IPS-325 REV D

DESIGN QUALIFICATION

MATERIAL TEST REPORT

FOR

MATERIALS USED IN CONAX

ELECTRIC PENETRATION ASSEMBLIES

AND

ELECTRIC CONDUCTOR SEAL ASSEMBLIES

CONAX®

NUCLEAR PRODUCTS DIVISION

B/1

IPS-325 REV D.

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ELECTRIC PENETRATION ASSEMBLIES

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CONAX CORPORATION

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CONAX CORPORATION
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Nuclear Products Division

NUCLEAR

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FOR
MATERIALS USED IN CONAX
ELECTRIC PENETRATION ASSEMBLIES
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MAY 22 1981

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No. IPS-325

REVISION RECORD

REV.	AFFECTED PARAGRAPHS	BRIEF DESCRIPTION OF REVISION	DATE	APPROVAL SIGNATURE
Orig.	All	Original Release		
A	All	Major up-date	E.O. N-0928 8/15/79	W.C. Federick W.C.Federick Project Engineer
B	Para. 2.0	Added references 2.18, 2.19 & 2.20	E.O. N-0934 8/24/79	W.C. Federick W.C.Federick Project Engineer
	Para. 5.1.3.1	Changed Ref. "2.11" to "2.12"		
	Para. 5.2.3.1	Changed ref. "2.11" to "2.10"		
	Para. 5.2.3.1 (A)	Changed first sentence		
	Para. 5.3.2.1	Changed "mistures" to "mixtures" & reworded last sentence		
	Para. 5.5	Renumbered subsections, deleted Section 5.5.3 and added section on radiation resistance		
	Para. 8.2	Reworded last sentence		
C	Para. 2.0	Added references 2.21 & 2.22	E.O. N-0995 11/2/79	W.C. Federick W.C Federick Project Engineer
	Para. 5.4.2	Deleted 5.4.2.1 B and Figure 5.4.2.2 Revised 5.4.2.1 A and 5.4.2.2 Added 5.4.3 and Fig. 5.4.3.1		
	Figure 6.2.1 & 6.2.2	Typed Figure heading number		
	Para 6.4.3 B	Changed real to seal		
	Appendix A	Added		
	Para. 2.16,3.2, 5.2.2,5.2.3, 5.3.2,6.1,6.2, 6.3	Capitalized Trade Names		
	Para. 5.2	Added footnote		
	Para. 5.2.1.1	Corrected 1st sentence		
	Para. 5.2.2.1	Added footnote		
	Para. 8.1	Changed "retentable" to retentive"		

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REVISION RECORD

REV.	AFFECTED PARAGRAPHS	BRIEF DESCRIPTION OF REVISION	DATE	APPROVAL SIGNATURE
D	Where required	Corrected miscellaneous spelling and typing errors	E.O. N-1514 5/14/81	W.C Federick W.Federick Proj.Engr.
	Abstract	Added		
	2.0	Deleted&added 2.13;added 2.23, 2.24, & 2.25.		
	Table 3.1	Revised Kapton formula; added Viton & GDI-30F		
	5.1	Deleted 5.1.3.2		
	5.2	Added 5.2.1.4; revised 5.2.3.1(250°C to 200°C)		
	5.5	Added 5.5.1 Fire Resistance; revised orig. 5.5.1 to 5.5.2; added 5.5.2.3 & Table 5.5; revised orig. 5.5.2 to 5.5.3		
	5.6	Added GDI-30F		
	6.4.2	Revised 5537 hours to 15852 hours		
	Appendix A	Updated to include 9/C #6AWG 4" sealant end data & to-date test hour accumulation; revised curves to include 1/°K curves		

Abstract

This document addresses design qualification of Conax electric penetrations and conductor seal assemblies from the standpoint of material tests. As a minimum, the materials used in the construction of Conax penetrations and conductor seal assemblies are discussed as required by section 6.3 of IEEE Std. 317-1976. It should be emphasized that this document is not a type test design qualification report as addressed by section 6.4 of IEEE Std. 317-1976.

Briefly, the format of this document is as follows: identification of materials used, raw material tests, compatibility of raw materials, and evaluation. Appendix A of this document addresses Conax's thermal evaluation program.

TABLE OF CONTENTS

1.0 SCOPE

This document describes tests performed by Conax and by others on materials used in Conax Electric Penetrations. These tests satisfy the objectives of IEEE 317-1976 Section 6.3, Material Test.

2.0 REFERENCE DOCUMENTS

2.1 [redacted]

2.2 [redacted]

2.3 [redacted]

2.4 Deleted.

2.5 [redacted]

2.6 [redacted]

2.7 [redacted]

2.8 Raychem - Addendum, Raychem Report #71100, Revision 1 "Heat Shrinkable Products for Nuclear Power".

2.9 Bugel, T.E., "Testing for Thermal Endurance: A Case History Based on Polysulfone Thermoplastic", Union Carbide Process Data, Reprinted from SPE Journal, Vol. 24, No. 3, March, 1968, pp. 52-55.

2.10 Elliot, D.K., "A standardized Procedure for Evaluating the Relative Thermal Life and Temperature Rating of Thin-Wall Airframe Wire Insulation", IEEE Transactions on Electrical Insulation, Vol. EI-7, No. 1, March, 1972.

2.11 Lewis, L.L., "Kapton' Polyimide Film a Thin Wall High Temperature Insulation for Wire and Cable". A paper presented at the Fourteenth Annual Symposium on Technical Progress in Communication Wires and Cables, December, 1965.

2.12 Union Carbide Technology Letter, Udel Polysulfone, Number 101, September 22, 1976, "The Radiation Response of Udel Polysulfone".

2.13 [redacted]

2.14 CERN, "Effects of Radiation on Materials and Components, Lectures Given (by M.H. Van de Voorde) in the Academic Training Programme of Cern 1968-1969".

2.15 Lewis, L.L., "Life vs. Aging Temperature 'Kapton' Polyimide Film Insulated Wire", 11-14-72.

2.16 Union Carbide Technology Letter, Engineering Polymers, Number 107, May 17, 1977, "Udel Polysulfone Combustion Characteristics".

2.17 [redacted]

2.18 Parker Seal Company, "O" Ring Handbook, 1977.

2.19 [redacted]

2.20 IEEE Std. 317-1976, Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.

2.21 The Franklin Institute Research Laboratories, Final Report F-C4033-3 "Tests of Raychem Thermofit Insulation Systems Under Simultaneous Exposure to Heat, Gamma Radiation, Steam and Chemical Spray while Electrically Energized Prepared for Raychem Corporation Menlo Park, California", January 1975.

2.22 Raychem Energy Division, EDR 2001, "Heat Aging Study of WCSF Compound", August 10, 1978.

2.23 "DuPont Viton Bulletin A-99064", E.I. DuPont de Nemours & Co. (Inc.), Elastomer Chemicals Department.

