Raychem
Energy Division

Report

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ANALYSIS OF HEAT AGING DATA ON -52 MOLDING MATERIAL TO DETERMINE PRE-AGING CONDITIONS FOR NUCLEAR QUALIFICATION TESTING.	Enclosures:

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1. OBJECTIVE

The objective of this report is to present and analyze the Arrhenius data obtained in a heat aging study of -52 molding material to determine pre-aging conditions for qualifying parts made from the material to IEEE Standard 383-1974[(1)] and IEEE Standard 323-1974.[(2)]

2. SUMMARY

IEEE 383-1974 requires components to be pre-aged to a condition equivalent to the design life of the nuclear generating station before exposure to a simulated design basis event (DBE). This report describes these requirements, outlines the heat aging test procedure, presents and analyzes the results using Arrhenius plots and discusses end-point criterion to determine the time-temperature relationship for this pre-aging.

3. CONCLUSIONS

A time-temperature relationship, based on Arrhenius plotting, has been established for -52 molding material which satisfies the requirements of IEEE 383-1974 for establishing the qualified service life of molded parts and for accelerated pre-aging of materials before exposure to radiation and DBE tests.

4. INTRODUCTION

An extensive study on the aging characteristics of the -52 molding material used for molded parts for nuclear applications has been conducted. This report documents the times required for the ultimate elongation of this material to decrease when die cut specimens were exposed to temperatures between 136°C and 175°C. The values are given in percent retention of the original value and cover the range of 70 percent to 30 percent.

These data have been analyzed using a 30 percent retention of elongation as the end point. The resulting Arrhenius plot, when adjusted to an end of life of 40 years at 90°C, yields a series of times at various temperatures for pre-aging the material.

5. REQUIREMENTS

The requirements for electric cables and related materials such as splice insulating parts for nuclear power plants are given in IEEE 383-1974. This document states that "type tests for design basis event conditions should consist of subjecting nonaged and aged cables, field splices, and connections to a sequence of environmental extremes which simulate the most severe postulated conditions of a design basis event and specified conditions of installation."

The aging requirement is further explained in another section of IEEE 383-1974 which states, "The basis for establishing time and temperature conditions for aging of samples to simulate their qualified life may be that of Arrhenius plotting or other method of proven validity and applicability for the materials in question."

It is generally specified that the design life of a nuclear generating station is 40 years and that the majority of the cables used in the plant are rated for a 90°C conductor temperature. Actual conductor operating temperatures typically will be lower than 90°C in use due to lower than "maximum design" ambient temperatures and cable derating practices. Also molded parts are typically not in contact with the actual conductor itself. It is conservative to assess the aging performance of the -52 molding material at the rated conductor temperature. The cables and splice systems must, therefore, be aged to the equivalent of 40 years life at 90°C before being subjected to the radiation and design basis event required by the standards. Since unaged systems must also be tested to the same radiation and design basis event conditions, a cable system passing the tests in both the aged and unaged condition would be qualified for the design life of the plant.

6. TEST PROCEDURE

6.1 Specimen Preparation

Standard, pelletized, virgin -52 molding compound was used. Slabs (6" x 6") were compression molded to a thickness of 0.075 inches. The slabs were cured in-situ to the same crosslink density specification as molded parts. Fifty slabs were prepared. Two Die D specimens from each slab were tested for tensile strength, ultimate elongation and tensile stress at 50 percent and 100 percent elongation (crosshead speed 2 inches per minute). The stress-strain values from this were averaged and used as the original values to which the heat aged samples were compared.

Standard deviations for tensile strength, ultimate elongation and tensile stress at 50 percent and 100 percent elongation were calculated based on the original data from the two Die D specimens from each slab. Slabs were discarded if the above original stress-strain values were outside the mean value ± twice the standard deviation for that value.

From the acceptable slabs, Die D specimens were cut and all combined. Five Die D specimens were chosen at random from the combined lot to provide each data point for the heat aging study.

6.2 Oven Aging

Forced air type ovens were used for heat aging at 136°C, 150°C, 162°C and 175°C. The ovens were calibrated with a 12 point recording thermocouple set-up at 12 different zones in the oven chamber. The temperature was monitored regularly with a single thermocouple permanently assigned to each oven. The temperature variation was less than + 2 percent of the specified exposure temperature in degrees centigrade.

