9.4×10^7
	CF-8794	1×10^8

DOE ENERGY Search Summary

The two numbers at the beginning of each entry are (1) the DOE accession number and (2) the item number of the search. NOTE: The dose unit Gy is a Gray, which equals 100 rads or 100 rem. The equivalent of Gy in rads have been inserted [] in the text.

1298331,52

RADIATION EFFECTS ON THE DYNAMIC MECHANICAL PROPERTIES OF EPOXY RESINS AND GRAPHITE FIBER/EPOXY COMPOSITES

T. W. Wilson, III
North Carolina State University, Raleigh
1986 Ph. D. Thesis

"The most notable deleterious property chance was a decrease of 30 C to 40 C in the glass transition temperature for the epoxy resins and NARMCO 5208
==> based composites after an absorbed does of 10,000 Mrads. [10^{10} rads]"

1298318,53

EFFECTS OF ENERGETIC PROTON BOMBARDMENT ON POLYMERIC MATERIALS: EXPERIMENTAL STUDIES AND DEGRADATION MODELS

D. R. Coulter, A. Gupta, M. V. Smith, R. E. Fores
Jet Propulsion Laboratory report, 1986

No numeric data available in abstract.

1289765,61

STUDIES ON RADIATION RESISTANCE OF FIBER REINFORCED PLASTIC COMPOSITES FEATURE BY EASINESS OF MANUFACTURING. 1. DEGRADATION BEHAVIOR UNDER ELECTRON IRRADIATION AT ROOM TEMPERATURE

Akir Udagawa, Miyuki Hagiwara, Shunichi Kawanishi
Japan Atomic Energy Research Inst., Tokyo, 1986

"... threshold dose was larger in case of carbon fiber reinforcement that
==> glass fiber reinforcement. For example, the threshold dose was about 10 MGy [10^9 rads] in case of glass fiber..."

1278011,66

ASSESS THE IMPACT OF THE STEEP-FRONT, SHORT DURATION IMPULSE ON ELECTRIC POWER SYSTEM INSULATION: PHASE I, FINAL REPORT

L. M. Burrage, et al.
McGraw-Edison Power Systems Division, Franksville, WI, 1987

Steep-front, short-duration "... impulse was found to be the result of several sources including both lighting and nuclear electromagnetic pulse... The power insulating systems believed to be at greatest risk are the porcelain/air structural insulation (line insulation) and the paper/oil-/enamel systems (transformers)."

1265767,70

RADIATION-RESISTANT CHARACTERISTICS OF EPOXY RESINS

Toshio Saito, Tadao Seguchi
Radia Industry Co., Ltd., Takaski, Gunma, Japan, 1985

"For the evaluation of radiation resistivity under conditions of low level irradiation in the atmospheric environment...to simulate 18 Gy/h [1800

rads/h], 12 years and 4.5 Gy/h [450 rads/h], 50 years of atmospheric deterioration. ...epoxy resins of acid anhydride hardening agent showed superior quality to those of amine-type hardening agent."

1149383,125

PERFORMANCE ASSESSMENT OF CLASS 1E PRESSURE TRANSDUCERS SUBJECT TO ENVIRONMENTAL STRESSES

D. T. Furgal, C. M. Craft
Sandia National Labs, Albuquerque, NM, 1985

"An experimental investigation into the performance of Class 1E electronic pressure transmitters... Emphasis was placed on determining the instruments' failure and degradation modes in separate and simultaneous environmental exposures... The transmitters tested proved to be exceptionally hard to
==> radiation effects and there appeared to be no significant synergistic effect between radiation and temperature. The observed responses of the transmitters offer support for the position...that electronic modules may be aged to
==> varying degrees of advanced life before testing."

1109705,152

RADIATION RESISTANCE OF INSULATION VARNISH

Yosuke Morita et al
Japan Atomic Energy Research Inst., Tokyo, Japan, 1984

"...polymer materials are used under the condition of low dose rate for a long time, and the deterioration is mainly caused by radiation oxidation, show a different behavior from that by the irradiation at high dose rate. In this study, the irradiation in pressurized oxygen atmosphere was carried out...evaluated mainly by the electrical properties and gel fraction... The specimens were enamel wires and thin varnish films. Co-60 gamma ray was used, and the dose rate was 1 Mrad/h in air; 0.5 Mrad/h in 7 kg/cmSG; and 0.1 Mrad/h in 30 kg/cmSG oxygen. Dose rate effect was hardly observed in polyimide varnish, but in other varnishes, the electrical properties were
==> remarkably lowered by the irradiation in oxygen."

1107600,153

GET **LESSONS LEARNED IN THE ENVIRONMENTAL QUALIFICATION OF CLASS 1E EQUIPMENT AT TENNESSEE VALLEY AUTHORITY**

1984 Symposium on Nuclear Power Systems
R. N. Bell, T. Akos
Tennessee Valley Authority, Knoxville, TN

"This paper describes some unique experiences in the qualification testing of main steam isolation valve control manifold assemblies, control relays, and motor control centers."

1089001,160

MATERIAL IRRADIATION TEST AT CERN

H. Schoenbacher
European Organization for Nuclear Research, Geneva, Switzerland, 1983

"It is shown that products can be found on the market for operation in a radiation environment up to doses of 10W Gy to 10Y Gy [unable to determine what the 10W or 10Y notation means], even though they were not especially designed for nuclear application."

1045907,186

RADIATION RESISTANCE OF EPOXY RESINS AND THEIR COMPOSITES

Katsumi Sonoda, et al.
Mitsubishi Electric Corporation, Tokyo, Japan, 1984

In the electric equipment installed inside containment vessels in nuclear power plants, many epoxy resins have been employed as insulating materials... Epoxy resins used for the experiment were... (1) bisphenol A group, (2) novolak group for improved humidity resistance, (3) triazine group for radiation, humidity and heat resistance... LOCA simulation [was]... up to
==> 2 MGy [2 x 10^8 rads] of Co-60 at 10^4 Gy/h [10^6 rads/h] with high temperature steam...the electrical properties of dielectric tangent, insulation breakdown voltage...were measured. The triazine group epoxy/Nomax composite did not show swelling...demonstrated stable radiation resistance."

1019190,196

GET RADIATION TESTS ON SELECTED ELECTRICAL INSULATION MATERIALS FOR HIGH-POWER AND HIGH-VOLTAGE APPLICATION

G. Liptak, et al.
European Organization for Nuclear Research, Geneva, Switzerland, 1985

"This report presents a comprehensive set of test results on the irradiation of insulating materials and systems used for the windings of rotating machines, dry-type transformers, and magnet coils. The materials were: Novolac, bisphenal-A, and cycloaliphatic types of epoxy, phenolic, and acrylic resins. ...irradiate in a 8MW pool reactor up to integrated doses of
==> 10^8 Gy [10^{10} rads]... For tapes and varnished, the breakdown voltage was measured. The adhesion of copper bars glued together with an epoxy resin was examined... The breakdown voltage tests show that the application of mechanical stress to most irradiated samples causes the insulation layer to crack, resulting in lower dielectric strength. For a number of materials, the critical properties of flexural strength and breakdown voltage are above
==> 50 percent of the initial value at doses between 10^7 and 10^8 Gy [10^9 and 10^{10} rads]."

958730,217

SYNERGY EFFECT IN ACCIDENT SIMULATION

International Symposium on Aging in Tests of Safety Equipment for Nuclear Power Plants, Paris, France, 1984
C. Alba, et al.
CEA Centre d'Etudes Nucleaires de Fontenay-aux-Roses, 92, France

"Some equipments have to work after accident in order to stop reactor running and blow out water calories. ...nine polymer materials were subjected to simultaneous and sequential test in CESAR cell... Two polyamide-imide varnishes used in motors and coils; one epoxydic resins, glass fiber charged (electrical insulating); polyphenylene sulfide, glass fiber charged. The Ryton R4 (electrical insulating); three elastomeric materials: Hypalon, fire proof by bromine or by alumina EPDM (cable jackets); VAMAC which is a polyethylene methyl polymethacrylate copolymer; a silicon thermoset material
==> glass fiber charged (electrical insulating). ...sequential experiment is more severe than simultaneous test, however, Hypalon does not follow this law."

370752,267

GAMMA RADIATION EFFECT ON PROPERTIES OF COATINGS BASED ON DIGLYCIDYL ESTER OF 1,1-BI-(HYDROXYMETHYL)-CYCLOHEXENE-3

V. V. Lyashevich, V. P. Pimenova, E. V. Roganov
Lakokrasoch. Mater. Ikh Primen (USSR) v 3, 1983

"Behavior of new coatings is studied in gamma radiation of radioactive
==> isotope Co-60. ...dose ranged within 0.2 - 1 MGy [0.2 - 1 x 10^8 rads], dose rate 0.075 MGy/h [7.5 Mrads/h]. Different radioresistance of epoxide coatings is explained by the difference in the chemical composition of solidifiers."