2.24 [redacted]

2.25 [redacted]

3.0 GENERAL INFORMATION

3.1 This document presents individual material testing, material compatibility testing, and a description of how the scope has been acceptably satisfied.

3.2 The materials qualified in this document are used in Conax's Instrumentation, Low Voltage Power and Control, and Medium Voltage Power service classification Electric Penetrations as well as Electric Conductor Seal Assemblies.

3.3 Table 3.1 is a listing of the materials, a description of each material, and their function.

Table 3.1

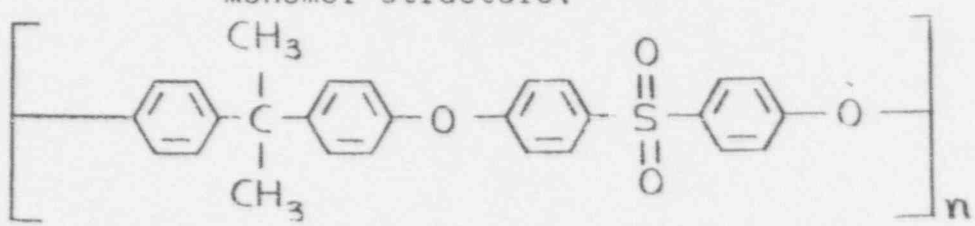
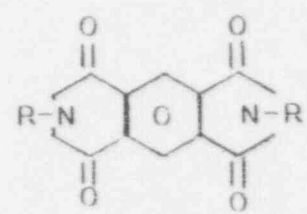
MATERIAL	DESCRIPTION	FUNCTION
Polysulfone	High temperture thermo plastic manufactured by Union Carbide Corp. (Trade-named Udel) with monomer structure:  n=50 TO 80	[redacted]
Kapton	Kapton is a trade name used by E.I. DuPont de Nemours and Co. for one of its polyimide engineered thermoplastics; its formula: 	[redacted]

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Table 3.1 (Cont'd)

MATERIAL	DESCRIPTION	FUNCTION
Kerite	This insulative material is the proprietary formulation of the Kerite Co.	[redacted]
Polyolefin with nuclear grad adhesive	Manufactured by Raychem (WCSF-N) Heat Shrinkable Tubing	[redacted]
Viton	A fluoroelastomer used for "O" rings	[redacted]
GDI-30F	Diallyl phthalate long glass fiber filled material used by Kulka Corp.	[redacted]

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4.0 INTRODUCTION TO MATERIAL TEST

4.1 The data presented in this document are the results of numerous tests performed by material manufacturer's, interested parties, and by Conax.

4.2 The goal of this document is to provide test results of material testing to verify Conax electric penetration design qualification from a standpoint of material tests. This will be accomplished by the presentation of tests and test results in the following logical manner:

4.2.1 Raw material tests - these tests will show the properties of materials before their incorporation into a Conax penetration. The properties are:

4.2.1.1 Fire resistance.

4.2.1.2 Radiation resistance.

4.2.1.3 Thermal aging effects.

4.2.1.4 Miscellaneous properties, i.e. electrical strength, mechanical strength.

4.3 In addition to the raw material tests, Conax has provided additional programs beyond the requirements of IEEE 317-1976. These tests are:

4.3.1 Material compatibility tests - these tests will show the compatibility of materials, i.e. material interface properties, and the ability of the combined material unit (feedthrough) to withstand radiation and the effects of thermal aging.

4.4 Section 7.0 of this document will evaluate the implications of the above tests and provide a correlation between the raw material tests and the material compatibility tests.

5.0 RAW MATERIAL TESTS

5.1 Polysulfone

5.1.1 Fire Resistance.

5.1.1.1 Reference 2.16 provides data concerning the flammability resistance of Polysulfone. The following is a reproduction of pertinent data from the referenced document:

A. The following tests were performed: "ASTM D-2863 is a test designed to find the lowest oxygen content atmosphere in which a material would continue to burn. All values above 20 mole % are higher in oxygen content than air. The UL 94 test is a vertical burning test with V-0 having the most stringent requirements. ASTM D-635 is a horizontal burning test and ASTM E-162 is a burning test with additional radiant heating of the material. FAR 25.583 is a vertical burning test developed for aircraft interior materials".

B. Table 5.1.1 is reproduced from the referenced document.

Table 5.1.1

Flammability*

Test	Thickness (mils)	Property	Measurement
ASTM D-635	250	ATB	5 sec
		AEB	0.4 in
ASTM E-162	20	F_s	6.1
		I_s	19
	60	F_s	4.1
		I_s	23
ASTM D-2863	125	LOI	30%
UL 94	58		V-2
	120		V-2
	240		V-0
FAR 25.853 (Vertical)	60	IT	.04 min[a]
		FT	.21 min[a]
		BL	1.3 in[b]
		CL	1.2 in[b]
		RATE	4.1 in/min[b]

(a) 12 sec flame exposure time.
(b) 60 sec flame exposure time.

* THESE NUMERICAL FLAME SPREAD RATINGS OR FLAMMABILITY RATINGS ARE NOT INTENDED TO REFLECT HAZARDS PRESENTED BY THESE OR ANY OTHER MATERIALS UNDER ACTUAL FIRE CONDITIONS.

Abbreviations

ATB	Average Time of Burning	(=)	sec
AEB	Average Extent of Burning	(=)	in
F_s	Flame-spread Factor	(=)	(0)
I_s	Flame-spread Index	(=)	(0)
LOI	Limiting Oxygen Index	(=)	mole %
FAR	Federal Aviation Regulation		
IT	Ignition Time	(=)	min
FT	Flame-out Time (after removal of burner)	(=)	min
BL	Burn Length	(=)	in
CL	Char Length	(=)	in
V-0	UL rating		
V-2	UL rating		

5.1.2 Combustion.

5.1.2.1 A test was performed to determine if the outgasses of polysulfone formed combustible mixtures with air.

5.1.2.2 Polysulfone samples were placed in a test chamber and heated to their pyrolysis region. A nichrome wire and spark producing electrodes in a combustion tube were used to test for combustion. The mixture ratio (air to outgasses) was varied throughout a wide range.

5.1.2.3 Runs were first made with the nichrome wire maintained at 1700°F and were then repeated by continuous exposure to the spark under the same set of conditions.

5.1.2.4 Results: [redacted]

5.1.2.5 Refer to Reference 2.1, [redacted], for detailed description of test apparatus and procedure.

5.1.3 Radiation resistance.

5.1.3.1 Reference 2.12, provides data and references to support polysulfone's radiation resistance. With respect to nuclear radiation, "Investigators at the University of Queensland reported polysulfone's resistance to such radiation to be the highest yet found for any organic polymer..." and also in Reference 2.12 "Davis and Gleaves et. al. (3) further report a high degree of polysulfone stability towards electron irradiation as measured by X-linking, molecular weight change, and chemical as well as mechanical properties".