The specimens, in groups of five, were hung vertically from the oven tray utilizing metal clips and hooks.

Groups of five specimens were periodically removed from each of the ovens and the elongation measured at a crosshead speed of 2 inches per minute[3]. The retention of elongation was calculated and the values plotted as shown in Figure 1. From this plot, the time corresponding to a specific retention of elongation could be found. This information is given in Table 1.

A list of data acquisition equipment and calibration information is given in Appendix A.

7. ARRHENIUS PLOTTING

When the times to reach a selected end point at several temperatures are plotted on a graph with the logarithm of time as the ordinate and the reciprocal of the absolute temperature as the abscissa, it is said to be an Arrhenius plot. The IEEE standards do not state which end point should be selected. Therefore, it becomes important to choose one that is consistent with the application. There are many possible parameters which can be used to select end point criteria, such as retention of elongation, retention of tensile strength, retention of dielectric strength, and voltage withstand tests after a mandrel bend test. It is also possible to select an end point not based on percent retention of the original properties but on a specific value of elongation or dielectric strength after aging.

For the work described in this report, a retention of 30 percent of the original elongation was chosen. The reason for this choice was that this end point left a wide margin of safety and was a logical end point for a material study. Since the ultimate elongation of the -52 material in the unaged state is typically over 500 percent, a retention of 30 percent of the original value would still give an ultimate elongation value of over 150 percent. This is well in excess of the amount of elongation needed for any functional purpose. Some wire insulation in general use has less than this amount of elongation initially or as manufactured.

For clarification, the results presented in Table 1 for 30 percent retention of elongation are given in Table 2. Using these results an Arrhenius plot has been drawn and is shown in Figure 2.

8. DETERMINATION OF ACCELERATED AGING CONDITIONS

An extrapolation of the data based on linear regression analysis indicates that the material will retain 30 percent of its initial elongation after 40 years at 103°C, a temperature 13°C above its required rated temperature. Therefore, to determine appropriate accelerated aging conditions for the purpose of pre-aging specimens for DBE tests, a line may be drawn which passes through the point corresponding to 40 years at 90°C and is parallel (i.e., same heat of activation) to the life curve. Such a line is shown as Curve B of Figure 2. Now, any point along Curve B represents a time-temperature combination that may be used to pre-age specimens to simulate end of life conditions for DBE tests. A few such conditions are given in Table 3. It can be seen that an aging time of 862 hours at 150°C is a practical and valid set of conditions for accelerated pre-aging based on a design life of 40 years at 90°C.

9. TABLES AND GRAPHS

TABLE 1 Oven Aging Data For -52 Molding Material

Oven Temperature (°C)	Time (h) to Various Levels of Retained Elongation				
	70%	60%	50%	40%	30%
136	920	2750	5800	8600	11600
150	510	1200	2025	2675	3225
162	160	525	1000	1225	1350
175	40	160	260	350	450

TABLE 2 Time-Temperature Relationship of -52 Molding Material Using 30 Percent Retention of Elongation

Temperature (°C)	Time (h)
175	450
162	1350
150	3225
136	11600

TABLE 3 Aging Times and Temperatures Needed To Satisfy a 40 Year Life at 90°C Requirement