370193,269

AGEING OF ORGANIC ELECTRICAL INSULATING MATERIALS DUE TO RADIATION. PHYSICAL PROPERTIES OF A CYCLOALIPHATIC EPOXY RESIN IRRADIATED UNDER VACUUM

G. Spadaro, et al.
Palermo University, Italy, 1984

"Physical properties...have been investigated...dielectric and tensile
==> measurements... The results indicate that, in the dose range investigated (0 to 1.5 x 10^6 Gy [0 to 1.5 x 10^8 rads]), the main effect of gamma rays under vacuum is to increase the degree of crosslinking."

018178,408

GET RESISTANCE TO IONIZING RADIATIONS OF MATERIALS INSTALLED AT CERN ACCELERATORS

H. Schoenbacher
European Organization for Nuclear Research, Geneva, Switzerland, 1982

"...presents a choice of materials and components which are used at CERN and which are resistant to radiation above an integral dose of 10^7 to 10^8 Gy [10^{10} rads]."

<u>EI ENGINEERING MEETINGS Search Summary</u>

A number of pertinent entries in this database are duplicates of the DOE ENERGY, and are not repeated here.

The numbers at the head of each entry are the Ei accession number and the item number of the database search.

0319868,60

DETERMINATION OF RADIATION THRESHOLDS USING THERMOGRAVIMETRIC ANALYSIS

C. P. Dulka, et al.
GE Nuclear Control & Instrumentation Product Design Corporation, Wayne, PA, 1984

"...simple, rapid technique to obtain thresholds of phenolic molded parts used in motors, switchgear, relays, and other equipment in both conventional
==> and nuclear-powered generating stations. ...showed that exposure to 12 x 10^6 rads had no significant effect on either electrical or mechanical properties."

0319867,60
GET RADIATION AGING OF INSULATING RESINS, ELECTRICAL EFFECTS

D. S. Johnson, et al.
GE Insulating Materials, Schenectady, NY, 1984

"...determine the effect radiation aging has on the electrical property performance of a number of materials...materials are commercially available solventless epoxy and solventless unsaturated polyester resins."

0170152,95

RADIATION RESISTANCE OF SOME COMMON INSULATING VARNISHES

D. S. Johnson, et al.
G.E., Schenectady, NY, 1983

No abstract.

0103772,107

ELECTRICAL AND MECHANICAL PROPERTIES IN EPOXY RESIN AFTER GAMMA-RADIATION AND LOCA SIMULATION

K. Yahagi, T. Amakawa, N. Tada
Waseda University, Tokyo, Japan, 1982

No abstract.

COMPENDEX Search Summary

A number of pertinent entries in this database are duplicates of the DOE ENERGY and EI ENGINEERING MEETINGS, and are not repeated here.

The two numbers at the head of each entry are the E.I. Monthly Account Number and the database search item number.

1809257,2

PROCEEDING OF THE 17TH SYMPOSIUM ON ELECTRICAL INSULATING MATERIALS

Institute of Electrical Engineers of Japan, Committee on Electrical Insulating Materials, Tokyo, Japan, 1984.

Individual papers are listed in file 165 [see EI ENGINEERING MEETINGS above].

1715130,28

RADIATION RESISTANCE OF EPOXY MOLDING COMPOUNDS

H. Schoenbacher, B. Schreiber, R. Stierli
Kunststoffe - German Plastics

"A representative selection of epoxy moulding compounds was irradiated in a research reactor with integrated doses of 5 x 10^6, 1 x 10^7, and 5 x 10^7 Gy [5 x 10^8, 1 x 10^9, and 5 x 10^9 rads]... With most of the products studied, the
==> bending strength amounted to more than 50 percent of the starting value with 5 x 10^7 Gy [5 x 10^9 rads]."

1555821,87

PULSE RADIOLYSIS STUDIES ON
RADIATION RESISTANCE OF EPOXY RESIN

S. Tagawa, et al.
University of Tokyo, Research Center for Nuclear Science & Technology, Tokai-mura, Japan, 1985

"The mechanisms of radiation damage in epoxy resin, especially the primary processes, have been studied..." No data given.

1482813,112 and 1390291,143

AGEING OF ORGANIC ELECTRICAL INSULATING MATERIALS DUE TO
RADIATION - II. PHYSICAL PROPERTIES OF A CYCLOALIPHATIC
EPOXY RESIN IRRADIATED IN MOISTURE SATURATED AIR

G. Spadaro, E. Calderaro, G. Rizzo
University of Palermo, Istituto di Ingegneria Chimica, Palermo, Italy, 1984.

"The results suggest that at low irradiation doses the degradation due to moisture absorption predominates, whereas at high doses the main effect is an increase of the degree of crosslinking due to irradiation."

==> "The results indicate that in the dose range investigated (0 to 1.5 x 10^6 Gy [1.5 x 10^8 rads]) the main effect...is to increase the degree of crosslinking."

1443724,122 and 1350827,150

IRRADIATION EFFECT ON THE MECHANICAL PROPERTIES OF
COMPOSITE ORGANIC INSULATORS

S. Egusa, et al.
Argonne National Laboratories, Materials Science & Technology Division,
Argonne, Ill., 1984

"Four kinds of cloth-filled organic composites(filler: glass or carbon fiber; matrix; epoxy or polyimide resin) were irradiated with 2 Mev electrons at room temperature... Following irradiation the Young's modulus...remains
==> unchanged...up to 15,000 Mrad [1.5 x 10^{10} rads]. Shear modulus and the ultimate strength...begin to decrease after the absorbed dose reaches about
==> 2000 Mrad for glass/epoxy composite and 5000-10000 Mrad [0.5 - 1 x 10^{10} rads] for the other composites. The result is ascribed to the decrease in the capacity of load transfer from the matrix to the fiber due to the radiation induced debonding at the interface...radiation-induced decrease in the bonding energy at the interface."

1128902,205

MOTORS FOR SAFETY ACTUATORS IN NUCLEAR POWER GENERATING STATIONS

U. Filippini, A. Moretti
Nuovo Pignone, Italy, 1980

Description of the building and testing of a motor.

0977784,238

MICALASTIC INSULATION SYSTEM IN LOW TO MEDIUM RATES H. V. MOTORS FOR OPERATION IN EXTREME CONDITIONS

Walter Amey, Hans Werner Rotter
Siemens, Erlangen, Germany, 1980

"...increase dielectric strength, high resistance to moisture, nuclear radiation..."

ATTACHMENT 3 TO AEP:NRC:0775AP

Attachment 1
SF Motor Test Review

RELIANCE ELECTRIC

Reliance Electric
24800 Tungsten Road
Cleveland, Ohio 44117
216-266-7000

April 12, 1989

American Electric Power Service Corp.
P.O. Box 16631
Columbus, Ohio 43216-6631

Attention: Mr. J.R. Anderson

Dear Mr. Anderson:

Enclosed please find data taken on your Westinghouse 4 KV, 60 Hz, 3 Phase, 400 HP motor 3S71. These data are heat runs and polarization index before and after irradiation.

Also please notice photos taken of damaged crate as received from Isomedix. We inspected motor and bearings and found no apparent damage. Crate is repaired and motor is ready to ship. Waiting for shipping instructions.

Note: Motor shaft shows evidence that a pipe wrench may have been used to turn the rotor. This was not done by Reliance.

Thank you.

Sincerely,

Ed Santavicca

Ed Santavicca
Lab Manager

ES/jw

enclosure

Attachment 1
SI MOTOR TEST
Review

RELIANCE ELECTRIC

24701 Euclid Avenue, Cleveland, Ohio 44117

REPORT OF TEST
For Induction Motor

Purchaser: ·INDIANA & MICHIGAN ELECTRIC

Date of Test 2/13/89,4/5/89**

Purchaser's Order No. 03009-040-8N

Serial No. 3S71

Nameplate Rating

Rated HP	Service Factor	Rated Speed r/min	Phase	Frequency Hz	Volts	Amperes	Type	Frame
400	1.15	3564	3	60	4000	52	P	509US

Temperature Rise

Conditions of Test				Temperature Rise °C					
				Stator		Rotor			
				Windings			Windings		
Hours Run	Line Volts	Line Amperes	Cooling Air, °C	*By RES. Method	*By Method		*By Method		
3.5	4280	52.5	25.0	50.0 C		** 2-13-89 (1)			
3.0	4260	52.7	24.0	50.9 C		** 4-05-89 (2)			

Characteristics

Rated Slip, Percent	No-Load Line Current, amperes	Secondary Volts at Standstill	Secondary Amperes per Ring at Rated Load	Resistance at 25°C (between lines) ohms
(1) .777	23.1	N/A	N/A	Prim. .8667
(2) .777	22.7	N/A	N/A	Sec. N/A

Torque and Starting Current

Break-Down Torque In LB.-FT. ** with___% volts applied	Locked-Rotor Torque In LB.-FT. ** with___% volts applied	Starting Current Amperes (locked rotor) with___% volts applied
-	-	-

High Potential Tests

Volts a-c for___Sec	
Stator	Rotor
-	N/A

Efficiencies and Power Factor

Efficiency, Percent			Power Factor, Percent		
Rated Load	75 Percent Load	50 Percent Load	Rated Load	75 Percent Load	50 Percent Load
96.2/96.2	-	-	79.9/80.0	-	-

Notes: (1) BEFORE (2) AFTER IRRADIATION

Data from test on THIS motor.
(this or duplicate)

Edmund Santacca
Laboratory Mgr.