5.1.4 Thermal Aging.

5.1.4.1 Reference 2.9, provides a detailed examination of the thermal endurance of polysulfone. The following is a brief description of the numerous tests conducted and their results:

A. Specimens of polysulfone were aged at temperatures of 150°C, 170°C, 180°C, 190°C, and 210°C. At prescribed intervals, the specimens were tested for mechanical and electrical properties as well as for dimensional stability. The half life at each temperature was defined as "the time required for one property to drop to 50% of its initial value". It was noted that "it was necessary to exceed the glass transition temperature (190°C) in order to hasten the aging process".

B. Table 5.1.4.1 is a reproduction of the initial test values. Table 5.1.4.2 is a reproduction of the half life data for the mechanical properties. Table 5.1.4.3 is a reproduction of the data given on the effects of heat aging on electrical properties.

C. Test for dimensional stability indicated that "shrinkage is low until the heat distortion temperature of 174°C is approached or exceeded".

D. An Arrhenius plot was produced based on the half life values for tensile impact strength and tensile strength (at 0.020 in thickness). "A parallel linear relationship is obtained indicating that a single process may account for the heat aging of polysulfone."

Table 5.1.4.1

Property	Specimen Thickness in.	Test Method	Initial Value
Tensile strength (ult), psi	1/8	ASTM D638	10173
Tensile strength (ult), psi	0.020	ASTM D638	9857
Tensile impact strength, ft-lb/in.	1/8	Modified* ASTM D1822 (short specimen)	393
Notched Izod, ft-lb/in.	1/8	ASTM D256	1.39
Dielectric str. (ST), volts/mil	1/8	ASTM D149	472
Dielectric str. volts/mil	0.020	Underwriters Laboratories test (in air)	1220
Arc resistance, sec	1/8	ASTM D495 (tungsten electrodes)	113
Flammability	1/8	ASTM D635	Self-extinguishing
Linear shrinkage, %	1/8		0

* Test specimen mounted in base.

Table 5.1.4.2

Half-Life Values for Heat Aged Polysulfone
Mechanical Properties
Half-life in days at -

Property	150°C	170°C	180°C	190°C	210°C
Tensile yield strength, psi, 1/8 in.	(728)	550	(294)	(244)	(187)*
Tensile yield strength, psi, 0.020 in.	(728)	(507)	265	188	85
Notched impact strength, ft-lb/in. 1/8 in.	(728)	530	254	201	134*
Tensile impact strength, ft-lb/in. 1/8 in.	(699)	261	178	95	44

Parentheses indicate half-life not reached.

* Uncorrected.

Table 5.1.4.3

Effect of Heat Aging on Polysulfone
Electrical Properties

Temperature, °C	23	150	170	180	190	190	210
Aging time, days	control	540	537	277	161	540	110
Dielectric strength, ST, 1/8 in., volts/mil .	472	478	461	538	461	412	497

All test measurements made at room conditions.

5.1.4.2 Reference 2.3, [redacted] provides data from thermal testing performed by Conax. The thermal tests were designed to measure and evaluate the rates of decomposition (outgassing) or weight loss of polysulfone. [redacted]

5.2 Kapton*

5.2.1 Fire Resistance.

5.2.1.1 Conax has performed two flame tests on Kapton FEP coated polyimide film insulated wire; one with respect to IPCEA S-19-81-NEMA WC 3 Para. 6.19.6, and the other with respect to IEEE Std. 383-1974.

5.2.1.2 The test performed with respect to IPCEA S-19-81 is described in Reference 2.2, [redacted] This test was performed on two specimens of #16 AWG copper wire insulated with Kapton. [redacted]

5.2.1.3 The test performed with respect to IEEE Std. 383-1974 is described in Reference 2.5, [redacted]

A. This test was performed on a nineteen conductor #10 AWG cable. Each conductor was Kapton insulated with a one-inch diameter heat shrink outer sheath over the nineteen conductors. Figure 5.2.1 shows the cable.

B. The flame source was folded burlap per IEEE Std. 383-1974. A test circuit was connected to the cable to indicate cable short circuit during test. Thermocouples were mounted in the flame area to measure flame temperature and provide a burn profile.

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[redacted]

*Tradename - Dupont

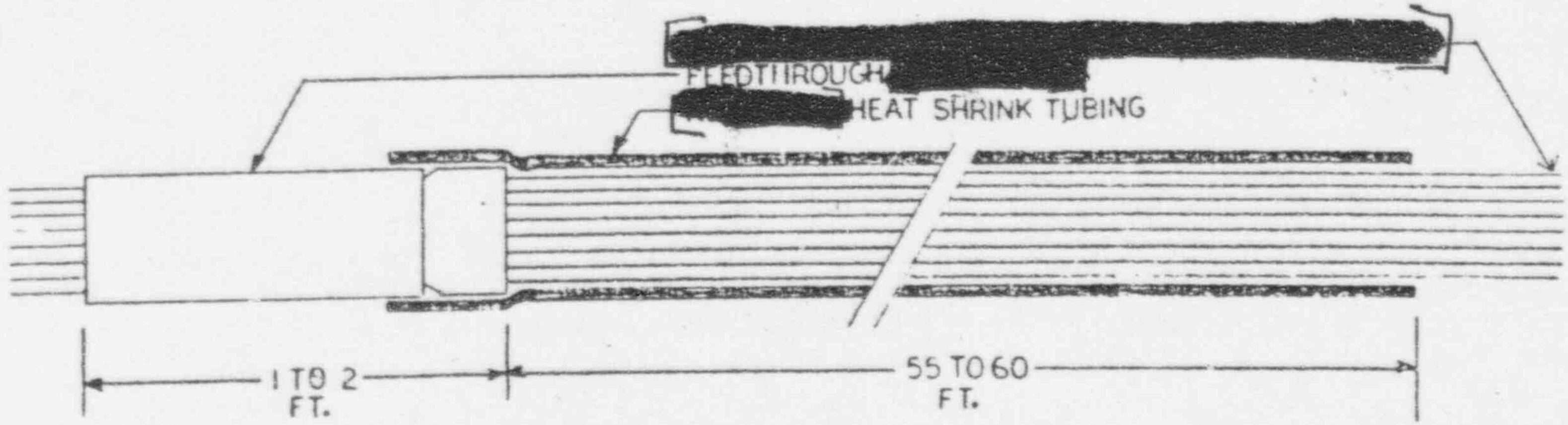
5.2.1.4 Additional testing on Kapton insulated and jacketed cables was performed by Underwriter Laboratory with respect to IEEE Std. 383 as augmented by NRC Reg. Guide 1.131 and with respect to ASTM E-84 (Steiner Tunnel Test). ok These tests are described in Reference 2.13.

