THE OKONITE COMPANY
Ramsey, New Jersey 07446

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NUCLEAR SAFETY RELATED

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# NUCLEAR ENVIRONMENTAL QUALIFICATION REPORT

for

OKOGUARD INSULATED CABLES

and

T-95 & NO. 35 SPLICING TAPES

OKONITE REPORT NO. NQRN-3

This report is The Okonite Company's nuclear qualification document for Okoguard insulated cables and splicing tapes. It complies with each paragraph in IEEE Standard 383-1974, Section 1.4 "Documentation". Section 1.4 documents the parameters specified in Section 1.3, "Type Tests a Qualification Method."

Included in this report are appendices which serve to further clarify Okonite's test procedures and results. These appendices are as follows:

| Appendix | | |
|---|---|---|
| 1 | Straight Splice -- 1/C Rubber Insulated, Shielded, Jacketed Nuclear Station Cable D-11489 | |
| 2 | 40-Year Life Detail Document | |
| 3 | Radiation Certification | |
| 4 | Okonite's LOCA Test Profile | R4 |
| 5 | LOCA Autoclave Drawing | |
| 6 | List of Equipment | |
| 7 | Elevated Temperature Moisture Absorption | |
| 8 | Vertical Tray Flame Test | |
| 9 | Insulation Resistance | R4 |
| 10 | Anomalies | |

Rev. 1 - 6/30/82
Rev. 2 - 2/16/84
Rev. 3 - 3/31/87
Rev. 4 - 10/24/88

NUCLEAR REGULATORY COMMISSION

Docket No. ____________ Official Exh. No. 21

In the matter of ALABAMA POWER CO.

Staff ✓ IDENTIFIED 2/12/92

Applicant ____________ RECEIVED 2/12/92

Intervenor ____________ REJECTED ____________

Cont'g Off'r ____________

Contractor ____________ DATE N/D

Other ____________ Witness ____________

Reporter L Estep

The necessary data to document satisfactory compliance as specified in Section 2.6 of IEEE 383, "Documentation of Type Testing" is provided in this report. The following cross-reference table illustrates where this information can be found.

| Section | Title | Section in Report |
|---|---|---|
| 2.3.1 | Temperature and Moisture | Appendix 7 |
| 2.3.2 | Long-term Physical Aging Properties | Appendix 2 |
| 2.3.3 | Thermal and Radiation Exposure | Paragraph 1.4.1.3 (Pre-aging and Irradiation and Appendix 3). |
| 2.4 | Testing for Operation During DBE-LOCA | Paragraph 1.4 and specifically 1.4.2, 1.4.3, and 1.4.4 |
| 2.5.1 | Vertical Tray Flame Test | Appendix 8 |

## 1.4 Documentation

1.4.1.1 Description: 5kV, #6, 7X BC, extruded semicon, .090" Okoguard, extruded semicon, .005" x 1" BC shielding tape, 12½% lap, no jacket. Two 15 ft. samples: 1-non-aged, 1-thermally aged.

1.4.1.2 Description of hand-wrapped filled splice: Per attached drawing D-11489, Appendix 1, with the following exceptions:

(1) The cable tested had no jacket. However, jacketing tape (No. 35) was applied over the splice.

(2) Grounding straps and tinned copper perforated strips were not utilized.

(3) A compression connector was used instead of a solder connector.

1.4.1.3 Identification of environmental features:

Listed below are the environmental parameters which the samples were subjected to. A temperature-pressure profile is given in Appendix 4.

Preaging: Aged sample was aged for 3 weeks @ 150°C in a forced draft circulating air oven. Temperature was monitored continuously by a chart recorder. Appendix 2 is a detailed discussion of 40 year life simulations.

Radiation: The samples received a minimum dose of 200M rads of gamma radiation at a rate of less than 1 megarad per hour. See attached certification (Appendix 3).

Temperature: 2 peaks at 345°F for 3 hrs. each
3 hrs. at 335°F    4 hrs. at 315°F
3 days 9 hrs. at 265°F    126 days at 212°F

Pressure: 2 peaks at 114 psi for 3 hrs. each
3 hrs. at 95 psi    4 hrs. at 69 psi
3 days 9 hrs. at 24 psi    126 days at 0 psi

Relative Humidity: Saturated steam conditions throughout profile.

Chemistry of Spray Solution: per IEEE 323, Appendix A

Table A-1
.28 molar $H_3BO_3$
.064 molar $Na_2S_2O_3$
NaOH approx. .59% to make a pH of 10.5 at 77°F dissolved in tap water
Spray rate of minimum .15 (gal/min)/ft.$^2$ of surface area of the test vessel.

1.4.1.4 Specific performance requirements (Acceptance Criteria)

(a) Cable and splice must maintain electrical load throughout entire LOCA profile.

(b) Cable and splice must withstand the 30 day and 130 day Post-LOCA withstand tests (40 x OD at 80 V/mil, 5 min.)

(c) Test sequence must provide a margin of assurance.

1.4.1.5 Test Program

(a) Sample selection

*(b) Pre-test electrical and physical (mechanical) characteristics -- to determine if samples are representative samples; capacitance, % PF, and IR.

(c) Prepare splices

*(d) Electrical characteristics after splices -- to determine if splices were made correctly.

(e) Thermal aging of one sample: 3 weeks at 150°C followed by electrical characteristics*

(f) Irradiation of samples: 200M rads

*(g) Pre-LOCA electrical characteristics -- to determine the condition of samples prior to LOCA

(h) Installation of samples into LOCA vessel

*(i) Pre-LOCA insulation resistance measurements and 5 min. 80 V/mil ac withstand test, to determine if samples were damaged during installation.

(j) Chemical solution sprayed into vessel.

(k) Initiation of LOCA simulation (see Profile-Appendix 4).

(l) Maintenance of LOCA profile thru 30 days with IR measurements* taken as shown in profile.

*(m) 30 day Post-LOCA withstand test (40 x OD bend, 80 V/mil ac, 5 minutes)

(n) Reinstallation of samples into vessel for additional 100 days at 212°F. IR measurements* taken once every two weeks.

(o) 130 day Post-LOCA withstand test (40 x OD bend, 80 V/mil ac, 5 minutes)

*(p) Electrical and physical characteristics after LOCA.

*(q) Dielectric strength.

*Electrical or physical tests are not requirements of IEEE 323 or 383.

NOTE: Test program and results of the vertical tray flame test are contained in Appendix 8.

1.4.1.6 Test Results

(a) The unaged specimen maintained the electrical load as given in paragraph 1.4.2.4 throughout the entire profile. The electrical load on the aged specimen was interrupted from the first day at 265°F through the 30th day due to a termination failure. (See Appendix 10, items 3 and 4). R3

(b) Both samples (cables and splices) passed the 30 and 130 days Post-LOCA withstand tests (40 x OD bend, 80 V/mil ac, for 5 minutes immersion in water).

(c) A margin of assurance was demonstrated by:

(1) Each sample passed the Post-LOCA withstand test twice, once at the 30 day point and again at the 130 day point.

(2) The cables passed all withstand tests as described in paragraph 1.4.1.5.

(3) Satisfactory Post-LOCA electrical measurement values.

(4) The insulating materials maintained flexibility.

(5) Adhesion remained between cable and splice.

(6) The cable maintained dielectric strength. Post-LOCA breakdowns were greater than 8 times rated voltage.

Margin may also be demonstrated when the environmental parameters of this test are compared to the postulated LOCA parameters of a particular nuclear station.

Test data to justify the above are available for audit by the purchaser or his authorized designates.

1.4.2 Test Program Outlined

1.4.2.1 Each sample was coiled into approximately a 22-inch coil. The ends were terminated for testing. One of the samples was thermally aged prior to irradiation, both samples were irradiated in this configuration. An epoxy-type terminal was installed on each end. The samples were then installed in the LOCA vessel. The samples were mounted around a vertical mandrel which was made out of 1" x ½" expanded steel. The physical arrangement is shown in Appendix 5. Test equipment utilized is included in Appendix 6.

1.4.2.2 The test program and sequence of environmental factors is outlined in Section 1.4.1.5 above.

1.4.2.3 Type & Location of all environmental and cable monitoring sensors for each variable.

Radiation: See attached Isomedix, Inc. certification, Appendix 3.

Thermal Aging: Forced draft circulating air oven monitored by thermocouple in rear of the oven connected to a continuous readout chart recorder.

Temperature during LOCA: Monitored by mercury thermometer and thermocapillary inside the vessel connected to the Taylor Instrument panel consisting of pressure gauges and a temperature-pressure chart recorder.

Pressure: Monitored by Taylor Instrument panel.

Spray Soluction: pH monitored initially with pH test paper and test liquid. Flow rate monitored by flowmeter made by Okonite. (Pressure measured before and after an orifice.)

Relative Humidity: A one to two inch reservoir of liquid was maintained within the test vessel. (IEEE 323, Appendix C.) Steam pressure was allowed to conform to saturated conditions. (100% relative humidity.)

1.4.2.4 Rated voltage, 5kV, was applied to each sample. 80 amps were applied initially. As the temperature profile changed the current was re-adjusted to 80 amps. Voltage and current were applied to the ends of the samples which protruded thru the vessel.

1.4.2.5 During environmental exposure, insulation resistance measurements are taken periodically. (See Appendix 9.) |R3

1.4.2.6 The following tests are performed after environmental exposure:

(a) Post LOCA AC Withstand Tests: These tests were performed per IEEE 383, Section 2.4.4. Charging current is measured by a milliammeter.