Temperature (°C)	Time (h)
175	116
162	342
150	862
136	2956

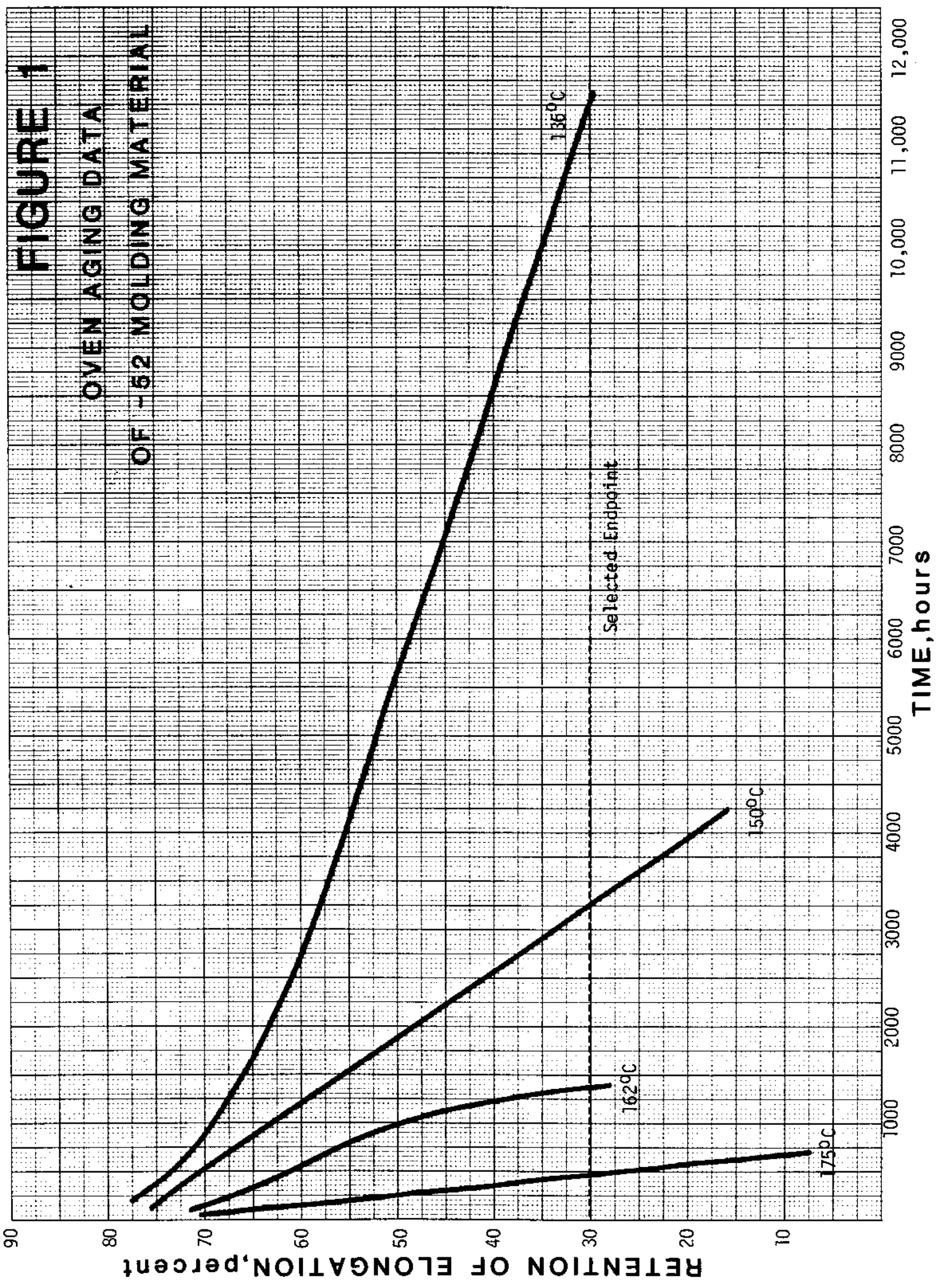

FIGURE 1
OVEN AGING DATA
OF -62 MOLDING MATERIAL

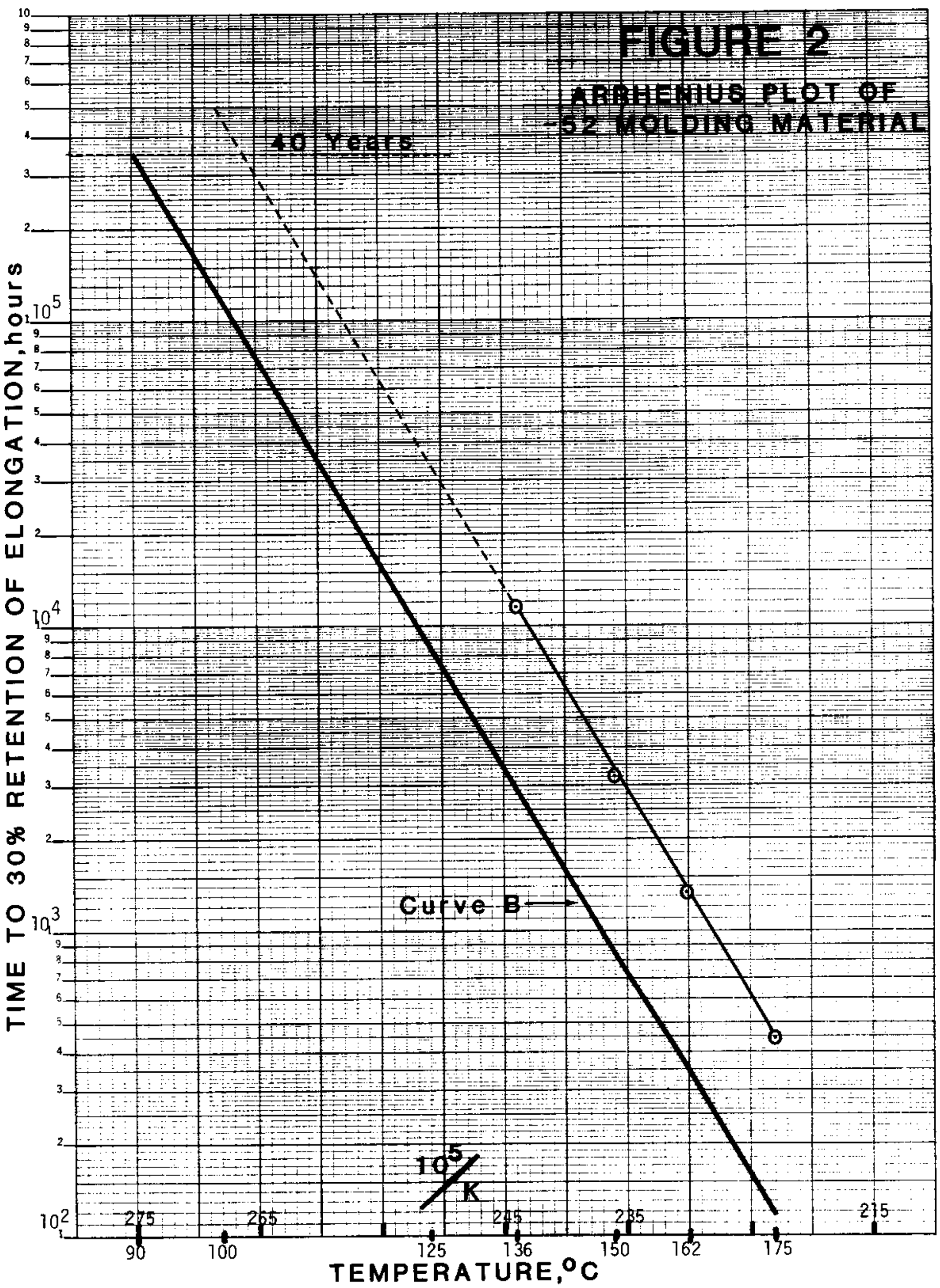
FIGURE 2
ARRHENIUS PLOT OF
-52 MOLDING MATERIAL
40 Years
Curve B
10^5/K
TIME TO 30% RETENTION OF ELONGATION, hours
10^5
10^4
10^3
10^2
275
265
245
235
215
90
100
125
136
150
162
175
TEMPERATURE, °C

10. REFERENCES

(1) IEEE Standard 383-1974, "IEEE Standard for Type Test of Class Electric Cables, Field Splices, and Connections for Nuclear Power Generation Stations."

(2) IEEE Standard 323-1974, "IEEE Standard for Qualifying IE Equipment for Nuclear Power Generating Stations."

(3) Raychem Laboratory Notebook 3980
Raychem Physical Test Laboratory Notebooks 307, 313, 314, 322

APPENDIX A

LIST OF DATA ACQUISITION EQUIPMENT

INSTRUMENT	MFG	SERIAL NO.	MODEL NO.	RANGE
Temperature Recorder	Honeywell	D8210735001	16303846/324-162	0-300°C
Instron (Calibration Weight)	Instron	-------	-------	5 Lb.
Indicating Pyrometer 7055	Lee Corp.	-------	7055	0-500°F

The instruments listed above were calibrated against standards traceable to the National Bureau of Standards or an acceptable natural physical standard per MIL-I-45208A and MIL-C-45662A requirements.