A. Briefly, the IEEE Std. 383 test was performed using a 210,000 Btu/hour flame on a 30% filled tray (completely filled). [redacted]

B. [redacted]

Figure 5.2.1

ILLUSTRATION OF CABLE TYPE III
19/C NO. 10 FEEDTHROUGH



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5.2.2 Radiation resistance.

5.2.2.1 Reference 2.14, provides radiation resistance of Kapton film. It should be noted that this reference addresses Kapton only and not Kapton with Teflon** FEP layers as used by Conax. From the report, "Mechanical tests performed at 175°C in air on irradiated specimens lead to the conclusion that the material could be used without trouble at 5 x 10^9 rads", and "only slight changes in dielectric strength and volume resistivity have been noted at 1.5 x 10^9 rads when irradiated in air".

5.2.2.2 Reference 2.11, provides radiation resistance data for Kapton type HF (Kapton bonded with Teflon FEP, topcoat Teflon FEP). Samples (7.2 mils insulation) were subjected to a 2 MeV electron beam from a Van deGraaff generator delivering 750 microamps. After exposure, the samples were bend tested and subjected to a wet dielectric test at 2.2 kv rms. Finally dielectric breakdown strength was determined.

A. Results:

(1) at 10^8 rads samples passed the bend test, the wet dielectric test and registered 14.2 kv dielectric breakdown strength.

(2) at 10^9 rads samples passed the bend test, the wet dielectric test and registered 10.9 kv dielectric breakdown strength.

5.2.3 Thermal Aging.

5.2.3.1 Reference 2.15, data reported by L.L. Lewis of DuPont, and Reference 2.10, data reported by D.K. Elliot, provide thermal aging data for Kapton bonded with FEP insulated conductors.

A. Reference 2.15 tests were conducted at 250°C, 225°C and 200°C. Corresponding life in total hours at each temperature was 2,250 hours, 6,000 hours, and 19,200 hours respectively.

B. Reference 2.10, tests were conducted at 300°C, 280°C, and 260°C. Corresponding life, or mean time to failure was 458 hours, 1,318 hours and 3,303 hours respectively. It should be

**Tradename - Dupont

noted that the insulation topcoat for these tests was a "modified aromatic polyimide coat in place of FEP". Bonding agent was still FEP.

C. From above, the total accumulated test time amounts to over 22,000 hours.

5.2.3.2 Reference 2.3, [redacted] provides data from thermal testing performed by Conax. The thermal tests were designed to measure and evaluate the rates of decomposition (outgassing) or weight loss of Kapton.

A. [redacted]

5.3 <u>Kerite</u>

5.3.1 Fire resistance.

5.3.1.1 The Kerite Company has certified their HT insulation with NS jacket satisfies the requirements of IEEE Std. 383-1974.

5.3.2 Combustion.

5.3.2.1 [redacted]

5.3.2.2 Results: [redacted]

5.3.3 Thermal Aging.

5.3.3.1 Thermal aging of HT insulation with NS jacket is Kerite proprietary information presented in Reference 2.17.

5.4 Polyolefin with Nuclear Grade Adhesive (WCSF-N)

5.4.1 Fire resistance.

5.4.1.1 Raychem Corporation has performed a fire resistance test in accordance with IEEE 383-1974, Section 2.5. The Raychem report is provided in Reference 2.7, [redacted]

5.4.1.2 The test was performed on spliced and unspliced cables subjected to vertical tray flame tests with 70,000 BTU/hour and 210,000 BTU/hour propane burner heat sources.

5.4.1.3 Test results found the cables and splices to be self-extinguishing.

5.4.2 Radiation resistance and thermal aging.

5.4.2.1 Raychem performed the following material and systems tests as further delineated in Reference 2.8.

A. WCSF sleeves and slab samples were heat aged in an oven for 168 hours at $121^{o} \pm 2^{o}C$. The sleeves were then subjected to a cobalt 60 gamma source for total doses of 100 and 200 Mrads. Figure 5.4.2.1 is a reproduction of the Raychem material test results.

5.4.2.2 Reference 2.21 provides additional data for the radiation resistance of WCSF type N splice material.

A. WCSF splices with cables were subjected to a combined thermal and radiation aging of $150^{o}C$ ($302^{o}F$) and 5×10^{7} rads gamma radiation. They were then subjected to a simultaneous exposure to steam, chemical spray, and an additional gamma radiation dose of 1.5×10^{8} rads, while being electrically energized.

B. Results showed that the splices were capable of withstanding high-potential withstand and bend tests.

5.4.3 Thermal Aging

5.4.3.1 Reference 2.22 provides Arrhenius data of Raychem WCSF tubing. Figure 5.4.3.1 is a reproduction from the Raychem report. Based on a failure criteria of 50% elongation the "useful service life of radiation crosslinked WCSF compound is predicted to be 40 years at a continuous operating temperature in excess of 90°C".

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Figure 5.4.2.1

Effects of Nuclear Radiation Upon Raychem WCSF Materials

	WCSF Tubing Samples	WCSF Slab Sample @.125" Thickness
Initial elongation, %	565	440
Elongation after 168 hours at 121°C plus 100 Mrads, %	-	145
*Elongation after 168 hours at 121°C plus 200 Mrads, %	100	70
Initial tensile strength, psi	2180	1600
Tensile strength after 168 hours at 121°C plus 100 Mrads, psi	-	1745
Tensile strength after 168 hours at 121°C plus 200 Mrads, psi	1500	1685
Initial hardness, Shore D	37	43
Hardness after 168 hours at 121°C plus 100 Mrads, Shore D	-	46
Hardness after 168 hours at 121°C plus 200 Mrads, Shore D	42	52

*Tubing samples were exposed to simultaneous heat aging and irradiation.

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Figure 5.4.3.1

Oven Aging Data - WCSF Compound

Oven Temperature oC	Time (hours) to Various Levels of Retained Elongation								
	90%	80%	70%	60%	50%	40%	30%	20%	10%
136	71	470	1230	2700	4500	6020	7510	9810	-
150	35	107	331	960	1570	2030	2600	3230	4720
162	12	30	130	350	521	637	744	876	1100
175	4	20	112	154	194	228	279	361	450

5.5 Viton

5.5.1 Fire Resistance

5.5.1.1 Considering the application of Viton as an O-ring, essentially completely enclosed within a metal groove and plate, the incident of exposure to flame is evaluated as extremely remote. As such, the fire resistance of Viton is not considered as a primary criteria for use.