(b) Capacitance and Dissipation Factor (% PF): These measurements were taken with the sample at room temperature in air. Measurements were taken at 40 and 80 V/mil of insulation.

(c) Dielectric Strength Tests: An ac rapid rise breakdown test per ASTM D149, para. 15(a) is performed on each sample after completion of all electrical tests.

(d) Mechanical Tests: Tensile strength and % elongation measurements are taken as indicated in the test program outline. Measurements were performed on dumbbell shaped samples taken from the midwall section of the cable insulation. The ASTM D470 test procedure is followed.

1.4.3 Test Results

1.4.3.1 The intended environmental sequences were achieved. Thermal aging was performed with the temperature recorded on the chart recorder. The radiation requirements were met as shown in Appendix 3. The temperature-pressure profile as shown in IEEE 323, Appendix A - Fig. A-1 was achieved except for the anomalies (1) and (2) described in Appendix 10. Actual temperature and pressures are shown on the LOCA profile in Appendix 4 of this report. R3

1.4.3.2 The samples were capable of performing their intended function as evidenced by:

(a) Electrical load was maintained during LOCA except during periods described in Appendix 10, items (3) and (4). R3

(b) Both samples withstood the 30 and 130 day Post-LOCA withstand tests.

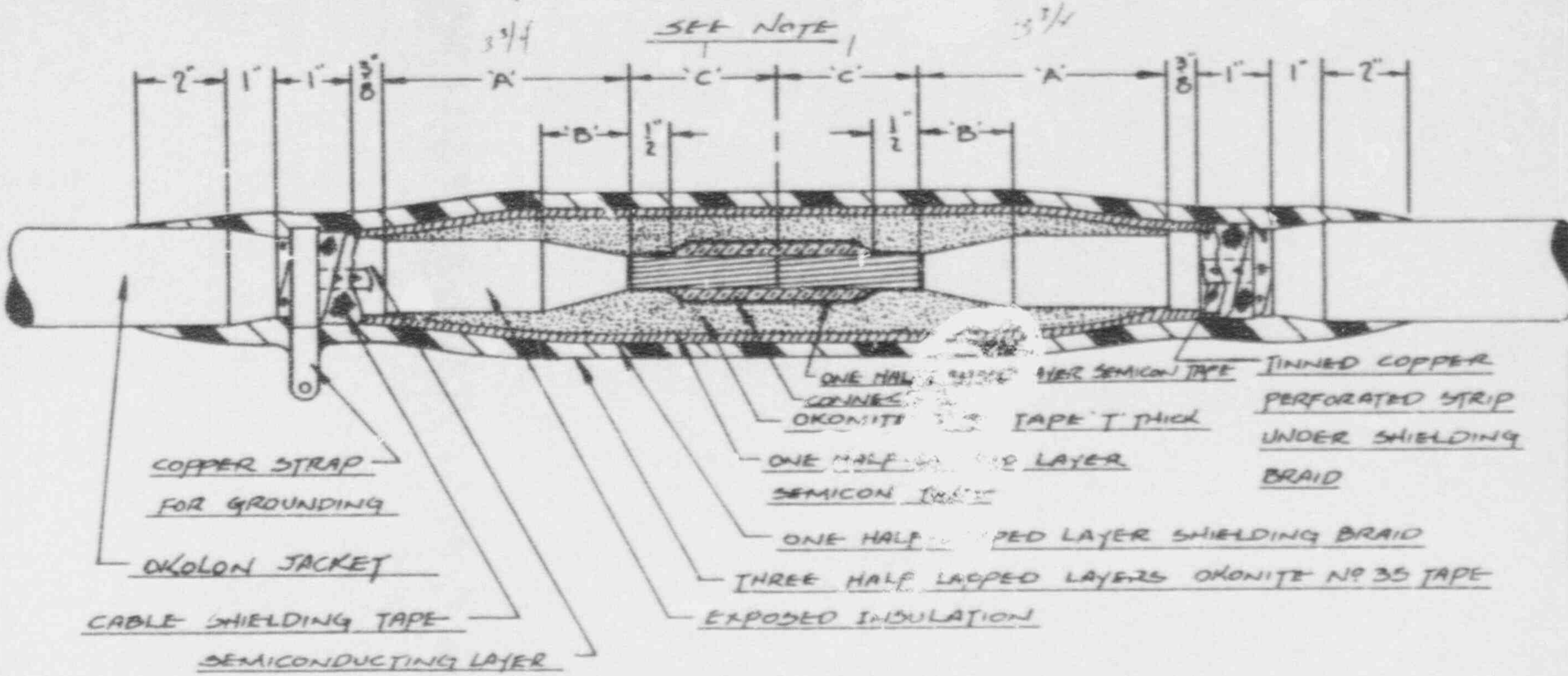
(c) A margin of assurance was demonstrated. See Section 1.4.1.6(c) above.

1.4.4 Test Evaluation -- Evaluation of Data

The 130 day Post-LOCA withstand test demonstrated that the samples were in good condition. Charging currents of less than 3mA were measured. Electrical characteristics demonstrated that the cable had degraded, yet was still in good condition when considering the severity and length of the test. Capacitance went from approximately 1100 picofarads to 1000 picofarads. The % PF increased from approximately 0.50 to 0.92% at 80 V/mil. The insulation resistance decreased from an average of 40,000 megohms-1000 ft. to approximately 5,000 megohms-1000 ft. AC dielectric breakdown for both samples was greater than 40kV (or 8 times the rated value of the cable). Percent retention of tensile strength and elongation were 103 and 41, and 95 and 52 for the unaged and aged samples, respectively.

The cable and splices are considered to have passed the DBE-LOCA qualification test since they met the requirements specified in IEEE 383 and 323 for Class 1E cables, and provided a margin of assurance which is demonstrated in the above data.

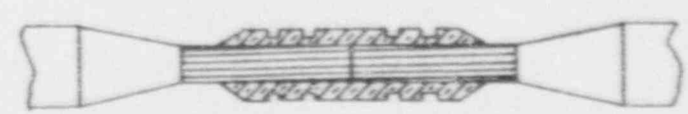
APPENDIX 1




NOTE
C = 1/2 CONNECTOR LENGTH PLUS 1/2"

| VOLTAGE RATING | DIMENSIONS | | |
|---|---|---|---|
| | A | B | T |
| 5 Kv. | 3 3/4" | 1 1/2" | 5/16" |
| 8 Kv | 3 3/4" | 1 1/2" | 5/16" |
| 15 Kv. | 5 1/2" | 2" | 9/16" |

Okonite Nuclear Grade Splicing Cement Was Utilized In The Qualification Test



ALTERNATE COMPRESSION TYPE CONNECTOR

STRAIGHT SPLICE - 1/C RUBBER INSUL. - SHLD. - JACKETED NUCLEAR STATION CABLE -

THE OKONITE COMPANY
RAMSEY, N.J.

| | | | |
|---|---|---|---|
| DATE 5-17-71 | SCALE ~ | REVISIONS C - 12-7-77 | |
| DR. CG | TR. | | DRAWING NO. |
| CH. | APP. | | D-11489 |

THE OKONITE COMPANY
Ramsey, New Jersey 07446

## APPENDIX 2

## DEMONSTRATION OF 40 YEAR LIFE FOR MATERIALS

This document is designed to present The Okonite Company's position on the subject of demonstration of 40 year life at 90°C for materials, as required by the nuclear industry, industry specifications, and various government regulatory agencies. We hope that this presentation will clarify our approach, aid our customers in their contacts with regulatory agencies, and demonstrate the pitfalls involved in extrapolation of experimental data.

Form: FYL-3

## Thermal Aging

To demonstrate 40 year life at 90°C, the approach used most frequently is the familiar Arrhenius technique. Data obtained on aging of materials at various elevated temperatures is collected and analyzed via this technique.

Some comments on the method and the scope and limitations of the method are in order.

It should be recognized that the Arrhenius equation is valid only if the data represents a single discreet chemical reaction and the activation energy of that single reaction is within the temperature limits of the data. This equation can be derived from collision theory and has been experimentally verified. It serves to define the temperature coefficient of a discreet chemical reaction and the activation energy of that reaction only within the temperature limits of the experimental data. The equation is:

$$k = Ae \frac{-\Delta E}{RT}$$

k = specific rate constant,

A = frequency factor or collision frequency,

$\Delta E$ = activation energy - the difference in the energy of a chemical species in the ground state and its activation state. The activated state is not isolable and has a very short life time (in the order of nano or picoseconds) and collapses either to the original ground state or reactants or to the ground state of the products,

R = gas content

T = absolute temperature

The specific reaction rate constant k reprsents a single discreet chemical reaction. In the case of a simple uni-molecular first order reaction A ⟶ B, the following describes the rate where C = concentration:

$$\frac{-dC_A}{dt} = kC_{Ao}$$

that is -- the change in concentration of reactant A with time is proportional to the initial concentration of A. The differential equation is solved and k determined from experimental measurements of concentration vs. time. Distinct values of K must be determined at various temperatures and must be constant over a considerable range of conversion in the reaction, say from 20 to 80%, for the data to be considered valid. It can be used correctly only when there are discreet chemical reactions whose rate can be

precisely measured, and described by solvable differential equation. A straight line will result from a plot of the logarithm of the reaction rate k vs. 1/T provided there is no change in the reaction mechanism.