*Indicate method as:
Thermometer
Thermocouple
Resistance
Embedded Detector

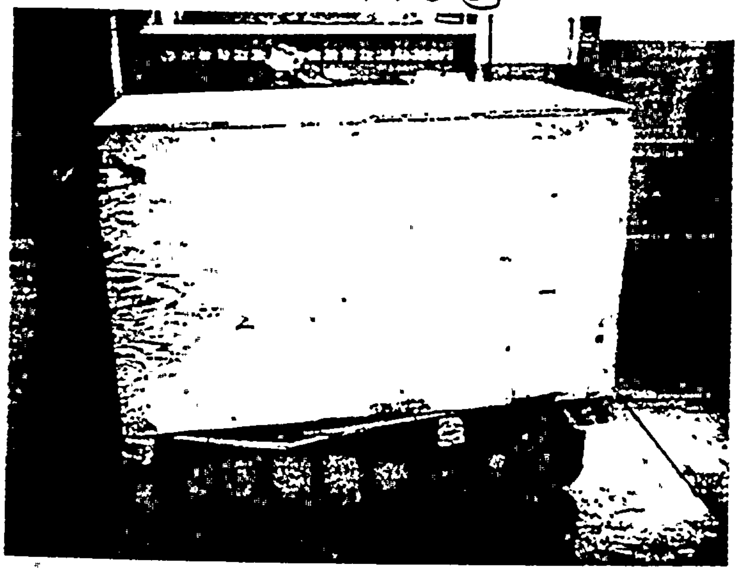
**Indicate torque units as N-m or lb-ft

Approved by J Pokelsek Date 04/06/89

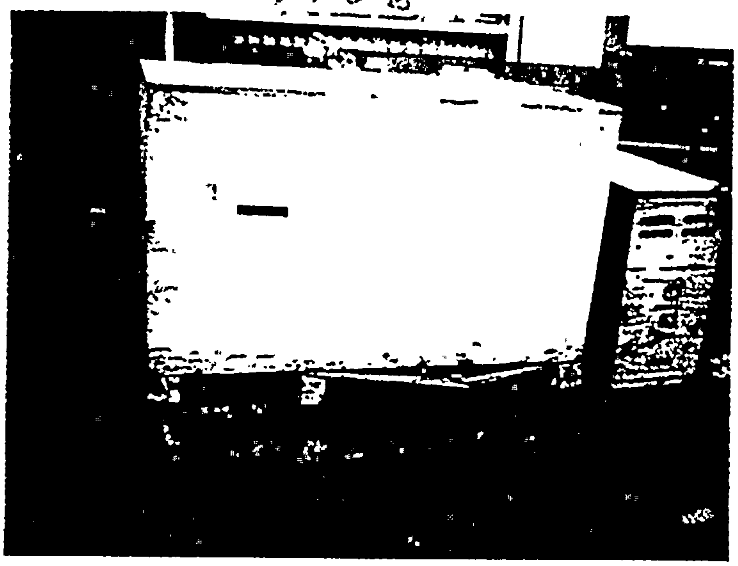
JIM POKELSEK File P00603
Manager, Nuclear Engineering

ATTACHMENT I
SI MOTOR TEST REVIEW

1705



9705



PHOTOS REFERENCE IN RELIANCE ELEC.
Ed Santavicca Letter Dated 4/12/89
Added KJM 5/8/89

REVISIONS

REVISION. A

REPORT NO. 40053-02

DATE: May 30, 1989

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

REV.NO.	DATE	PAGE OR PARAGRAPH AFFECTED	BY	APP'L	DESCRIPTION OF CHANGES
A	5/30/89	ii, I-4	RTW	[illegible]	Correct typographical error
				05-30-89 [illegible]	
A	5/30/89	I-2	RTW	[illegible]	Post-test inspection observa-
				05-30-89 [illegible]	tions included
A	5/30/89	I-11, I-12A, I-12B, I-2	RTW	[illegible]	Added plot of insulation
				05-30-89 [illegible]	resistance data versus time
				[illegible] 5/31/89	

LAB JOB # 9705
WESTINGHOUSE MOTOR
SERIAL # 70F70184

ATTACHMENT 1
SI MOTOR TEST REVIEW

TEMPERATURES	AIR 21 °C WINDING 21°C	
Resistance Reading In Meg. Ohms	Actual Meg. Ohms	Corrected to 40°C
15 sec.	.7 x 10GΩ	.182 X 10GΩ
30 sec.	1.5 X 10GΩ	.39 X 10GΩ
45 sec.	2.1 X 10GΩ	.546 X 10GΩ
60 sec.	2.45 X 10GΩ	.637 X 10GΩ
1½ min.	3.1 X 10GΩ	.806 X 10GΩ
2 min.	3.75 X 10GΩ	.975 X 10GΩ
3 min.	4.6 X 10GΩ	1.196 X 10GΩ
4 min.	5.5 X 10GΩ	1.43 X 10GΩ
5 min.	6.4 X 10GΩ	1.664 X 10GΩ
6 min.	7.1 X 10GΩ	1.846 X 10GΩ
7 min.	7.7 X 10GΩ	2.0 X 10GΩ
8 min.	8.3 X 10GΩ	2.158 X 10GΩ
9 min.	9.0 X 10GΩ	2.34 X 10GΩ
10 min.	9.6 X 10GΩ	2.49 X 10GΩ

POLARIZATION INDEX = $\frac{2.49}{.637}$ = 3.9 @ 40°C

Tester: Bob Olw
Date: 2-13-89
Approved: E S
Date: 2-13-89

4.0 SUMMARY (Continued)

This report contains two sections. Section I presents the data recorded during the Receiving/Visual Inspection, Radiation Exposure, and Post-Test Inspection. Section II presents the Wyle Laboratories' Test Procedure No. 40053-01, Revision B, used to perform the test program.

The test program was performed in the sequence indicated in the previous paragraph and as specified in the Test Procedure. During the irradiation period, the test specimen showed no indication of degradation or damage. The insulation resistance values, recorded before, during, and after the exposure period, showed no appreciable difference in levels such as to indicate degradation. The test specimen is therefore considered to have met the acceptance criteria specified for the radiation exposure.

5.0 REFERENCES

5.1 American Electric Power Service Corporation Purchase Order Number 03010-040-8N dated May 12, 1988.

5.2 Wyle Laboratories' Quality Assurance Program Manual, June 1988.

5.3 Wyle Laboratories' Test Procedure No. 40053-01, Revision B.

5.4 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," U. S. Nuclear Regulatory Commission.

5.5 Regulatory Guide 1.89, Revision 1, June 1984, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants," U. S. Nuclear Regulatory Commission.

5.6 IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations."

6.0 EQUIPMENT DESCRIPTION

The 400 Horsepower AC Motor, manufactured by Westinghouse Company, was determined to have identification information as follows:

400 HP, 3-phase, 60 Hertz
4000VAC, 52 Amps, 3564 RPM
Model ABDP
Frame 509US
Service Factor 1.15
S # 70F70184
Ser. 3S-71 A

NEQ

Nuclear Environmental Qualification

Test Report

REPORT NO. 40053-02

WYLE JOB NO. 40053

CUSTOMER P. O. NO. 03010-040-8N

DATE March 20, 1989

SPECIFICATION (S) See References in Paragraph 5.0 of this Summary Section

1.0 CUSTOMER American Electric Power Service Corporation (AEPSC)

ADDRESS 1 Riverside Plaza, Columbus, Ohio 43215

2.0 TEST SPECIMEN 400 Horsepower, 3-Phase, AC Motor

3.0 MANUFACTURER Westinghouse

4.0 SUMMARY

The 400 Horsepower AC Motor, as described in Paragraph 6.0, was subjected to the Radiation Exposure Test as specified by AEPSC. The test specimen described herein was provided by, and is typical of, installations at Indiana Michigan Power Company.

This test program was performed to verify the ability of the test specimen to maintain integrity during radiation exposure. The test report was prepared in accordance with the documentation requirements of IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations."

STATE OF ALABAMA } ss. Alabama Professional
COUNTY OF MADISON } Engineer Reg. No. 7948

Frederick M. Sittason, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

SUBSCRIBED and sworn to before me this 6th day of April, 1989

Notary Public in and for the State of Alabama at large.

My Commission expires June 12, 1991

Wyle shall have no liability for damages of any kind to person or property, including special or consequential damages, resulting from Wyle's providing the services covered by this report.

PREPARED BY R. T. Walter 03-29-89

APPROVED BY F. R. Jo[illegible] 4/6/89

WYLE Q. A. for G. W. Hight 4/6/89

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
HUNTSVILLE, ALABAMA

2.0 TEST REQUIREMENTS

2.1 Acceptance Criteria

The test specimen shall demonstrate electrical intergrity during the radiation exposure test. Leakage current to ground, monitored before, during, and/or after radiation exposure, shall be addressed by the Customer.