5.5.2 Thermal Aging

5.5.2.1 Parker Seal Company, one of Conax's approved "O" ring vendors reports the following results (Ref. 2.18). This report is the most complete available commercial data to date.

A. The recommended temperature range for Viton (a fluoroelastomer) is -20 to 400°F (-23° to 204°C).

B. "The maximum temperature recommendation for all Parker "O" rings is based upon long term functional service. If used at this temperature, or below, it will seal almost indefinitely."

C. Figure 5.5 illustrates seal life vs. temperature for a number of materials including Viton based upon exposure to oven air aging at various temperatures.

5.5.2.2 From Figure 5.5 it can be seen that Viton has an almost indefinite life expectancy for temperatures at or below 400°F.

5.5.2.3 Reference 2.23 provides DuPont high temperature data reproduced on Table 5.5, for considered continuous service limits for Viton [redacted]

5.5.3 Radiation Resistance

5.5.3.1 Reference 2.19 provides data from irradiation tests performed on Viton "O" rings utilized in their intended function [redacted] The specimen was exposed to gamma irradiation level o[redacted] Before and after irradiation, the specimen was leak tested and maintained a leak rate less than [redacted]

FIGURE 5.5

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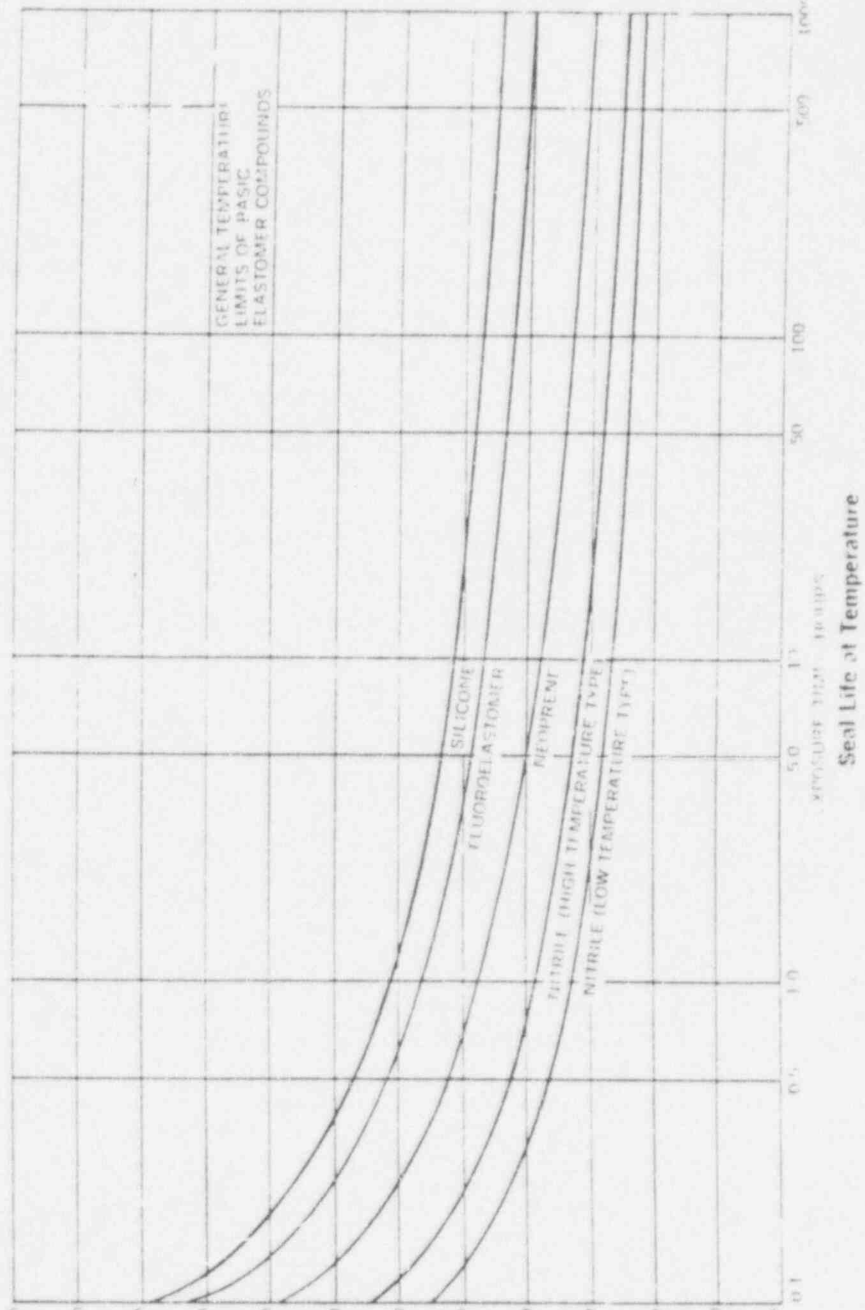


Table 5.5

Viton Considered Service Limits
(DuPont)

Temperature °F	°C	Hours
450	232	> 3,000
500	260	1,000
550	288	240
600	315	48

5.6 GDI-30F

5.6.1 Fire Resistance

5.6.1.1 Fire resistance of type GDI-30F material is specified by MIL-M-14G type GDI-30F. The test for flame resistance in MIL-M-14G is a modified Method II of ASTM D229-69. Briefly, five test samples (one at a time) of 1/2 by 1/2 by 5 inches are exposed to a surrounding Nichrome V heater coil at 860°C in a flame cabinet with blower.

A. Ignition time - greater than 90 sec.
Burning time - less than 90 sec.

5.6.2 Radiation Resistance

5.6.2.1 Reference 2.24 describes radiation testing of Kulka type GDI-30F terminal blocks. The terminal blocks were irradiated to [redacted] Post irradiation tests and test results are as follows:

A. Visual inspection showed no damage or deterioration.

B. Dielectric strength test [redacted] between adjacent terminals and terminals to ground indicated no breakdowns.

C. Insulation (resistance) measurements at 550 VDC between adjacent terminals and terminals to ground were all above [redacted]

5.6.3 Thermal Aging

5.6.3.1 IEEE Std. 650-1979 implies no age related failure mechanisms over 40 years life have been identified for glass-filled diallyl phthalate material.

5.6.3.2 Investigative thermal studies performed by Conax Reference 2.25, indicate that this material possesses an activation energy of [redacted]

5.6.3.3 Based on the above activation energy, terminal blocks age conditioned in Reference 2.24 had an equivalent conditioning to 40 years at [redacted] After age conditioning and then irradiation, the terminal blocks were evaluated for electrical function; the results are in section 5.6.2.1 of this report.

6.0 MATERIAL COMPATIBILITY TESTS

6.1 Raw Material Corrosion Test

6.1.1 Conax performed a test to verify that the alloys and metals used to encapsulate electric penetrations were not corroded by polymer outgassing. A detailed description of this test is provided in Reference 2.1 [redacted]

6.1.2 The test was performed on [redacted] with samples of stainless steel alloys.

6.1.3 Samples of polymers and stainless steel alloys were placed in crucibles which were then placed in an oven. [redacted]

6.1.4 [redacted]

6.1.5 Table 6.1 is a reproduction of the test results given in Reference 2.1, [redacted]

6.2 Thermal Compatibility of Kapton and Polysulfone

6.2.1 Reference 2.3, [redacted] provides data to substantiate that both "Kapton and polysulfone can successfully withstand long term exposure to temperatures as high as [redacted]

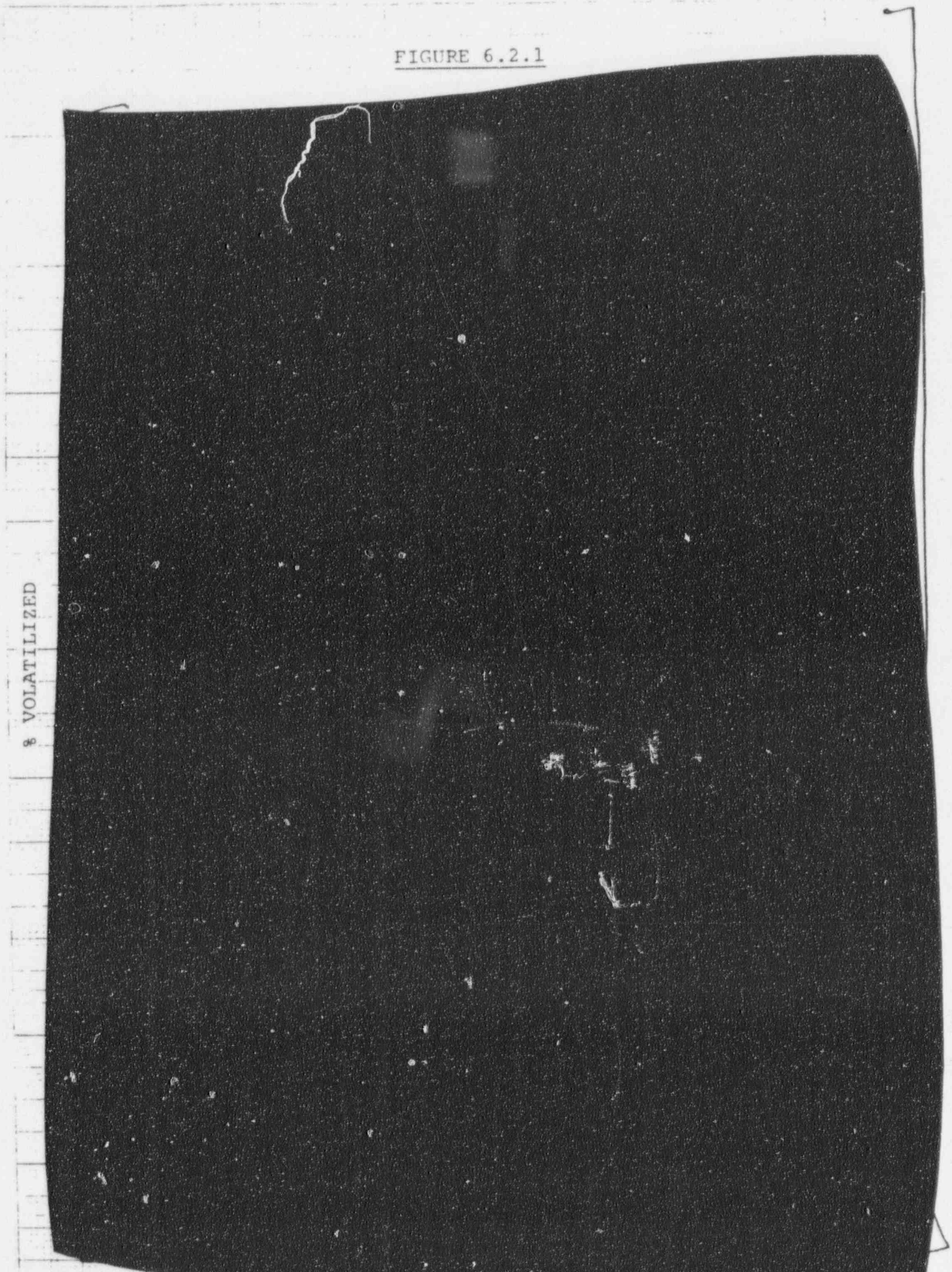
6.2.1.1 Figures 6.2.1 and 6.2.2 are reproduced from the referenced document. [redacted]

Table 6.1

[redacted]

Figure 6.2.1

FIGURE 6.2.1



FIGURE

6.3 Radiation Resistance of Feedthroughs

6.3.1 Reference 2.3, [redacted] provides data for feedthroughs irradiated to a total gamma dose of [redacted]

6.3.1.1 [redacted]

6.3.1.2 Radiation dose rate was between 1 and 5×10^6 rads per hour for a total of [redacted]. The equilibrium temperature during exposure was $127^{o}F$.

6.3.1.3 Table 6.3.1 is a reproduction of the evaluation test results given in the referenced document. As can be seen from the table, the irradiation effects of 1×10^8 rads, does not exceed the performance characteristic requirements of the feedthroughs.

6.3.2 Reference 2.6, [redacted] provides data for feedthroughs irradiated to a total gamma dose between [redacted]

6.3.2.1 Feedthrough assemblies consisted of: 37C/#16 AWG, 19C/#10 AWG, 12C/#8 AWG, 9C/#6 AWG, and 7C/#4 AWG. [redacted]

6.3.2.2 Radiation dose rate from a cobalt 60 source was between [redacted] per hour for a total exposure duration of [redacted] hours. Temperature of the feedthroughs during exposure was less than [redacted]

6.3.2.3 Comparison of test parameters measured before and after irradiation are provided in Table 6.3.2, reproduced from the referenced document. As indicated on this table, the leakage rate, dielectric strength, continuity and insulation resistance parameters have not exceeded the performance characteristic requirements.

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[redacted]

Table 6.3.1

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TABLE 6.3.2

6.4 Thermal Aging/Conditioning of Feedthroughs

6.4.1 Presently Conax is conducting a thermal effects study program on electric penetration conductor feedthrough modules in its Nuclear Products Test Laboratory. This study is being conducted to provide thermal life data of feedthrough modules in addition to life data already provided for individual materials. The current thermal study program will augment the materials thermal tests and will provide meaningful data in that materials in combination along with fabrication processes are fully evaluated. Present preliminary data from the feedthrough module study indicate that Conax's age conditioning procedure is conservative. The results of this study upon completion will be attached to this document as [redacted]

6.4.2 The thermal effects study program referred to in 6.4.1, has been underway since September 7, 1978 with conductor feedthrough modules being exposed to elevated temperatures in accordance with IEEE Std. 98, 99, and 101. Procedures for temperature exposure and periodic examination and test data reduction and interpretation is in accordance with these standards. [redacted]

6.4.3 For the conductor feedthrough modules, two primary modes of safety-related failure exist:

A. Loss of electric integrity

B. Loss of seal integrity

Each of these failure modes is considered in the periodic examination of the test specimens used in the thermal effects studies. Leakage through the feedthrough seals in excess of [redacted] of helium/sec is a failure criteria (this provides a margin of more than two orders of magnitude over that which would be permissible for a feedthrough in an installed penetration assembly). Electrically, dielectric strength withstand capability insulation resistance values below [redacted] and loss of continuity are failure modes.

6.4.4 The Conax electric penetration conductor feedthrough module is an integral assembly [redacted] The thermal effects study of the assembled Feedthrough module considers:

A. The primary sealant [redacted]

B. The conductor insulation [redacted]

C. The manufacturing process for producing the conductor feedthrough module.

7.0 EVALUATION

7.1 Section 5.0 of this document has presented results of raw material tests. From these results, the applicability of the raw materials used to meet design service requirements, i.e. fire resistance, radiation resistance, thermal withstand and life, has been verified. The properties of the materials have been examined and shown to be retentive after exposure to conditions simulating these design service requirements. These material tests have demonstrated conformance to the requirements of sections 6.3.1, 6.3.2 and 6.3.3 of IEEE Std. 317-1976.

7.2 As the material tests exhibited favorable results, Section 6.0 of this document describes the compatibility of raw materials used as well as verification towards meeting individual design service requirements of temperature and radiation conditions. This effort is beyond the requirements of IEEE Std. 317-1976.

8.0 CONCLUSION

8.1 The materials used in Conax electric penetrations and electric conductor seal assemblies have been carefully chosen after extensive investigative testing for nuclear power plant environment suitability as exemplified by this document. Further testing by Conax and others have shown the materials selected by Conax have properties that are retentive under nuclear power plant environmental conditions.

8.2 The test results provided in this document have shown the compatibility of materials used. Tests performed on assembled units (feedthroughs) have shown that the materials used retain their properties in meeting individual design service requirements. Based on the results of the tests delineated in this document the material testing requirements of IEEE 317-1976 are satisfied.

8.3 The data provided in this document summarizing the comprehensive Conax material testing, extrapolation of that material test data by analysis, and substantiation of analysis by the thermal effects study program of electric conductor feedthrough assemblies firmly establishes the qualified life of Conax electric penetrations conservatively at more than 40 year within the current state-of-the-art. The validity of the Conax age conditioning time and temperature is justified.

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APPENDIX A

Conax Thermal Evaluation Program

of

Electric Conductor Feedthroughs

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Table of Contents

Abstract

This report covers status and converts data available from Conax's ongoing Thermal Evaluation Program on electric conductor feedthroughs. A statistical analysis based on IEEE Std. 101-1972 was performed on present data for 42/C #18 AWG, 19/C #10 AWG, and 9/C #6 AWG [redacted] Regression lines were calculated and indicated satisfactory correlation to test data. F-Test for linearity gave positive indication that the assumed linear relationship (Arrhenius equation) is applicable. 90% confidence bounds for mean life were calculated. Initial results demonstrate that a qualified life of 40 years at a temperature in excess of 130°C is justifiable and that Conax's approach to Age Conditioning is valid.

It should be noted that Conax's Thermal Evaluation Program is an ongoing study which includes test samples with Conax's standard 6" sealant design. Insufficient sample failures for the [redacted] sealant design precludes analysis in this initial report but accumulated data in excess of [redacted] hours on these samples demonstrates the viability of the [redacted] sample data and the permissibility to use this data with conservatism for all Conax feedthroughs. When sufficient [redacted] sealant failure data becomes available for analysis, this document will be expanded.

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1.0 INTRODUCTION

This report is a statistical analysis of data from Conax's ongoing Thermal Evaluation Program on electric conductor feedthroughs. The data is on the 42/C #18 AWG, 19/C #10 AWG, and 9/C #6 AWG [redacted] The basis of the statistical analysis is IEEE Std. 101-1972.

Tables presenting test data and calculated data are provided in the attachments to this report. Arrhenius life-temperature curves plotted on semi-log paper for convenience in interpretation are also provided in the appendices of this report.

Calculations performed for this report are:

1. Regression line and correlation.
2. F-Test for linearity.
3. 90% confidence bounds for mean life.

2.0 TEST DATA

The data of this report are for 42/C #18 AWG, 19/C #10 AWG and 9/C #6 AWG [redacted] electric feedthroughs. Other size feedthroughs are included in the thermal evaluation study but do not have enough failure points to support analysis. (See Attachment E for tabulation of accumulated hours for all feedthrough samples being evaluated.) Analysis will be performed on other size feedthroughs as forthcoming information becomes available.

Aging temperatures and test cycles are:

[redacted]

Failure criteria is leakage of greater than [redacted] scc/sec when pressurized to [redacted] Dielectric strength tests have also been conducted but no failures in any of the feedthroughs have occurred.

Sample size is two sealant ends at each temperature level for the test specimens noted above. The actual sample population at each test temperature is [redacted] with samples distributed by conductor size as shown in Attachment E.*

*When the test program was initiated, failure was predicted to be a function of conductor size and/or number of conductors per module.

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3.0 CALCULATIONS

Regression lines were calculated by the method of least squares. Data points (estimated failure points) used were the midpoint between detection of failure and last test. Calculations were performed with the Arrhenius variable of $Log_{10}Y$ (life) and $1/^{o}k$ (temperature).

The correlation coefficient (r) was calculated for each of the regression lines as well as the coefficient of determination (r^2). The coefficient of determination indicates the proportion of the variability in the failure time data which is explained by the regression line with $1/^{o}k$ as the independent variable.

An F-Test for linearity was performed to determine whether there was any evidence suggesting a non-linear relationship. F was calculated as the ratio of Mean Square Lack of Fit (MSLF) to Mean Square Pure Error (MSPE). This F was then compared to a critical value F at [redacted] percent significance level with 1 and ? degrees of freedom [redacted]

90% confidence bounds for [redacted] calculated for the three test temperatures [redacted] 90% was chosen to give the tightest bounds above and below the regression line.

4.0 42/C #18 AWG [redacted]

Test data, calculated data, and Arrhenius curve are provided in Attachment A. The regression line correlation to test data indicates a good fit. The 90% confidence bounds indicates tight bound above and below the three test temperatures. The F-Test indicates a definite linear relationship. Based on industry practice, extrapolation to [redacted] (160^{o}-30^{o}) can be performed with reasonable confidence.

5.0 19/C #10 AWG [redacted]

Test data, calculated data, and Arrhenius curve are provided in Attachment B.

The regression line correlation to data limits the amount of extrapolation to lower temperatures for this feedthrough sample. The failure times at [redacted] suggest the possibility of a different slope for the regression line had they been closer together at either the shorter or longer time. This is also suggested by the looseness of the 90% confidence bounds above and below the three test temperatures. The F-Test indicates that the relationship between the data points is definitely linear and that the Arrhenius equation is applicable, i.e., one predominant reaction causing failure.

6.0 9/C #6 AWG [redacted]

Test data, calculated data, and Arrhenius curve are provided in Attachment C.

The regression line correlation to test data indicates a good fit. The 90% confidence bounds indicates tight bound above and below the three test temperatures. The F-Test for linearity indicates a definite linear relationship. Based on industry practice, extrapolation to [redacted] can be performed with reasonable confidence.

7.0 40 YEAR SERVICE AGE CONDITIONING CURVE AT [redacted]

Attachment D shows a 40 year service age conditioning curve for 70°C. Within the current state-of-the-art, this curve is based on the slope of the end of life curve (Arrhenius curve) of the 42/C #18 AWG [redacted] feedthrough. Within the acceptable state-of-the-art extrapolation guidelines (Ref. 9.7), extrapolation from the lowest test temperature to the 40 year intercept represents a ΔT of less than [redacted]. The 42/C #18 AWG [redacted] feedthrough Arrhenius curve was chosen as a basis due to its conservative time-temperature relationship.

The points along the 40 year service age conditioning curve denote an equivalency to a service condition of 40 years at mean service temperature of [redacted]

8.0 CONCLUSION

The purpose of this report is to analyze data from Conax's Thermal Evaluation Program on electric conductor feedthroughs. Results of the analysis indicate the applicability of the Arrhenius model for interpreting thermal life data of Conax Feedthroughs. Based on performance of the ten test specimens forming the sample population of each test temperture, future data will continue to support the above statements and demonstrate conservatism.

Statistical conservatism has been employed in this report. It should be noted that although statistical predictions predicate themselves to the interval tested, the known thermal stability of engineering polymers at lower temperatures will allow predictions to be made at the lower temperatures with reasonable confidence.

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Again, it should be noted that this initial report analyses failure data for [redacted] design whereas Conax standard design is [redacted] samples of which are also included in this ongoing thermal evaluation study (See Attachment E). Although these test samples have not produced sufficient failure data to date to permit analysis, they do contain a significant number of accumulated test hours and test temperatures to demonstrate the viability of the [redacted] data and increased life capability of the [redacted] and permits justifiable use of [redacted] data with taci[redacted] conservatism for all Conax conductor feedthroughs.

9.0 REFERENCES

9.1 IEEE Std. 1-1969, "General Principles for Temperature Limits in the Rating of Electric Equipment".

9.2 IEEE Std. 98-1972, "Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indexes of Solid Electrical Insulating Materials".

9.3 IEEE Std. 99-1970, "Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment".

9.4 IEEE Std. 101-1972, "Guide for the Statistical Analysis of Thermal Life Test Data".

9.5 IEEE Std. 317-1976, "Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations".

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

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Attachment A

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Attachment A

42/C #18 AWG [redacted] Test Data

Temp. °C	Cum Hrs (T)	Last Test Hrs (T')	Est. Fail $Y = \frac{T + T'}{2}$	$Log_{10} Y$	$\frac{1}{°K}$
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]				

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Attachment A

42/C #18 AWG [redacted] End Calculated Data

Regression Line Equation: [redacted]

Correlation Coefficient: .9860 (1)

F-Test for Linearity: $F = .028828 < F_{.05}(1,3) = 10.1$ Linear

Temp. °C	Predicted Fail Time ($Log_{10}Y$)	Predicted Fail Time (Hrs)	Confidence Bounds for Mean Life (Hrs (2)) Lower	Confidence Bounds for Mean Life (Hrs (2)) Upper
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

1. r^2 = [redacted] where r^2 is the proportion of variation in data that is explained by the independent variable temperature (1°K).

2. When expressed in hours, the confidence bounds delineate the confidence interval for the geometric mean of real time to end of life rather than the arithmetic mean when the bounds are expressed as logarithms.

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Attachment B

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Attachment B

19/C #10 AWG [redacted] Test Data

Temp. °C	Cum Hrs (T) Failure	Last Test Hrs (T')	Est. Fail $Y = \frac{T + T'}{2}$	$Log_{10} Y$	$\frac{1}{°K}$
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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Attachment B

19/C #10 AWG [redacted] End Calculated Data

Regression Line Equation: [redacted]

Correlation Coefficient: .81722 (1)

F-Test for Linearity: $F = .18956 < F_{.05}(1,3) = 10.1$ Linear

Temp. °C	Predicted Fail Time ($Log_{10}Y$)	(Hrs)	Confidence Bounds for Mean Life (Hrs (2)) Lower	Upper
[redacted]				

1. r^2 = [redacted] where r^2 is the proportion of variation in data that is explained by the independent variable temperature (1/°K).

2. No predicted fail time has been extrapolated at this temperature.

3. When expressed in hours, the confidence bounds delineate the confidence interval for the geometric mean of real time to end of life rather than the arithmetic mean when the bounds are expressed as logarithms.

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Attachment C

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Attachment C

9/C #6 AWG [redacted] Test Data

Temp °C	Cum Hrs (T)	Last Test Hrs (T')	Est. Fail $Y = \frac{T + T'}{2}$	$Log_{10}Y$	$\frac{1}{°K}$
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]				

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Attachment C

9/C #[redacted] Sealant End Calculated Data

Regression Line Eq: $Log_{10}Y$ = [redacted]

Correlation Coefficient: .987(1)

F-Test for Linearity: $F = 1.1365 < F_{.05}(1,3) = 10.1$ Linear

Temp °C	Predicted Fail Time ($Log_{10}Y$)	Predicted Fail Time (Hrs)	Confidence Bounds for Mean Life (Hrs) (2) Lower	Confidence Bounds for Mean Life (Hrs) (2) Upper
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

1. r^2 = [redacted] where r^2 is the proportion of variation in data that is explained by the independent variable temperature (1/°K).

2. When express in hours, the confidence bounds delineate the confidence interval for the geometric mean of real time to end of life rather than the arithmetic mean when the bounds are expressed as logarithms.

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Attachment E

Accumulated Hours vs. Test Temperatures

Feedthru Type/Density	Sample Size	Test Temperature 150°C	160°C	166°C	172°C
[redacted]					
[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]			

*Denotes failure.