The Okonite Company in applying this Arrhenius analysis to the aging data utilizes the time to 40% retention of elongation plotted on semilog paper against a reciprocal of absolute temperature in degrees Kelvin. Parameters other than 40% retention of elongation can be utilized and have been utilized. Some have used electrical failure in water after subjecting the material to high temperature aging for different times and bending around a 10 or a 20X mandrel. It should be recognized that times obtained from this latter type of test are far longer than those obtained from a 40% retention of elongation type plot since the electrica integrity really depends on the insulation not cracking and the elongations obtained in these bend tests are on the order of 50% or less. Thus, it is emphasized that a 40% retention of elongation time is a very long way from an electrical failure. It is a very conservative measure of life and as such provides a very large margin of safety in terms of circuit integrity in use if one can show that such a parameter can indeed demonstrate 40 years of service before 40% retention of elongation time is reached.

In examining the validity of the Arrhenius treatment as applied to thermal aging, it should be noted that there are at least four simultaneous reactions going on -- (1) oxidative cleavage, (2) oxidative crosslinking, (3) thermal cleavage, (4) thermal crosslinking. The first two of these reactions are at least second order kinetically in that their rate law must depend at a minimum on the concentration of oxygen and the concentration of reacting chemical bonds. Since vulcanized rubber is a complex mixture of many chemical bond species, there are a multiple of individual rate constants that must be measured. This is an impossibility or at best beyond the scope of current technical expertise. From the above, it is apparent that the occurrence of a linear plot in an Arrhenius treatment of aging data is indeed a fortuitous event.

Since this is so, i.e., a straight line is really a fortuitous event, and if careful work is done, it can be shown that there are slope changes occurring in the Arrhenius plot indicating mechanism changes. At lower temperatures, oxygen diffusion rates may be the rate controlling phenomena. These two among other possibilities have differing activation energy, i.e. the slope of the log k vs. 1/T in a chemical reaction study is the activation energy $\Delta E$ in the Arrhenius equation. Other complications can and undoubtedly do arise leading to variations in slope. At The Okonite Company, we recognize these pitfalls and complications, but we take our time to 40% retention of elongation, plot it vs. 1/T and construct via at least square method the best straight line through the experimental data points.

Since the above complications unquestionably do occur, extrapolation of the lines constructed from experimental data to temperatures beyond the measured experimental points is at lest a very risky matter and is indeed not valid, and should not be done, and will, if done, lead to errors. In our experience in terms of aging, i.e. loss of elongation, extrapolation to temperatures beyond those experimentally measured leads to very considerable errors in terms of life. We have consistently found extrapolations to give lifetimes, i.e., times to 40% retention of elongation, far shorter than experimentally observed when older, well established materials are measured and treated by the Arrhenius technique. To demonstrate this, reference is made to the curves of charts 1, 2 and 3.

On chart #1, the lowest curve labelled Okolite is the Arrhenius plot of aging data to 40% retention of elongation of this insulation with data collected at temperatures between 75°C and 136°C. Temperatures below 75° are extrapolated. Utilizing this curve, one would predict that Okolite (a natural rubber oil based insulation manufactured by The Okonite Company in the past) would have a life, i.e., a time to 40% retention of elongation, of 17 years at 20°C and 7.5 years at 30°c. This latter is saying that if Okolite insulation were left at 30°C for 7½ years, the sample after that time would have retained 40% of its original elongation.

A sample of this insulation that has been in service at Hagood Station of the South Carolina Electric & Gas Co. for 25 years at an ambient temperature between 20 and 30°C had 50% retention of its original elongation after the 25 year service period.

Referring to chart #2, the Arrhenius plot for neoprene is constructed from data collected between 75°C and 136°C. The line is extrapolated to lower temperatures. This line would predict that at 13°C continuous, neoprene would have 40% retention of elongation after 14.7 years. An actual sample of neoprene jacketed cable has been exposed on the roof of The Okonite Company Passaic Research Laboratories since 1934. This cable sample has been examined every five years since then. The time to 40% retention of elongation of this sample was 35 years. The average temperature is 13°C on an annualized basis in New Jersey.

Also shown on chart #2 is a curve of time to 10% retention of elongation of natural rubber insulation of the type manufactured in the late 1920's. Data collected between 75°C and 121°C has been plotted from old Okonite records to establish the slope of the line. Temperatures below 75°C are extrapolated. From this plot, one would predict that this natural rubber type insulation would have retained 10% of its original elongation after approximately 6½ years at 43°C. An actual sample of natural rubber insulation was obtained from the Duke Power Company. This sample had been installed in 1926 and has been in service for 49 years. The sample after this service period had 50% absolute elongation which is approximately 10% retention of the original elongation of natural rubber type insulation manufactured in the late 1920's.

With reference to chart #3, there is shown the curve for the time to 80% retention of elongation for butyl rubber. Data was collected between 136°C and 75°C for this material with extrapolation to lower temperatures. From this extrapolation, one predicts a life of approximately 4½ years at 50°C. A sample of butyl insulation returned from the Southern California Edison Company - Los Alamitos Station which served as a fan cable has been evaluated. The load on the cable as well as its installation condition was available and the calculations considering the ambient temperature showed that the cable operated with its insulation for 7 years at 50°C and for 3 years at 40°C. As noted above, the projected life at 50°C is 4½ years.

The data presented on charts 1, 2 and 3 and the allied unambiguous demonstration that extrapolation of accelerated aging data treated via the Arrhenius technique leads to lifetimes lower than actually observed on real materials that have been in service clearly points out the major pitfalls of extrapolation of Arrhenius type treatments.

Recognizing this pitfall and recognizing the above demonstrated low life projections obtained by extraplation of Arrhenius plots, it is not at all surprising nor mysterious that the Arrhenius treatment plot of accelerated thermal aging data of EP and polyethylene shown on chart #1 as the center curve does not, if extrapolated, go through 40 years at 90°C.

The curve shown for EP and PE is a masterplot of the accelerated aging data of four different EP compounds and two different cross-linked polyethylene compounds. Data was collected on all of these materials between 135°C and 180°C. Very recently data on two EP's for time to 40% retention of elongation at 121°C were obtained. The life to 40% retention at 121°C was in excess of 5000 hours whereas the masterplot constructed by least squares treatment of data as noted above predicts a life of a little more than 4000 hours. This 121°C point is not included in the least squares treatment for obtaining the slope but does indicate that the slope of the line is bending upward as long term aging data at lower temperatures is obtained.

We have thus far shown that extrapolation of Arrhenius type plots beyond the temperatures where experimental data has been collected leads to low predicted lives for insulations. We have further pointed out that it is therefore not surprising that the extrapolation of a plot of EP or polyethylene to 90°C does not go through 40 years but indeed predicts values between 7 and 8 years life to 40% retention. It should be remembered as pointed out before that 40% retention of elongation is not an end point.

On chart #1, there is shown a line that is labelled 40 years at 90°C. This line is constructed by taking the point of 40 years at 90°C and drawing a line parallel to the experimentally determined line. This hypothetical line represents a material that would have times to 40% retention of elongation that when extrapolated to 90° gives a point at 40 years. The construction of this

line parallel to the experimental EP polyethylene line is justified on the basis that in general the various mechanisms leading to loss of elongation in materials, particularly of the EP and polyethylene type are very similar and it is our experience that various EP's and various polyethylenes of rather different compound formulations do indeed give essentially identical slopes.

The experimental line, i.e., that one on chart #1 labelled EP and PE was constructed from data collected on single conductor #12 or #14 coated copper wire with 30 and/or 47 mils of the various insulations. These samples were aged at the temperatures indicated previously in forced draft ovens.

Samples of these insulated conductors with the various EP and polyethylene insulations applied at 30 and/or 47 mils have been prepared as multiple conductor cables with an overall jacket. The samples in jacketed form are as they would be installed in a nuclear plant, i.e. a finished cable. These cables were then placed in forced draft ovens at 150, 165 and 180°C for times determined by the 40 year at 90°C. This is, at 180°, the samples were in the oven for 360 hours, at 165°, they were in the oven for 960 hours and at 150°C, they were in the oven for 2500 hours. After the above mentioned aging times in jacketed form, the samples were removed and tested. The % retention of elongation obtained from the single conductors after aging for the long times indicated above at the elevated temperatures were all in excess of 40% retention. The actual retention values ranged depending upon the specific sample and temperature between 60 and 90% retention of elongation. It is to be emphasized that the aging conditions in jacketed form simulate the installation conditions.

Thus, it has been shown that polyethylene and EP aged for times as derived from a line consistent with the aging mechanism of the materials and drawn through 40 years at 90°C do retain better than 40% of their elongation, the parameter used by The Okonite Company for its measure of life.

However, it is The Okonite Company's conviction that a more convincing aspect of the argument for demonstration of 40 year life resides in the comparison of the behavior of EP and crosslinked polyethylene to butyl and to Okolite, a natural rubber insulation. By examining chart #1 at temperatures where actual experimental data were gathered, one can see that EP and crosslinked polyethylene exceed the life of butyl when measured in terms of 40% retention of elongation by a factor of between 6 and 10 in terms of comparison with the Okolite natural rubber insulation by even larger factors.