3.0 TEST PROGRAM

3.1 Receiving/Visual Inspection

Upon delivery at the radiation test facility, the test specimen shall be subjected to an inspection in order to verify size, model, manufacturer, and any other pertinent data with respect to the equipment to be tested. All observations and recorded information shall be printed on a Test Specimen Inspection Sheet for inclusion into the test report.

3.2 Radiation Exposure

The test specimen shall be placed in a hot cell and subjected to a total integrated dose of 10E6 rads gamma, air equivalent, at a dose rate not to exceed 1.0E6 rads/hour.

3.2.1 Insulation Resistance Test

Prior to initiation of the radiation exposure test, the three-phase motor leads shall be connected together and attached to a DC insulation resistance measurement test unit. Insulation resistance measurements shall be conducted by applying 1000VDC for 1 minute prior to the reading of the resistance between the motor phases (connected together) and the frame (ground). The recorded insulation resistance measurements shall be plotted versus time and included in the test report. The insulation resistance of the specimen windings to ground shall be monitored and recorded prior to initiation of the radiation exposure period. The insulation resistance of the specimen windings shall be monitored and recorded, during the period of radiation exposure, at approximately every four hours. Upon completion of the radiation exposure, the insulation resistance of the specimen windings shall be monitored and recorded and the test unit de-energized. A

3.3 Post-Test Inspection

The test specimen shall be visually inspected. The specimen shall be disassembled (i.e., removal of inspection covers) to the extent necessary to perform the inspection. The condition of the specimen shall be recorded. Photographs shall be taken of any noticeable physical damage which may occur.

3.4 Quality Assurance

All test equipment and instrumentation to be utilized in the performance of this test program shall be calibrated in accordance with Wyle Laboratories Quality Assurance Program Manual, which conforms to the applicable portions of ANSI N 45.2, 10 CFR 50 Appendix B, and Military Specification MIL-STD-45662A. Standards utilized in the performance of all calibrations are traceable to the National Bureau of Standards. B

3.5 Report

A letter test report shall be issued, describing the test requirements, procedures, and results. The report shall be prepared in accordance with IEEE Standard 323-1974.

TEST PROCEDURE

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
P O Box 1008, Huntsville, AL 35807
TWX (910) 997-0886, Phone (205) 837-4411

TEST PROCEDURE NO. 40053-01

DATE: July 18, 1988

REVISION A 08-08-88
REVISION B 03-20-89

RADIATION EXPOSURE TEST PROGRAM FOR A WESTINGHOUSE 400HP MOTOR FOR AMERICAN ELECTRIC POWER SERVICE

APPROVED BY PROJECT MANAGER: [signature] 8/2/88

APPROVED BY QUALITY ENGINEER: [signature] 8/3/88

PREPARED BY PROJECT ENGINEER: [signature] 08-02-88

REVISIONS

FORM 1054-1 Rev. 4/74

REV. NO.	DATE	PAGES AFFECTED	BY	APP'L.	DESCRIPTION OF CHANGES
A	08/08/88	Page 2	RTW	RTW 08-09-88	Revise method of monitoring and
				[initials] 8/12/88 TRH for GWH	specimen degradation during
				8/19/88	radiation exposure
B	03/20/89	Page 3	RTW	[initials]	Incorporate revision to Military
				[initials] 4/6/89	Specification MIL-STD-45662
				TRH for GWH 4/6/89	

COPYRIGHT BY WYLE LABORATORIES. THE RIGHT TO REPRODUCE, COPY, EXHIBIT, OR OTHERWISE UTILIZE ANY OF THE MATERIAL CONTAINED HEREIN WITHOUT THE EXPRESS PRIOR PERMISSION OF WYLE LABORATORIES IS PROHIBITED. THE ACCEPTANCE OF A PURCHASE ORDER IN CONNECTION WITH THE MATERIAL CONTAINED HEREIN SHALL BE EQUIVALENT TO EXPRESS PRIOR PERMISSION.

1.0 SCOPE

This document has been prepared by Wyle Laboratories for testing of a Westinghouse motor, as further identified in Paragraph 1.3, for use by Indiana Michigan Power Company.

1.1 Purpose

The purpose of this document is to present the test procedure for subjecting the specimen electric motor to a radiation exposure test. The test specimen shall be provided by the Customer, upon completion of a functional test, and shall be returned to the Customer, for post-radiation exposure functional testing, upon completion of this test program.

1.2 Applicable Qualification Standards, Specifications, and Documents

- 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," U. S. Nuclear Regulatory Commission.
- Regulatory Guide 1.89, Revision 1, June 1984, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants," U. S. Nuclear Regulatory Commission.
- IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations."
- Wyle Laboratories Quality Assurance Program Manual, April, 1987.

1.3 Equipment Description

The equipment to be tested shall be a 400HP, 3-phase, electric motor, manufactured by Westinghouse. Preliminary information of the test specimen is available as follows:

Motor Weight:	2450 pounds
Rotor Weight:	500 pounds
Rated Voltage:	4 KV
Full Load Amps:	52 Amps
Locked Rotor Amps:	314 Amps
Approximate Motor Dimensions:	49" (L) X 25" (W) X 25" (H)

1.4 Test Sequence

The test program shall be performed in the following sequence:

- Receiving/Visual Inspection
- Radiation Exposure
- Post-Test Inspection

APPENDIX IV

INSTRUMENTATION EQUIPMENT SHEET

INSTRUMENTATION EQUIPMENT SHEET

DATE: 03/03/89
TECHNICIAN: S. SIMMONS

JOB NUMBER: 40053-00
CUSTOMER: A.E.P.S.C.

TEST AREA: ~~JCJC LAB~~ ISOMEDIX WHIPPANY NJ SMM 03-03-89
TYPE TEST: RAD I.2.

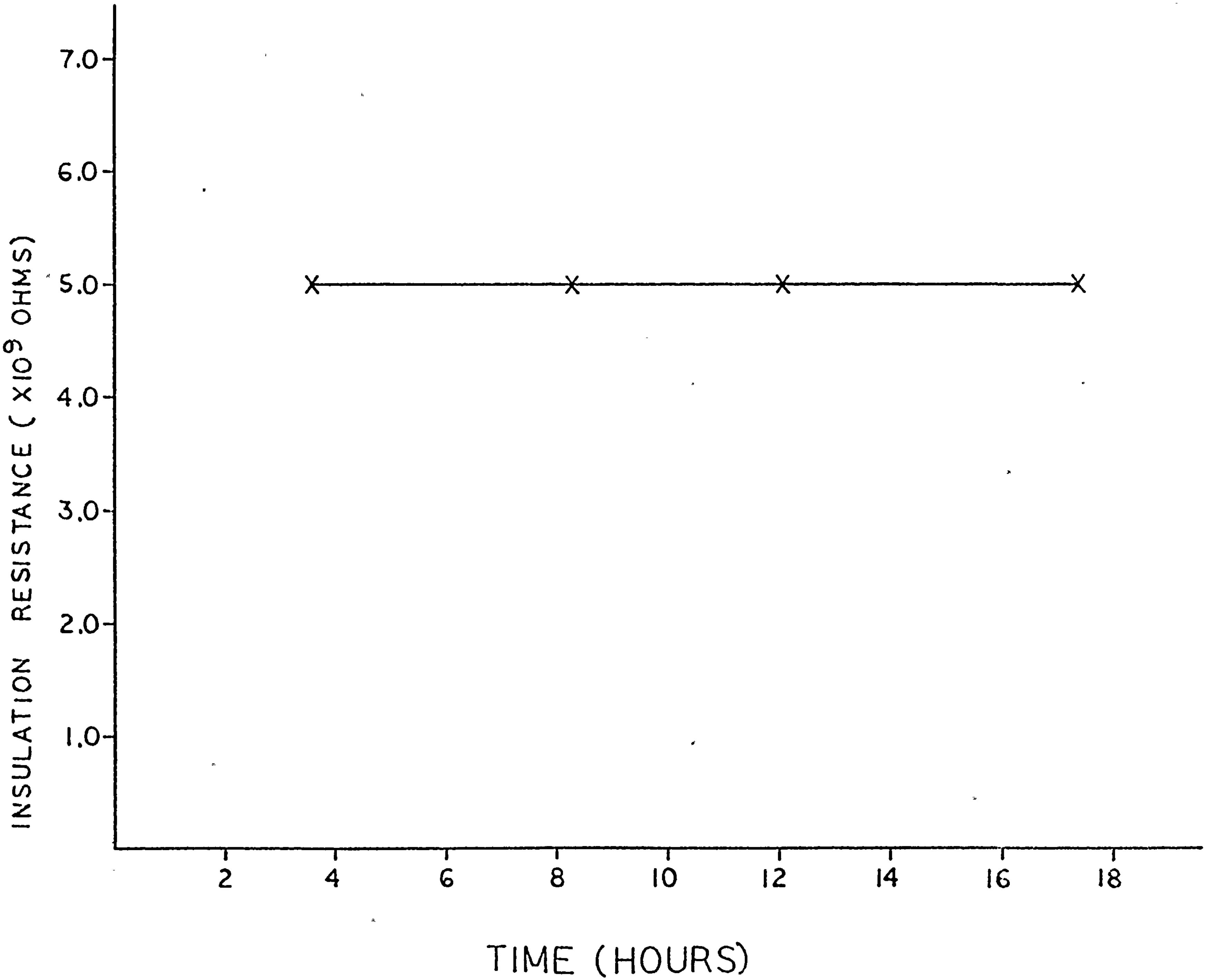
NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	MEG MTR TSTR	GENERAL RADIO	18620	2374	097892	.5-2000KM	3% LOW END	11/08/88	05/05/89
2	MEGOHM METER	MULTI-VOLT	MG-251	A2875	102977	1K-200MEG OHM	+-2%	11/11/88	05/10/89

This is to certify that the above instruments were calibrated using state-of-the-art techniques with standards whose calibration is traceable to the National Institute of Standards and Technology.

