

## VERIFICATION OF THE BEHAVIOR OF INSULATING MATERIALS UNDER IONIZING RADIATION

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### ABSTRACT

To analyze the behavior of specific electrical insulating materials and components under ionizing radiation, a test program was developed to verify the overall effects of general electrical equipments under high radiation fields conditions. The main objective is for maintenance purposes, in the substitution of electrical components installed in the Reactor Building of the Angra 1 Nuclear Power Plant.

Knowing the characteristics of electrical insulating materials available in the country and determining by tests their ability to withstand the ionizing radiation effects, is feasible to implement specific maintenance services of electrical equipments, maintaining the same level of quality and safety for the specified application. This procedure reduces the time and also costs of maintenance services, in comparison with materials acquired or services performed abroad.

The insulating materials and components of electrical equipment should be specified, manufactured and qualified to withstand aggressive environmental conditions in the Reactor Building during the normal operation and postulated accident.

Additional tests should be conducted to verify the conditions of the aged material by ionizing radiation. Examples of additional tests: Dielectric strength, Tensile strength and elongation and Impact resistance.

### 1. INTRODUCTION

Parameters values under postulated accident in the Reactor Building will reach the following environmental conditions:

- Temperature: 165°C (10 minutes);
- Accumulated Radiation: 1,500 K Gy (150 Mrads) (after 31 days);
- Pressure: 65 Psia (4.6 bar) (31 days);
- Vapors contend chemical products: System of Spray of the Building of the Reactor (24 hours).

The study of the engineering staff from Eletronuclear, has technically decided to study the effect of the ionizing radiation (gamma rays), as an aggressive agent not considering other

agents such as temperature, pressure and chemicals products present in the spray system during loss of coolant accident, considering that the consequences of these agents are mitigated by packs and enclosures of equipments.

## 2. TYPES OF MATERIALS AND COMPONENTS ACQUIRED ON THE DOMESTIC MARKET - BRAZIL

- Enameled wire # 15 AWG;
- Electrical cable # 50 mm<sup>2</sup> silicon insulation (200°C);
- Flexible Laminated Paper;
- Mica Tape;
- Fiber Glass Tape with Mica;
- Spaghetti of Silicon;
- Celeron;
- Varnish;
- Isolating Tape

**Table 1. Isolating and Components Materials for Ionizing Radiation**

Samples of the Materials	Type	Manufacturer/ Supplier In Brazil	Samples N°	Ionizing Radiation Tests	Electrical and Mechanical Tests (Laboratories)
Enameled Wire # 15 AWG	Piretherm H (180°C)	Pirelli	A1	IPEN	PPE
Electrical Cable #50 mm <sup>2</sup> (750V) - Silicon	Class N (200°C)	Tramar	A3	IPEN	Tramar
Flexible Laminated Paper (Mica Compost)	DMD 0,14 mm	DMI	A4	IPEN	DMI
Mica Tape	1230 GM	DMI	A7	IPEN	DMI
Fiber Glass Tape	0,22 mm	DMI	A8	IPEN	DMI
Spaghetti of Silicon	Trançasil H (180°C)	Tramar	A10	IPEN	Tramar
Celeron	TC 300	Eletrisol	A11	IPEN	DMI
Varnish	Lacktherm 1314	WEG	A13	IPEN (1)	WEG
Isolating Tape	PVC	3M	A14	IPEN	DMI

**Table 1**, in the text, presents a summary of the isolating and components materials used in electrical equipments repair:

### 3. TESTS

#### 3.1. Ionizing Radiation Tests

For the verification of the behavior of each sample front the ionizing irradiation had been applied 5 distinct doses:

- 1a Dose: 400 Gys (40 Krad) referent the normal operation;
- 2a Dose: 400 Kgys (40 Mrad) referent the partial postulated accident, (27%);
- 3a Dose: 800 Kgys (80 Mrad) referent the partial postulated accident, (54%);
- 4a Dose: 1,200 Kgys (120 Mrad) referent the partial postulated accident, (80%);
- 5a Dose: 1,500 Kgys (150 Mrad) referent the partial postulated accident, (100%);  
(Future ionizing radiation tests in the IPEN Laboratories).

#### 3.2. Electrical and Mechanical Tests and Other Tests

Tests in samples new and aged by the ionizing radiation had been carried through.

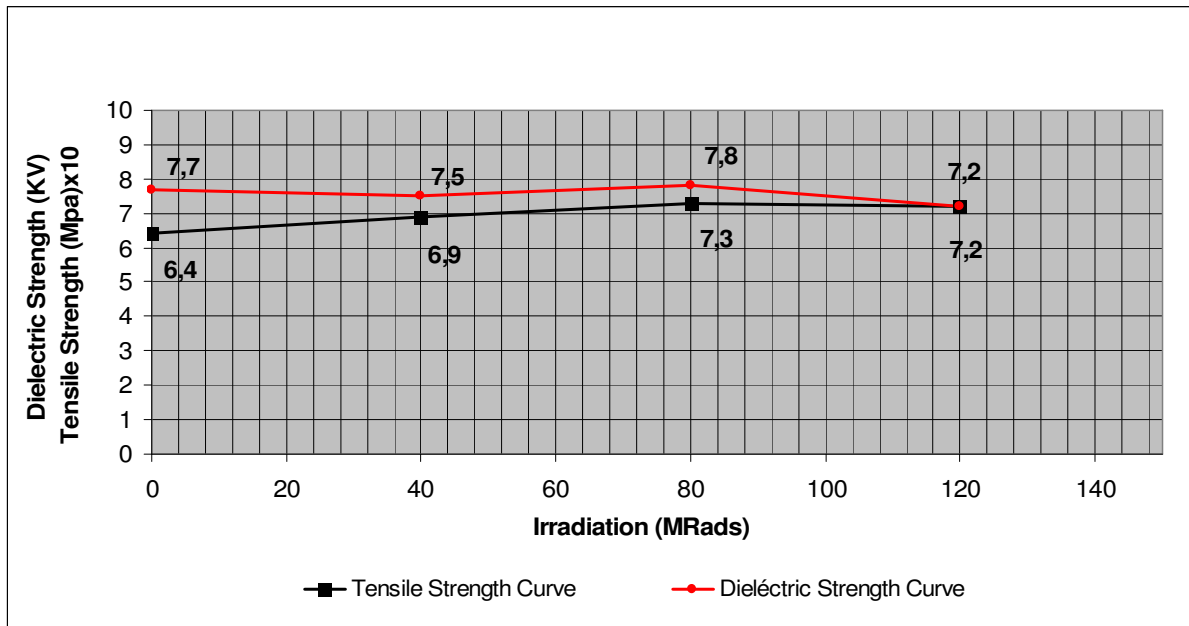
**Table 2. Summary of the Tests Types in Samples of isolating and Components Materials**

Type Testes	DMI	TRAMAR	WEG	PPE
Dimensional	-	X	-	-
Dielectric Strength	X	X	X	X
Tensile Strength	X	X	-	X
Impact Resistance	X	-	-	-
Elongation	-	X	-	-

**Table 2**, in the text, presents a summary of the tests types in samples of isolating and components materials used in Electricals Equipments:

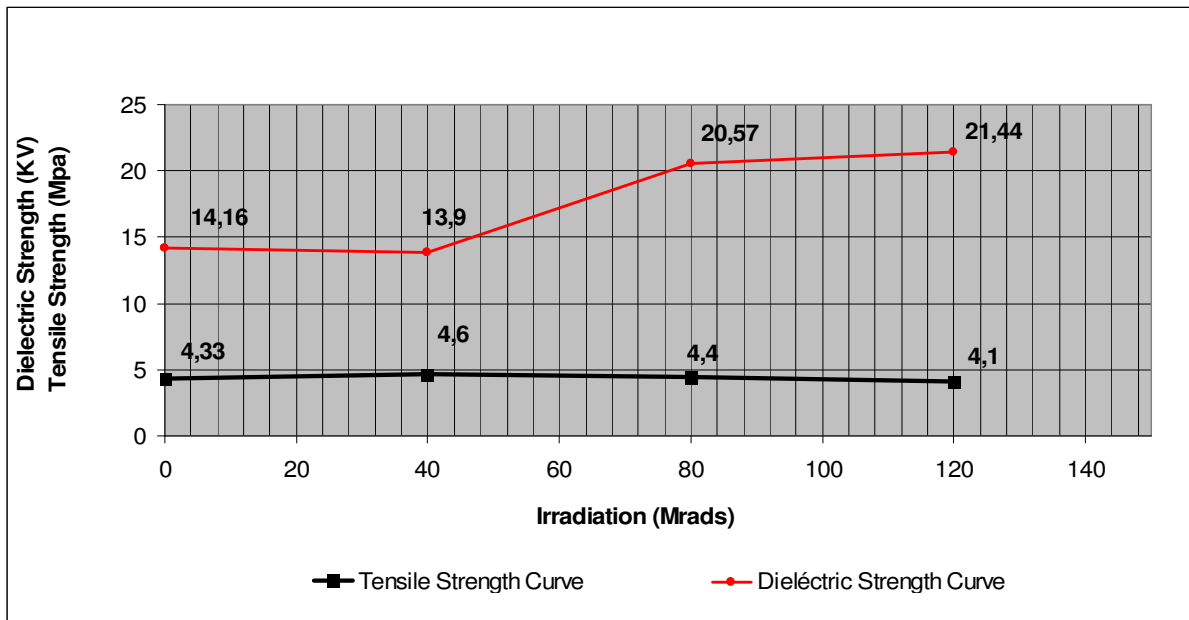
## 4. EXAMPLES OF RESULTS IN CURVES

### 4.1 Laminated Paper for Insulation



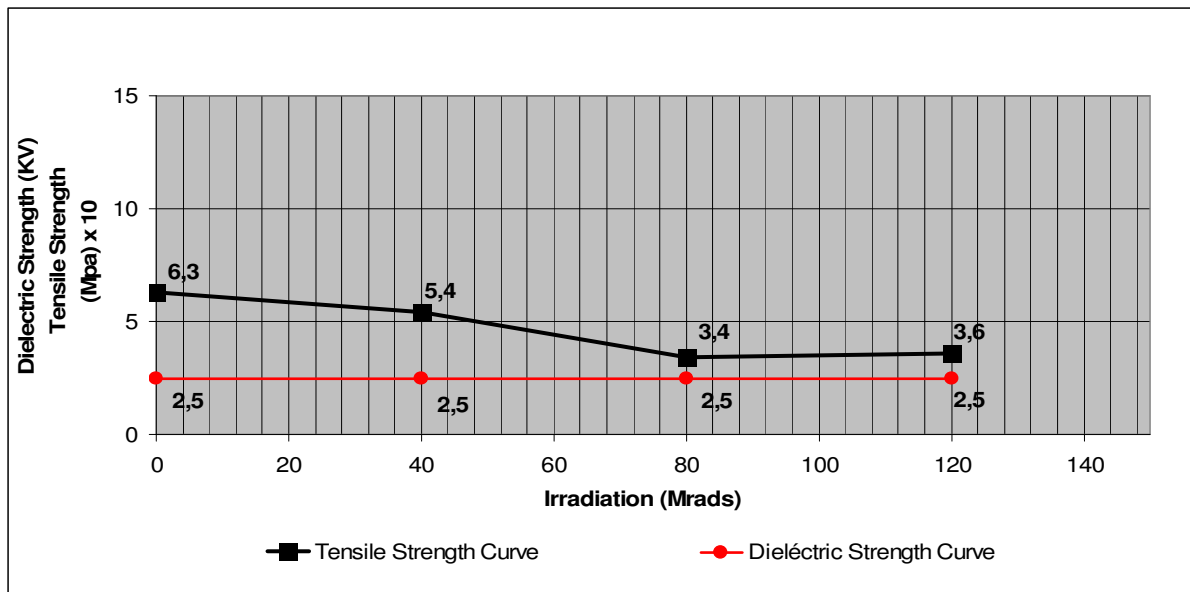
**Figure 1. Dielectric and Tensile Strength Tests Curves - Sample A4 – Flexible Laminated Paper Type DMD - DMI**

### 4.2 Isolating Tape



**Figure 2. Dielectric and Tensile Strength Tests Curves - Sample A14 – Isolating Tape PVC - 3M**

### 4.3 Electrical Cable # 50 mm<sup>2</sup> Silicon Insulation



**Figure 3 – Dielectric and Tensile Strength Tests Curves – Sample A3 – Electric Cable Silicon Insulation - TRAMAR**

## 5. ANALYSIS

### 5.1 Sample A1 – Enamelled Wire # 15 AWG – Piretherm, Class H (180°C) – PPE

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	8,9	10,2	+12,7%	- 50%	Approved

### 5.2 Sample A3 – Electrical Cable # 50 mm<sup>2</sup> (750V) – Silicon, Class N (200°C) – Tramar

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	2,5	2,5	0 %	- 50%	Approved
Tensile Strength (Mpa)	6,3	3,6	- 42,9%	- 50%	Approved

### 5.3 Sample A4 – Flexible Laminated Paper – DMD 0,14mm – DMI

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	7,7	7,2	- 6,5 %	- 50%	Approved
Tensile Strength (Mpa)	64,83	72,38	+ 11,6%	- 50%	Approved

#### 5.4 Sample A7 – Mica Tape – 1230 GM – DMI

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	4,87	4,9	- 0 %	- 50%	Approved

#### 5.5 Sample A8 – Cadarço of Faber Glass – CFM 0,22mm – DMI

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Tensile Strength (Mpa)	177	91	+ 48,6%	- 50%	Approved

#### 5.6 Sample A10 – Spaghetti of Silicon – Trançasil Class H (180°C) – Tramar

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	2,1	1,4	- 33,3 %	- 50%	Approved

#### 5.7 Sample A11 – Celeron – TC 300 – Eletrisol

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	<i>It did not pierce</i>	12,3	-	- 50%	Approved (Note 1)
Tensile Strength (Mpa)	<i>It did not breach</i>	52,0	-	- 50%	Approved (Note 1)

#### 5.8 Sample A13 – Varnish – Lacktherm 1314 - WEG

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	60	92,4	+54%	- 50%	Approved (Note 2)

#### 5.9 Sample A14 – Isolating Tape – PVC – 3M

Type Tests	Values in New Samples	Values in Aged Samples	Alterations of the Characteristics	Acceptance Criteria	Situation
Dielectric Strength (kV)	4,3	4,0	- 7,0 %	- 50%	Approved
Tensile Strength (Mpa)	14,1	21,4	+ 34,0%	- 50%	Approved

Notes: 1) A11 sample has high dielectric resistance and traction. After aged it has presented a degradation however the gotten values are high;

2) The varnish was applied in body of metallic tests indicated by WEG.

- 3) It is consensus, following EPRI TR 104872 (item 7.2.1.1) instructions, to reprove the insulating materials and components that have been damaged and presented higher reductions of 50% of their originals electrical and mechanical properties. This criterion of acceptance is conservative and is used in tests procedures proposed by ASTM, IEEE, UL and IEC.

## 6. CONCLUSIONS

During this work it was verified that the dielectric rigidity of the materials has not been affected. Some materials as the enameled wire and varnish Lacktherm 1314, presented an increase in their dielectric characteristics, contributing for a better dielectric rigidity of the block. On the basis of this observation and others characteristics, is concluded that these evaluated materials are able to be used in electrical equipments maintenance, that will be submitted to high doses of radiation.

## ACKNOWLEDGMENTS

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