Since Okolite and butyl have performed satisfactorily in power plants and butyl in nuclear power plants, (40 years + in the case of the natural rubber type insulations, and at least 15 years for butyl in a nuclear plant) it is clear that the much improved behavior of the modern EP and crosslinked polyethylene materials

in accelerated tests, when compared at temperatures where actual data were gathered, on each of the materials, indicates that the polyethylenes and EP's will outperform the older insulations or at the very worst at least equal their performance.

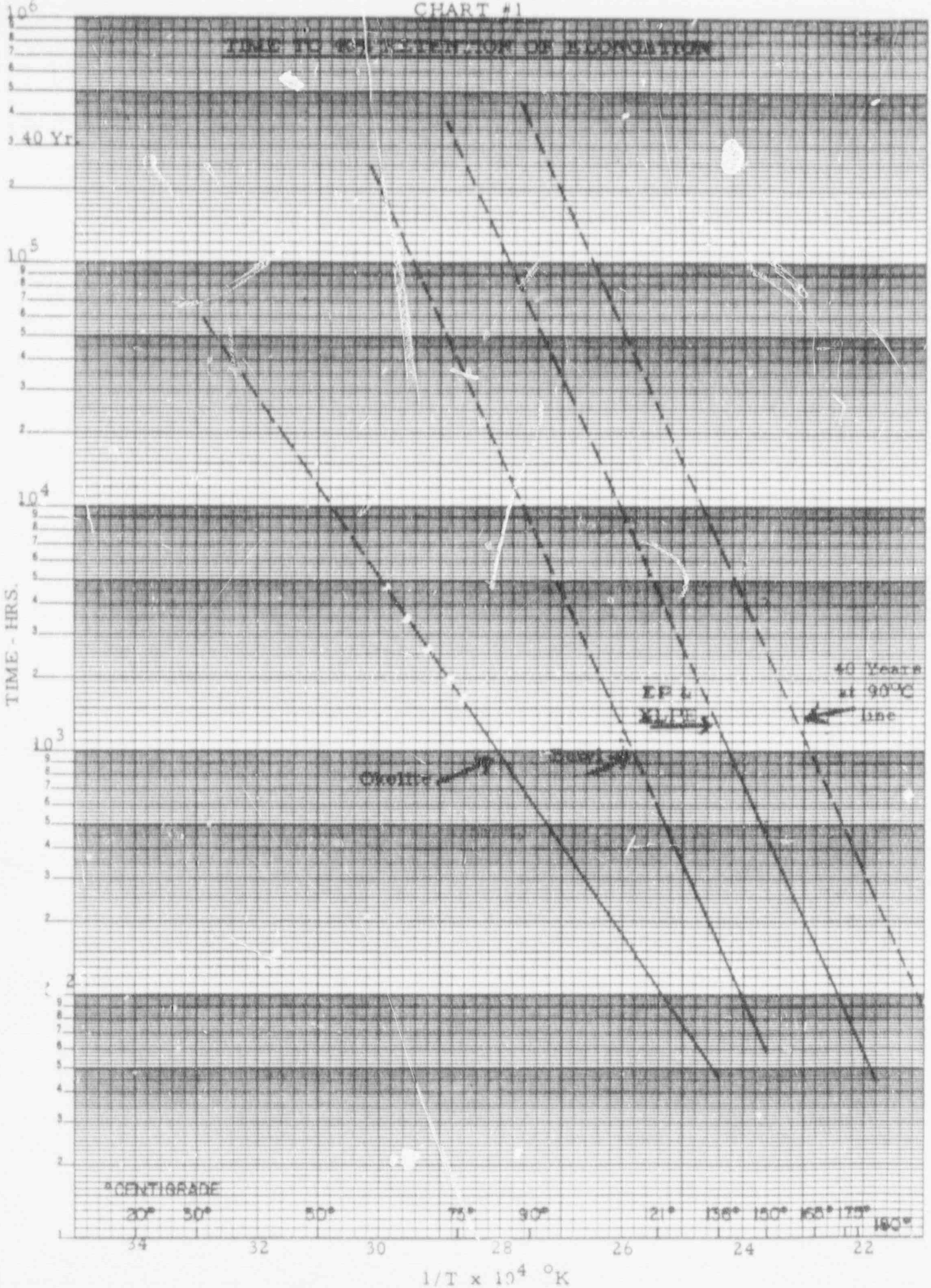
It is The Okonite Company's conviction that comparison of accelerated aging behavior of modern insulations with those of well established insulations having excellent service records is a more reliable and better method of demonstrating useful life for long time periods than the utilization of extrapolations. It is also better and more convincing from an engineering view that the utilization of the 40 year at 90°C line method described above even though the 40 year at 90°C line method described above is acceptable.

The next requirement in qualification of materials for use in a nuclear plant is the preaging to simulate 40 year life followed by irradiation and LOCA simulation per IEEE 323 and 383. The Okonite Company has presented data where preaging was performed for three weeks at 121°C and has stated that this aging period is adequate to demonstrate the point on the basis of the relative performance of EP's and crosslinked polyethylene vs. butyl. There has been considerable criticism that this aging period not fall on our experimental aging line for EP and polyethylene. The rationale for utilizing the 3 weeks at 121°C preaging for EP was that this is the time to 40% retention of butyl at 121°C. We have shown the superiority of EP and polyethylene vs. butyl and have pointed out the satisfactory service of butyl so that we feel the above pre-conditioning is adequate. In any event radiation and LOCA simulations are being performed on single conductor cables with 30 mils and 45 mil walls of insulation aged for 3 weeks at 150°C which is a point a little above the experimentally determined Arrhenius aging line.

It has been shown above that aging single conductors without jacket for 3 weeks at 150°C is more severe than aging for the times determined by the 40 year at 90°C line in jacketed form. We, therefore, maintain that the aging of 3 weeks at 150°C is more than adequate and more severe aging than is required prior to the irradiation and LOCA simulation.

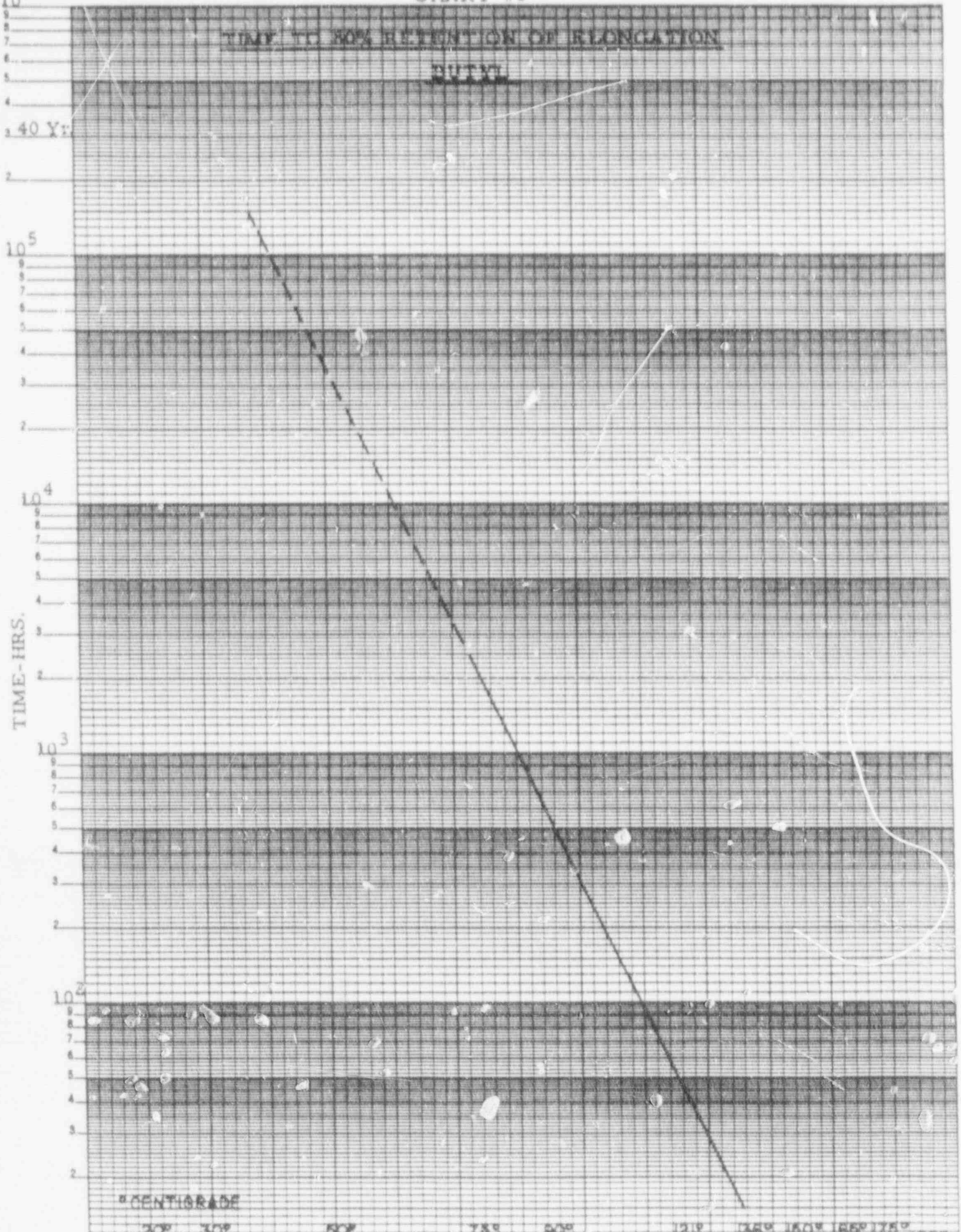
It is of interest to note that aging of three weeks at 150°C in jacketed form are less severe giving between 95 and 100% retention of elongation on EP's and crosslinked polyethylene than agings of the same insulations in unjacketed form, i.e., as bare single conductors for 3 weeks at 121°C which gave between 90 and 95% retention of elongation. Indeed aging to the 40 years at 90°C line jacketed give retention of elongation only somewhat more severe than the 3 weeks at 121°C.