INSTRUMENTATION R.E. Archer 3-3-89

CHECKED & RECEIVED BY S.M. McMicken 03-03-89

Q.A. T.R. Hamilton 3-3-89


INSULATION RESISTANCE (X10^9 OHMS)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
2
4
6
8
10
12
14
16
18
TIME (HOURS)

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX III

DATA SHEET AND DATA PLOT

A

DATA SHEET

WYLE LABORATORIES

Customer AMERICAN ELECTRIC POWER SERVICE CORP.
Specimen WESTINGHOUSE 400HP MOTOR
Part No. MODEL ABDP
Spec. WLTP 40053-01, REV. A
Para. 3.2
S/N N/A
GSI N/A

Amb. Temp. 74°F
Photo NO
Test Med. AIR
Specimen Temp. AMBIENT

Job No. 40053
Report No. 40053-02
Start Date 03-07-89

Test Title INSULATION RESISTANCE MEASUREMENTS

TEST TIME	TIME	VOLTAGE	READING
— BEFORE IRRADIATION			
N/A	1 MIN	500 VDC	$1.0 \times 10^{10}\ \Omega$
|	5 MIN	500 VDC	$1.2 \times 10^{10}\ \Omega$
|	1 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
N/A	5 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
— DURING IRRADIATION			
3.6 HOURS	1 MIN	1000 VDC ~~100 VDC~~	$>5.0 \times 10^{9}\ \Omega$
	5 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
8.3 HOURS	1 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
	5 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
12.1 HOURS	1 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
	5 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
17.4 HOURS	1 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
	5 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
— AFTER IRRADIATION			
N/A	1 MIN	500 VDC	$1.1 \times 10^{10}\ \Omega$
|	5 MIN	500 VDC	$2.1 \times 10^{10}\ \Omega$
|	1 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$
N/A	5 MIN	1000 VDC	$>5.0 \times 10^{9}\ \Omega$

Notice of Anomaly NONE

Tested By [signature] Date: 3/11/89
Witness N/A Date:
Sheet No. 1 of 1
Approved [signature] 03-17-89

COMPONENT IRRADIATION CERTIFICATION

CUSTOMER: WYLE LABS P.O. NO. 4-4623-P

AIR EQUIV. REQUIRED DOSE (MRADS) 10.0

RATE NOT TO EXCEED (MRADS/HR) < 1.0

SPECIMENS:

QTY	PART NO.	SERIAL NO.	DESCRIPTION
1		70F70184	400 HP Motor

DATA:
SOURCE TYPE: COBALT-60 / GAMMA

TOTAL DELIVERED DOSE (AIR): MIN. 10.01 MRADS MAX. 10.79 MRADS

DOSE RATE (AIR): MIN. 0.58 MRADS/HR MAX. N/A MRADS/HR

TOTAL EXPOSURE HOURS: 17.4

SPECIMEN ROTATION: TWO WAY X FOUR WAY N/A NONE N/A

DATE IN: 3/7/89 DATE OUT: 3/8/89

DOSIMETRY:
DOSIMETER TYPE: Harwell 4034 BATCH AW TOLERANCE ± 8%

CALIBRATION DATE: 11/21/88

READOUT INSTRUMENT: B & L Spectronic 1001

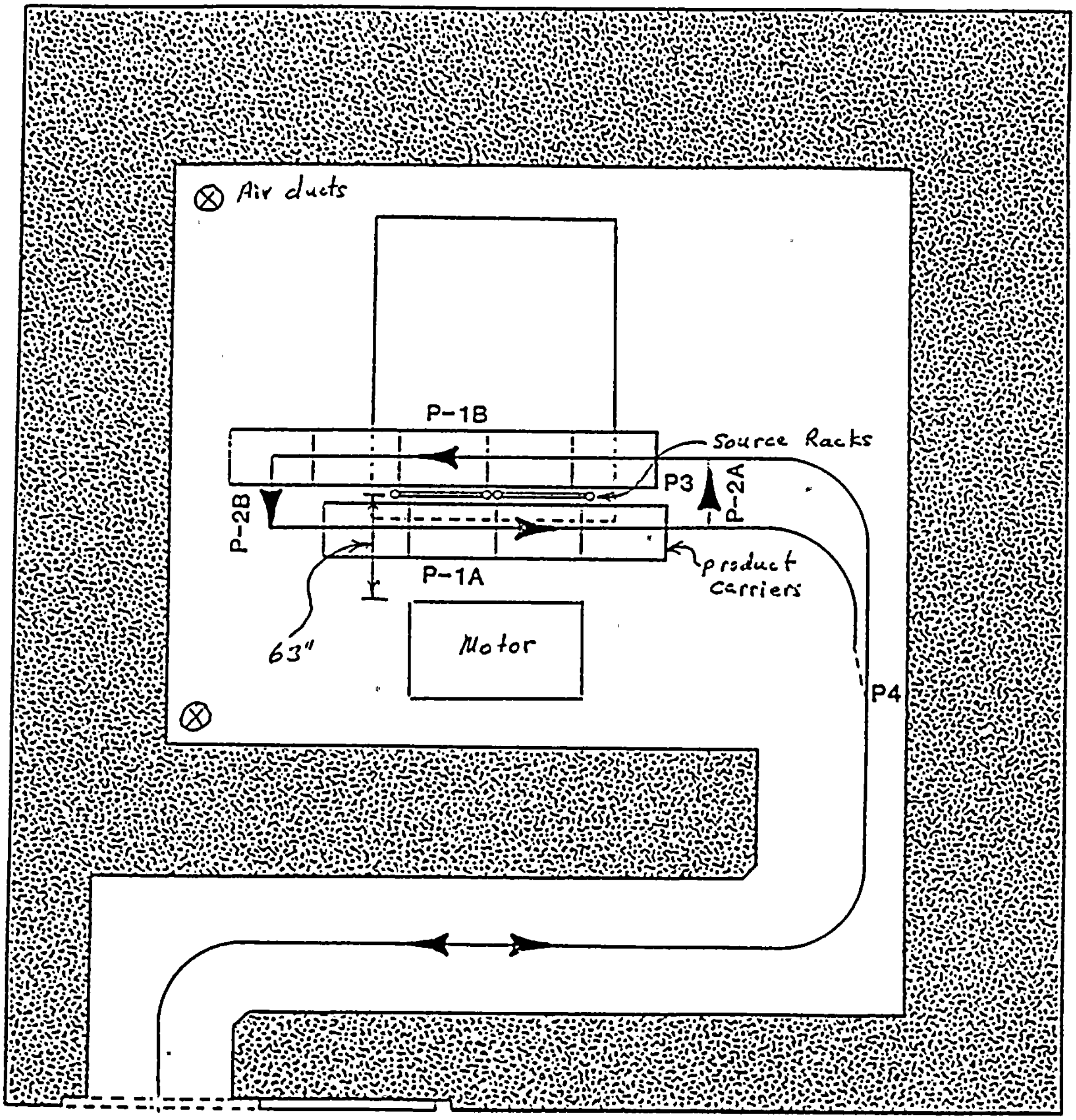
SERIAL NO. 0715493N CALIBRATION DATE: 9/29/88

COMMENTS: See attached report

ATTACHMENTS: WORKSHEETS N/A DRAWINGS N/A NOTICE OF ANOMOLY N/A

AUTHORIZED SIGNATURE: Albert L. De Carlo

TITLE: GENERAL MANAGER DATE 3/8/89



PRODUCT FLOW DIAGRAM

ISOMEDIX

March 9, 1989

Wyle Labs
7800 Goveners Drive
P.O. Box 077777
Huntsville, AL 35807-7777

ATTN: MR. TODD WALTERS

Dear Mr. Walters,

This letter summarizes the parameters pertinent to the irradiation of one (1) electrical motor. Reference your Purchase Order number 4-4623-P dated August 8, 1988.

A. Description of the Irradiated Material

The equipment tested consisted of one (1) 400 Horsepower, 3-phase, electric motor, manufactured by Westinghouse. (S/N 70F70184)

B. Arrangements for Gamma Irradiation

As per your test procedure number 40053-01 dated July 18, 1988 (Revision A 08-08-88), the motor was in a hot cell and subject to a total integrated dose of 10E6 rads gamma, air equivalent, a dose rate less than 1.0 E6 rads/hour.

C. Procedure for Uniform Gamma Irradiation

Prior to the initiation of the motor exposure, a gamma field dose rate check was performed. This simply was to confirm that the dose rate would not exceed 1.0 Mrad per hour.