CHART #1



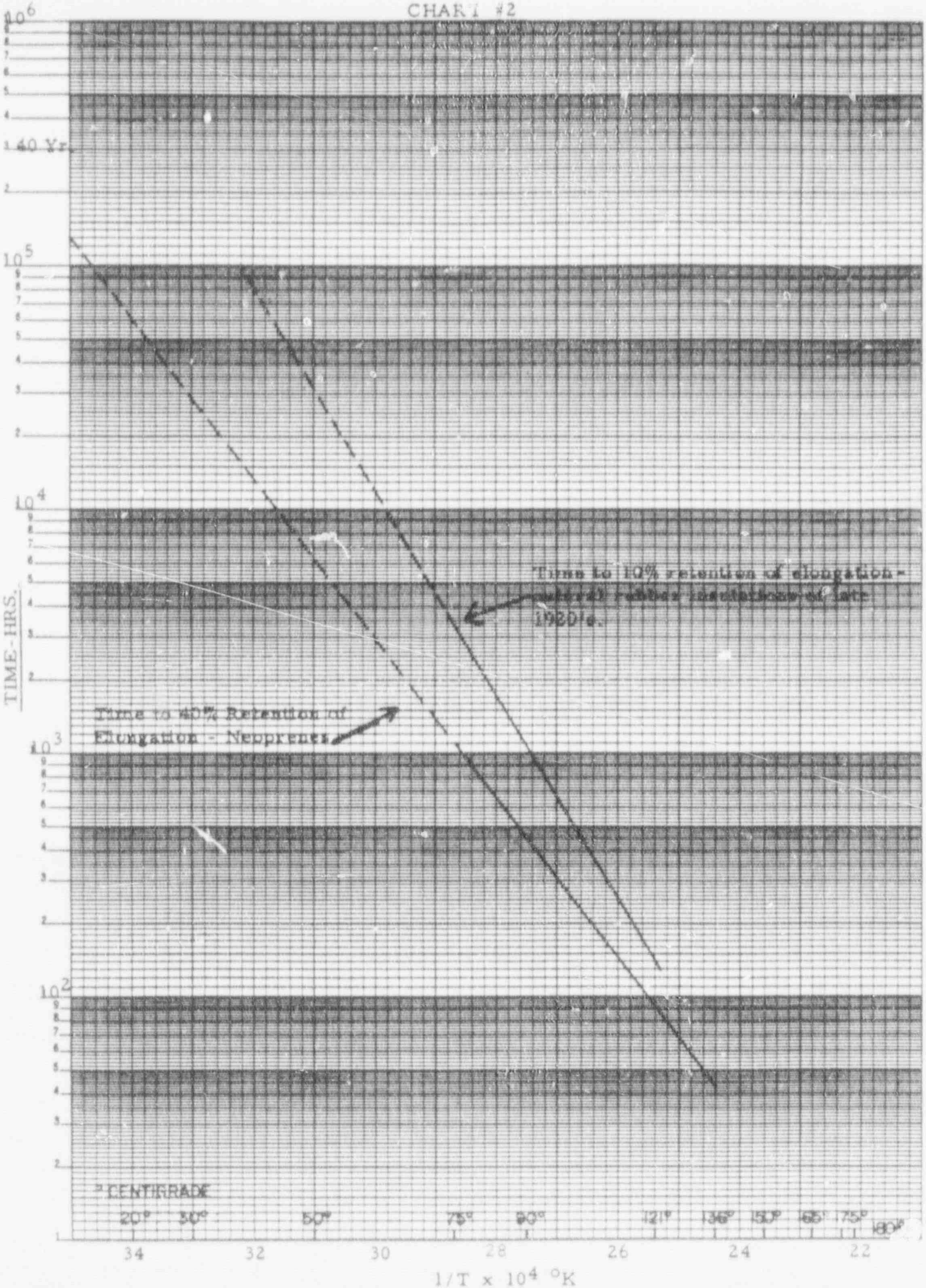
RETENTION OF ELONGATION
40 Yr.
TIME - HRS.
40 Years
at 90°C
line
EP &
XLPE
Okolite
°CENTIGRADE
20° 30° 50° 75° 90° 121° 136° 150° 165° 175° 180°
34 32 30 28 26 24 22
1/T x 10^4 °K

CHART #3



TIME TO 80% RETENTION OF ELONGATION
BUTYL
TIME-HRS.
40 Yr.
°CENTIGRADE
20°
30°
50°
75°
90°
121°
150°
165°
175°
180°
34
32
30
28
26
24
22
1/T x 10^4 °K

CHART #2



40 Yr.
TIME-HRS.
Time to 10% retention of elongation - natural rubber insulations of late 1920's.
Time to 40% Retention of Elongation - Neoprenes
° CENTIGRADE
20° 30° 50° 75° 90° 121° 136° 150° 165° 175° 180°
34 32 30 28 26 24 22
1/T x 10^4 °K

ISOMEDIX

December 27, 1976

Mr. George Dobrowsky
The Okonite Co.
Canal & Jefferson Street
Passaic, New Jersey 07055

Dear Mr. Dobrowsky:

This will summarize parameters pertinent to the irradiation of electric cable samples and splices for the Okonite Company, per your Order 9-76-509, dated December 10, 1976. A listing of samples exposed to irradiation is attached.

Samples were placed in a Cobalt-60 gamma field ranging in intensity from 0.50 to 0.58 megarads per hour, for a period of 400 hours. Cables received a minimum dose of 200 Mrad. Maximum overdose to any cable was 1.16 times the dose specified, or 232 Mrad.

The samples, mounted on flat boards, were rotated and turned during exposure to obtain the dose distribution described. Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 100°F, as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on October 16, 1975 by the Victoreen Instrument Company, using Cobalt-60 and Cesium-137 sources whose calibrations are traceable to the U.S. National Bureau of Standards. A copy of the calibration certificate is available. Backup dosimetry using a Red Perspex System confirmed the Victoreen readings.

Irradiation was completed on December 15, 1976. Samples were picked up by your personnel and transported back to Okonite on December 16, 1976.

Very truly yours,

George R. Dietz

George R. Dietz
Manager, Radiation Services

Att.
GRD:km

**Isomedix Inc.** • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address Post Office Box 177 Parsippany, New Jersey 07054

CHICAGO DIVISION • 7828 Nagle Ave., Morton Grove, Illinois 60053 (312) 966-1160

Okonite Samples for irradiation 200 Mrads

Repairs 2 factory repairs per sample

1) #12 7x .030" Okonite...............unaged & thermally aged
2) #12 7x .030" FMR X-Olene...........2 unaged, 2 thermally aged
3) #6 7x .055" Okonite, 030" Okolon..Unaged & aged
4) #6 7x semicon, .090" Okoguard, semicon, .005" copper shield....Unaged & aged

New Compounds

| | | |
|---|---|---|
| 1) | #12 7x .030" Firmer Okonite .015"CPE...... | Unaged & thermally aged |
| 2) | #12 7x .030" Firmer Okonite............... | " " " " |
| 3) | #12 7x .030" Flame Retardant Okonite...... | " " " " |
| 4) | #12 7x .030" Flame Retardant Okonite...... | " " " " |
| 5) | #12 7x .030" FMR X-Olene type............. | " " " " |
| 6) | #12 7x .030" FMR X-Olene type............. | " " " " |
| 7) | #12 7x .030" FMR X-Olene type............. | " " " " |

Field Splice

| | |
|---|---|
| 5KV #6 Okoguard Field Splice for LOCA......... | Unaged & thermally aged |
| 5KV #6 Okoguard Field Splice for test after irradiation............ | " " " " |

Plus various short samples of the above compounds and others for physical property tests after irradiation.