The cardboard model was checked at three plans (front, back and middle) with five (5) dosimeters on each plan to determine the average center point dose rate.

The motor was rotated 180 degrees throughout its exposure. The rotation occurred when the center point dose reached 50% of the required minimum dose. The total length of time between rotation intervals is called a half exposure.

D. Calculation of the Dose

The delivered dose to the motor was calculated by multiplying the dose

ISOMEDIX

rate by the time for each half exposure and adding them together. The minimum reported dose is the lowest total value from any of the three (3) plans accumulated from the two half exposures. The maximum reported dose is the highest.

E. Dosimetry

Dosimetry was performed using Harwell 4034 Perspex dosimeters utilizing a Bausch and Lomb Model 1001 spectrophotometer and a Texas Instrument 59 Calculator as the read out instrument. The Batch AW dosimeters were calibrated traceable to a recognized standards laboratory with the last calibration date being November 21, 1988. The spectrophotometer used (S/N 0715493 N) was last calibrated by Baush and Lomb personnel on October 29, 1988 using standards traceable to NBS. The Measurement tolerance for this dosimetry system is estimated to be ± 8.0%.

The dose rate values stated in this report were calculated by dividing measured dose by exposure time. Combining the estimated uncertainty of the dose measurement (± 8.0%) with that of the time measurement (± 0.01%) yields an uncertainty of ∓ 8.01% for rate measurements.

The total dose values stated in this report are calculated by multiplying measured dose rates by exposure time. Combining the estimated uncertainty of the dose rate measurement (± 8.01%) with that of the time measurement (±0.09%) yields an uncertainty of ± 8.10% for total dose measurements.

G. Quality Assurance

The processing of this motor followed the procedures outlined in the Isomedix Inc. Quality Assurance Manual for Reactor Component Processing, Revision I dated May 18, 1988. The program specified in this manual is designed to comply with the quality assurance requirements of 10-CFR-50, appendix B and the reporting requirements of 10-CFR-21.

Sincerely,

ALBERT L. DE CARLO
GENERAL MANAGER

OREST PACLAWSKYJ
MANAGER QUALITY ASSURANCE

APPENDIX II

IRRADIATION TEST REPORT

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX I

TEST SPECIMEN INSPECTION SHEET

TEST SPECIMEN INSPECTION

Revision A

CUSTOMER American Electric Power Service Company

JOB NO. 40053

SPECIFICATION WLTP 40053-01, Rev. A

DATE 03-07-89

CHECK AS APPROPRIATE

ITEM NO.	DESCRIPTION	MANUF.	PART/MODEL NO.	SAME I.D. AS SPEC	CONDITION SATISFACTORY	PHOTO TAKEN
1.0	WESTINGHOUSE 400HP	WESTINGHOUSE	MODEL ABDP	YES	YES	NO
	MOTOR - 3PHASE 60 HZ		FRAME 509US			
	4000VAC, 52 AMPS,					
	3564 RPM					
	MAX. AMB. 40°C					
	INS. CLASS F					
	SERVICE FACTOR 1.15					
	LOCKED KVA CODE F					
	S. # 70F70184					
	SER. 35-71					
	SPIN No. AMP-SIAPSI-01					
	DRIVE END BRG - SLEEVE					
	FRONT END BRG - SLEEVE					
	LOAD INERTIA AT MOTOR SHAFT 315 lbFT²					
	MOTOR COLD - 2 CONSECUTIVE STARTS					
	MOTOR AT OPERATING TEMPERATURE - 1 CONSECUTIVE START					
	SUBSEQUENT STARTS WITH MOTOR RUNNING BETWEEN STARTS -					
	15 MINUTES APART					
	~~3E~~ 8TH SUBSEQUENT STARTS WITH MOTOR STANDING BETWEEN STARTS -					
	45 MINUTES APART					

A

NOTES: NONE

Specimen Failed No
Specimen Passed YES
NOA Written NONE

Inspected By [signature] Date: 3/7/89
Witness N/A Date:
Sheet No. 1 of 1
Approved [signature] 03-17-89

SECTION I

RECEIVING/VISUAL INSPECTION, RADIATION EXPOSURE, AND POST-TEST INSPECTION

1.0 REQUIREMENTS

1.1 Receiving/Visual Inspection

The test specimen shall be subjected to an inspection for the purpose of identification and documentation. The inspection shall be performed as specified in Paragraph 3.1, Section II, of this report.

1.2 Radiation Exposure

The test specimen shall be subjected to the Radiation Exposure Test as specified in Paragraph 3.2, Section II, of this report. Before, during, and after the irradiation period, the test specimen shall be subjected to Insulation Resistance Tests as specified in Paragraph 3.2.1, Section II, of this report.

1.3 Post-Test Inspection

Upon completion of the radiation exposure, the test specimen shall be subjected to a post-test inspection. The inspection shall be performed as specified in Paragraph 3.3, Section II, of this report.

2.0 PROCEDURES

2.1 Receiving/Visual Inspection

A visual inspection of the test specimen was conducted upon receipt at the radiation facility. The inspection was performed in order to document the manufacturer and model number of the specimen to be tested and any noticeable damage.

2.2 Radiation Exposure

The test specimen was placed in the hot cell at Isomedix, Inc. Facility and subjected to a dose rate of approximately 0.58 X 10^6 rads/hour. At a point midway through the radiation exposure, the test specimen was rotated 180° to ensure uniform exposure distribution. The test specimen was subjected to a minimum total integrated dose of 10.01 X 10^6 rads gamma, air equivalent. Upon completion of irradiation, the test specimen was removed from the hot cell.

Insulation resistance measurements were performed on the test specimen before, during, and after the period of radiation exposure. The test specimen was positioned in the hot cell during all insulation resistance measurements. Each insulation resistance measurement was conducted by applying 1000VDC to the specimen motor phases (connected together) for one minute. Insulation resistance values were recorded upon completion of the one minute interval.

2.0 PROCEDURES (Continued)

2.2 Radiation Exposure (Continued)

The resistance readings were between the motor phases and the frame (ground) for all testing. Insulation resistance measurements performed during irradiation were conducted at intervals of approximately four hours each. All measurements performed during irradiation were conducted at 1000VDC.

Additional insulation resistance measurements, performed at the Test Engineer's direction, were as follows:

The initial insulation resistance measurements (performed prior to irradiation) and the final insulation resistance measurements (performed upon completion of irradiation) were conducted at the additional test voltage of 500VDC. The insulation resistance measurements were performed at a five minute interval, in addition to the required one minute time frame. The additional insulation resistance information was recorded on a Test Data Sheet for inclusion in the test report.

2.3 Post-Test Inspection

Upon completion of the radiation exposure, the test specimen was visually inspected. The inspection was performed without disassembly of the test specimen. The condition of the test specimen was recorded and compared to the condition prior to the Radiation Exposure Test.

3.0 RESULTS

The test specimen was subjected to the test of Paragraph 2.0 and met the requirements of Paragraph 1.0. The post-test inspection indicated that there was no observable damage to, or degradation of, the test specimen as a result of the radiation exposure. There was no evidence of discoloration, cracking, or flaking of the non-metallic materials composing the test specimen. There was no evidence of test specimen degradation as a result of the Irradiation Test. A

The data recorded during the test program is presented in Appendices I through IV of this section as noted below:

- Appendix I contains the Test Specimen Inspection Sheet.
- Appendix II contains the test report on the irradiation performed at the Radiation Test Facility.
- Appendix III contains the Data Sheet for the insulation resistance measurements and a plot of the data versus time. A
- Appendix IV contains the Instrumentation Equipment Sheet generated for the insulation resistance measurements.

7.0 QUALITY ASSURANCE

All work performed on this test program was done in accordance with Wyle Laboratories' Quality Assurance Policies and Procedures Manual, which conforms to the applicable portions of ANSI N45.2, 10 CFR 50 Appendix B, 10 CFR 21, and Military Specification MIL-STD-45662A. Standards utilized in the performance of all calibrations are traceable to the National Institute of Standards and Technology.

8.0 TEST EQUIPMENT AND INSTRUMENTATION

All instrumentation, measuring, and test equipment used in the performance of this test program were calibrated in accordance with Wyle Laboratories' Quality Assurance Program, which complies with the requirements of Military Specification MIL-STD-45662A. Standards used in performing all calibrations are traceable to the National Institute of Standards and Technology (NIST) by report number and date. When no national standards exist, the standards are traceable to international standards or the basis for calibration is otherwise documented.

NEQ

Nuclear Environmental Qualification

Test Report

REPORT NO. 40053-02

WYLE JOB NO. 40053

CUSTOMER P. O. NO. 03010-040-8N

PAGE i OF 21 PAGE REPORT

DATE March 20, 1989

SPECIFICATION (S) See References in Paragraph 5.0 of this Summary Section

1.0 CUSTOMER American Electric Power Service Corporation (AEPSC)

ADDRESS 1 Riverside Plaza, Columbus, Ohio 43215

2.0 TEST SPECIMEN 400 Horsepower, 3-Phase, AC Motor

3.0 MANUFACTURER Westinghouse

4.0 SUMMARY

The 400 Horsepower AC Motor, as described in Paragraph 6.0, was subjected to the Radiation Exposure Test as specified by AEPSC. The test specimen described herein was provided by, and is typical of, installations at Indiana Michigan Power Company.

This test program was performed to verify the ability of the test specimen to maintain integrity during radiation exposure. The test report was prepared in accordance with the documentation requirements of IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations."

STATE OF ALABAMA } ss.
COUNTY OF MADISON

Alabama Professional Engineer Reg. No. 7948

Frederick M. Sittason, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

Frederick M. Sittason

SUBSCRIBED and sworn to before me this 6 day of April, 1989

Virginia R. West

Notary Public in and for the State of Alabama at large.

My Commission expires June 12, 1991

Wyle shall have no liability for damages of any kind to person or property, including special or consequential damages, resulting from Wyle's providing the services covered by this report.

PREPARED BY R. T. Walter 03-29-89

APPROVED BY F. R. Johnson 4/6/89

WYLE Q. A. R Hamilton for G. W. Hight 4/6/89

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
HUNTSVILLE, ALABAMA

4.0 SUMMARY (Continued)

This report contains two sections. Section I presents the data recorded during the Receiving/Visual Inspection, Radiation Exposure, and Post-Test Inspection. Section II presents the Wyle Laboratories' Test Procedure No. 40053-01, Revision B, used to perform the test program.

The test program was performed in the sequence indicated in the previous paragraph and as specified in the Test Procedure. During the irradiation period, the test specimen showed no indication of degradation or damage. The insulation resistance values, recorded before, during, and after the exposure period, showed no appreciable difference in levels such as to indicate degradation. The test specimen is therefore considered to have met the acceptance criteria specified for the radiation exposure.

5.0 REFERENCES

5.1 American Electric Power Service Corporation Purchase Order Number 03010-040-8N dated May 12, 1988.

5.2 Wyle Laboratories' Quality Assurance Program Manual, June 1988.

5.3 Wyle Laboratories' Test Procedure No. 40053-01, Revision B.

5.4 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," U. S. Nuclear Regulatory Commission.

5.5 Regulatory Guide 1.89, Revision 1, June 1984, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants," U. S. Nuclear Regulatory Commission.

5.6 IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations."

6.0 EQUIPMENT DESCRIPTION

The 400 Horsepower AC Motor, manufactured by Westinghouse Company, was determined to have identification information as follows:

400 HP, 3-phase, 60 Hertz
4000VAC, 52 Amps, 3564 RPM
Model ABDP
Frame 509US
Service Factor 1.15
S # 70F70184
Ser. 3S-71

REVISIONS

REVISION. A

REPORT NO. 40053-02

DATE: May 30, 1989

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

REV.NO.	DATE	PAGE OR PARAGRAPH AFFECTED	BY	APP'L	DESCRIPTION OF CHANGES
A	5/30/89	ii, I-4	RTW	[illegible] 05-30-89	Correct typographical error
A	5/30/89	I-2	RTW	[illegible] 05-30-89	Post-test inspection observations included
A	5/30/89	I-11, I-12A, I-12B, I-2	RTW	[illegible] 05-30-89	Added plot of insulation resistance data versus time

APPENDIX III

DATA SHEET AND DATA PLOT A

DATA SHEET

Customer AMERICAN ELECTRIC POWER SERVICE CORP.

WYLE LABORATORIES

Specimen WESTINGHOUSE 400HP MOTOR

Part No. MODEL ABDP

Amb. Temp. 74°F

Job No. 40053

Spec. WLTP 40053-01, REV. A

Photo NO

Report No. 40053-02

Para. 3.2

Test Med. AIR

Start Date 03-07-89

S/N N/A

Specimen Temp. AMBIENT

GSI N/A

Test Title INSULATION RESISTANCE MEASUREMENTS

TEST TIME	TIME	VOLTAGE	READING
— BEFORE IRRADIATION			
N/A	1 MIN	500 VDC	1.0×10^{10} Ω
❘	5 MIN	500 VDC	1.2×10^{10} Ω
❘	1 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
N/A	5 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
— DURING IRRADIATION			
3.6 HOURS	1 MIN	1000 VDC ~~100 VDC~~	$>5.0 \times 10^{9}$ Ω
	5 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
8.3 HOURS	1 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
	5 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
12.1 HOURS	1 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
	5 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
17.4 HOURS	1 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
	5 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
— AFTER IRRADIATION			
N/A	1 MIN	500 VDC	1.1×10^{10} Ω
❘	5 MIN	500 VDC	2.1×10^{10} Ω
❘	1 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω
N/A	5 MIN	1000 VDC	$>5.0 \times 10^{9}$ Ω

Tested By [signature] Date: 3/11/89

Witness N/A Date:

Sheet No. 1 of 1

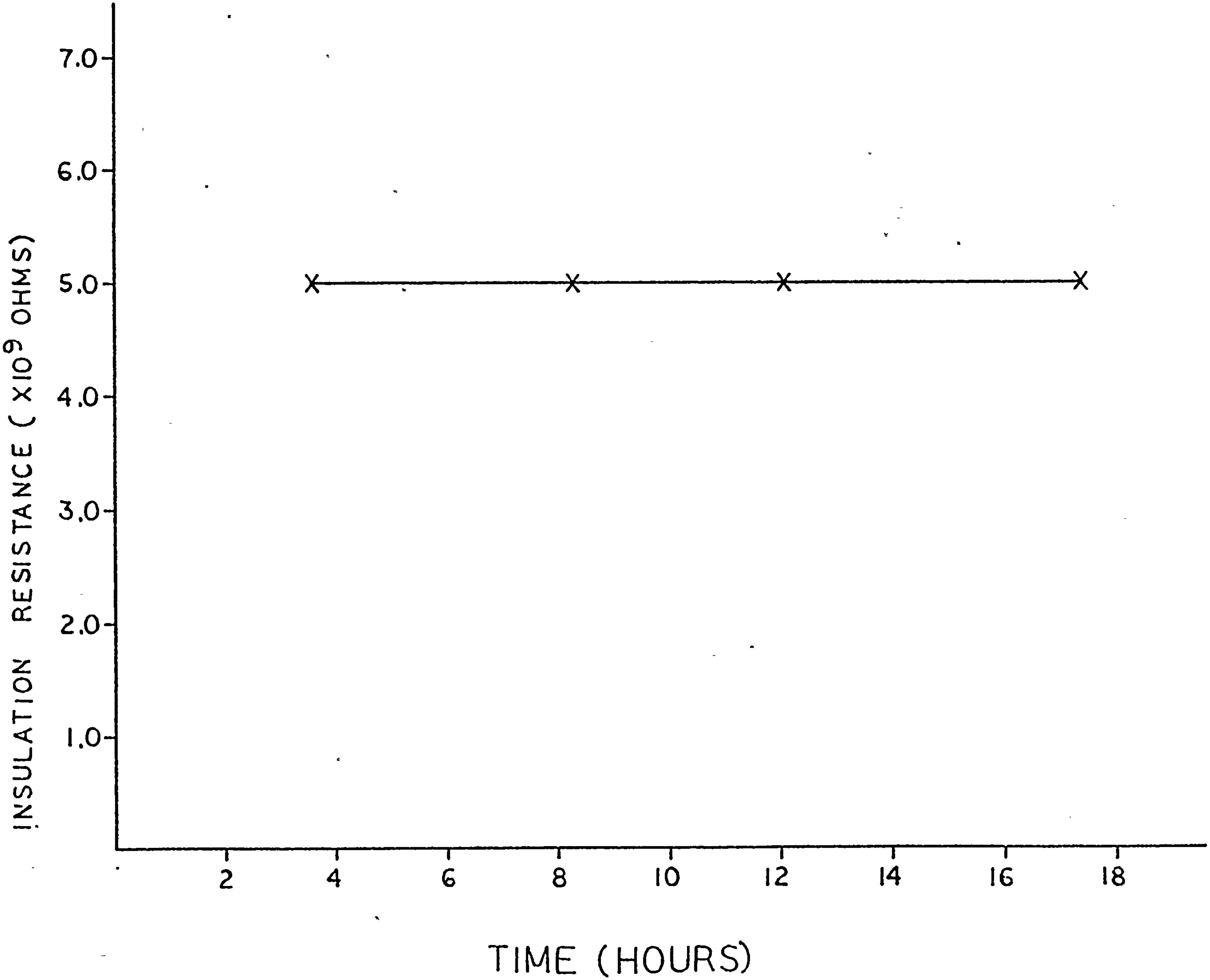
Approved [signature] 03-17-89

Notice of Anomaly NONE

RADIATION EXPOSURE TEST PROGRAM
ON A
WESTINGHOUSE 400 HP MOTOR
FOR
AMERICAN ELECTRIC POWER
SERVICE CORPORATION

For

American Electric Power Service Corporation
1 Riverside Plaza
Columbus, Ohio 43215


INSULATION RESISTANCE (X10^9 OHMS)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
2
4
6
8
10
12
14
16
18
TIME (HOURS)