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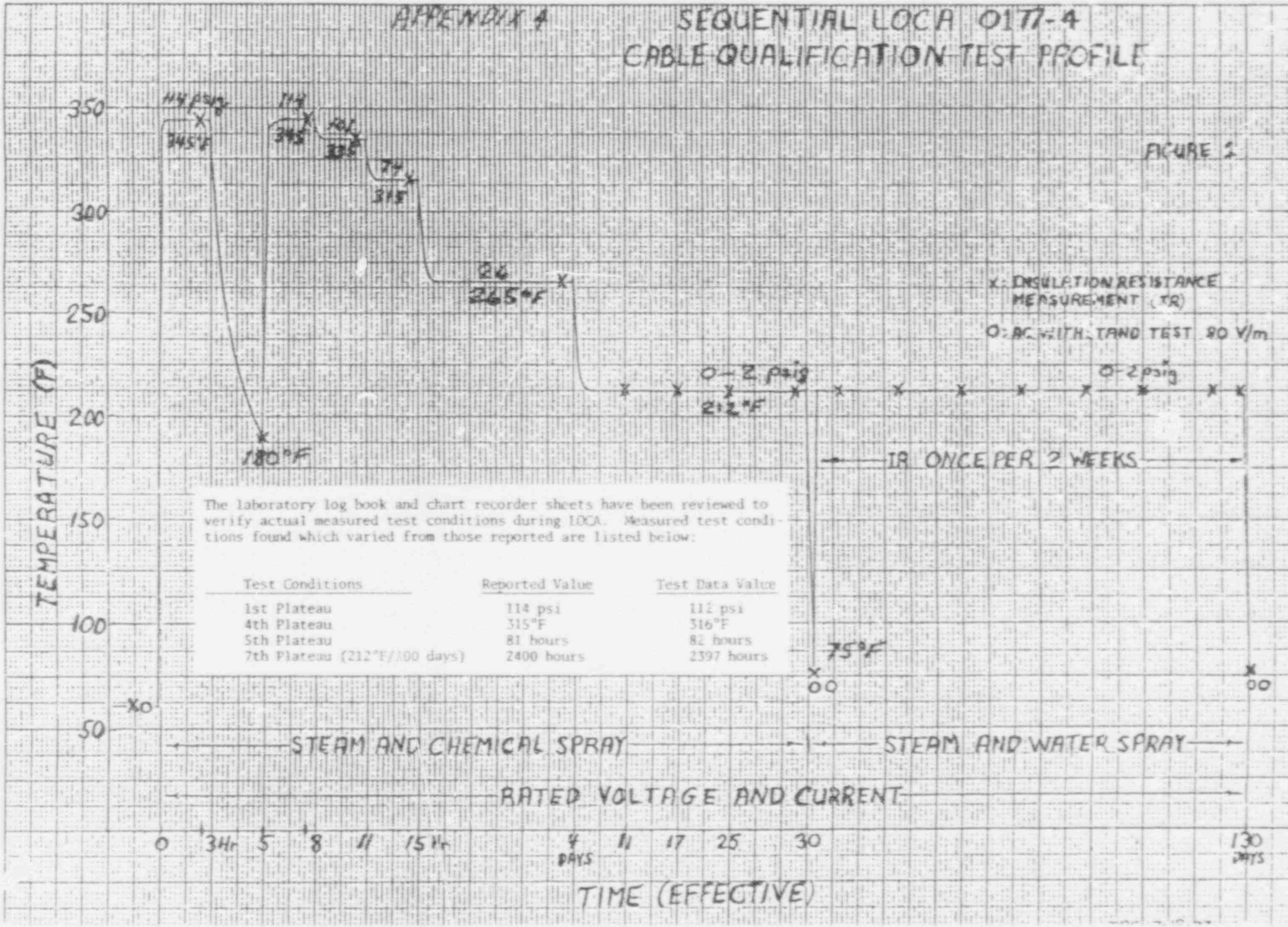
Mailing Address: Post Office Box 177, Parsippany, New Jersey 07054

CHICAGO DIVISION • 7828 Nagle Ave. Morton Grove, Illinois 60053 (312) 966-1160

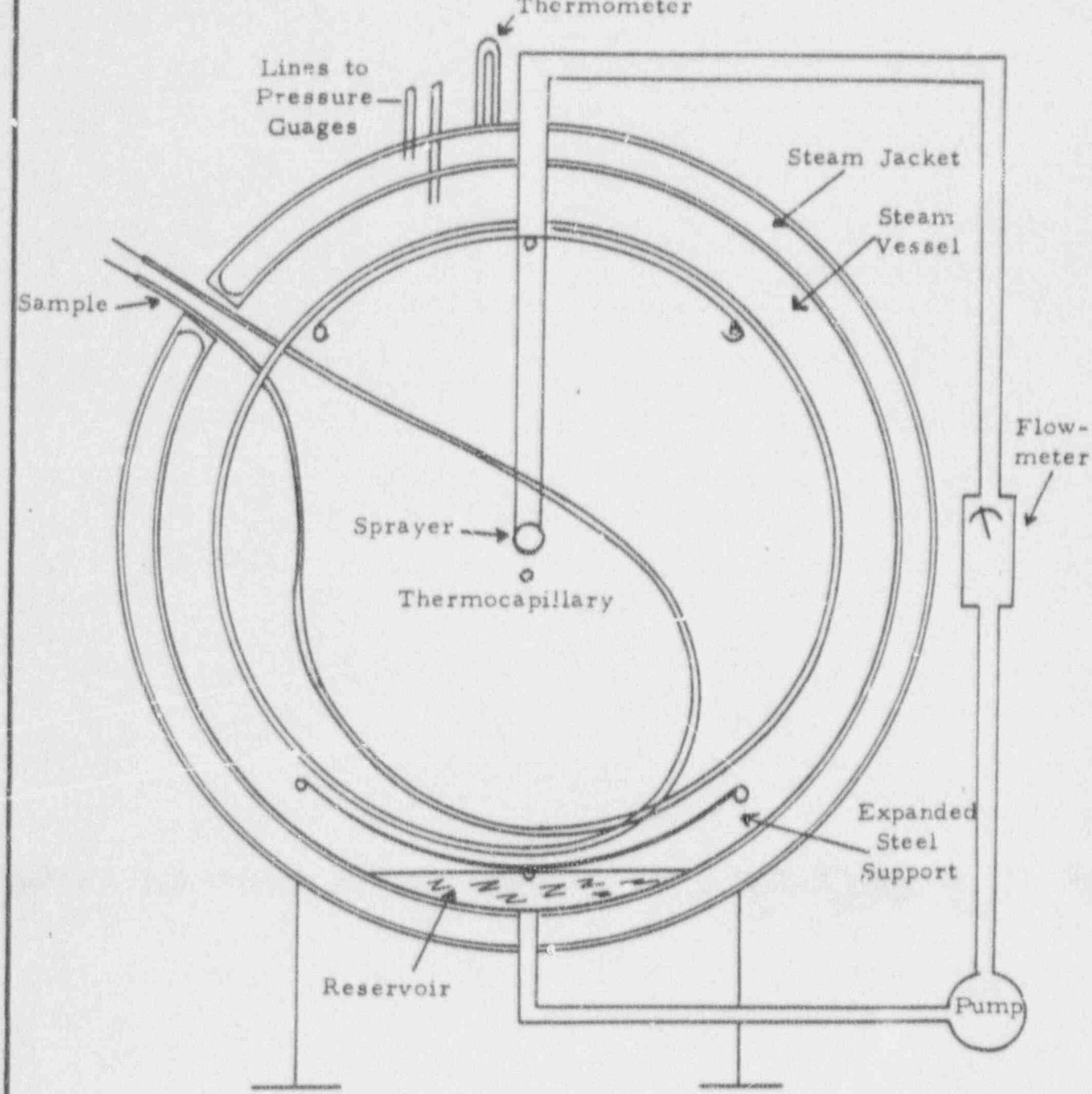
Rev 4




The laboratory log book and chart recorder sheets have been reviewed to verify actual measured test conditions during LOCA. Measured test conditions found which varied from those reported are listed below:

| Test Conditions | Reported Value | Test Data Value |
|---|---|---|
| 1st Plateau | 114 psi | 112 psi |
| 4th Plateau | 315°F | 316°F |
| 5th Plateau | 81 hours | 82 hours |
| 7th Plateau (212°F/100 days) | 2400 hours | 2397 hours |

# PHYSICAL ARRANGEMENT OF CABLE WITHIN LOCA VESSEL




THE PHYSICAL ARRANGEMENT OF CABLE WITHIN LOCA VESSEL

| THE OKONITE COMPANY RAMSEY, N.J., U.S.A. | DATE 10/6/77 | SCALE | REVISIONS B - 10/22/80 |
|---|---|---|---|
| | DR. JRC | TR. | DRAWING NO. |
| | CH. | APP. | |

THE OKONITE COMPANY
Ramsey, New Jersey 07446

APPENDIX 6

LIST OF EQUIPMENT

The Okonite Company's Quality Assurance Department maintains a program which includes as found conditions, frequency status identification, and the use of calibration standards traceable to NBS. The electrical equipment used in Okonite LOCA tests has been calibrated and certified by either Electrical Testing Laboratories or Electrical Calibration Laboratories on a yearly basis. Tolerances for each instrument were determined by The Okonite Company. The test equipment accuracies are in Okonite's Manufacturing Standard, Section 8.11.02 (7/17/79) "Equipment Calibration Accuracy and Requirements." Section 8.11.02 and calibration reports written by the above testing laboratories are available for audit by the purchaser or his authorized designates.

THE OKONITE COMPANY
Ramsey, New Jersey 07446



## LIST OF EQUIPMENT

1. Power Supplies

A. 100 kVA Testing Transformer
General Electric 0-50 kV
Serial #D938528

B. 10 kVA Transformer
General Electric 0-50 kV
Serial #2833724

C. 200 kVA Transformer
Westinghouse 0-200 kV
Serial #235,230

D. 20 kVA Transformer
Nothelfer Winding Labs., Inc., 0-100 kV
Model ID 7-67

E. 4 kVA Transformer
Hipotronics 0-20 kV
Model 720-2

F. Current Transformers - (2)
Scientific Electric

G. 2.5 kVA Transformer Power Supplies - (5)
Nothelfer Winding Labs., Inc. 0-5 kV
Model NWL 19082 - Units No. 1 through 5

H. Powerstat 0-230 volts
Superior Electric Co.
Model No. MZ 1256-2P

2. Measurement Equipment

A. Ammeters

1. Weston Multiscale Clip on AC Ammeter
0-100 amps
Model 633

2. AC Milliammeter 0-1 amp
Simpson Model 288

B. Insulation Resistance Meters

1. Leeds & Northrup Insulation Resistance Test Set
   Catalog #2100
   Galvanometer Catalog #2500F

2. Hipotronics Megohmmeter
   1 to $10^7$ MΩ Model HM 6 B
   Unit #1 - Serial #3810-1028
   Unit #2 - Serial #3810-1080

3. Associated Research, Inc.
   1 M ohm to 1 T ohm
   Unit #2 - Serial #534

4. General Radio Megohmmeter
   Model 1862
   Serial #3323

C. Capacitance & Dissipation Factor Equipment

1. High Voltage Schering Bridge
   F & G Neptun
   F #150255 MF01

2. Capacitance & Loss Factor Bridge
   Hartmann and Braun
   Model EH/G16
   Serial #25151

3. Gas Filled Standard Capacitor - 100 picofarads
   General Electric
   Serial #HV-1M-63-107-A

4. Oil Filled Standard Capacitor - 100 picofarads
   R. Jahre Berlin W35
   F. No. 6918

5. Gas Filled Standard Capacitor - 205 picofarads
   Lapp Serial 39.16

## MISCELLANEOUS EQUIPMENT

Okonite Flowmeter .150" orifice, 0-200 psig - Pressure Gauge

Cranford Sectional Oven with Honeywell Temperature Indicator
0-200 C, Model No. 18 IC, Serial #678672001

Scott Tester, Scott Tester, Inc., Model L3, Serial D 4260

LOCA Chamber 24" ID, N. Y. Engineering Co., Manufacture #57003
NB #650

Pressure & Temperature Monitoring Equipment
Taylor Instruments, Serial #D251R2231-613

THE OKONITE COMPANY

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APPENDIX 7

MOISTURE RESISTANCE

Long term moisture stability is one of the essential factors in the selection of an insulation for many applications. It is not unusual for a power cable to be required to operate in an environment alternately wet and dry. To determine the long term water stability of a cable, a sample insulated with a thin wall dielectric is immersed in water at an elevated temperature to accelerate the deteriorating effects of moisture. Monitoring the electrical properties provides an indication of long term behavior. Based upon actual experience with installed cables over many years, insulations which have the capability of withstanding total water immersion at 90C should be capable of a life in excess of a generating station's designed life in an environment of 100% humidity.

Figure I shows long term 90C water immersion on a 1/C #14 AWG Okoguard insulated cable, and Figure I-A shows comparable data on a 1/C #4/0 AWG Okoguard insulated power cable.

FIGURE I

LONG TERM MOISTURE RESISTANCE

Method: ICEA S-68-516, Section 6.21.2 except (1)water temperature at 90°C, (2) test time extended, (3) ac withstand at 110 volts ac/mil at 90°C after electrical measurements, and (4) 600 volts dc continuous stress applied.

Sample: 1/C #14 AWG Solid Copper, 0.045" Okoguard

Measurements shown below are average of three samples.

| Immersion Time | Stress Volts/mil (dc) | SIC | % PF | SIR* |
|---|---|---|---|---|
| 1 day | 40 | 2.81 | 1.89 | 849 |
| | 80 | 2.81 | 1.92 | |
| 1 week | 40 | 2.85 | 1.45 | 1220 |
| | 80 | 2.85 | 1.61 | |
| 2 weeks | 40 | 2.89 | 1.40 | 1314 |
| | 80 | 2.89 | 1.43 | |
| 1 month | 40 | 2.93 | 1.29 | 2276 |
| | 80 | 2.94 | 1.31 | |
| 2 months | 40 | 2.99 | 1.27 | 2186 |
| | 80 | 2.99 | 1.42 | |
| 3 months | 40 | 3.04 | 1.21 | 2498 |
| | 80 | 3.04 | 1.24 | |
| 4 months | 40 | 3.08 | 1.06 | 3388 |
| | 80 | 3.09 | 1.09 | |
| 5 months | 40 | 3.12 | 0.98 | 2612 |
| | 80 | 3.13 | 1.03 | |
| 6 months | 40 | 3.17 | 1.01 | 4132 |
| | 80 | 3.18 | 1.04 | |

## FIGURE 1A

## LONG TERM 90°C WATER IMMERSION

Sample: 1/C #4/0 AWG (19 x .1055) bare copper, 0.025" EP Semicon, .175 wall of Okoguard ——— 3 sample with 14.0 kV ac (80V/mil) continuous stress (EO 03-96548)

### Measurements at 90°C

| Time Period | Stress V/Mil | P.F. % | SIC Constant | SIR (meg. ohms) |
|---|---|---|---|---|
| 3 days | 40 | 2.09 | 2.99 | 505 |
| | 80 | 2.12 | 2.99 | - |
| 1 week | 40 | 1.85 | 2.97 | 673 |
| | 80 | 1.94 | 2.97 | - |
| 2 weeks | 40 | 1.71 | 2.98 | 932 |
| | 80 | 1.80 | 2.98 | - |
| 1 month | 40 | 1.88 | 2.95 | 1475 |
| | 80 | 2.03 | 2.95 | - |
| 2 months | 40 | 1.71 | 3.13 | [illegible]45 |
| | 80 | 1.77 | 3.13 | - |
| 4 months | 40 | 1.37 | 3.06 | 2881 |
| | 80 | 1.42 | 3.07 | - |
| 6 months | 40 | 1.48 | 3.07 | 3858 |
| | 80 | 1.61 | 3.07 | - |

THE OKONITE COMPANY
Ramsey, New Jersey 07446

APPENDIX 8

# FLAME TEST QUALIFICATION

for

# OKOGUARD INSULATED OKOLON JACKETED MEDIUM VOLTAGE POWER CABLE

The attached flame test summary sheets demonstrate that Okoguard insulated - Okolon jacketed medium voltage power cables are capable of meeting the flame test requirements of IEEE Standard 383-1974, Section 2.5. Several tests have been performed to demonstrate compliance to the IEEE flame test requirements for a wide variety of Okoguard-Okolon constructions.

# VERTICAL TRAY FLAME TEST
## IEEE STANDARD 383-1974

Criteria: The flame test should demonstrate that the cable does not propagate fire even if its outer covering and insulation have been destroyed in the area of flame impingement.

Test Specimens: Test specimens are specified in the attached table.

Fire Test Facility and Procedure: The test should be conducted in a naturally ventilated room or enclosure free from excessive drafts and spurious air currents. The tray is a vertical, metal, ladder type tray, 3" deep, 12" wide, and 8' high. Multiple lengths of cable are arranged in a single layer filling at least the center six inch portion of the tray with a separation of approximately 1/2 the cable diameter between each cable.

The flame source is a gas ribbon burner manufactured by the American Gas Furnace Company -- 10" wide, 11-15 drilling ribbon type Cat. No. 10 X11-55 with a Venturi mixer Cat. No. 14-18 (2 psig max.) The burner is mounted horizontally such that the flame impinges on the specimen midway between the tray rungs and so that the burner face is 3" behind and approximately 2' above the bottom of the vertical tray. Due to its uniform heat content, natural grade propane is preferred to commercial gas.

Under dynamic conditions, the propane pressure is $-2.6 \pm 0.3$ cm of water at the supply side of the Venturi mixer. The air pressure is set at $4.3 \pm 0.5$ cm of water. If commercial gas is used the gas and air pressures shall be $-0.9 \pm 0.1$ and $5.6 \pm 0.5$ cm of water, respectively. In practice the flame length is approximately 15 inches long when measured along its path.

The gas burner is ignited and allowed to burn for 20 minutes. The impingement temperature is recorded throughout the test. Length of time the flame persists after the burner is shut off (afterburn), jacket char distance, and insulation damage distance are measured and recorded.

Evaluation: Cables which propagate the flame and burn the total length of the tray above the flame source fail the test. Cables which self-extinguish when the flame source is removed pass the test. Cables which continue to burn after the flame source is shut off should be allowed to burn in order to determine the extent.

## 15 kV Okoguard Shielded Okolon

Specimen:

(A) 1/C 250 MCM (37x) BC, extruded strand screen, .220 Okoguard insulation, extr. insulation screen, .005 tinned copper tape, .080 Okolon jacket (FL-141, 228)

(B) 3-1/C triplexed 250 MCM ([illegible]) BC, extr. [illegible] .220 Okoguard insulation, extr. insulation screen, .00[illegible] tape, .080 Okolon jacket (FL-196)

(C) 3/C #4/0 (19x) BC, extr. SS, .175 Okoguard insulation, extr. insulation screen, .005 TC tape, cabled with fillers, .110 Okolon jacket (FL-96)

Results:

| | | A | B | C |
|---|---|---|---|---|
| Afterburn, | minutes | 0 | 0 | 0 |
| Jacket Damage, | inches | 21 | 23 | 25.5 |
| Core Damage, | inches | 0 | 0 | 0 |
| Propagate | | No | No | No |
| | | Avg. of 2 tests | | |

Test: IEEE Standard 383-1974, Paragraph 2.5

Flame Source: Ribbon Gas Burner

Sample Construction: 1/C #4/0 (19x) CC, strand screen, .140" Okoguard insulation, insulation screen, .005" TC shielding tape, cable tape, .080" Okolon jacket (FL-199, 200, and 201)

| Results: | Test 1 | Test 2 | Test 3 |
|---|---|---|---|
| Afterburn, minutes; seconds | 1:05 | 0 | 0 |
| Jacket damage, inches | 28 | 25 | 26 |
| Core damage, inches | 12 | 4 | 12 |
| Propagate | NO | NO | NO |

## 1/C, 5 & 15kV Okoguard Constructions

**Construction A:** 1/C #2 AWG, extruded strand screen, .125" Okoguard insulation, .080" Okolon jacket - non-shielded

**Construction B:** 1/C, 4/0 AWG copper, extruded strand screen, .175" Okoguard insulation, extruded insulation screen, copper tape, .080" Okolon jacket

**Flame:** 70,000 BTU per hour

| Test Time, Minutes | Flame Height, (Inches) A | B |
|---|---|---|
| 1 | 27 | 27 |
| 2 | 20 | 25 |
| 3 | 33 | 24 |
| 4 | 34 | 27 |
| 5 | 33 | 26 |
| 6 | 33 | 27 |
| 7 | 32 | 28 |
| 8 | 29 | 28 |
| 9 | 29 | 28 |
| 10 | 28 | 28 |
| 11 | 28 | 28 |
| 12 | 30 | 27 |
| 13 | 29 | 26 |
| 14 | 29 | 26 |
| 15 | 29 | 26 |
| 16 | 30 | 27 |
| 17 | 30 | 29 |
| 18 | 29 | 27 |
| 19 | 28 | 32 |
| 20 | 28 | 34 |

| | A | B |
|---|---|---|
| Afterburn, min:sec | 3:05 | 1:05 |
| Core Damage, inches | No Measured | 27 |
| Jacket Char, inches | 25 | 29 |
| Propagate | No | No |

## 1/C 5kV Okoguard Shielded Okolon

Specimen: A - 1/C 750 MCM (61 X) bare copper, extruded strand screen, .090" Okoguard, extruded insulation screen, .005" tinned copper, cable tape, .080" Okolon jacket (FL-179)

B - 1/C 250 MCM (37 X) bare copper, extruded strand screen, .115" Okoguard, extruded insulation screen, .005" tinned copper cable tape, .080" Okolon jacket (FL-132)

Flame Source: 70,000 BTU/hour -- 20 minute application

Results:

| | A | B |
|---|---|---|
| Impingement Temperature, °F | 1400 to 1500 | 1400 to 1490 |
| Afterburn, minutes | 0 | 1 |
| Jacket Damage, inches | 26 | 26 |
| Core Damage, inches | 0 | 12 |

# FLAME TEST DATA

Test: IEEE 383-1974, Paragraph 2.5

Flame Source: Ribbon Gas Burner, 70,000 BTU/hr.

Construction: 1/C #2/0 AWG, 19X BC, SS, .115" Okoguard, .030" Semicon, .005" Cu Tape, Cable Tape, .080 Okolon.

Test Results:

| | A | B | C |
|---|---|---|---|
| Measured BTU rate | 71,051 | 71,051 | 70,116 |
| Afterburn, min: | 10 | 11 | 9 |
| Jacket Damage, in. | 24 | 25 | 23 |
| Core Damage, in. | 14 | 15 | 14 |
| Propagation | No | No | No |

THE OKONITE COMPANY
Ramsey, New Jersey 07446

R4

# APPENDIX 9

## INSULATION RESISTANCE
## Megohm - 1000 ft.

### Okoguard Cable With T-95/No. 35 Splice

| Time & Temperature | Unaged | | Aged | |
|---|---|---|---|---|
| Initial (pre-irradiation) @ 68°F | 2.1 | E4 | 3.0 | E4 |
| Pre LOCA @ 60°F | 1.4 | E4 | >1.5 | E4 |
| First Peak @ 344°F | 1.5 | E0 | 8.8 | E-1 |
| Between Peaks @ 208°F | 6.0 | E1 | 5.3 | E1 |
| 2nd Peak @ 345°F | 7.5 | E-1 | 5.1 | E-1 |
| Plateau @ 335°F | 8.3 | E-1 | 6.2 | E-1 |
| Plateau @ 315°F | 1.1 | E0 | 9.5 | E-1 |
| After 1 day, 265°F | 5.1 | E0 | <1.5 | E-3 @ 50V* |
| After 4 days, 265°F | 4.1 | E0 | <1.5 | E-3 @ 50V* |
| After 11 days, 212°F | 3.6 | E1 | <1.5 | E-3 @ 50V* |
| After 17 days, 212°F | 4.5 | E1 | <1.5 | E-3 @ 50V* |
| After 25 days, 212°F | 5.0 | E1 | <1.5 | E-3 @ 50V* |
| After 29 days, 212°F | 5.1 | E1 | <1.5 | E-3 @ 50V* |
| After 30 days, 80°F | 3.8 | E3 | <1.5 | E-3 @ 50V* |
| After 35 days, 212°F | 5.7 | E1 | 8.4 | E1 |
| After 49 days, 212°F | 6.0 | E1 | 9.8 | E1 |
| After 63 days, 212°F | 7.5 | E1 | 1.1 | E2 |
| After 77 days, 212°F | 9.0 | E1 | 1.3 | E2 |
| After 91 days, 212°F | 7.5 | E1 | 1.1 | E2 |
| After 105 days, 212°F | 9.0 | E1 | 1.3 | E2 |
| After 121 days, 212°F | 9.8 | E1 | 1.3 | E2 |
| After 128 days, 212°F | 9.9 | E1 | 1.3 | E2 |
| After 130 days, 80°F | 5.3 | E3 | 4.8 | E3 |

* After the sample was removed from the test vessel it was determined that the poor IR was the result of a terminal failure. Sample was reterminated and test was continued.

All IR tests were performed at 500 volts dc unless otherwise indicated.

Prepared by: J R Cancelosi 10/24/88
J. R. Cancelosi

Approved by: J S Lasky 10/24/88
J. S. Lasky

## APPENDIX 10

## ANOMALIES

Anomalies which occurred during environmental qualification test are listed below.

(1) The rise time to 280°F was approximately 30 seconds.

Discussion: IEEE 323-1974 Appendix A, Figure A1, suggests a 10 second rise to 280°F. This anomaly was not deemed significant since electrical cable is a passive electrical device (i.e., no moving parts). As such, rate of temperature rise is not considered significant.

(2) A temperature excursion occurred during the 79th hour. The test vessel temperature rose from 265°F to 293°F and remained at this temperature for approximately five hours.

Discussion: This event made the LOCA sequence more severe than designed. No adjustment to the test was necessary.

(3) The continuous stress voltage was off for the first twelve hours at 265°F on both the aged and unaged samples.

Discussion: The twelve hour loss of voltage on both samples is less than 0.4% of the total test time and is therefore considered insignificant.

(4) The continuous stress voltage and current was disconnected from the aged sample from the twelve hour point during the 265°F plateau until the thirty day point.

Discussion: The voltage and current load was disconnected because of a termination failure. The termination failure could not be cleared until the vessel was unloaded at the thirty day point. The aged specimen was reterminated, passed the 30 day "Post LOCA Withstand Test" and returned to the test vessel for continuation of the test.

Environmental qualification was not jeopardized due to this unscheduled event because of the following reasons:

(a) During the time voltage was applied, the test voltage was much higher than required. The test voltage was 5kV phase to ground. IEEE 383 requires that the specimens be energized to rated voltage. The cables rated voltage is 5kV phase to phase. The required test voltage is 2.89kV phase to ground (shield). Although the test under voltage stress was reduced by approximately 29/130 or 22.3%, the voltage stress was 73% higher than required. The higher stress more than compensates for the reduction in time.

(b) If the specimen was in a marginal condition, it could be argued that the 29 days under an electrical load could possibly have been the difference between passing or failing the test. However, this was not the case. An examination

APPENDIX 10 (Continued)

of the electrical and physical measurements reveals that the sample was in good condition with plenty of margin at the end of the 130 day test. In particular, insulation resistance measurements of the unaged and aged specimens during and after LOCA were similar. At 212°F the insulation resistance was in the hundred megohm-1000 ft. range. Post-LOCA SIR corrected to 60°F was approximately 40,000 M ohms-1000 ft. The guaranteed value for this insulation when new is 50,000. During the Post-LOCA 40xOD bend withstand test, a charging current of only 2.5mA was measured. This value is similar to that expected from new cable. In addition, the rising voltage breakdown strength for the aged specimen was 48kV, approximately 16 times higher than the phase to ground rating of the cable.

Physical tests also demonstrate the margin available at the end of the test. Both the unaged and irradiated and the thermally aged and irradiated specimens had similar tensile and elongation values prior to LOCA (i.e., after irradiation to $2 \times 10^8$ rads). Tests performed after LOCA simulation demonstrate similar changes between the unaged sample, which was continuously loaded, versus the thermally aged samples which saw the interruption of the electrical load.

| | Unaged | Thermally Aged |
|---|---|---|
| After $2 \times 10^8$ rads | | |
| Tensile, % Retention | 121 | 113 |
| Elongation, % Retention | 33 | 30 |
| After LOCA Simulation | | |
| Tensile, % Retention | 103 | 95 |
| Elongation, % Retention | 41 | 52 |

Prepared by: J R Cancelosi 3/27/87
J. R. Cancelosi

Approved by: J S Lasky 3/30/87
J. S. Lasky