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX I

TEST SPECIMEN INSPECTION SHEET

TEST SPECIMEN INSPECTION

Revision A

CUSTOMER AMERICAN ELECTRIC POWER SERVICE COMPANY

JOB NO. 40053

SPECIFICATION WLTP 40053-01, REV. A

DATE 03-07-89

CHECK AS APPROPRIATE

ITEM NO.	DESCRIPTION	MANUF.	PART/MODEL NO.	SAME I.D. AS SPEC	CONDITION SATISFACTORY	PHOTO TAKEN
1.0	WESTINGHOUSE 400 HP	WESTINGHOUSE	MODEL ABDP	YES	YES	NO
	MOTOR - 3 PHASE 60 HZ		FRAME 509 US			
	4000 VAC, 52 AMPS,					
	3564 RPM					
	MAX. AMB. 40°C					
	INS. CLASS F					
	SERVICE FACTOR 1.15					
	LOCKED KVA CODE F					
	S. # 70F70184					
	SER. 35-71					
	SPIN No. AMP-SIAPSI-01					
	DRIVE END BRG - SLEEVE					
	FRONT END BRG - SLEEVE					
	LOAD INERTIA AT MOTOR SHAFT 315 lbFT²					
	MOTOR COLD - 2 CONSECUTIVE STARTS					
	MOTOR AT OPERATING TEMPERATURE - 1 CONSECUTIVE START					
	SUBSEQUENT STARTS WITH MOTOR RUNNING BETWEEN STARTS -					
	15 MINUTES APART					
	3R 6TH SUBSEQUENT STARTS WITH MOTOR STANDING BETWEEN STARTS -					
	45 MINUTES APART					

A

NOTES: NONE

Specimen Failed NO

Specimen Passed YES

NOA Written NONE

Inspected By [signature] Date: 3/7/89

Witness N/A Date:

Sheet No. 1 of 1

Approved [signature] 03-17-89

NEQ

Nuclear Environmental Qualification

Test Report

REPORT NO. 40053-02

WYLE JOB NO. 40053

CUSTOMER P. O. NO. 03010-040-8N

PAGE 1 OF 21 PAGE REPORT

DATE March 20, 1989

SPECIFICATION (S) See References in Paragraph 5.0 of this Summary Section

1.0 CUSTOMER American Electric Power Service Corporation (AEPSC)

ADDRESS 1 Riverside Plaza, Columbus, Ohio 43215

2.0 TEST SPECIMEN 400 Horsepower, 3-Phase, AC Motor

3.0 MANUFACTURER Westinghouse

4.0 SUMMARY

The 400 Horsepower AC Motor, as described in Paragraph 6.0, was subjected to the Radiation Exposure Test as specified by AEPSC. The test specimen described herein was provided by, and is typical of, installations at Indiana Michigan Power Company.

This test program was performed to verify the ability of the test specimen to maintain integrity during radiation exposure. The test report was prepared in accordance with the documentation requirements of IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations."

STATE OF ALABAMA } ss. Alabama Professional
COUNTY OF MADISON } Engineer Reg. No. 7948

Frederick M. Sittason, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

SEAL [signature]

SUBSCRIBED and sworn to before me this [illegible] day of April, 1989

[signature]

Notary Public in and for the State of Alabama at large.

My Commission expires June 12, 1991

Wyle shall have no liability for damages of any kind to person or property, including special or consequential damages, resulting from Wyle's providing the services covered by this report.

PREPARED BY [signature] 03-29-89
R. T. Walter

APPROVED BY [signature] 4/6/89
F. R. Johnson

WYLE Q. A. R Hamilton 4/6/89
for G. W. Hight

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
HUNTSVILLE, ALABAMA

AEPSC/ INDIANA MICHIGAN POWER CO/ COOK NUCLEAR PLANT
THIS DOCUMENT MEETS THE QA CERTIFICATION REQUIREMENTS OF
P.O. NO. 03010-040-8N; P.O. ITEMS________
AUTH SIG. [signature] DATE 2/30/89
J. R. ANDERSON [SHEET 1 OF 21]

SECTION I

RECEIVING/VISUAL INSPECTION, RADIATION EXPOSURE, AND POST-TEST INSPECTION

1.0 REQUIREMENTS

1.1 Receiving/Visual Inspection

The test specimen shall be subjected to an inspection for the purpose of identification and documentation. The inspection shall be performed as specified in Paragraph 3.1, Section II, of this report.

1.2 Radiation Exposure

The test specimen shall be subjected to the Radiation Exposure Test as specified in Paragraph 3.2, Section II, of this report. Before, during, and after the irradiation period, the test specimen shall be subjected to Insulation Resistance Tests as specified in Paragraph 3.2.1, Section II, of this report.

1.3 Post-Test Inspection

Upon completion of the radiation exposure, the test specimen shall be subjected to a post-test inspection. The inspection shall be performed as specified in Paragraph 3.3, Section II, of this report.

2.0 PROCEDURES

2.1 Receiving/Visual Inspection

A visual inspection of the test specimen was conducted upon receipt at the radiation facility. The inspection was performed in order to document the manufacturer and model number of the specimen to be tested and any noticeable damage.

2.2 Radiation Exposure

The test specimen was placed in the hot cell at Isomedix, Inc. Facility and subjected to a dose rate of approximately 0.58 X 10^6 rads/hour. At a point midway through the radiation exposure, the test specimen was rotated 180° to ensure uniform exposure distribution. The test specimen was subjected to a minimum total integrated dose of 10.01 X 10^6 rads gamma, air equivalent. Upon completion of irradiation, the test specimen was removed from the hot cell.

Insulation resistance measurements were performed on the test specimen before, during, and after the period of radiation exposure. The test specimen was positioned in the hot cell during all insulation resistance measurements. Each insulation resistance measurement was conducted by applying 1000VDC to the specimen motor phases (connected together) for one minute. Insulation resistance values were recorded upon completion of the one minute interval.

2.0 PROCEDURES (Continued)

2.2 Radiation Exposure (Continued)

The resistance readings were between the motor phases and the frame (ground) for all testing. Insulation resistance measurements performed during irradiation were conducted at intervals of approximately four hours each. All measurements performed during irradiation were conducted at 1000VDC.

Additional insulation resistance measurements, performed at the Test Engineer's direction, were as follows:

The initial insulation resistance measurements (performed prior to irradiation) and the final insulation resistance measurements (performed upon completion of irradiation) were conducted at the additional test voltage of 500VDC. The insulation resistance measurements were performed at a five minute interval, in addition to the required one minute time frame. The additional insulation resistance information was recorded on a Test Data Sheet for inclusion in the test report.

2.3 Post-Test Inspection

Upon completion of the radiation exposure, the test specimen was visually inspected. The inspection was performed without disassembly of the test specimen. The condition of the test specimen was recorded and compared to the condition prior to the Radiation Exposure Test.

3.0 RESULTS

The test specimen was subjected to the test of Paragraph 2.0 and met the requirements of Paragraph 1.0. The post-test inspection indicated that there was no observable damage to, or degradation of, the test specimen as a result of the radiation exposure. There was no evidence of discoloration, cracking, or flaking of the non-metallic materials composing the test specimen. There was no evidence of test specimen degradation as a result of the Irradiation Test. A

The data recorded during the test program is presented in Appendices I through IV of this section as noted below:

- Appendix I contains the Test Specimen Inspection Sheet.
- Appendix II contains the test report on the irradiation performed at the Radiation Test Facility.
- Appendix III contains the Data Sheet for the insulation resistance measurements and a plot of the data versus time. A
- Appendix IV contains the Instrumentation Equipment Sheet generated for the insulation resistance measurements.

Lab Job #9705
WESTINGHOUSE 400 HP
SERIAL # 70F70184

ATTACHMENT 1
SI MOTOR TEST
REVIEW

Due Date
9-23-89

Calibrated
2-23-89

Equipment
General Radio
Megohm Bridge

TEMPERATURES	AIR 23 °C	
Resistance Reading In Meg. Ohms	Actual Meg. Ohms	Corrected to 40°C
15 sec.	1.0 X 10GΩ	.3 X 10GΩ
30 sec.	1.79 X 10GΩ	.537 X 10GΩ
45 sec.	2.25 X 10GΩ	.675 X 10GΩ
60 sec.	2.55 X 10GΩ	.765 X 10GΩ
1½ min.	2.92 X 10GΩ	.876 X 10GΩ
2 min.	3.9 X 10GΩ	1.17 X 10GΩ
3 min.	4.65 X 10GΩ	1.395 X 10GΩ
4 min.	5.35 X 10GΩ	1.605 X 10GΩ
5 min.	6.0 X 10GΩ	1.8 X 10GΩ
6 min.	6.6 X 10GΩ	1.98 X 10GΩ
7 min.	7.2 X 10GΩ	2.16 X 10GΩ
8 min.	7.7 X 10GΩ	2.31 X 10GΩ
9 min.	8.25 X 10GΩ	2.475 X 10GΩ
10 min.	8.8 X 10GΩ	2.64 X 10GΩ

POLARIZATION INDEX = $\frac{\text{10 MIN READ}}{\text{1 MIN READ}}$ = 3.45 @ 40°C

Tester: Bob Ellm
Date: 4-6-89
Approved: [signature] AEPSC
Date: