CERN 72-7
Laboratory I
Intersecting Storage
Rings Division
17 May 1972

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

SELECTION GUIDE TO ORGANIC MATERIALS FOR NUCLEAR ENGINEERING

M.H. Van de Voorde and C. Restat

G E N E V A

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CERN - Service d'Information scientifique - H/498 - 2500 - mai 1972
1000 - janvier 1979

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INTRODUCTION

One of the aims of design engineering is to select a material which performs reliably under the most adverse conditions. A specific example of this is the growing need for materials which perform satisfactorily in radiation fields.

Organic materials occupy a role of major significance in nuclear technology. They rank with metals and ceramics as the principal category of materials used in the construction of components in this field. Of all materials, organic materials are amongst those that are most sensitive to the effects of radiation.

The aim of this report is therefore twofold:

i) to give the main engineering properties of commercial organic materials used in an accelerator;

ii) to report on the degeneration of these properties under nuclear radiation.

Thus by cross reference, a guide is provided for the selection of organic materials which have to fulfil specific requirements, even when subjected to high doses of absorbed radiation. It has to be emphasized that the information presented in this document should only be used as a guide for the selection and design of critical materials and components. It is recommended that, wherever possible, prototypes and simulation tests should be used where the interaction of the environment and the material is likely to alter the material characteristics.

The values of the parameters given in this report are functions of composition and manufacturing techniques. Therefore in some cases ranges of values are given; otherwise mean values are quoted as typical examples for those materials.

The majority of the available irradiation data are those obtained from gamma source and nuclear reactor irradiation, particularly from the ASTRA reactor, and measured under static conditions. None of the data listed in this report were taken during irradiation; only remanent effects have been reported. While some of the mechanical properties may differ slightly when measured during irradiation, the volume resistivity, for example, can be significantly different.

In reporting the data compiled in this report, exposures received by the various materials in different irradiation conditions have been expressed in a single unit of absorbed dose, the rad. One rad is equivalent to the absorption of 100 ergs of energy per gramme of material.

This document up-dates and replaces CERN MPS reports 66-25 and 66-27, and includes additional information obtained during the ISR construction.

A bibliography is given after each chapter in order to maintain clarity of the text, figures, and tables.

EXPLANATION OF TABLES AND FIGURES

1. General engineering properties

Tables I.1 to I.4 (Chapter I) represent in alphabetical order the mechanical, electrical, and physical properties of

- thermoplastic moulding materials
- thermoplastic films
- thermosetting moulding materials
- elastomeric materials.

Although the diversity of organic materials is enormous, the choice for a given application will lie within a narrow band of the spectrum of available materials. Within this band there may, however, be several polymers which come close to having the desired requirements. In order to select the best one, the properties of each material have to be compared. A selection guide based on types of applications is given in Chapter II.

2. Radiation effects

The figures of Chapter III.1 show the relative radiation resistance of the most common thermoplastics, thermosettings, and elastomers. It should be mentioned that these figures reflect resistance to radiation, and that a consideration of irradiation conditions, manufacturing techniques, and composition as adding fillers, diluents, etc., could change the order in which the materials are ranked.

The most evident and, from an engineering point of view, the most important changes which occur in organic materials under irradiation affect their mechanical properties. These changes for commercial polymers are shown in alphabetical order (Chapter III.2).

in Figs. III.1 to III.25 for thermoplastics
in Figs. III.26 to III.58 for thermosettings
in Figs. III.59 to III.76 for elastomers.

For completeness, the changes in the electrical (Chapter III.3) and physical (Chapter III.4) properties are given in the following tables:

- Tables III.1a to III.1f: Effect of nuclear radiation on electrical properties (volume resistivity, dielectric strength, arc resistance, dielectric constant, and dissipation factor).
- Tables III.2a to III.2e: Effect of nuclear radiation on physical properties (water absorption, specific gravity, gas evolution).
- Table III.3: Radiation stability of plastics at a temperature above the usual service temperature are listed in Table III.3. For high temperature applications, mineral-filled resins have to be considered.

Most plastics are known by their trade names; therefore two lists, in alphabetical order, are given, the first consisting of trade names and the second consisting of the chemical composition. A third list, also in alphabetical order, gives the commonly used names of elastomers together with their chemical designations and trade names.

Appendix I	Plastics	:	Family name - Chemical name - Trade name
Appendix II	Plastics	:	Trade name - Chemical name
Appendix III	Elastomers	:	Popular name - Chemical designation and Trade name.

CHAPTER I

GENERAL ENGINEERING PROPERTIES

Table I.1: **THERMOPLASTIC MOULDING MATERIALS**

PROPERTIES \ POLYMERS	ASTM	ACETALS		ACRYLICS	CELLULOSICS				
		HOMOPOLYMER	COPOLYMER	POLYMETHYL METHACRYLATE	CELLULOSE ACETATE	CELLULOSE ACETOBUTYRATE	CELLULOSE ACETOPROPIONATE	CELLULOSE NITRATE	ETHYL CELLULOSE
SPECIFIC GRAVITY (g/cm^3)	D792	1.42	1.41	1.19	1.20 - 1.40	1.15 - 1.25	1.18 - 1.24	1.35 - 1.70	1.12 - 1.20
WATER ABSORPTION (%)	D570	0.2 - 0.3	0.2 - 0.3	0.3 - 0.4	0.7 - 6.0	0.5 - 2.5	1.2 - 2.8	0.6 - 2.0	0.5 - 1.5
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.19	0.23	0.17	0.20	0.20	0.20	0.20	0.15
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	8.1	8.5	8.1	10 - 16	10 - 16	10 - 16	8 - 12	10 - 20
TENSILE STRENGTH (kg/cm^2)	D638	700	600	560 - 800	700 - 900	500	500	400 - 700	400 - 600
ELONGATION (%)	D638	25	60	3 - 10	10 - 70	8 - 90	30 - 100	10 - 80	5 - 40
TENSILE MODULUS (10^4 kg/cm^2)	D638	3.5	2.0	3	0.3 - 3.5	0.3 - 2	0.4 - 1.5	1 - 3	0.7 - 3.5
FLEXURAL STRENGTH (kg/cm^2)	D790	990	900	910 - 1100	400 - 1000	400 - 1000	490 - 560	600 - 770	280 - 700
IMPACT STRENGTH (notched) (kgcm/cm)	D256	7.6	6.5	1.4 - 2.2	1.0 - 53	2.7 - 34.5	2.7 - 65.2	20 - 40	10 - 40
VOLUME RESISTIVITY (Ω cm)	D257	10^{16}	10^{14}	$> 10^{15}$	$10^{10} - 10^{13}$	$10^{10} - 10^{15}$	$10^{12} - 10^{16}$	$10^{10} - 10^{13}$	$10^{12} - 10^{16}$
DIELECTRIC STRENGTH (kV/mm)	D149	20	28	18	6 - 49	10 - 21	12 - 59	6 - 50	31 - 60
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.0048 0.0048	0.001 0.006	0.04 - 0.06 0.02 - 0.03	0.01 - 0.2 0.01 - 0.1	0.01 - 0.04 0.01 - 0.05	0.01 - 0.04 0.01 - 0.04	0.03 - 0.15 0.07 - 0.1	0.007 0.007 - 0.03
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	3.7 3.7	3.7 3.7	3.5 - 4.5 2.7 - 3.2	3.5 - 7.5 3.2 - 7.2	3.5 - 6.4 3.2 - 6.2	3.7 - 4.0 3.0 - 3.7	6.0 - 8.0 6.0	2.7 2.0 - 3.0
HEAT DISTORTION TEMPERATURE (°C)	D648	125	110	60 - 80	90	90	70 - 80	60 - 70	50 - 70

Table I.1 (cont.): **THERMOPLASTIC MOULDING MATERIALS**

PROPERTIES / POLYMERS		HALOGENATED POLYMERS							
		POLYVINYL-CHLORIDE rigid	PTFE	PCTFE	POLYVINYLIDENE FLUORIDE	CHLORINATED POLYETHER	FLUORINATED(FEP) ETHYLENE PROPYL.		
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.35 – 1.60	2.10 – 2.30	2.10 – 2.30	1.77	1.40	2.14 – 2.17		
WATER ABSORPTION (%)	D570	0.07 0.40	0.005	0.005	0.03	0.01	0.01		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.15	0.21	0.20	0.20	0.11	0.17		
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	5 – 6	10	7	15	12	15–20		
TENSILE STRENGTH (kg/cm^2)	D638	560 – 800	105 – 210	400 – 525	560	420	175		
ELONGATION (%)	D638	3 – 10	250 – 350	35 – 190	200 – 300	60 – 160	250 – 330		
TENSILE MODULUS (10^4 kg/cm^2)	D638	2.8 – 3.10	0.4	1.3	1.4	1.1	0.6		
FLEXURAL STRENGTH (kg/cm^2)	D790	910	no fracture	497 – 580	140	350	–		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	2.7	16.3	6.5 – 19.5	20.6	2.1	no break		
VOLUME RESISTIVITY (Ω cm)	D257	$5\ 10^{14}$ – 10^{15}	10^{17} – 10^{20}	10^{18}	$5\ 10^{14}$	$1.5\ 10^{16}$	$>2\ 10^{18}$		
DIELECTRIC STRENGTH (kV/mm)	D149	19	19	25	10	16	20		
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.007 – 0.02 0.006 – 0.05	0.0002 0.0002	0.002 – 0.0025 0.005 – 0.0085	0.05 0.184	0.01 –	0.0003 0.0003		
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	3.2 – 3.6 2.8 – 3.5	2.0 2.0	2.3 – 2.4 2.1 2.5	10 7.5	3 –	2.1 2.1		
HEAT DISTORTION TEMPERATURE (°C)	D648	60 – 80	–	70 – 80	110	100	–		

Table I.1 (cont.): **THERMOPLASTIC MOULDING MATERIALS**

PROPERTIES \ POLYMERS		PHENOXY	POLYAMIDES				POLYCARBONATE		
			6.6	6.10	6	11			
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.18	1.09 - 1.16	1.09	1.13 - 1.14	1.04 - 1.05	1.20		
WATER ABSORPTION (%)	D570	0.13	0.80 - 1.50	0.30 - 0.50	1.90 - 6.20	0.20	0.20 - 0.40		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	-	0.21	0.20	0.15	0.20	0.13		
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	-	8.1	9.0	8.5	9.9	6.7		
TENSILE STRENGTH (kg/cm^2)	D638	670	500 - 800	600	400 - 2500	350 - 600	630 - 670		
ELONGATION (%)	D638	90	80 - 150	100 - 250	10 - 400	30 - 300	60 - 100		
TENSILE MODULUS (10^4 kg/cm^2)	D638	2.7	1.3 - 3	2.1	0.4 - 3.3	1.3	2.2 - 2.5		
FLEXURAL STRENGTH (kg/cm^2)	D790	980	560 - 1000	630	350 - 1400	-	770 - 850		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	10 - 25	5 - 25	6 - 25	3 - 30	40	10 - 12		
VOLUME RESISTIVITY (Ω cm)	D257	5 10^{13}	10^{10} - 10^{14}	10^{14}	10^{11} - 10^{15}	10^{11} - 10^{14}	10^{15} - 2.1 10^{16}		
DIELECTRIC STRENGTH (kV/mm)	D149	19	10 - 19	10 - 19	12 - 20	9 - 16	14 - 24		
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.0012 0.03	0.01 - 0.09 0.02 - 0.08	0.02 0.03	0.011 0.04 - 0.13	0.02 - 0.05	0.0007 - 0.0009 0.01		
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	4.1 3.8	3.9 7.6 3.4 - 3.6	3.6 3.9 3.5	3.4 4.0 - 8.5	3.2 - 3.3	3 3.3 2.9 - 3		
HEAT DISTORTION TEMPERATURE (°C)	D648	-	100	60	70	50	130		

Table I.1 (cont.): THERMOPLASTIC MOULDING MATERIALS

PROPERTIES \ POLYMERS		POLYOLEFINES							
		POLYETHYLENE low density	POLYETHYLENE high density	POLYPROPYLENE	IONOMER	ETHYLENE VINYL ACETATE (EVA)	ETHYLENE ETHYL ACRYLATE (EEA)		
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	0.91 - 0.93	0.94 - 0.96	0.90 - 0.91	0.93 - 0.96	0.94	0.93		
WATER ABSORPTION (%)	D570	< 0.01	< 0.01	< 0.03	0.1 - 1.5	< 0.01	-		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.28	0.28	0.15	–	–	-		
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	16 - 19	15 - 30	7 - 10	–	-	-		
TENSILE STRENGTH (kg/cm^2)	D638	60 - 170	120 - 400	300 - 400	140 - 175	280	140		
ELONGATION (%)	D638	125 - 800	20 - 600	220 - 900	300 - 400	500 - 1500	500 - 1500		
TENSILE MODULUS (10^4 kg/cm^2)	D638	0.09 - 0.23	0.35 - 7.20	0.90 - 1.20	0.20 - 0.30	0.02 - 0.10	-		
FLEXURAL STRENGTH (kg/cm^2)	D790	no fracture	140 - 180	490	no fracture	no fracture	no fracture		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	> 87	5 - 108	2.7 - 21.0	31 - 60	no break	no break		
VOLUME RESISTIVITY (Ω cm)	D257	$3\ 10^{16}-10^{20}$	$> 3\ 10^{16}$	$3\ 10^{15} - 5\ 10^{16}$	$> 10^{16}$	$1.5\ 10^{14}$	$2.4\ 10^{15}$		
DIELECTRIC STRENGTH (kV/mm)	D149	17 - 39	15 - 40	20 - 30	39	20.6	22		
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	< 0.005 0.0002 - 0.002	0.0001 > 0.0001	0.0005 0.0002 - 0.0003	0.001	0.003	0.001		
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	2.2 - 2.3 2.3 - 2.4	2.3 2.3 - 2.35	2.2 2.0 - 2.2	2.4 - 2.5	3.2 2.8	2.8 2.7		
HEAT DISTORTION TEMPERATURE (°C)	D648	80 - 90 (Vicat)	130 (Vicat)	60	70	65	65		

Table I.1 (cont.): **THERMOPLASTIC MOULDING MATERIALS**

PROPERTIES \ POLYMERS		POLYPHENYLENE OXIDE	POLYSULFONE	POLYURETHANE					
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.06	1.10	1.10 - 1.30					
WATER ABSORPTION (%)	D570	0.10	0.22	0.60 - 0.80					
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.16	0.22	–					
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	5.2	5.6	–					
TENSILE STRENGTH (kg/cm^2)	D638	660 - 740	710	315 - 560					
ELONGATION (%)	D638	80	50 - 100	400 - 650					
TENSILE MODULUS (10^4 kg/cm^2)	D638	2.6	2.5	0.007 - 0.026					
FLEXURAL STRENGTH (kg/cm^2)	D790	1015	1080	–					
IMPACT STRENGTH (notched) (kgcm/cm)	D256	8.7	7.0	no break					
VOLUME RESISTIVITY (Ω cm)	D257	10^{17}	$5\ 10^{16}$	$2\ 10^{11}$					
DIELECTRIC STRENGTH (kV/mm)	D149	15	17	33 - 43					
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.0003-0.0009	0.0008 - 0.008 0.0003-0.0056	0.08 0.11					
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	2.6 2.6	2.8 - 3.4 2.7 - 3.1	8.2 5.9					
HEAT DISTORTION TEMPERATURE (°C)	D648	170	170	–					

Table I.1 (cont.): **THERMOPLASTIC MOULDING MATERIALS**

PROPERTIES \ POLYMERS		STYRENE POLYMERS				VINYL ESTERS			
		GEN. PURPOSE	TOUGHENED	A B S COPOLYMER	STYRENE (SAN) ACRYLONITRILE	POLYVINYL BUTYRAL	POLYVINYL FORMAL		
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.04 - 1.07	1.04 - 1.07	1.01 - 1.07	1.07 - 1.10	1.08 - 1.12	1.20 - 1.25		
WATER ABSORPTION (%)	D570	0.03 - 0.04	0.03 - 0.3	0.57	0.15 - 0.30	0.30 - 0.60	1.00 - 1.30		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.15	0.15	0.15 - 0.25	–	–	0.15		
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	5.9 - 8.6	5 - 9	5.9 - 8.6	6.5 - 6.7	0.8 - 2.3	0.6 - 0.7		
TENSILE STRENGTH (kg/cm^2)	D638	350 - 525	210 - 455	340 - 610	560 - 840	300 - 600	630 - 770		
ELONGATION (%)	D638	1 - 3.6	10 - 40	15 - 30	2.0 - 4.0	5 - 60	5 - 60		
TENSILE MODULUS (10^4 kg/cm^2)	D638	1.05 - 3.5	1.75 - 4	1.75 - 2.5	3 - 4	2.45 - 2.8	3.5 - 4.9		
FLEXURAL STRENGTH (kg/cm^2)	D790	630 - 910	490 - 1190	560 - 950	805 - 1300	700	910 - 1260		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	1 - 3.2	2.2 - 16	8 - 54	13.6 - 38	6.5	2.17 - 10.8		
VOLUME RESISTIVITY (Ω cm)	D257	10^{17} - 10^{21}	10^{12} - 10^{17}	> 10^{15}	7 10^{15}	> 10^{14}			
DIELECTRIC STRENGTH (kV/mm)	D149	20 - 28	12 - 26	12 - 15	16 - 22	–	34 - 40		
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.0002 0.0005	0.0009 0.00012 - 0.002	0.004 - 0.016 0.007 - 0.03	0.004 - 0.006 0.001 - 0.01	0.007 –	0.007 –		
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	2.5 - 2.65 2.5 - 2.65	2.45 - 4.75 2.4 - 4.0	2.76 - 4.76 2.44 - 3.78	2.9 - 3.4 2.8 - 3.1	3.6 3.3	3.7 3.0		
HEAT DISTORTION TEMPERATURE (°C)	D648	100	100	100	100	10	30		

Table I.2: THERMOPLASTIC FILMS

PROPERTIES / POLYMERS		CELLULOSICS				HALOGENATED POLYMERS					PARYLENES
		CELLULOSE ACETATE	CELLULOSE ACETOBUTYRATE	CELLULOSE TRIACETATE	ETHYL CELLULOSE	PCTFE	FEP	PVF	PVC RIGID	PVC FLEXIBLE	
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1,3 – 1,5	1,2	1,3	1,1 - 1,3	2,1	2,2	1,5	1,4 - 1,5	1,15 - 1,5	1,1 - 1,3
WATER ABSORPTION (%)	D570	3,6 – 6,8	0,1 – 3,4	3,5 – 4,5	2,5 – 7,5	negligible	0,01	0,05	negligible	negligible	
TENSILE STRENGTH (kg/cm^2)	D638	380 – 940	260 – 625	630 – 1000	350 – 740	350 – 560	170 – 210	490 – 1400	385 – 700	70 – 390	630 – 910
ELONGATION (%)	D638	15 – 45	20 – 100	10 – 40	20 – 80	50 – 150	300 – 400	115 – 250	2 – 25	50 – 500	200
TEAR STRENGTH (kg/mm)	D689	0.07 – 0.9	0.11 – 0.62	0.15 – 0.23	0.07 – 1.4	0.4 – 1	4 – 6	0.5 – 4	0.4 – 10	0.4 – 40	
VOLUME RESISTIVITY (Ω cm)	D257	10^{10} – 10^{12}	10^{14}	10^{13} – 10^{14}	10^{12} – 10^{15}	> 10^{18}	> 2 10^{18}	> 10^{13}	5 10^{14} – 10^{16}	5 10^{8} – 5 10^{14}	10^{17}
DIELECTRIC STRENGTH (kV/mm)	D149	67 – 110	89 – 100	90 – 110	30 – 60				140	50 – 120	160 – 240
POWER FACTOR	D150	at 50 cycl/s: 0,018 – 0,02	at 8 10^2 c/s: 0,012 – 0,024	at 8 10^2 c/s: 0,02	60 c/s: 0,007 10^6 c/s: 0,007 – 0,03				8 10^2 c/s: 0,05 10^3 c/s: 0,02	8 10^2 cycl/s: 0,07 – 0,35 10^3 c/s: 0,1 – 0,13	10^6 cycl/s: 0,0002 – 0,0006
DIELECTRIC CONSTANT (same frequency)	D150	4,9	3,5 – 4,1	3,9	2,7 2,0 – 3,0				10^3 cycl/s 3,0 – 3,5	10^3 cycl/s 4,5 – 8	10^6 cycl/s 2,7

Table I.2 (cont.): THERMOPLASTIC FILMS

PROPERTIES \ POLYMERS		POLYAMIDES				POLYCARBONATE	POLYETHYLENE TEREPHTHALATE	POLYIMIDE
		6	66	610	12			
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1,12	1,14	1,11	1,01	1.20	1.38	1,42
WATER ABSORPTION (%)	D570	8,0	1,5	0.4	0.25	0,2 – 0,6	> 0.5	1,3
TENSILE STRENGTH (kg/cm^2)	D638	630 - 900	840	700	490 - 630	450 - 1400	1200 - 1800	1800
ELONGATION (%)	D638	> 400	> 250	> 250	120 - 350	50 - 120	35 - 130	70 - 100
TEAR STRENGTH (kg/mm)	D 689	2	2	3	–	0,4 - 0,62	0,07 - 1,5	0,3 - 1,5
VOLUME RESISTIVITY (Ω cm)	D257					$8\ 10^{15} - 3\ 10^{16}$	$10^{17} - 10^{19}$	10^{18}
DIELECTRIC STRENGTH (kV/mm)	D149	20	16	20		118 – 155	157	275
POWER FACTOR	D150	60 cycl/s : 0.014			60 cycl/s : 0.009	50 cycl/s : 0,0009 - 0,002 10^6 cycl/s: 0,009	10^3 cycl/s : 0.006	10^3 cycl/s : 0.003
DIELECTRIC CONSTANT (same frequency)	D150	4.8	4	3,6	4.2	50 c/s: 3.0 - 3,1 10^6 c/s: 2,9 - 2,9	10^3 c/s : 2,9 – 3,2	10^3 c/s : 3,5

Table I.2 (cont.): THERMOPLASTIC FILMS

PROPERTIES / POLYMERS	ASTM	POLYOLEFINS: POLYETHYLENE LOW DENSITIY	POLYOLEFINS: POLYETHYLENE HIGH DENSITIY	POLYOLEFINS: POLYPROPYLENE	POLYSTYRENE	POLYVINYLALCOHOL	RUBBER HYDROCHLORIDE
SPECIFIC GRAVITY (g/cm^3)	D792	0.91 - 0.93	0.93 - 0.96	0.90 - 0.91	1.05 - 1.07	1.21 - 1.32	1.11 - 1.15
WATER ABSORPTION (%)	D570	negligible	negligible	negligible	< 0.06	30 - 80	5 - 7
TENSILE STRENGTH (kg/cm^2)	D638	100 - 280	240 - 320	210 - 460	490 - 850	210 - 700	245 - 420
ELONGATION (%)	D638	100 - 800	70 - 400	100 - 1000	3 - 10	200 - 800	200 - 800
TEAR STRENGTH (kg/mm)	D689	4.7 - 11	0.62 - 2.3	1.5 - 3	0.1	2.4 - 32	2.4 - 80
VOLUME RESISTIVITY (Ω cm)	D257	$3\ 10^{16} - 10^{20}$	$3\ 10^{16} - 10^{18}$	$3\ 10^{15} - 5\ 10^{16}$	$10^{17} - 10^{19}$		$1.5\ 10^{13}$
DIELECTRIC STRENGTH (kV/mm)	D149	17 - 39	20 - 47	29 - 39	120 - 160		
POWER FACTOR at 10^6 cycl/s	D150	0.0002 - 0.001	0.0001	0.0002 - 0.0003	at 10^9 cycl/s: 0.0003		at 50 cycl/s → 0.003 at 10^6 cycl/s → 0.006
DIELECTRIC CONSTANT at 10^6 cycl/s	D150	2.2 - 2.3	2.3 - 2.35	2.0 - 2.2	at 10^9 cycl/s: 2.6 - 2.7	at 10^3 cycl/s: > 3	at 10^3 cycl/s: 3.51

Table I.3: **THERMOSETTING MOULDING MATERIALS**

PROPERTIES \ POLYMERS		AMINOS: MELAMINE				AMINOS: UREA		DIALLYL PHTHALATE		
		UNFILLED	CELLULOSE	MINERAL	GLASS FIBRE	WOOD FLOUR	α CELLULOSE	UNFILLED	GLASS FILLED	ORLON FILLED
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.48	1.43 - 1.50	1.49	1.90 - 2.00	1.50 - 1.60	1.50 - 1.60	1.27	1.60 - 1.75	1.31 - 1.34
WATER ABSORPTION (%)	D570	0.20 - 0.50	0.30 - 0.80	0.50	0.09 - 0.60	0.70	0.40 - 0.80	0.09	0.05	0.10 - 0.20
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	–	0.25	–	0.42	–	–	–	–	–
THERMAL COEFFICIENT OF EXPANSION (10^{-5} / °C)	D696	–	3.60	–	1.47	–	–	–	3.6	9.0
TENSILE STRENGTH (kg/cm^2)	D638	–	560 - 840	280 - 400	700	500 - 1000	500 - 800	280	470 - 700	480
ELONGATION (%)	D638	–	0.6	–	–	–	–	–	–	–
TENSILE MODULUS (10^4 kg/cm^2)	D638	–	9.1	11.2	–	6.3 - 7.0	6.6 - 7.0	5.1	11.2	7.5
FLEXURAL STRENGTH (kg/cm^2)	D790	700	700 - 1450	420 - 770	700 - 1400	800 - 1300	800 - 1200	490 - 720	700 - 1300	600 - 800
IMPACT STRENGTH (notched) (kgcm/cm)	D256	–	1.4 - 1.9	1.6	2.7 - 6.5	0.9 - 1.8	0.9 - 1.8	1.7	2.1 - 5.4	2.6 - 20
VOLUME RESISTIVITY (Ω cm)	D257	–	10^{12} - 10^{13}	10^{12}	1 - 7 10^{11}	5 10^{11} 10^{14}	5 10^{11} 10^{14}	2 10^{16}	10^{13}	10^{10}
DIELECTRIC STRENGTH (kV/mm)	D149	–	16	16	12	0.8 - 1.2	0.8 - 1.2	18	18	15 - 16
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.05 - 0.16 0.031 - 0.04	0.026 - 0.19 0.032 - 0.12	0.031	0.14 - 0.23 0.013 - 0.03	0.03 - 0.032 0.017 - 0.019	0.024 - 0.038 0.018 - 0.022	0.08	0.01 - 0.017	0.02 - 0.03
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	7.9 - 11 6.3 - 7.3	6.2 - 7.7 5.2 - 6.0	6.4	7.0 - 11.1 6.9 - 7.9	7 - 9.5 6.4 - 6.9	7 - 9.5 6.4 - 6.9	3.6	4.25	3.8
HEAT DISTORTION TEMPERATURE (°C)	D648	150	130	150	200	130 - 140	130	130	180 - 260	110 - 130

Table I.3 (cont.): **THERMOSETTING MOULDING MATERIALS**

PROPERTIES \ POLYMERS		EPOXY RESINS							
		BISPHENOL A			EPOXY NOVOLAC				
		NO FILLER	GLASS	MINERAL	NO FILLER	GLASS	MINERAL		
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.15	2.0 - 2.1	1.8 - 2.0	1.2	1.97	1.7		
WATER ABSORPTION (%)	D570	0.1 – 0.2	0.02 – 0.08	0.30 - 0.80	–	0.04 – 0.06	0.11 – 0.20		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.15 – 0.45	1	–	–	–	–		
THERMAL COEFFICIENT OF EXPANSION (10^{-5} / °C)	D696	6	0.6	–	3	–	–		
TENSILE STRENGTH (kg/cm^2)	D638	700 – 800	3500 – 4000	700	700	3500 – 4000	380		
ELONGATION (%)	D638	4.4	–	–	2 – 5	–	–		
TENSILE MODULUS (10^4 kg/cm^2)	D638	3.5	30	10 – 15	3.5	21 – 22	–		
FLEXURAL STRENGTH (kg/cm^2)	D790	800 – 1300	3600	1500 – 1700	600 – 1000	3900	700 – 800		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	1.1 – 2.7	6.4 – 8.2	2.2 - 2.7	2.7	7.0 – 9.2	2.2 – 2.7		
VOLUME RESISTIVITY (Ω cm)	D257	6.1 10^{15}	–	1.5 10^{15}	2.1 – 10^{14}	–	1.4 – 5.5 10^{14}		
DIELECTRIC STRENGTH (kV/mm)	D149	> 16	18 – 22	15 – 16	–	–	12 – 16		
POWER FACTOR at 10^6 cycl/s	D150	0.032	0.024	0.013	0.029	0.015	–		
DIELECTRIC CONSTANT at 10^6 cycl/s	D150	3.4	4.7 – 4.8	4.1 – 4.6	3.5	5.1	4.3 – 4.8		
HEAT DISTORTION TEMPERATURE (°C)	D648	110	–	–	150 – 200	–	–		

Table I.3 (cont.): **THERMOSETTING MOULDING MATERIALS**

PROPERTIES \ POLYMERS		PHENOLICS							
		NO FILLER	WOOD FLOUR	ASBESTOS	FIBRE AND FABRIC	MINERAL	NYLON		
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.30 – 1.32	1.29 - 1.51	1.78 - 2.00	1.3 - 1.4	1.5 - 1.9	1.2 - 1.5		
WATER ABSORPTION (%)	D570	0.30 - 0.40	0.70 - 1.20	0.03 - 0.30	0.50 - 1.6	0.04 - 0.25	0.25 - 0.4		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	-	0.15 - 0.45	0.15 - 0.25	0.3	0.3	-		
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	4.3	3.6	-	3	1.8	-		
TENSILE STRENGTH (kg/cm^2)	D638	140 - 630	385 - 630	210 - 490	315 - 630	140 - 595	315 - 630		
ELONGATION (%)	D638	~ 5	~ 5	~5	~5	4 - 9			
TENSILE MODULUS (10^4 kg/cm^2)	D638	1.4 - 3.1	4.9 - 14.0	11 - 20.0	5.6 - 10.0	9.5 - 21.0	2.8 - 14.0		
FLEXURAL STRENGTH (kg/cm^2)	D790	840 – 1000	600	450 – 770	490 – 1100	560 - 840	420 - 910		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	2.7 - 4.3	1 - 2.8	0.8 - 16	2 - 36	0.97 - 3.9	1.4 - 2.8		
VOLUME RESISTIVITY (Ω cm)	D257	2.5 10^{10} - 10^{12}	10^9 - 10^{13}	10^8 - 10^{13}	10^8 - 10^{12}	10^{10} - 10^{14}	10^{11} - 10^{14}		
DIELECTRIC STRENGTH (kV/mm)	D149	10 – 16	0.6 – 10	0.4 - 10	0.4 - 7	3 - 16	1 - 11		
POWER FACTOR at 10^6 cycl/s	D150	0.04 - 0.05	0.015 - 0.06	0.03 - 0.25	0.03 - 0.08	0.007 - 0.08	0.15 - 0.2		
DIELECTRIC CONSTANT at 10^6 cycl/s	D150	4-9.7 (10^3 c/s)	3.9 - 6.5	5 - 6	4.8 - 7	4 - 6	3.7 - 4.5		
HEAT DISTORTION TEMPERATURE (°C)	D648	150 - 180	130 - 180	-	250	180 - 200	-		

Table I.3 (cont.): **THERMOSETTING MOULDING MATERIALS**

PROPERTIES \ POLYMERS		POLYESTERS							
		α CELLULOSE	MINERAL	GLASS	NO FILLER				
SPECIFIC GRAVITY (g/cm^3)	ASTM D792	1.35 - 1.40	1.70 - 2.20	1.20 - 2.00	1.20 - 1.40				
WATER ABSORPTION (%)	D570	0.01 - 1	—	0.1 - 2	0.03 - 0.4				
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	—	—	1.8 - 2.2	0.15				
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	—	—	2	7				
TENSILE STRENGTH (kg/cm^2)	D638	420 - 500	210 - 460	420 - 900	350 - 810				
ELONGATION (%)	D638	—	—	0.3 - 0.5	1.7 - 2.6				
TENSILE MODULUS (10^4 kg/cm^2)	D638	—	9.8 - 19.0	4.2 - 12.0	2.8 - 4.6				
FLEXURAL STRENGTH (kg/cm^2)	D790	700 - 840	175 - 630	840 - 1500	450 - 910				
IMPACT STRENGTH (notched) (kgcm/cm)	D256	1.6 - 2.5	1 - 4	40 - 54	1.6 - 10				
VOLUME RESISTIVITY (Ω cm)	D257	> 10^{14}	> 10^{14}	10^{12} - 10^{15}	2.7 10^{14} 2 10^{15}				
DIELECTRIC STRENGTH (kV/mm)	D149	10 - 14	10 - 17	6 - 14	10 - 17				
POWER FACTOR at 10^6 cycl/s	D150	0.03 - 0.05	0.013 - 0.04	1.1 - 0.04	0.01 - 0.03				
DIELECTRIC CONSTANT at 10^6 cycl/s	D150	3.5 - 5.5	4.5 - 7.0	4.5 - 6.0	3.0 - 4.01				
HEAT DISTORTION TEMPERATURE (°C)	D648	—	—	200	50 - 200				

Table I.3 (cont.): **THERMOSETTING MOULDING MATERIALS**

POLYMERS / PROPERTIES		POLYIMIDES			POLYURETHANES	SILICONES			
		UNFILLED	GRAPHITE	GLASS		GLASS	MINERAL		
SPECIFIC GRAVITY (g/cm³)	ASTM D792	1.47	–	1.90	1.21	1.88	1.88 – 2.8		
WATER ABSORPTION (%)	D570	0.68	–	0.20	0.30 – 0.90	0.10 – 0.30	0.05 – 0.22		
THERMAL CONDUCTIVITY (kcal/m.h.°C)	D325	0.60	–	–	–	0.27	0.50		
THERMAL COEFFICIENT OF EXPANSION (10^{-5}/°C)	D696	5.4	–	1.5	–	6	5		
TENSILE STRENGTH (kg/cm²)	D638	740	460	2100	450 – 600	280 – 560	175 – 310		
ELONGATION (%)	D638	< 1.5	< 1	< 1	>	< 3	< 3		
TENSILE MODULUS (10^4 kg/cm²)	D638	3.2	3.9	28 – 30	3.3 – 8.4	14.7 – 17.5	8.7 – 15.9		
FLEXURAL STRENGTH (kg/cm²)	D790	1000	1200	3500	–	910 1330	490 700		
IMPACT STRENGTH (notched) (kgcm/cm)	D256	5	–	17	> 5.4	50	2		
VOLUME RESISTIVITY (Ω cm)	D257	10^{16} – 10^{17}	1.5 10^{15}	9.2 10^{15}	6 10^{12} – 10^{14}	3 10^{14}	10^{14}		
DIELECTRIC STRENGTH (kV/mm)	D149	22	10	–	20	10 – 11	11 – 16		
POWER FACTOR at 60 cycl/s at 10^6 cycl/s	D150	0.005	0.004	0.0055	0.03 – 0.05	0.003 – 0.02	0.002 – 0.01		
DIELECTRIC CONSTANT at 60 cycl/s at 10^6 cycl/s	D150	3.4	7.6	4.7	3.3 – 3.9	4.35	3.4 – 4.5		
HEAT DISTORTION TEMPERATURE (°C)	D648	300	–	350	–	> 450	270 – 450		

Table I.4: **ELASTOMERS**

POLYMER / PROPERTIES (ASTM)	ACRYLICS (PURE GUM)	BUTYL (PURE GUM)	ETHYLENE PROPYLENE	FLUOROELASTOMERS			HYPALON (PURE GUM)	NATURAL RUBBER (PURE GUM)
				VINYLIDENE FLUORIDE HEXAFLUOROPROPYLENE	FLUOROSILICONE	POLYCHLOROTRIFLUOROETHYLENE		
SPECIFIC GRAVITY (g/cm^3) (D 792)	1.09	0.90	0.86	–	1.40	1.85	1.18	0.93
DIELECTRIC STRENGTH (kV/mm) (D 149)	5	6 - 20	16 - 30	12 – 24	12 - 24	12 - 24	16 - 30	8
VOLUME RESISTIVITY (Ω cm) (D 257)	$10^{10} - 10^{12}$	$10^{12} - 10^{14}$	$10^{12} - 10^{14}$	$> 10^{14}$	$10^{12} - 10^{14}$	$> 10^{14}$	$10^{11} - 10^{14}$	$> 10^{14}$
DIELECTRIC CONSTANT (D 150) 60 cycl/s 1000 cycl/s	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10
TENSILE STRENGTH (kg/cm^2) (D 412)	18 - 28	175 - 210	140 - 238	140	70	25 - 42	250 - 280	175 - 245
ELONGATION * (%)	450 - 750	750 - 950	400 - 600	> 350	200	500 - 800	600	750 - 850
HARDNESS	A40 - A90	A40 - A90	A30 - A90	A60 - A90	A50 - A60	A45	A45 - A90	A30 - A90
COMPRESSION SET (%)	5	7.2	1.5 - 3	< 2	< 2	< 2	3 - 5	13
STRAIN AT 28 kg/cm^2 (%)	36	31	–	–	–	–	–	30
ABRASION RESISTANCE	Good	Good	Good	–	Poor	–	Excellent	Excellent
WATER RESISTANCE	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
OIL RESISTANCE	Excellent	Poor	Poor	Excellent	Excellent	Excellent	Good	Poor
OZONE RESISTANCE	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Poor
PERMEABILITY TO GAS	Low	Very Low	Low	Low	Low - Medium	Very Low	Low	Low
MINIMUM SERVICE TEMPERATURE (°C)	- 19	- 46	- 50	- 46	- 68	- 50	- 40	- 50
MAXIMUM SERVICE TEMPERATURE (°C)	175	150	150	232	200	200	160	80

* ELONGATION IS STRONGLY DEPENDENT OF FILLER CONTENT.

Table I.4 (cont.): **ELASTOMERS**

PROPERTIES (ASTM) \ POLYMER	NEOPRENE (PURE GUM)	NITRILE (PURE GUM)	POLYBUTADIENE (PURE GUM)	POLYISOPRENE-SYNTHETIC	POLYSULFIDE	POLYURETHANE	S B R	SILICONE
SPECIFIC GRAVITY (g/cm^3) (D 792)	1.25	1.00	0.91	0.93	1.35	1.25	0.94	1.1 - 1.6
DIELECTRIC STRENGTH (kV/mm) (D 149)	12	6 - 22	6 - 22	6 - 22	6 - 22	> 10	6 - 22	12 - 24
VOLUME RESISTIVITY (Ω cm) (D 257)	10^{10} - 5 10^{12}	10^{10} - 10^{12}	~ 10^{14}	> 10^{14}	10^{8} - 10^{10}	10^{8} - 5 10^{10}	> 10^{14}	10^{12} - 10^{15}
DIELECTRIC CONSTANT (D 150) 60 cycl/s 1000 cycl/s	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10	3 - 3.5 7 - 10
TENSILE STRENGTH (kg/cm^2) (D 412)	210 - 280	35 - 63	14 - 70	70 - 140	> 70	> 350	14 - 21	42 - 91
ELONGATION (%)	800 - 900	450 - 700	400 - 1000	-	450 - 650	540 - 750	400 - 600	100 - 500
HARDNESS	A 40 - A95	A 40 - A95	A 40 - A90	A 40 - A80	A 40 - A85	A 35 - A100	A 40 - A90	A 30 - A90
COMPRESSION SET (%)	5 - 9	6 - 9	4 - 6	6	8 - 11	1.5 - 3	2 - 5	~ 1.5
STRAIN AT 28 kg/cm^2 (%)	31	25	-	-	26	-	28	3.4
ABRASION RESISTANCE	Good	Good	Excellent	Excellent	Poor	Excellent	Good	Poor
WATER RESISTANCE	Good	Excellent	Excellent	Excellent	Good	Good	Excellent	Good
OIL RESISTANCE	Good	Excellent	Poor	Poor	Excellent	Excellent	Poor	Poor
OZONE RESISTANCE	Excellent	Poor	Poor	Poor	Excellent	Excellent	Poor	Excellent
PERMEABILITY TO GAS	Low	Low	Low	Very Low	Very Low	Very Low	Low	High
MINIMUM SERVICE TEMPERATURE (°C)	- 40	- 50	- 100	- 46	- 50	- 54	- 50	- 117
MAXIMUM SERVICE TEMPERATURE (°C)	115	120	95	80	120	115	80	240

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CHAPTER II

MATERIAL SELECTION GUIDE

Bibliography: see p. 21.

1. SELECTION OF MOULDING MATERIALS

1.1 Plastics for mechanical applications

1.1.1 Heavily stressed components: cams, gears, couplings, racks, rollers

Properties required:

- high impact strength
- high tensile strength
- good fatigue resistance
- stability at elevated temperatures
- excellent machinability or mouldable to close tolerance.

Types of plastics with particular applications:

Thermoplastics

Acetals for maximum fatigue life; highly accurate parts; exposure to extremely humid and corrosive conditions.

Polyamides for general purpose gears and impact problems.

Polyurethanes for high abrasion resistance.

Thermosets

Epoxies for ultimate tensile applications; chemical resistance.

Phenolics (fabric filled and cams) for thin stamped gears and for heavy duty gears.

Polyimides for high temperature and highly accurate parts.

1.1.2 Low-friction applications: bearings, guides, impellers, slides, valves, valve liners, wearing surface

Properties required:

- high resistance to abrasion
- low friction coefficient
- good heat resistance
- corrosion resistance
- good form stability.

Types of plastics with particular applications:

Acetals for humid service when resistance to creep is important; for valve liners or slides to eliminate jerky starts.

Aromatic polyesters for high temperature applications and very high loads.

Fluorocarbons for highly corrosive applications; extreme temperatures (-200°C to +260°C); sliding or low-speed rotating, dry bearing, non-stick surfaces.

Polyamides for general purpose bearings; impact problems; wear surface.

Polycarbonate (PTFE and glass filled) for accurate dimensional parts and for impact problems.

Polysulfone (PTFE or glass filled) for supporting or transmitting loads at elevated temperature.

Polyurethane for light loads at moderate temperature in oil, fuel, or grease medium; for impact problems.

Polypropylene and polyethylene for very low speed and loads at medium temperature.

Filled fluorocarbons for heavy loadings and high creep resistance.

1.2 Plastics for electrical applications

1.2.1 Types of plastics for high-voltage insulation: magnet coils, high-voltage switchers, transformers

Properties required:

- excellent insulation resistance
- high tensile and impact strength
- ozone resistance
- good fatigue resistance
- good dimensional stability
- excellent moulding characteristics.

Types of plastics with particular application:

Thermosets

Diallyl phthalates for very good chemical resistance; thermal resistance; high-dimensional stability.

Epoxies for very good chemical resistance; excellent dimensional stability; good thermal resistance; easy moulding (impregnation, encapsulation).

Melamines for hardness; high impact resistance; high resistance to burning.

Phenolics for punched and stamped parts.

Polyimides for heat resistance; very good dimensional stability, but difficult to mould.

Silicones for very high heat resistance; easy moulding.

Thermoplastics excluded at high temperature and in highly corrosive environment.

Polycarbonate for transparent parts requiring impact resistance.

Ionomers, PVC, polyethylene for flexible items.

1.2.2 *Types of plastics for high-frequency applications*

Properties required:

- low power factor at radio frequencies
- good mechanical properties
- good fatigue resistance.

Types of plastics with particular applications:

Polystyrene for general purpose applications.

Polyethylene for flexible applications.

Crosslinked polyethylene for medium temperature.

Polytetrafluoroethylene (PTFE) for extreme temperature; very good chemical resistance.

Polychlorotrifluoroethylene (PCTFE) for extreme temperature; very good chemical resistance; transparent properties.

Silicones for extremely low and high temperatures and hydrofuge properties; particularly recommended for encapsulation of electronic components.

1.3 Plastics for thermal and chemical equipment (plating components)

Properties required:

- resistance to very high temperature
- resistance to a wide range of chemicals
- minimum moisture absorption
- good mechanical properties.

Types of plastics with particular application:

Diallyl phthalate for electrical application.

Epoxies for greatest mechanical strength.

Fluorocarbons

- PTFE for general chemical purpose; extreme temperature applications.
- PTFCE for transparency.
- PVF and PTFC for extreme chemical resistance combined with mechanical strength and stiffness.
- Polypropylene, polyethylene (high density), polyvinylchloride for plating and less severe chemical and thermal exposures.

1.4 Plastics for light transmission components, models

Properties required:

- good light transmission
- excellent formability and mouldability
- shatter resistance
- fair to good mechanical properties.

Types of plastics with particular applications:

Acrylics and polystyrene for general purpose applications, especially for optical use. Acrylics have excellent low-temperature properties.

Cellulose acetates and vinyls for flexible glazing guards.

Cellulose butyrates for excellent impact resistance and deep formability.

Ionomers for excellent clarity.

Polycarbonate for maximum mechanical strength.

Vinyls for maximum formability and printability.

2. SELECTION OF PLASTIC FILMS AND SHEETS

2.1 Packaging and protection applications

Properties required:

- high tensile and shear strength
- chemical resistance
- weatherability performance.

Types of plastics with particular applications:

Polyethylene, polyamide, polypropylene, polyvinylchloride for general purpose applications.

PCTFE and PVF for extreme temperature; highly corrosive service.

Polyethylene terephthalate for extreme mechanical conditions.

2.2 Films and sheets for electrical applications

Properties required:

- excellent insulation resistance
- low water absorption
- high tensile and impact strength

Types of plastics with particular application:

PCTFE for extreme temperature and humidity service; high-frequency applications.

Polyimides for high temperature; high voltage; high chemical resistance; excellent mechanical properties.

Polycarbonates for medium temperature; high-voltage application.

Polyethylene terephthalate for good mechanical strength; chemical resistance; high-voltage application.

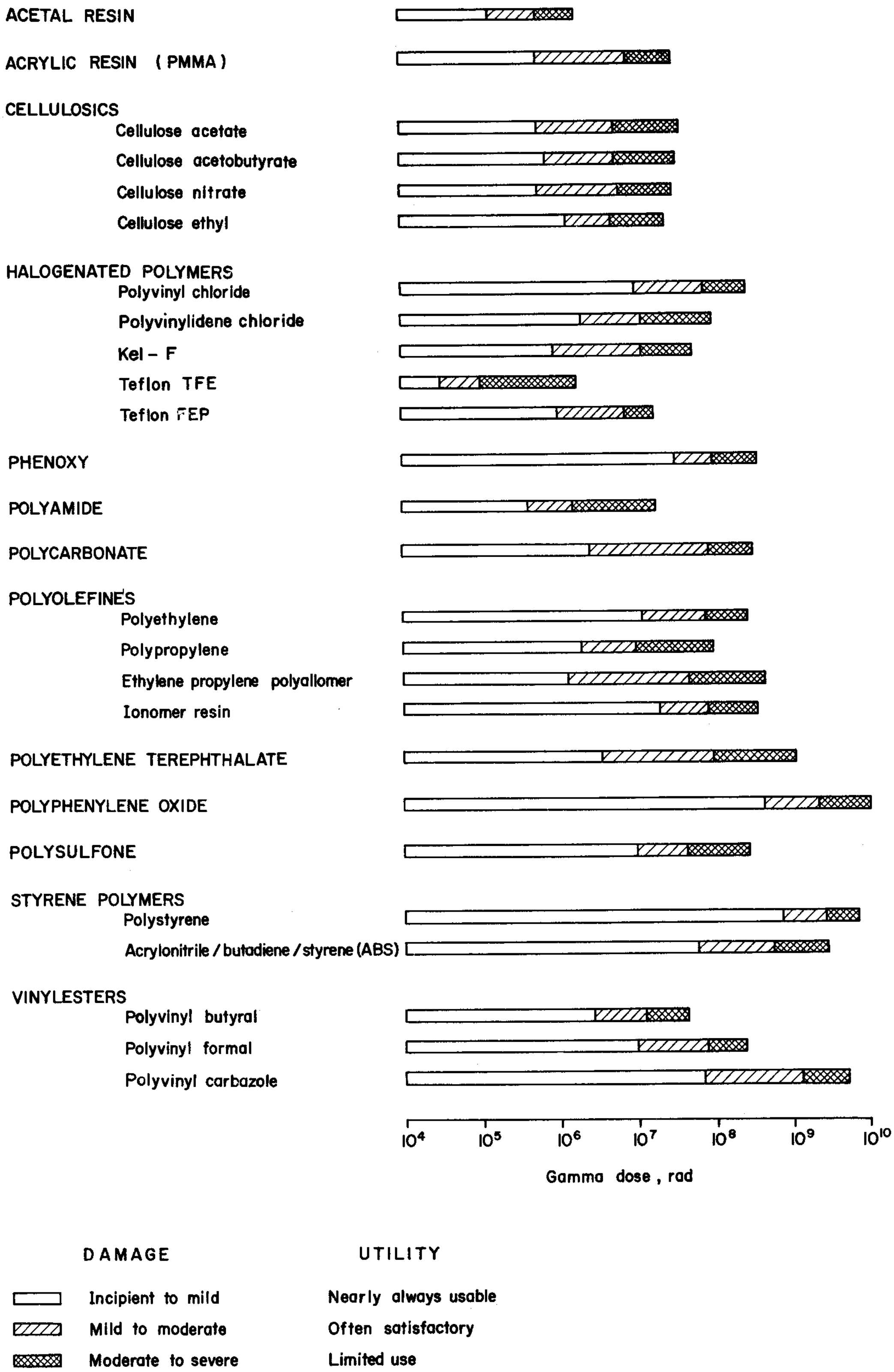
Polystyrene for high-frequency application.

	Polybutadiene			Fluoro				
olyurethane atural rubber eoprene		Polyurethane Natural rubber Neoprene	Natural rubber Synthetic rubber Polybutadiene Polyurethane	Butyl Ehtylene propylene Silicone Hypalon Acrylics	Natural rubber Synthetic rubber Polybutadiene	Natural rubber Synthetic rubber Polybutadiene SBR Ethylene propylene	Polyurethane Nitrile Thiokol Acrylics Fluoro	Natural rubber Synthetic rubb Polybutadiene Neoprene Polyurethane
olyurethane atural rubber BR utyl	Polyurethane Natural rubber Neoprene		Polyurethane Natural rubber Synthetic rubber Polybutadiene	Ethylene propylene Fluoro Hypalon Butyl	Polyurethane Natural rubber SBR Neoprene	Natural rubber Synthetic rubber SBR Butyl	Polyurethane Polysulfide Nitrile Fluoro	Polyurethane Synthetic rubb Polybutadiene Natural rubber Neoprene
atural rubber ynthetic rubber BR olybutadiene	Synthetic rubber Natural rubber Polybutadiene Neoprene	Synthetic rubber Natural rubber Polybutadiene Polyurethane		Nitrile Butyl Ethylene propylene Silicone	SBR Natural rubber Synthetic rubber Polybutadiene	Natural rubber Synthetic rubber Ethylene propylene Neoprene	Polyurethane Fluoro Nitrile Neoprene	Natural rubber Synthetic rubb Polybutadiene Ethylene propy Polyurethane
utyl olyurethane atural rubber BR	Natural rubber Synthetic rubber Polybutadiene Neoprene Polyurethane	Polyurethane Natural rubber Ethylene propylene Fluoro	Nitrile SBR Ethylene propylene		Nitrile Natural rubber Neoprene Hypalon	Butyl Ethylene propylene Silicone Natural rubber Synthetic rubber	Fluoro Acrylics Nitrile Polyurethane Thiokol	Butyl Hypalon Ethylene propy
htylene propylene BR olybutadiene	Polybutadiene Neoprene Polyurethane	Natural rubber Polyurethane Polybutadiene Neoprene	Natural rubber Synthetic rubber Polybutadiene SBR	Silicone Ethylene propylene Hypalon Fluoro		Ethylene propylene SBR Synthetic rubber Natural rubber Polybutadiene	Nitrile Neoprene Thiokol Fluoro	Silicone Hypalon Polybutadiene Natural rubber
atural rubber utyl BR olyurethane	Natural rubber Synthetic rubber Polybutadiene Neoprene Polyurethane	Natural rubber Polyurethane Butyl Neoprene	Natural rubber Synthetic rubber Polybutadiene SBR	Butyl Ethylene propylene Silicone Hypalon	Natural rubber SBR Ethylene propylene		Thiokol Polyurethane Acrylics Fluoro Hypalon	Butyl Natural rubber SBR Silicone Polyurethane
olyurethane itrile crylics luoro ypalon	Polyurethane Neoprene Nitrile Thiokol Acrylics	Polyurethane Polysulfide Fluoro Neoprene	Nitrile Neoprene Fluoro	Fluoro Acrylics Hypalon Nitrile Thiokol	Nitrile Neoprene Thiokol	Thiokol Polyurethane Acrylics Fluoro Hypalon		Thiokol Nitrile Nitrile
utyl BR atural rubber ynthetic rubber	Natural rubber Synthetic rubber Polybutadiene Neoprene	Butyl Natural rubber Polybutadiene SBR	SBR Ethylene propylene Butyl	Ethylene propylene Polyurethane Fluoro Hypalon	Ethylene propylene Natural rubber Neoprene Butyl	Butyl Ethylene propylene Natural rubber SBR	Polyurethane Nitrile Neoprene Fluoro Hypalon	

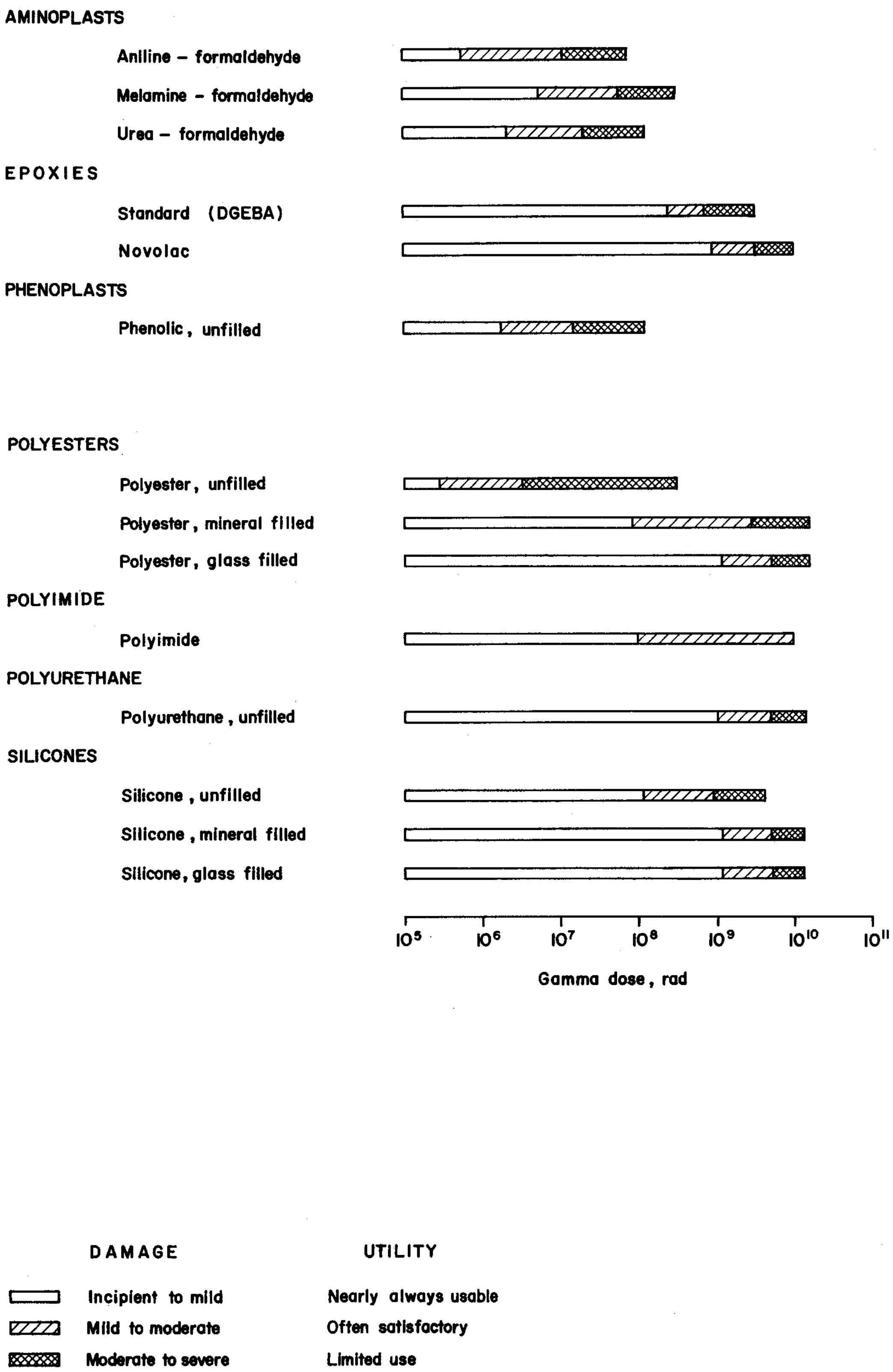
CHAPTER III

RADIATION EFFECTS ON ORGANIC MATERIALS

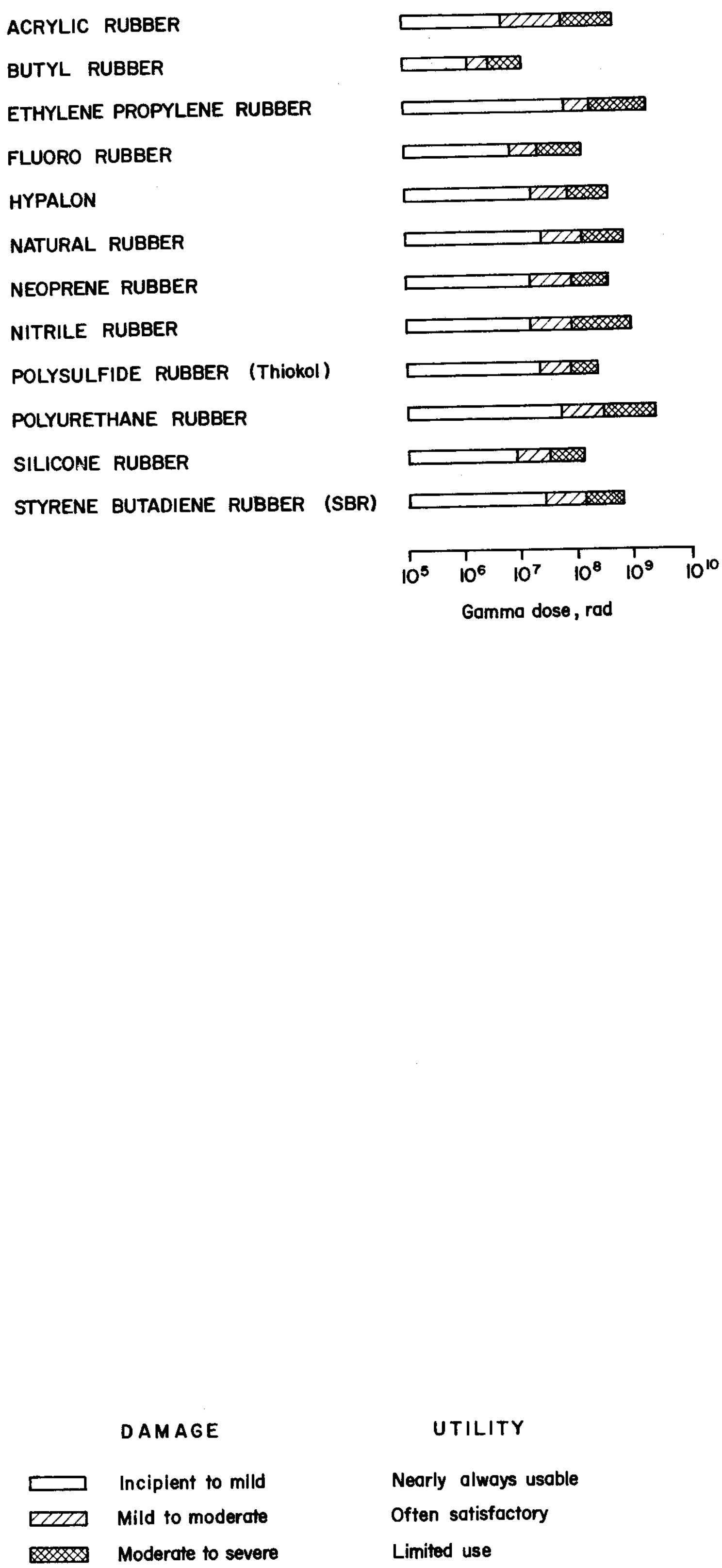
III.1 GENERAL RELATIVE RADIATION EFFECTS ON POLYMERS



RADIATION STABILITY OF THERMOPLASTIC RESINS



RELATIVE RADIATION RESISTANCE OF THERMOSETTING RESINS



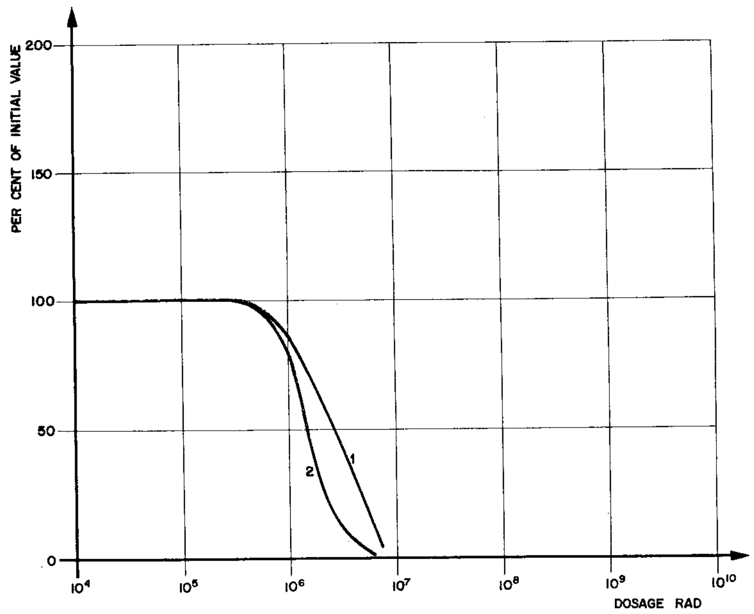
RADIATION STABILITY OF ELASTOMERS

III.2 EFFECT OF RADIATION ON THE MECHANICAL PROPERTIES

Figs. III.1 to III.25 : Thermoplastics
Figs. III.26 to III.58 : Thermosettings
Figs. III.59 to III.76 : Elastomers

THERMOPLASTICS

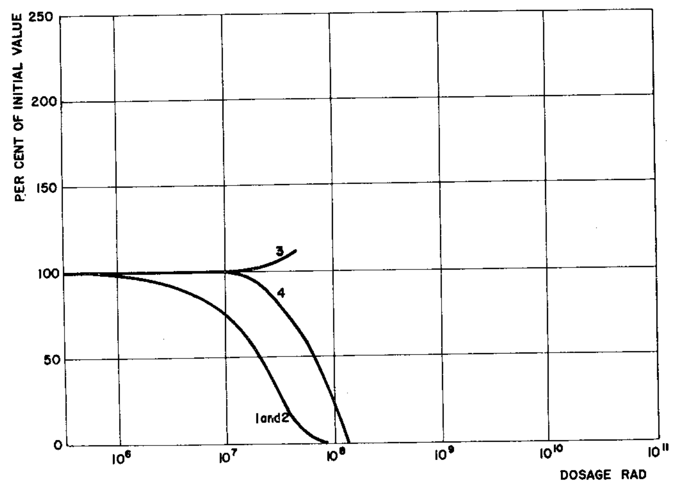
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	695 kg/cm²
2	ELONGATION	30 %
3	FLEXURAL STRENGTH	kg/cm²
4	ELASTIC MODULUS	kg/cm²
5	HARDNESS	Shore D

ACETAL RESIN (DELRIN)

Fig. III.1

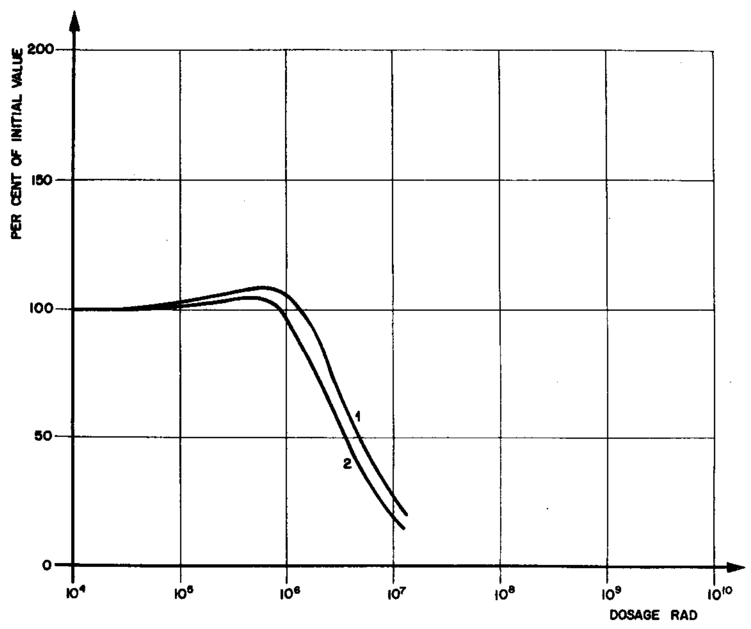


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	750 kg/cm²
2	ELONGATION	4.5 %
3	ELASTIC MODULUS	33.6 x 10^3 kg/cm²
4	SHEAR STRENGTH	470 kg/cm²

ACRYLIC RESIN : POLYMETHYLMETHACRYLATE

Fig. III.2

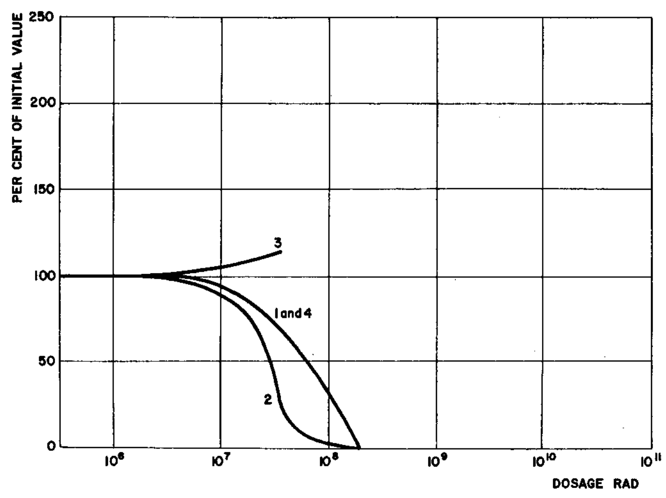
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	980 kg/cm^2
2	ELONGATION	2,4 %
3	FLEXURAL STRENGTH	kg/cm^2
4	ELASTIC MODULUS	kg/cm^2
5	HARDNESS	Shore D

POLY-α-METHYLCHLOROACRYLATE

Fig. III.3

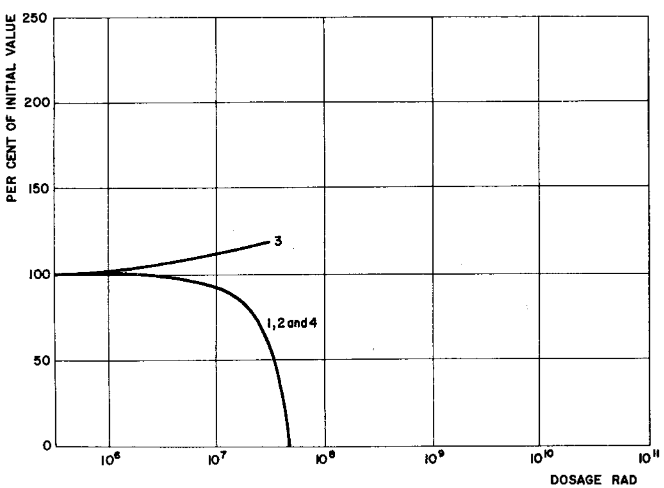


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	371 kg/cm^2
2	ELONGATION	20%
3	ELASTIC MODULUS	18.2×10^3 kg/cm^2
4	SHEAR STRENGTH	448 kg/cm^2

CELLULOSE ACETATE (FILM)

Fig. III.4

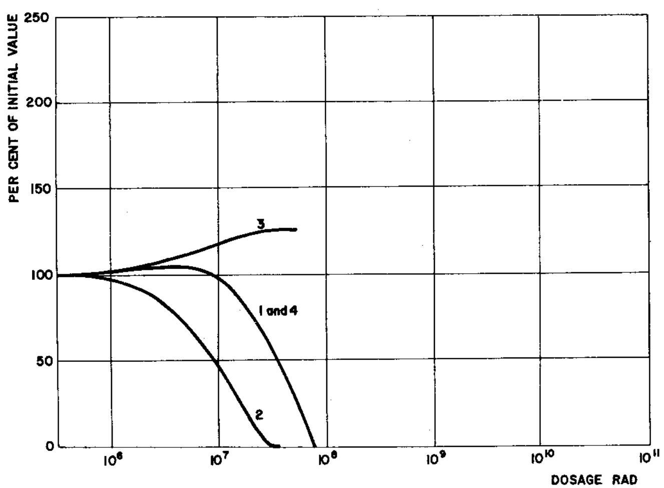
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	294 kg/cm²
2	ELONGATION	60 %
3	ELASTIC MODULUS	11.2×10^3 kg/cm²
4	SHEAR STRENGTH	280 kg/cm²

CELLULOSE ACETATE BUTYRATE (FILM)

Fig. III.5

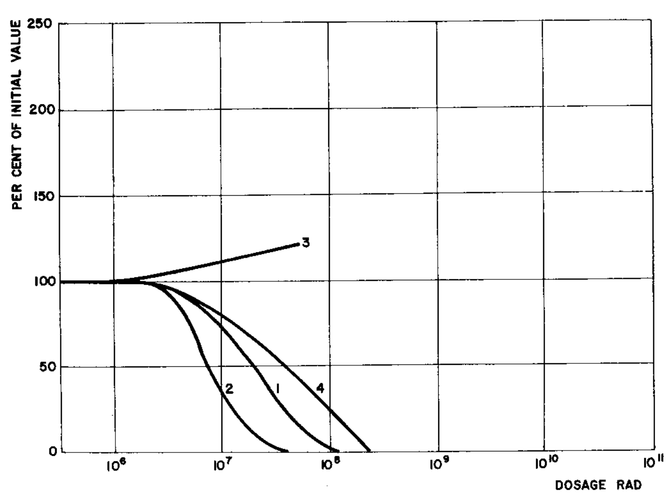


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	532 kg/cm²
2	ELONGATION	30 %
3	ELASTIC MODULUS	25.2×10^3 kg/cm²
4	SHEAR STRENGTH	616 kg/cm²

CELLULOSE NITRATE (FILM)

Fig. III.6

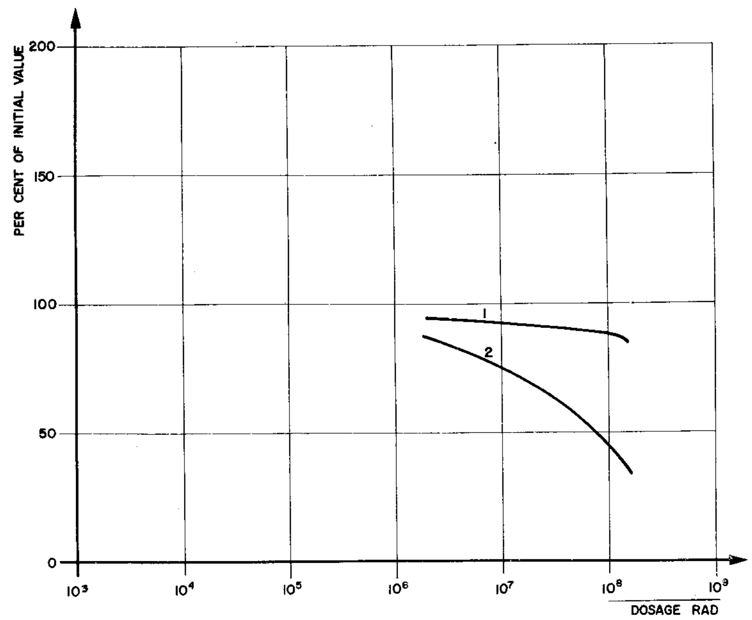
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	420 kg/cm²
2	ELONGATION	40%
3	ELASTIC MODULUS	14.7×10^3 kg/cm²
4	SHEAR STRENGTH	469 kg/cm²

ETHYL CELLULOSE (FILM)

Fig. III.7

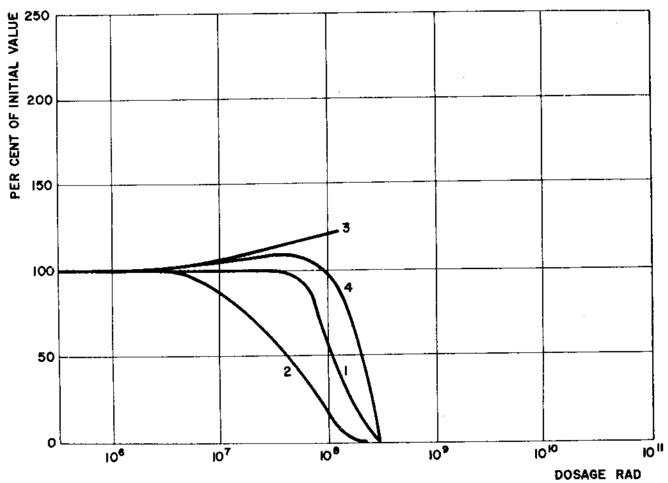


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	220 kg/cm²
2	ELONGATION	310 %
3	FLEXURAL STRENGTH	kg/cm²
4	ELASTIC MODULUS	kg/cm²
5	HARDNESS	Shore D

PLASTICIZED POLYVINYLCHLORIDE (CABLE INSULATION)

Fig. III.8

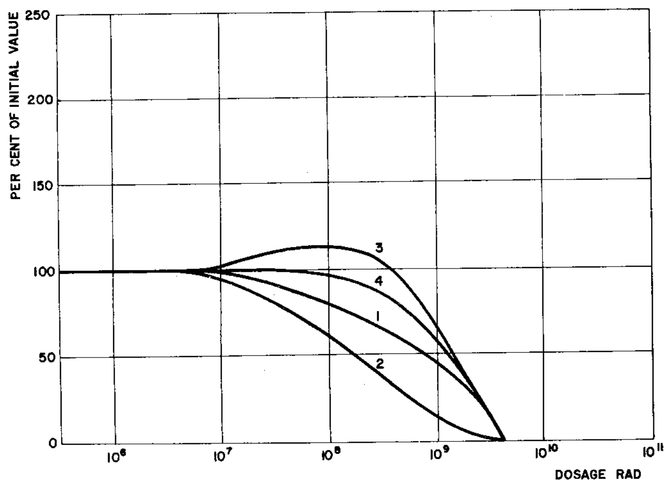
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	343 kg/cm^2
2	ELONGATION	50 %
3	ELASTIC MODULUS	12.6×10^3 kg/cm^2
4	SHEAR STRENGTH	371 kg/cm^2

POLYCHLOROTRIFLUOROETHYLENE

Fig. III.9

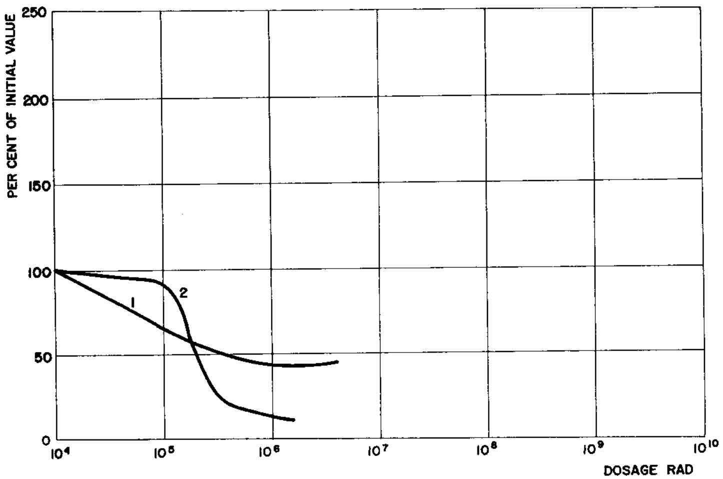


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	259 kg/cm^2
2	ELONGATION	200 %
3	ELASTIC MODULUS	4.5×10^3 kg/cm^2
4	SHEAR STRENGTH	203 kg/cm^2

POLYVINYLIDENECHLORIDE

Fig. III.10

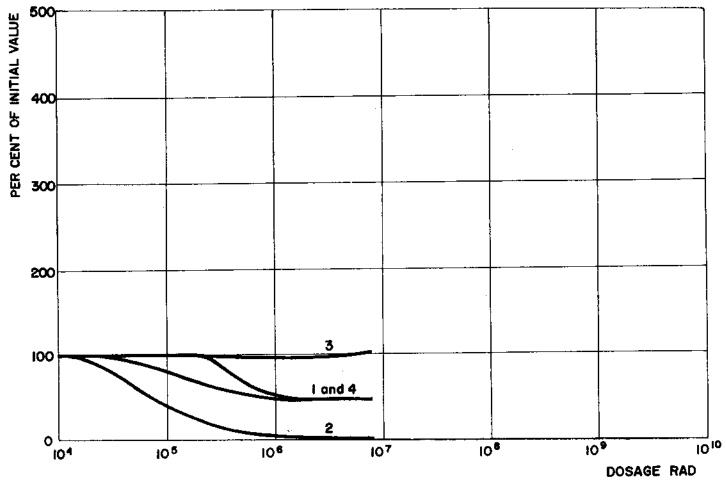
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	210 kg/cm²
2	ELONGATION	265 %
3	ELASTIC MODULUS	—
4	SHEAR STRENGTH	—

TEFLON FEP

Fig. III.11

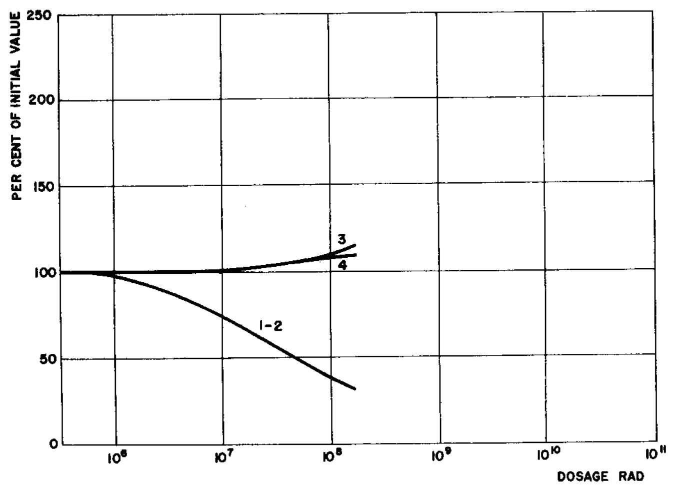


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	238 kg/cm²
2	ELONGATION	250 %
3	ELASTIC MODULUS	7×10^3 kg/cm²
4	SHEAR STRENGTH	200 kg/cm²

POLYTETRAFLUOROETHYLENE (PTFE) "TEFLON"

Fig. III.12

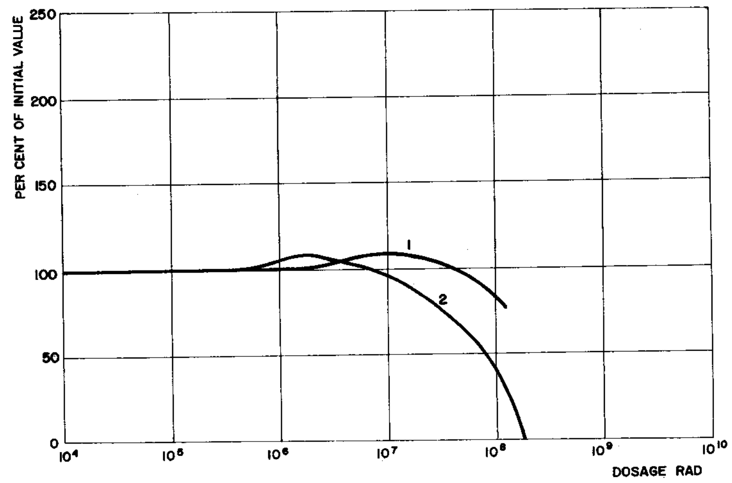
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	532 kg/cm²
2	ELONGATION	62 %
3	ELASTIC MODULUS	14 x 10³ kg/cm²
4	SHEAR STRENGTH	511 kg/cm²

POLYAMIDE

Fig. III.13

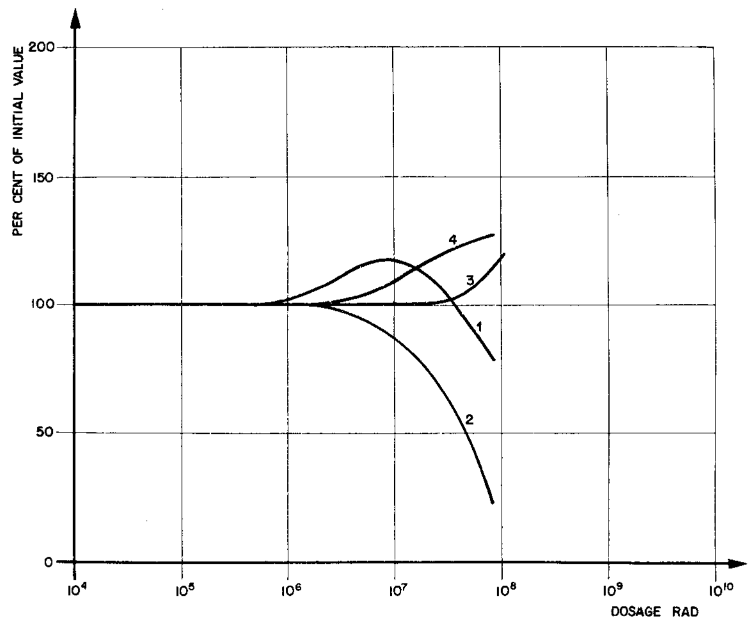


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	434 kg/cm²
2	ELONGATION	96 %
3	ELASTIC MODULUS	—
4	SHEAR STRENGTH	—

POLYCARBONATE (FILM)

Fig. III.14

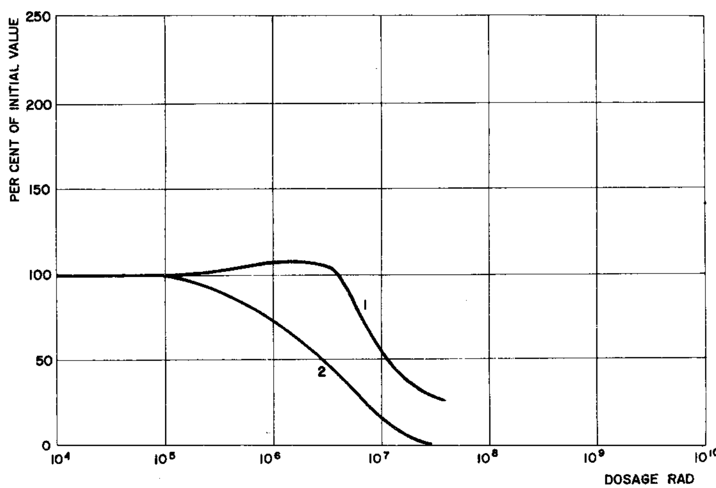
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	191 kg/cm^2
2	ELONGATION	655 %
3	ELASTIC MODULUS	180 kg/cm^2
4	TEAR STRENGTH	4.5 kg/mm
5	HARDNESS	Shore D

POLYETHYLENE (CABLE INSULATION)

Fig. III.15

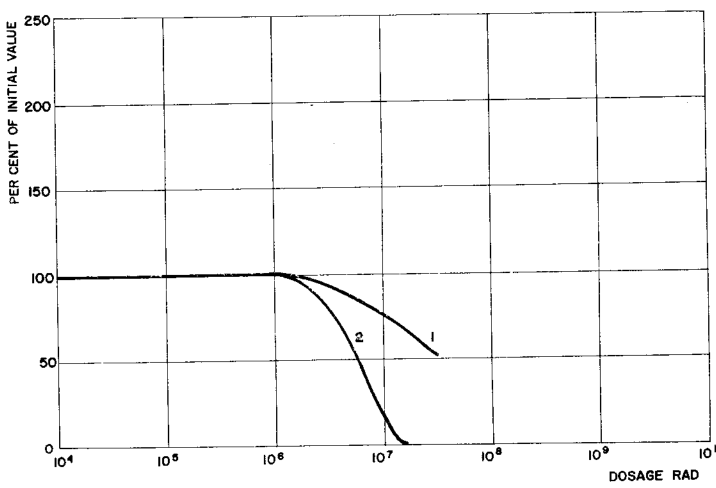


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	326 kg/cm^2
2	ELONGATION	700 %
3	ELASTIC MODULUS	—
4	SHEAR STRENGTH	—

POLYPROPYLENE

Fig. III.16

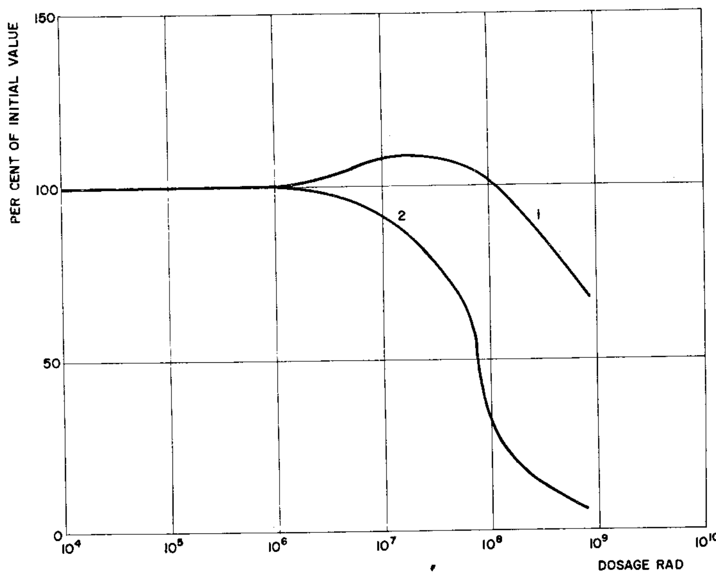
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	306 kg/cm^2
2	ELONGATION	770 %
3	ELASTIC MODULUS	
4	SHEAR STRENGTH	

POLYPROPYLENE – ETHYLENE POLYALLOMER

Fig. III.17

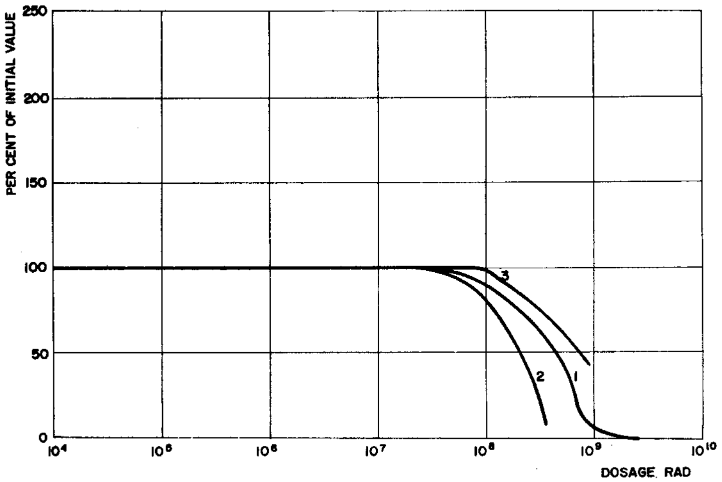


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	156 kg/cm^2
2	ELONGATION	408 %
3	ELASTIC MODULUS	–
4	SHEAR STRENGTH	–

IONOMER RESIN

Fig. III.18

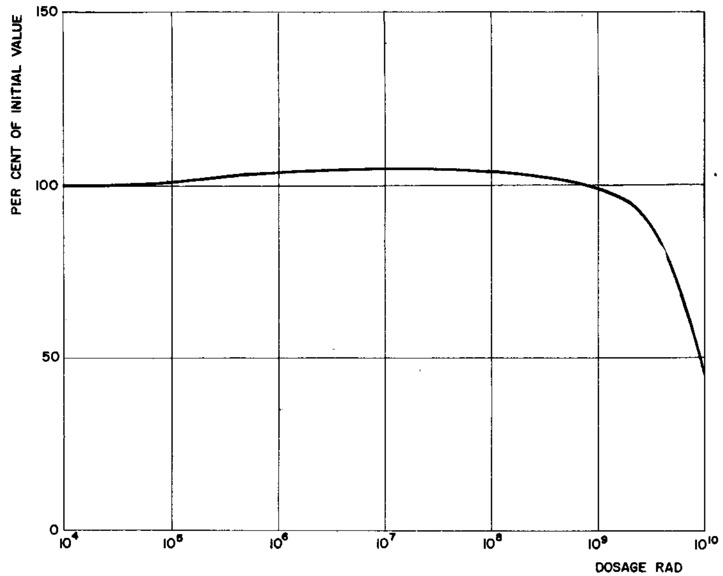
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	1.76×10^3 kg/cm²
2	ELONGATION	50 %
3	ELASTIC MODULUS	20.7×10^3 kg/cm²
4	SHEAR STRENGTH	—

POLYETHYLENE TEREPHTHALATE (FILM)

Fig. III.19

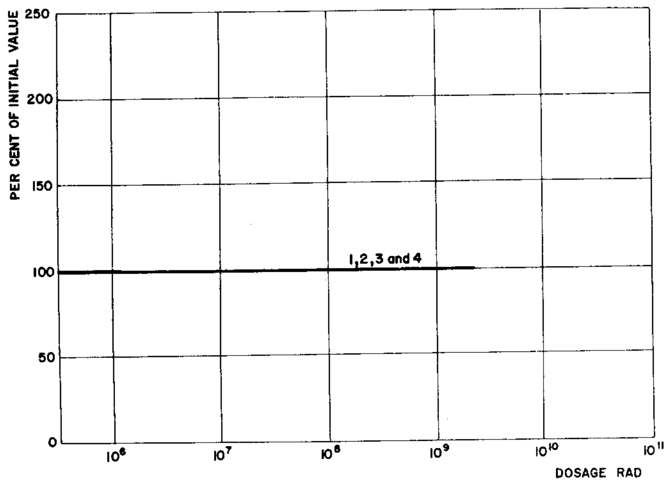


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	660 kg/cm²
2	ELONGATION	—
3	ELASTIC MODULUS	—
4	SHEAR STRENGTH	—

POLYPHENYLENE OXIDE

Fig. III.20

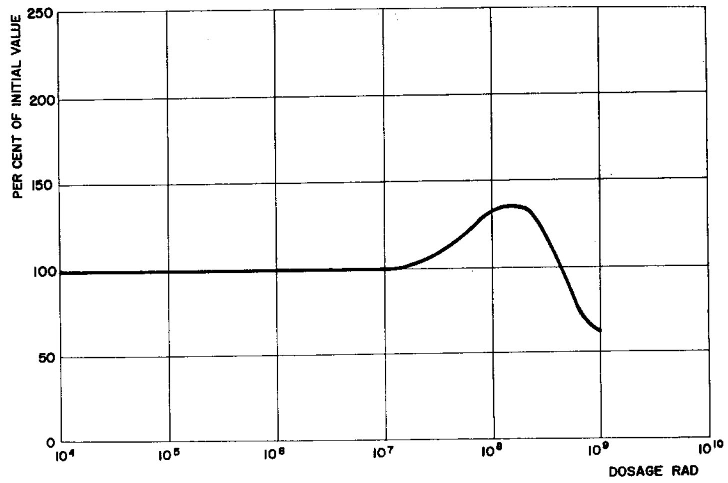
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	308 kg/cm^2
2	ELONGATION	1.0 %
3	ELASTIC MODULUS	33 x 10^3 kg/cm^2
4	SHEAR STRENGTH	385 kg/cm^2

POLYSTYRENE

Fig. III.21

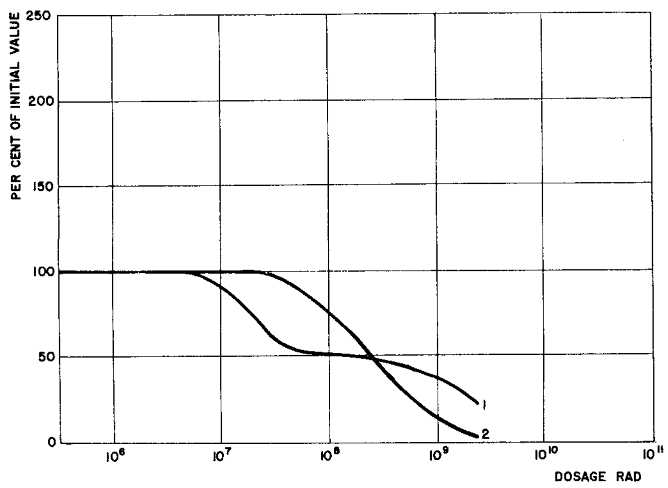


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	261 kg/cm^2
2	ELONGATION	–
3	ELASTIC MODULUS	–
4	SHEAR STRENGTH	–

ACRYLONITRILE – BUTADIENE – STYRENE TERPOLYMER – ABS

Fig. III.22

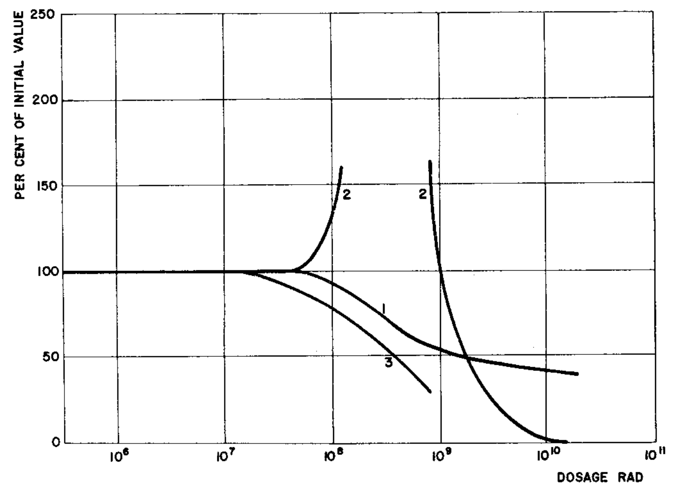
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	154 kg/cm^2
2	ELONGATION	225 %
3	ELASTIC MODULUS	—
4	SHEAR STRENGTH	—

POLYVINYLBUTYRAL

Fig. III.23

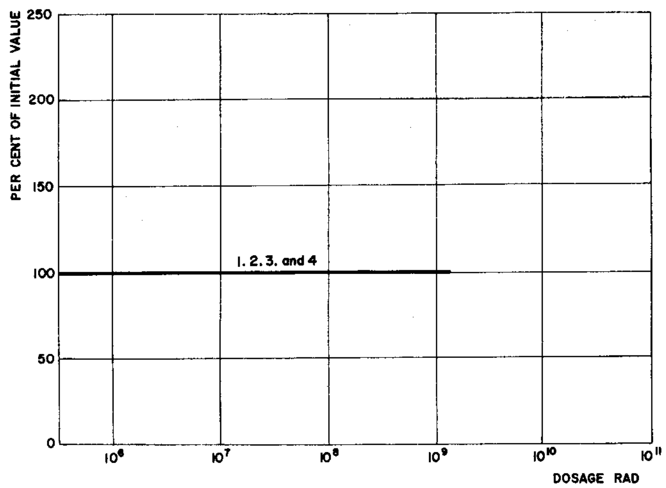


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	518 kg/cm^2
2	ELONGATION	2 %
3	ELASTIC MODULUS	35×10^3 kg/cm^2
4	SHEAR STRENGTH	—

POLYVINYLFORMAL

Fig. III.24

EFFECT OF RADIATION ON MECHANICAL PROPERTIES



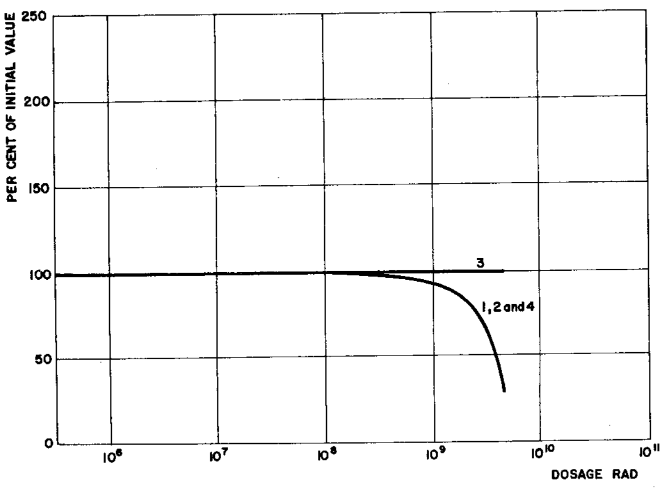
CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	126 kg/cm^2
2	ELONGATION	0.32 %
3	ELASTIC MODULUS	40×10^3 kg/cm^2
4	SHEAR STRENGTH	245 kg/cm^2

POLYVINYLCARBAZOLE

Fig. III.25

THERMOSETTINGS

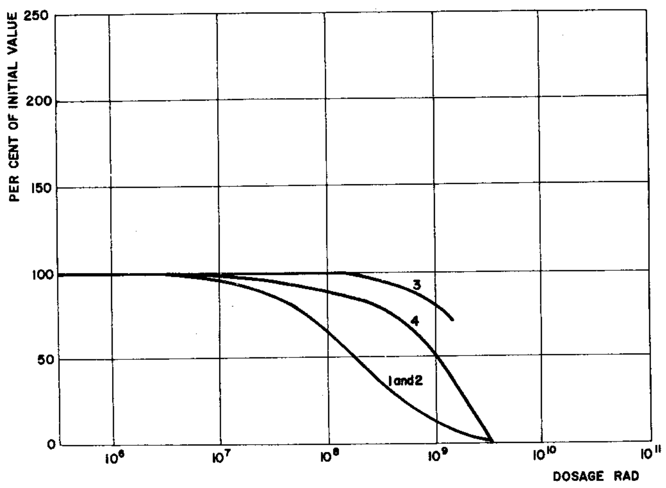
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	644 kg/cm²
2	ELONGATION	1.8 %
3	ELASTIC MODULUS	42×10^3 kg/cm²
4	SHEAR STRENGTH	679 kg/cm²

AMINOPLASTS : ANILINE FORMALDEHYDE - UNFILLED

Fig. III.26

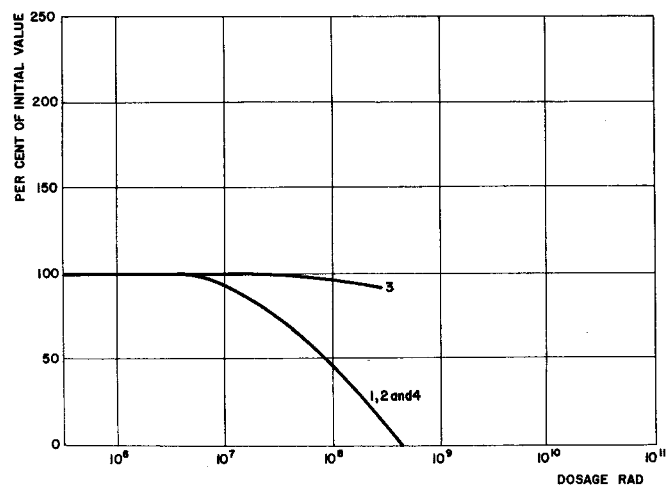


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	637 kg/cm²
2	ELONGATION	0.65 %
3	ELASTIC MODULUS	98×10^3 kg/cm²
4	SHEAR STRENGTH	770 kg/cm²

AMINOPLASTS : MELAMINE FORMALDEHYDE - CELLULOSE FILLER

Fig. III.27

EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	546 kg/cm^2
2	ELONGATION	0.5 %
3	ELASTIC MODULUS	98 x 10^3 kg/cm^2
4	SHEAR STRENGTH	700 kg/cm^2

AMINOPLASTS: UREA FORMALDEHYDE

Fig. III.28

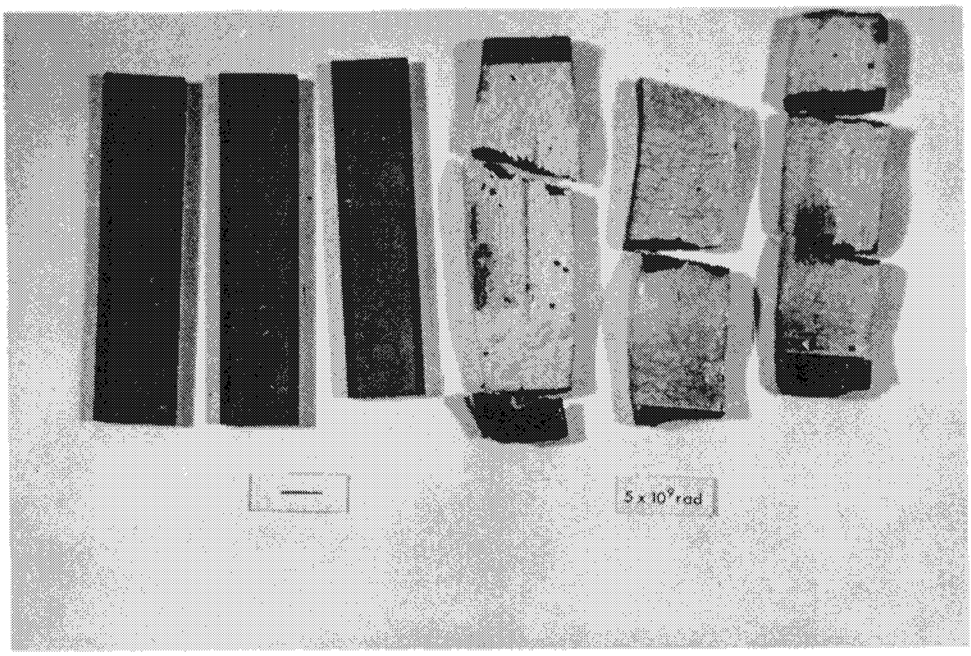


Fig. III.29 Visible changes of Araldite F + DADPS as a function of absorbed dose

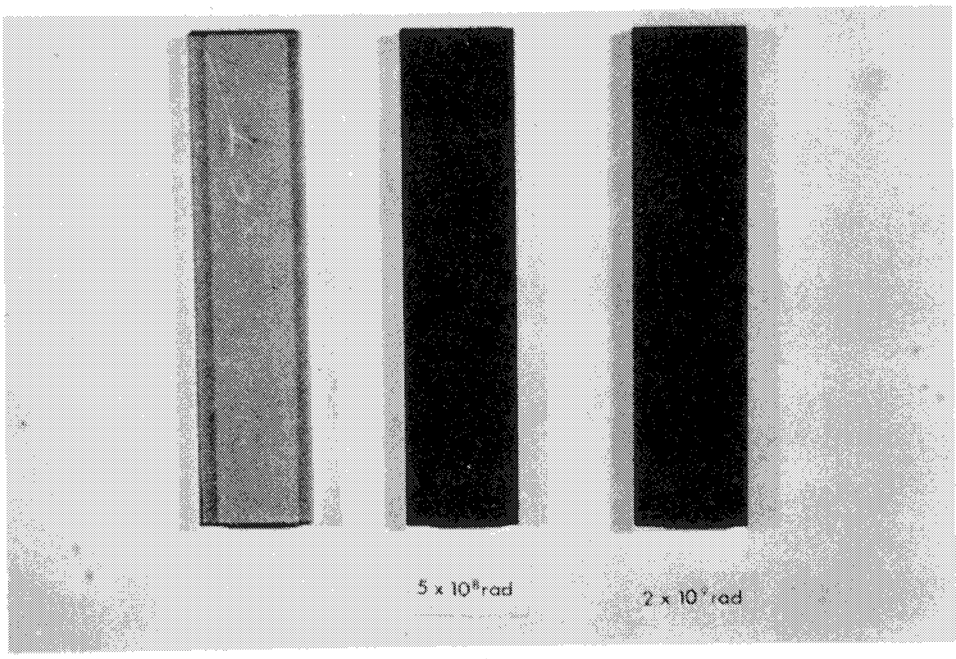


Fig. III.30 Visible changes of EPN + DADPS as a function of absorbed dose

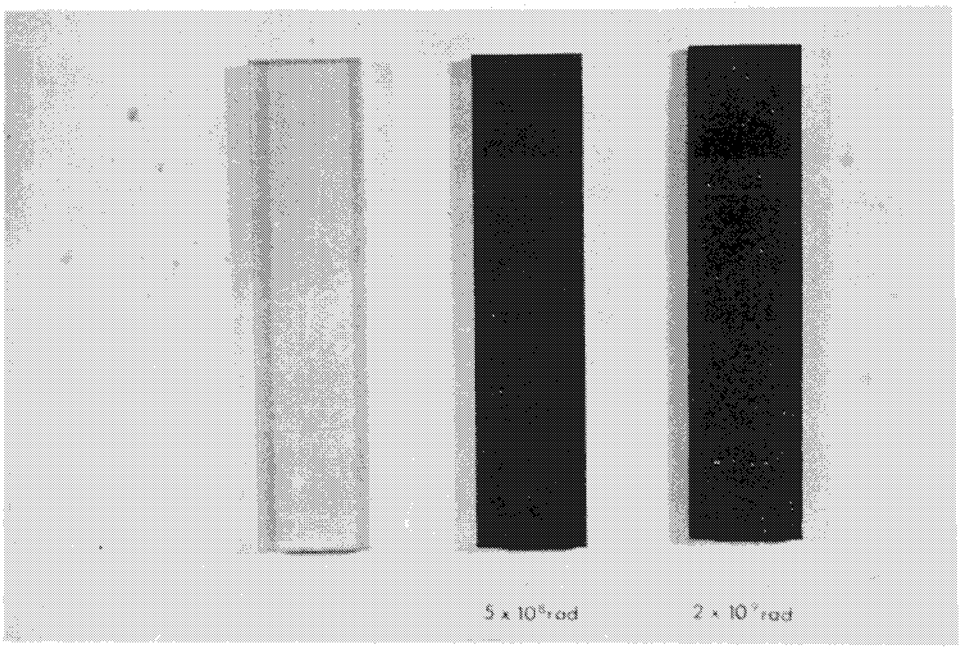
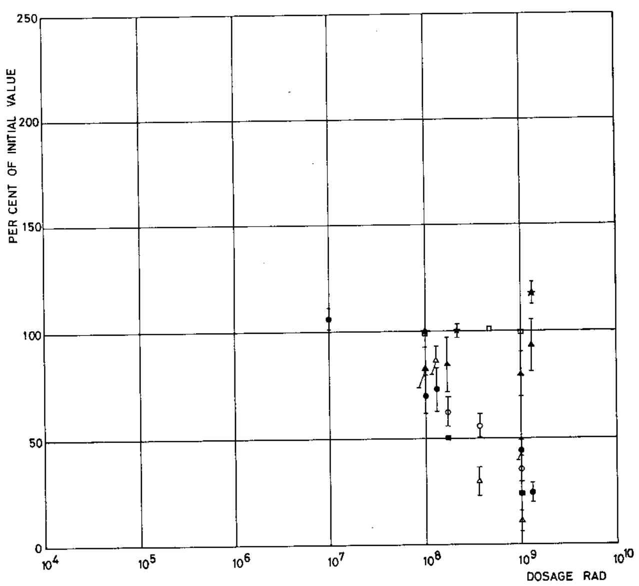


Fig. III.31 Visible changes of Araldite F + MDA as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

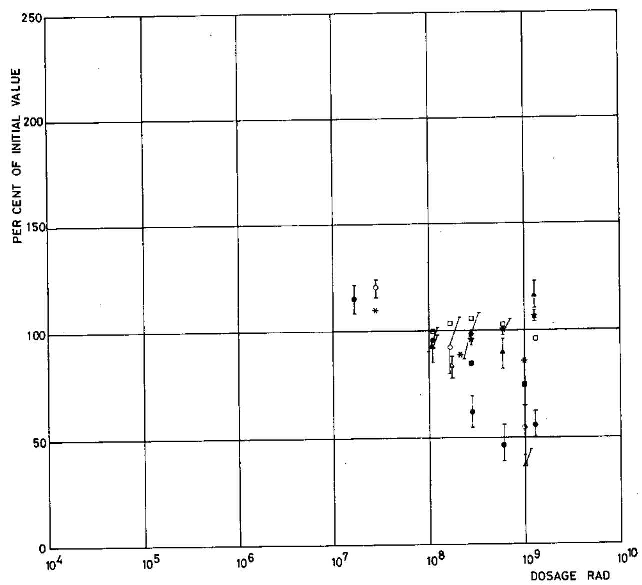


CURVE Nº		PROPERTY	INITIAL VALUE	
○	1	TENSILE STRENGTH	6	kg / mm²
△	2	ELONGATION	2.5	mm
▲	3	ELASTIC MODULUS	283	kg / mm²
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	12.3	kg / mm²
■	6	IMPACT STRENGTH	14	kg-m/cm²
□	7	HARDNESS	87	Shore D
★	8	WATER ABSORPTION (25 °C, 4 DAYS)	0.4	%
*	9	HEAT DISTORTION TEMPERATURE		

ARALDITE F + HY 905 + DY 063 + DY 061

Fig. III.32 Changes in the mechanical properties of DGEBA + MA + BDMA + Po.Gl. as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

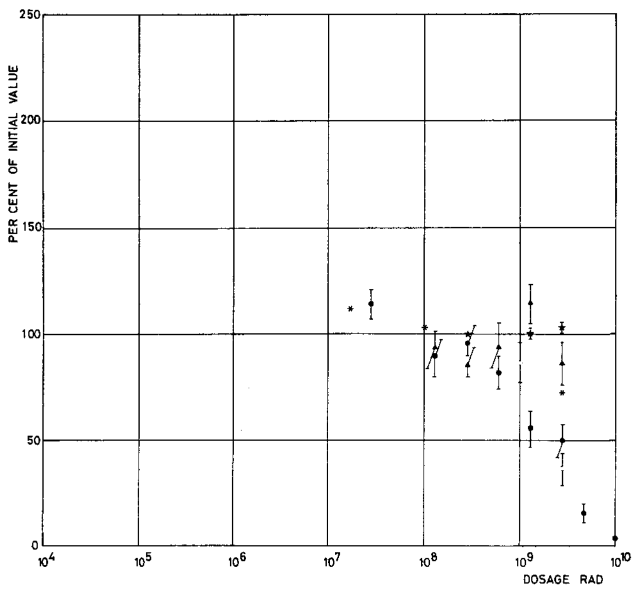


CURVE Nº		PROPERTY	INITIAL VALUE	
○	1	TENSILE STRENGTH	6.8	kg / mm²
△	2	ELONGATION		
▲	3	ELASTIC MODULUS	221	kg / mm²
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	15.6	kg / mm²
■	6	IMPACT STRENGTH	15	kg-m /cm²
□	7	HARDNESS	88	Shore D
★	8	WATER ABSORPTION (25 °C, 4 DAYS)	0.8	%
*	9	HEAT DISTORTION TEMPERATURE	185	°C

ARALDITE F + HT 976

Fig. III.33 Changes in the mechanical properties of DGEBA + DADPS as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

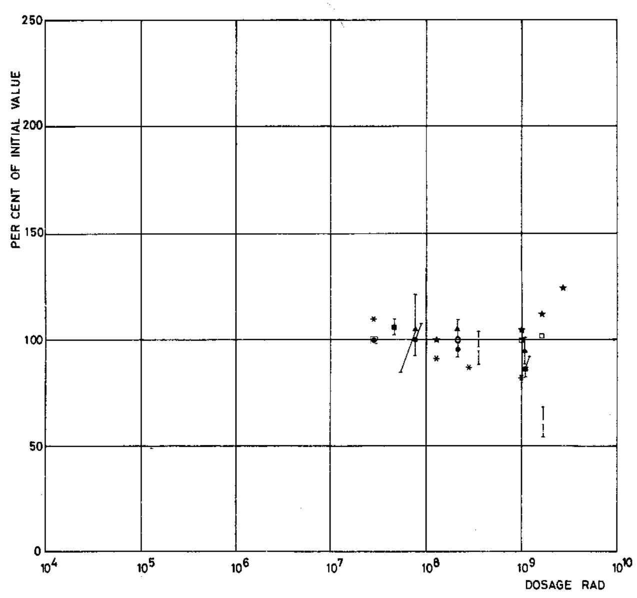


CURVE Nº		PROPERTY	INITIAL VALUE	
○	1	TENSILE STRENGTH	9.1	kg/mm²
△	2	ELONGATION		
▲	3	ELASTIC MODULUS	245	kg/mm²
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	14.5	kg/mm²
■	6	IMPACT STRENGTH		
□	7	HARDNESS		
★	8	WATER ABSORPTION (25 °C, 4 DAYS)	0.5	%
*	9	HEAT DISTORTION TEMPERATURE	216	°C

EPOXY NOVOLAC + HT 976

Fig. III.34 Changes in the mechanical properties of EPN + DADPS as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

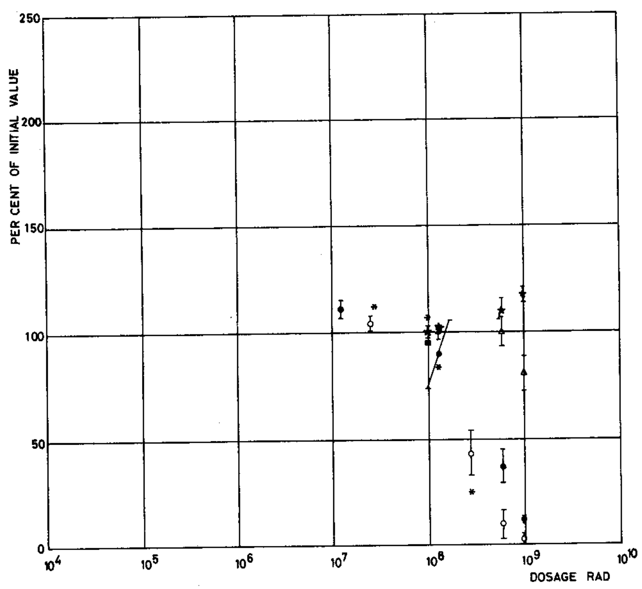


CURVE Nº		PROPERTY	INITIAL VALUE	
○	1	TENSILE STRENGTH	7.2	kg/mm²
△	2	ELONGATION		
▲	3	ELASTIC MODULUS	325	kg/mm²
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	17	kg/mm²
■	6	IMPACT STRENGTH	25	kg-m/cm²
□	7	HARDNESS	86	Shore D
★	8	WATER ABSORPTION (25 °C, 4 DAYS)	0.6	%
*	9	HEAT DISTORTION TEMPERATURE	158	°C

ARALDITE F + HT 972

Fig. III.35 Changes in the mechanical properties of DGEBA + DDM as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

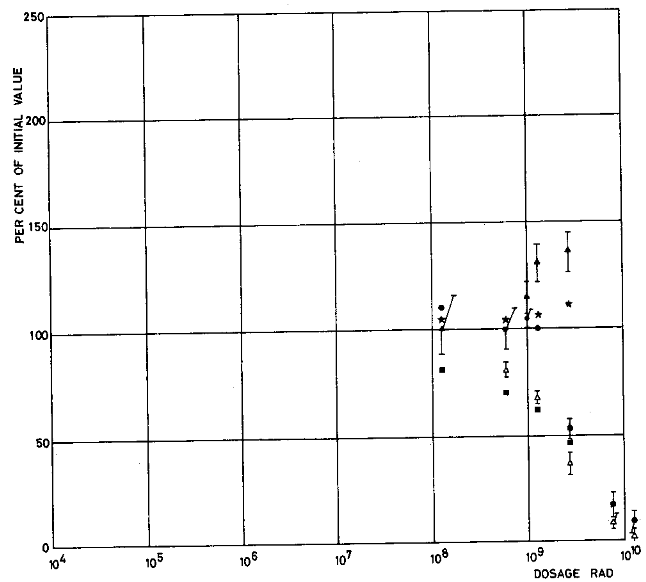


CURVE Nº		PROPERTY	INITIAL VALUE	
○	1	TENSILE STRENGTH	2.7	kg/mm²
△	2	ELONGATION		
▲	3	ELASTIC MODULUS	250	kg/mm²
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	4.8	kg/mm²
■	6	IMPACT STRENGTH	2.6	kg-m/cm²
□	7	HARDNESS		
★	8	WATER ABSORPTION (25 °C, 4 DAYS)	0.8	%
*	9	HEAT DISTORTION TEMPERATURE	186	°C

CYCLO ALIPHATIC RESIN + HY905 + DY061

Fig. III.36 Changes in the mechanical properties of VCD + MA + BDMA as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

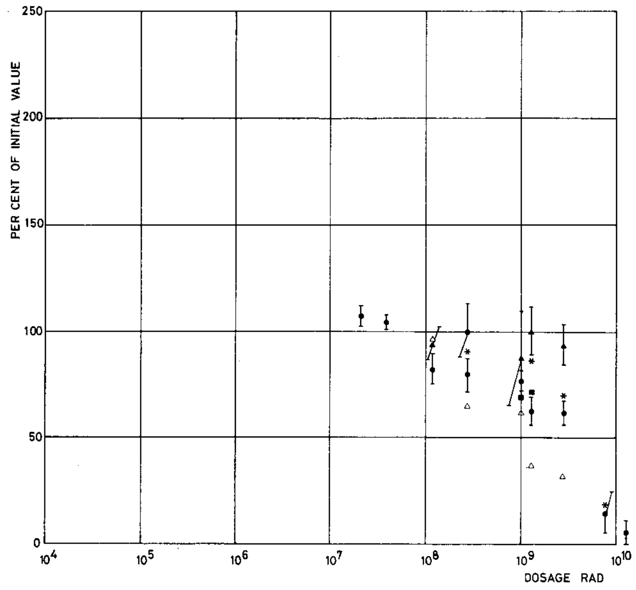


CURVE Nº		PROPERTY	INITIAL VALUE	
○	1	TENSILE STRENGTH		
△	2	ELONGATION	2.8	mm²
▲	3	ELASTIC MODULUS	423	kg/mm²
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	6.3	kg/mm²
■	6	IMPACT STRENGTH	6.8	kg-m/cm²
□	7	HARDNESS		
★	8	WATER ABSORPTION (25 °C, 4 DAYS)	0.11	%
*	9	HEAT DISTORTION TEMPERATURE		

ARALDITE F + HT 972 + GRAPHITE

Fig. III.37 Changes in the mechanical properties of DGEBA + MDA + Graphite as a function of absorbed dose

EFFECT OF RADIATION ON MECHANICAL PROPERTIES

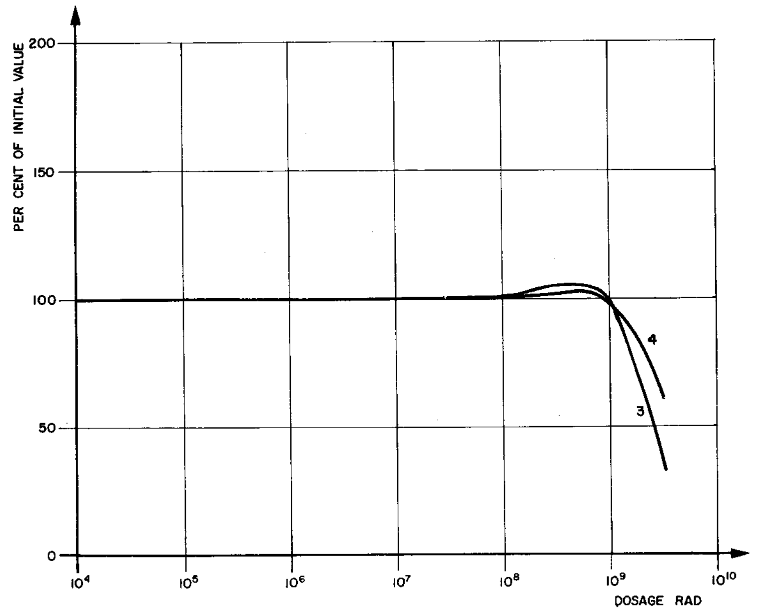


CURVE Nº		PROPERTY	INITIAL VALUE	
o	1	TENSILE STRENGTH		
△	2	ELONGATION	2.1	mm^2
▲	3	ELASTIC MODULUS	541	kg/mm^2
	4	SHEAR STRENGTH		
●	5	FLEXURAL STRENGTH	11.4	kg/mm^2
■	6	IMPACT STRENGTH	7	$kg\text{-}m/cm^2$
□	7	HARDNESS		
★	8	WATER ABSORPTION (25 °C, 4 DAYS)		
*	9	HEAT DISTORTION TEMPERATURE	152	°C

ARALDITE F + HT 972 + ALUMINA

Fig. III.38 Changes in the mechanical properties of DGEBA + MDA + alumina as a function of absorbed dose

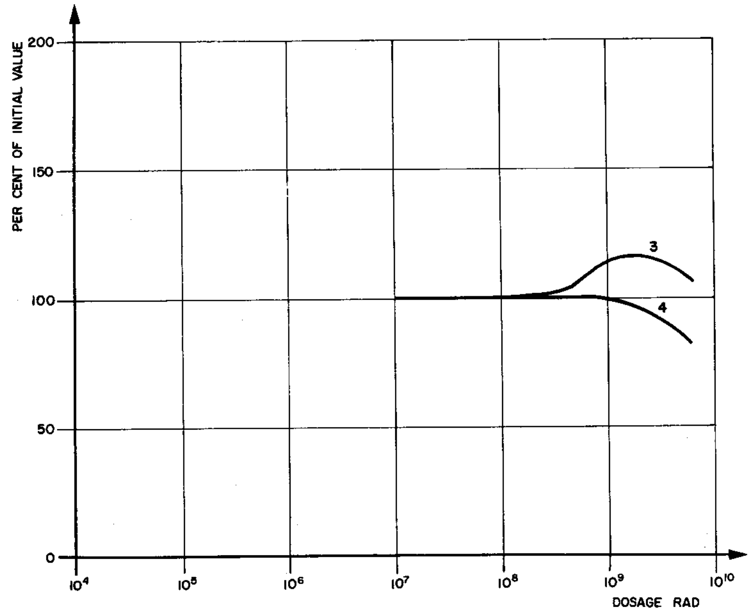
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm²
2	ELONGATION	%
3	FLEXURAL STRENGTH	1190 kg/cm²
4	ELASTIC MODULUS	28030 kg/cm²
5	HARDNESS	Shore D

COIL INSULATION : IMPREGNATING RESIN (WITHOUT GLASS OR MICA)
GLYCIDYL ETHER / EPOXY NOVOLAC + ANHYDRIDE HARDENER

Fig. III.39

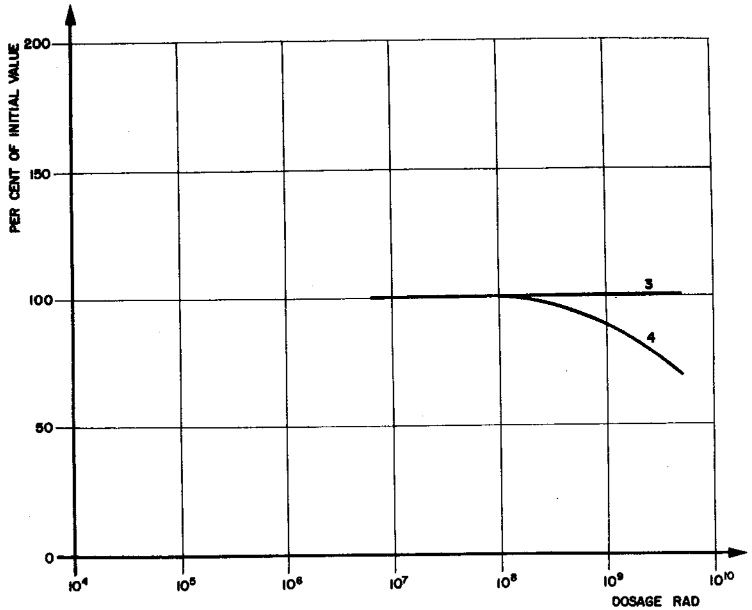


CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm²
2	ELONGATION	%
3	FLEXURAL STRENGTH	3140 kg/cm²
4	ELASTIC MODULUS	87500 kg/cm²
5	HARDNESS	Shore D

COIL INSULATION "PREPREG" : GLASS REINFORCED EPOXY NOVOLAC

Fig. III.40

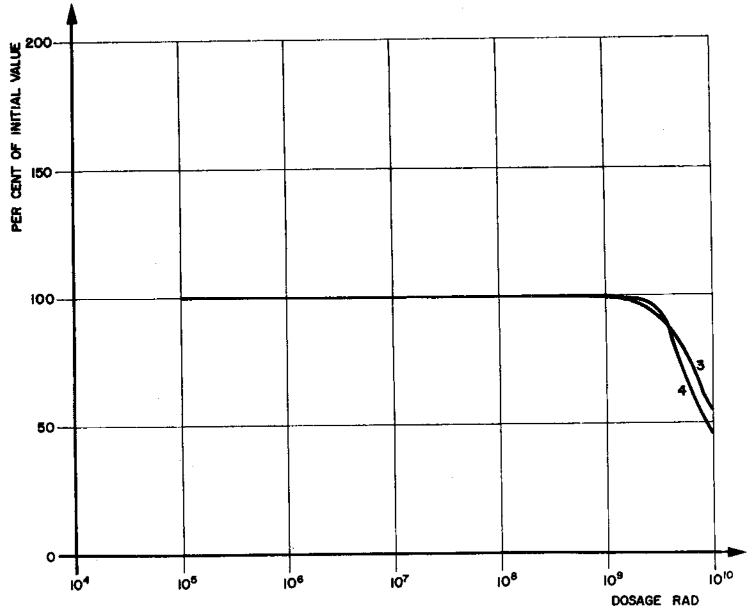
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm^2
2	ELONGATION	%
3	FLEXURAL STRENGTH	2 440 kg/cm^2
4	ELASTIC MODULUS	81 000 kg/cm^2
5	HARDNESS	Shore D

COIL INSULATION "PREPREG" : EPOXY NOVOLAC + GLASS + MICA TAPE

Fig. III.41

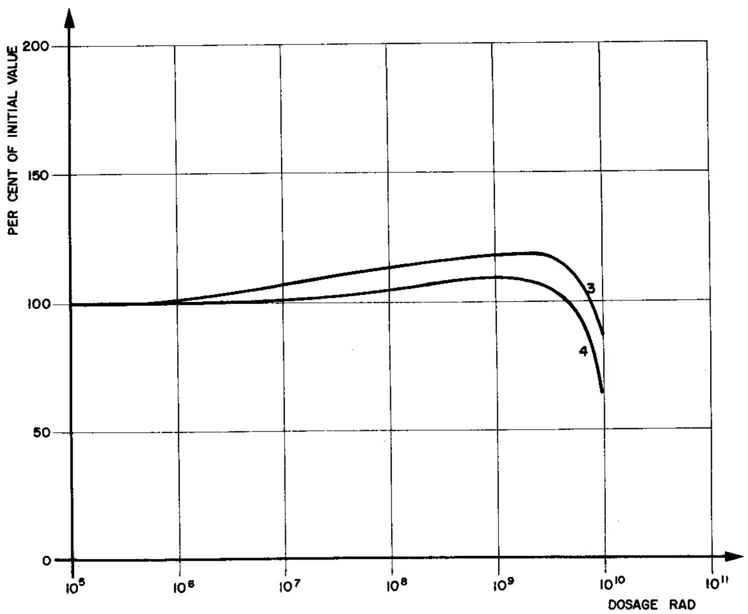


CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm^2
2	ELONGATION	%
3	FLEXURAL STRENGTH	4000 kg/cm^2
4	ELASTIC MODULUS	180 000 kg/cm^2
5	HARDNESS	Shore D

EPOXY NOVOLAC + HY 906 (GLASS LAMINATE)

Fig. III.42

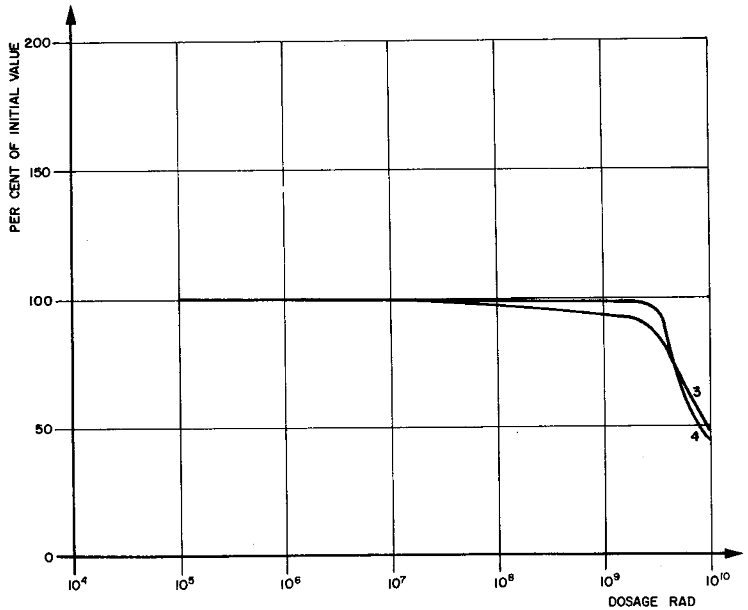
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm^2
2	ELONGATION	%
3	FLEXURAL STRENGTH	3200 kg/cm^2
4	ELASTIC MODULUS	180 000 kg/cm^2
5	HARDNESS	Shore D

X 33 1020 + HY 906 (GLASS LAMINATE)

Fig. III.43

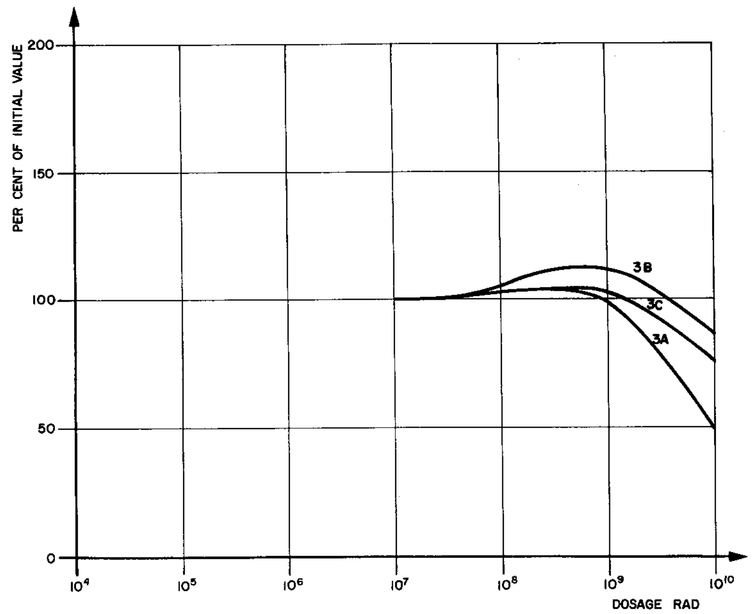


CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm^2
2	ELONGATION	%
3	FLEXURAL STRENGTH	3 600 kg/cm^2
4	ELASTIC MODULUS	160 000 kg/cm^2
5	HARDNESS	Shore D

ARF + HY 906 (GLASS LAMINATE)

Fig. III.44

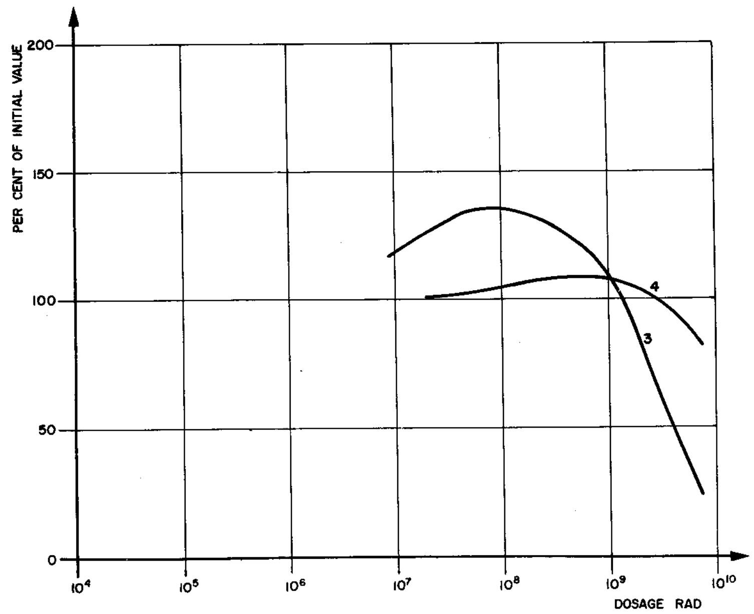
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE A	B	C	
1	TENSILE STRENGTH				kg/cm²
2	ELONGATION				%
3	FLEXURAL STRENGTH	3910 -	3940 -	3640	kg/cm²
4	ELASTIC MODULUS				kg/cm²
5	HARDNESS				Shore D

60 % GLASS REINFORCED EPOXY RESINS
A : ARALDITE F + DDM
B : X33 1020 + DDM
C : EPN 1138 + DDM

Fig. III.45

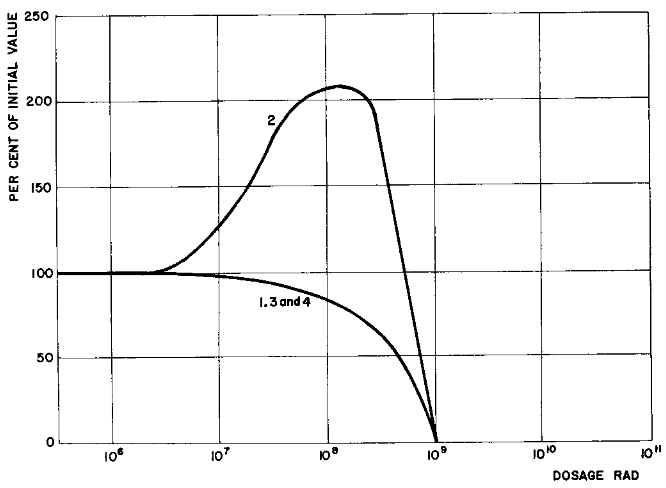


CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm²
2	ELONGATION	%
3	FLEXURAL STRENGTH	5210 kg/cm²
4	ELASTIC MODULUS	238 x 10³ kg/cm²
5	HARDNESS	Shore D

PROPERTIES OF IRRADIATED EPOXY GLASS LAMINATES
AFTER 2 HOURS IN BOILING WATER

Fig. III.46

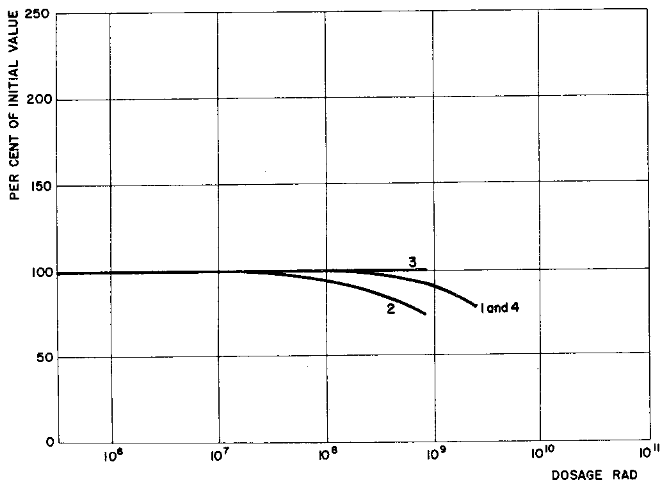
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	700 kg/cm²
2	ELONGATION	2%
3	ELASTIC MODULUS	32×10^3 kg/cm²
4	SHEAR STRENGTH	602 kg/cm²

PHENOL FORMALDEHYDE - UNFILLED

Fig. III.47

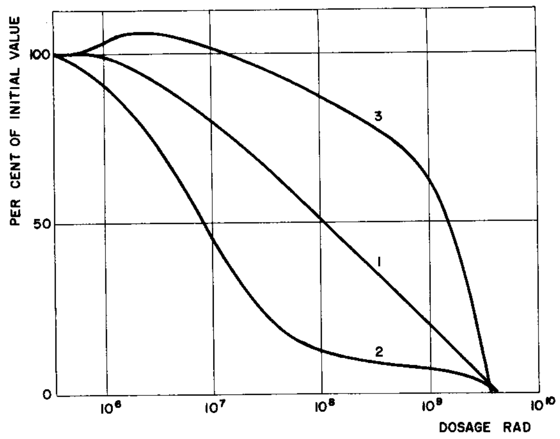


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	770 kg/cm²
2	ELONGATION	1.3%
3	ELASTIC MODULUS	126×10^3 kg/cm²
4	SHEAR STRENGTH	1050 kg/cm²

PHENOL FORMALDEHYDE - ASBESTOS LAMINATE FILLER

Fig. III.48

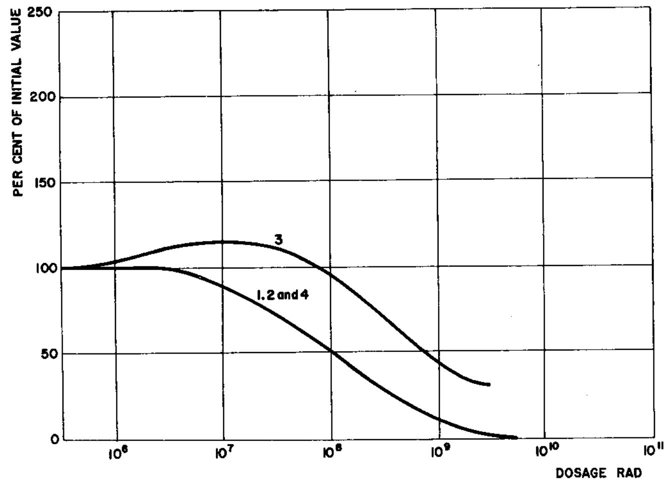
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	770 kg/cm²
2	ELONGATION	4.0 %
3	ELASTIC MODULUS	77 x 10³ kg/cm²
4	SHEAR STRENGTH	—

PHENOL FORMALDEHYDE - LINEN LAMINATE FILLER

Fig. III.49

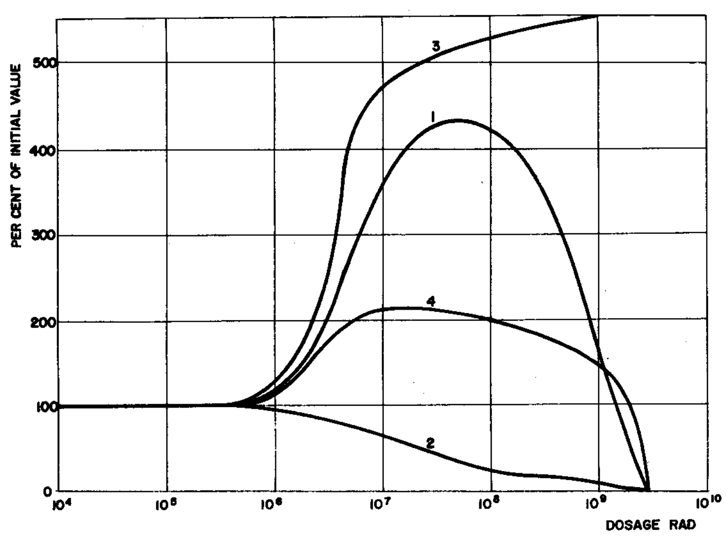


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	847 kg/cm²
2	ELONGATION	1.8 %
3	ELASTIC MODULUS	112 x 10³ kg/cm²
4	SHEAR STRENGTH	1008 kg/cm²

PHENOL FORMALDEHYDE - PAPER FILLER

Fig. III.50

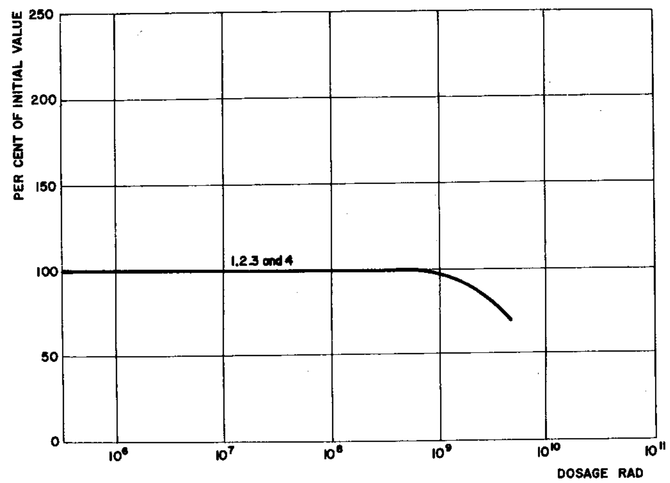
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	140 kg/cm²
2	ELONGATION	20%
3	ELASTIC MODULUS	4×10^3 kg/cm²
4	SHEAR STRENGTH	217 kg/cm

POLYESTER (flexible)

Fig. III.51

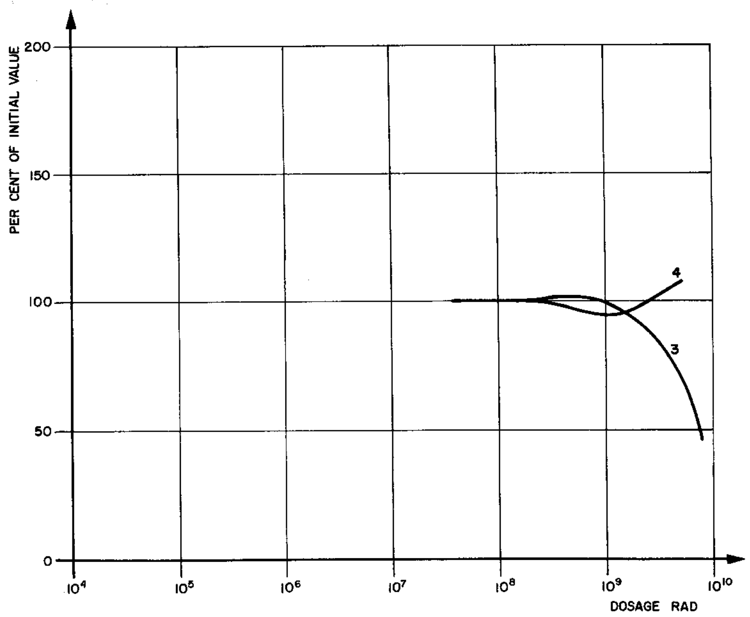


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	329 kg/cm²
2	ELONGATION	0.17%
3	ELASTIC MODULUS	224×10^3 kg/cm²
4	SHEAR STRENGTH	490 kg/cm²

POLYESTER - MINERAL FILLER

Fig. III.52

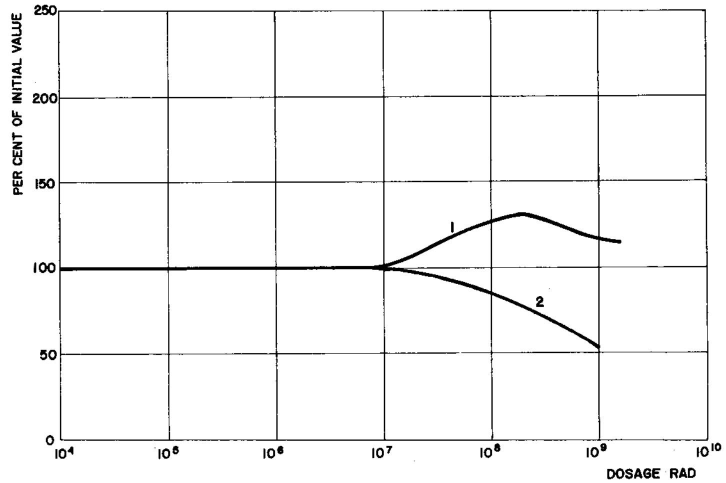
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm²
2	ELONGATION	%
3	FLEXURAL STRENGTH	3570 kg/cm²
4	ELASTIC MODULUS	182×10^3 kg/cm²
5	HARDNESS	Shore D

PROPERTIES OF IRRADIATED POLYESTER GLASS LAMINATES
AFTER 2 HOURS IN BOILING WATER

Fig. III.53

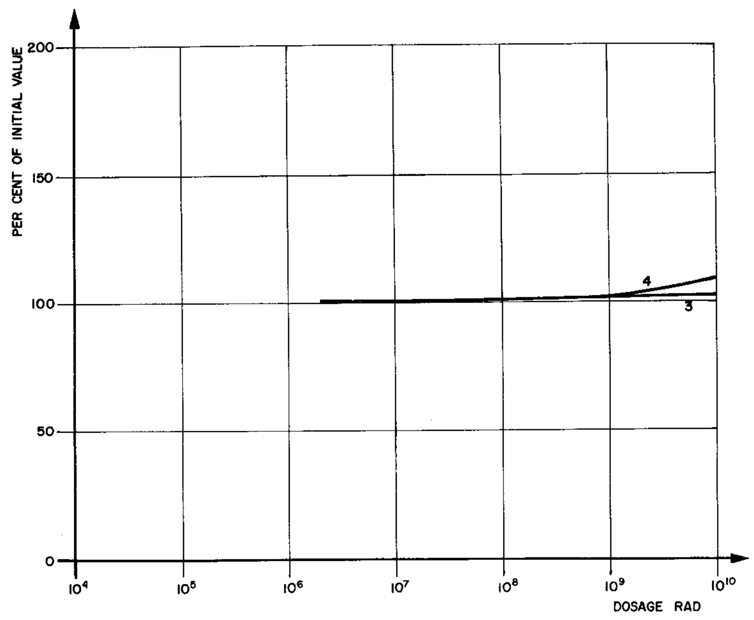


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	1.6×10^3 kg/cm²
2	ELONGATION	80 %
3	ELASTIC MODULUS	20×10^3 kg/cm²
4	SHEAR STRENGTH	—

POLYIMIDE (FILM)

Fig. III.54

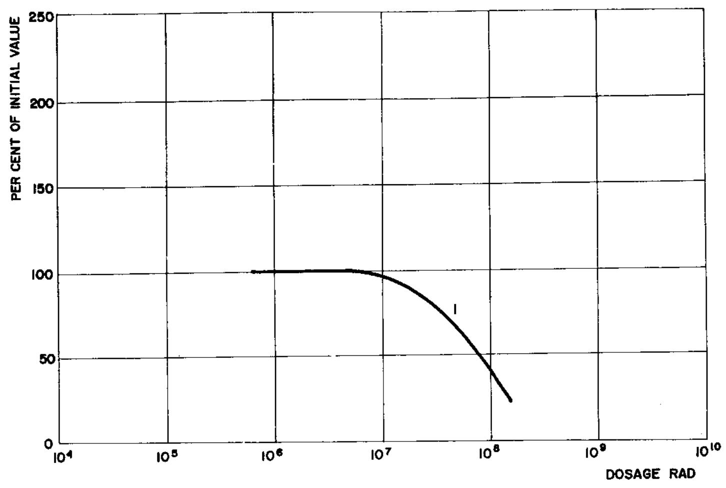
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm^2
2	ELONGATION	%
3	FLEXURAL STRENGTH	168 kg/cm^2
4	ELASTIC MODULUS	57 10^3 kg/cm^2
5	HARDNESS	Shore D

PYRRONE

Fig. III.55

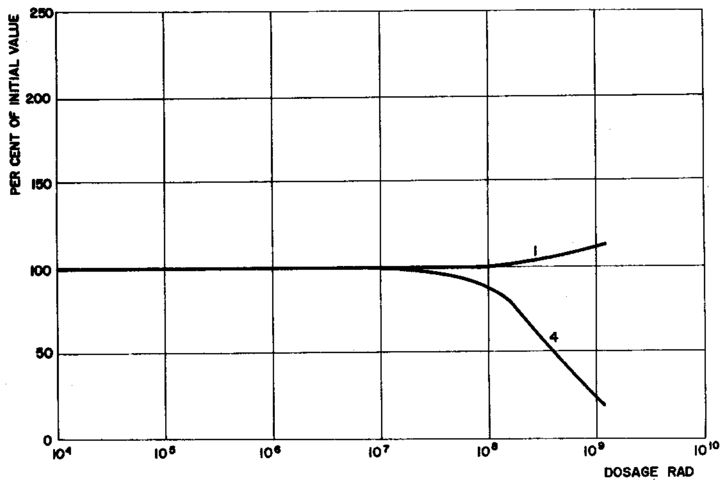


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	260 kg/cm^2
2	ELONGATION	
3	ELASTIC MODULUS	
4	SHEAR STRENGTH	

SILICONE — UNFILLED

Fig. III.56

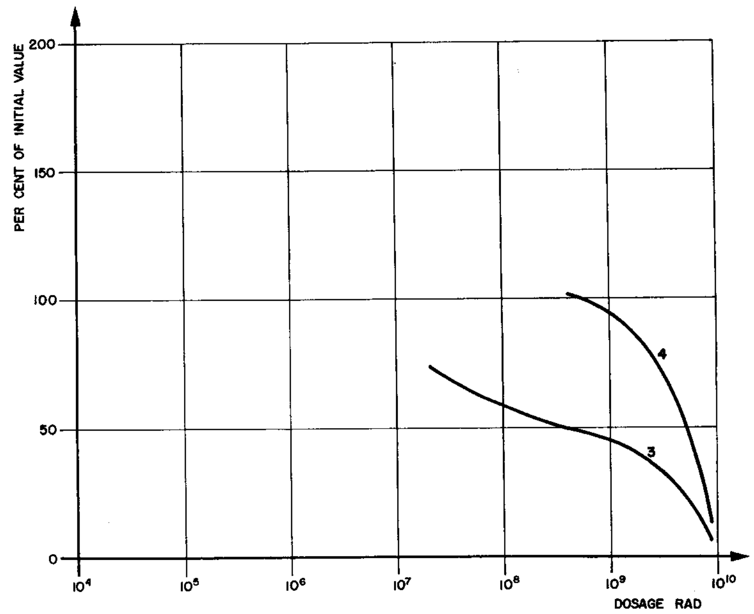
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	520 kg/cm^2
2	ELONGATION	
3	ELASTIC MODULUS	
4	SHEAR STRENGTH	0.945 kg/cm^2

SILICONE — GLASS FILLED

Fig. III.57



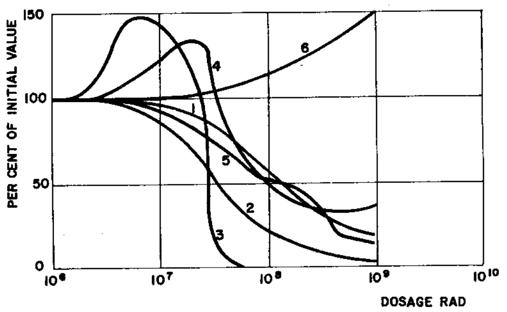
CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	kg/cm^2
2	ELONGATION	%
3	FLEXURAL STRENGTH	1610 kg/cm^2
4	ELASTIC MODULUS	140×10^3 kg/cm^2
5	HARDNESS	Shore D

PROPERTIES OF IRRADIATED SILICONE GLASS LAMINATES
AFTER 2 HOURS IN BOILING WATER

Fig. III.58

ELASTOMERS

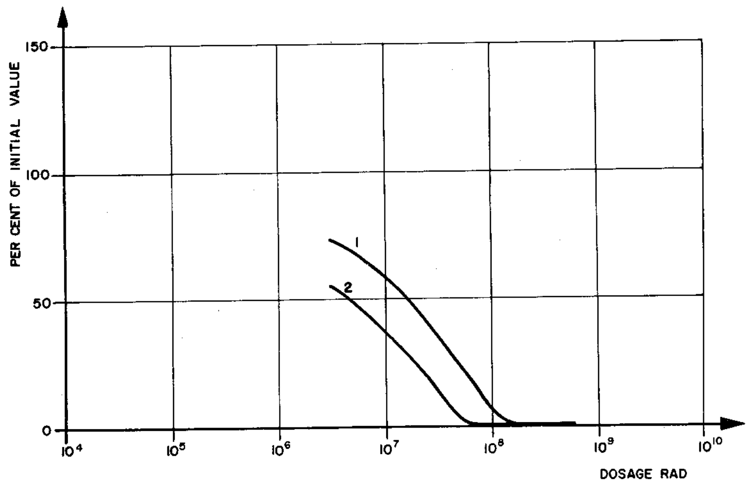
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	140 kg/cm²
2	ELONGATION	230 %
3	SET AT BREAK	10 %
4	COMPRESSION SET	5 %
5	STRAIN AT 28 kg/cm²	36 %
6	DUROMETER HARDNESS	60

ACRYLIC ELASTOMER

Fig. III.59

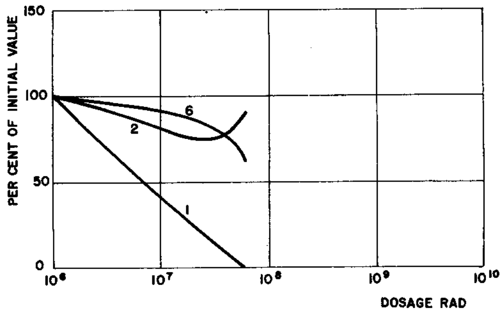


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	3.59 kg/cm²
2	ELONGATION	305 %
3	SET AND BREAK	kg/cm²
4	COMPRESSION SET	kg/cm²
5	HARDNESS	Shore

POLYBUTADIENE (CABLE INSULATION)

Fig. III.60

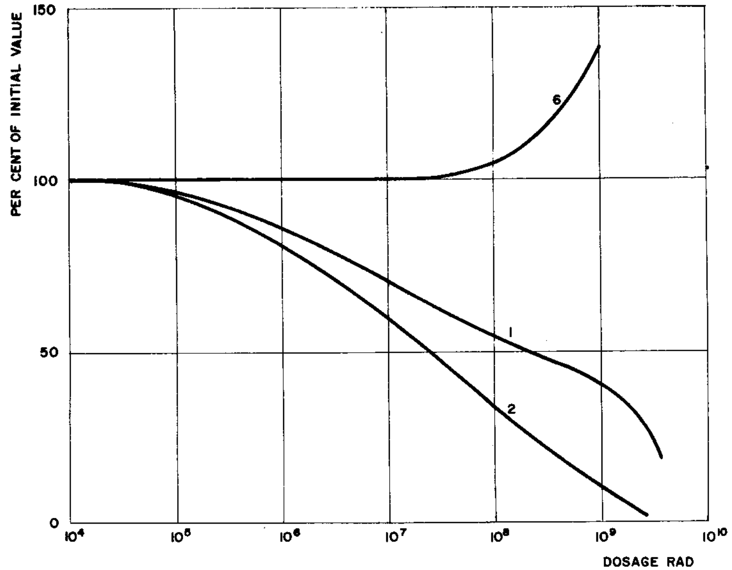
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	150 kg/cm²
2	ELONGATION	345 %
3	SET AT BREAK	—
4	COMPRESSION SET	—
5	STRAIN AT 28 kg/cm²	—
6	DUROMETER HARDNESS	73

BUTYL ELASTOMER

Fig. III.61

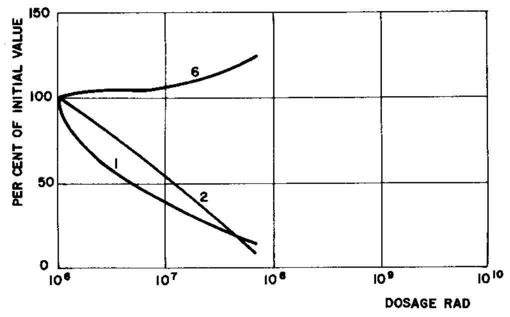


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	140 kg/cm²
2	ELONGATION	418 %
3	ELASTIC MODULUS	
4	SHEAR STRENGTH	
5	STRAIN AT 28 kg/cm²	
6	DUROMETER HARDNESS	67

ETHYLENE PROPYLENE F234

Fig. III.62

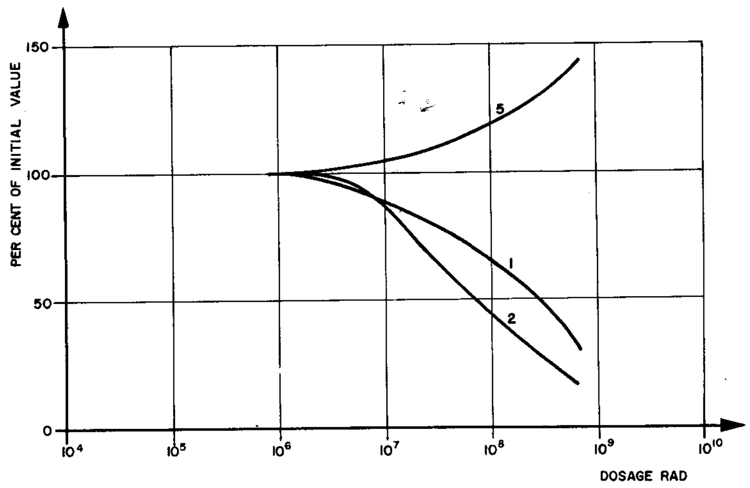
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	98 kg/cm²
2	ELONGATION	220 %
3	SET AT BREAK	–
4	COMPRESSION SET	–
5	STRAIN AT 28 kg/cm²	–
6	DUROMETER HARDNESS	59

FLUOROSILICONE ELASTOMER

Fig. III.63

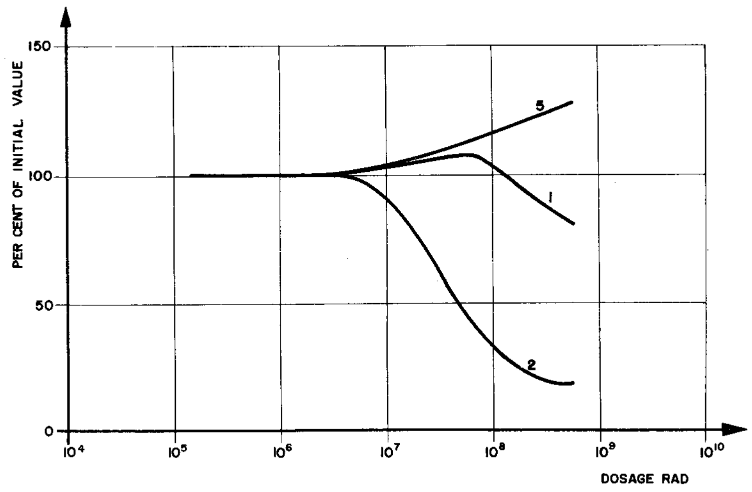


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	107 kg/cm²
2	ELONGATION	340 %
3	SET AND BREAK	kg/cm²
4	COMPRESSION SET	kg/cm²
5	HARDNESS	61 Shore D

FLUOROELASTOMER : KEL F

Fig. III.64

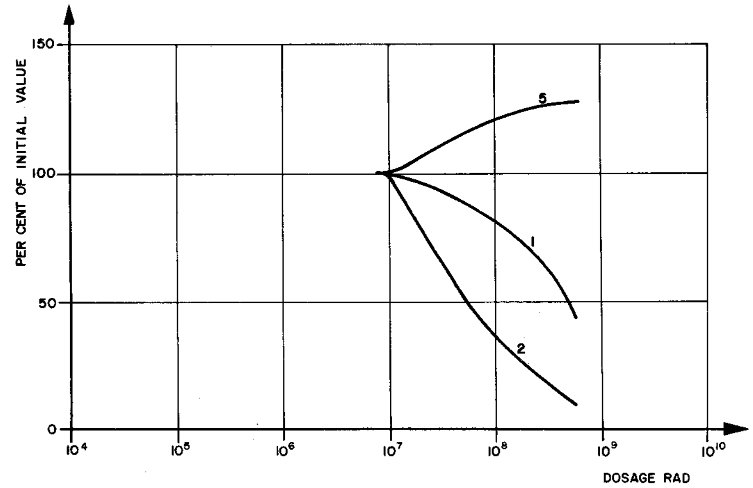
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	146 kg/cm^2
2	ELONGATION	315 %
3	SET AND BREAK	kg/cm^2
4	COMPRESSION SET	kg/cm^2
5	HARDNESS	80.5 (Shore D

FLUOROELASTOMER : VITON

Fig. III.65

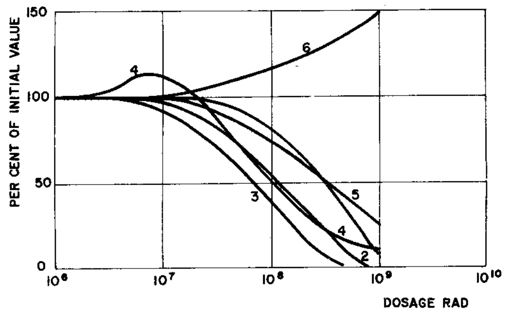


CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	68 kg/cm^2
2	ELONGATION	99 %
3	SET AND BREAK	kg/cm^2
4	COMPRESSION SET	kg/cm^2
5	HARDNESS	75 Shore D

HYPALON (CABLE INSULATION)

Fig. III.66

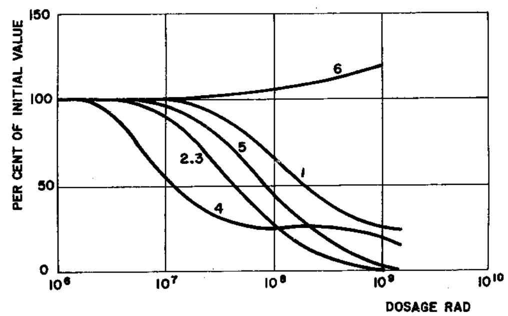
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	182 kg/cm²
2	ELONGATION	420 %
3	SET AT BREAK	32 %
4	COMPRESSION SET	13 %
5	STRAIN AT 28kg/cm²	30 %
6	DUROMETER HARDNESS	60

NATURAL RUBBER

Fig. III.67

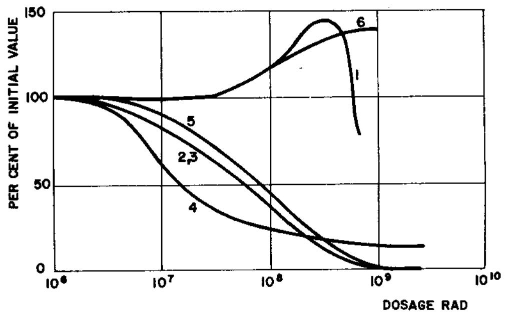


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	203 kg/cm²
2	ELONGATION	450 %
3	SET AT BREAK	6 %
4	COMPRESSION SET	9 %
5	STRAIN AT 28kg/cm²	31 %
6	DUROMETER HARDNESS	80

NEOPRENE ELASTOMER

Fig. III.68

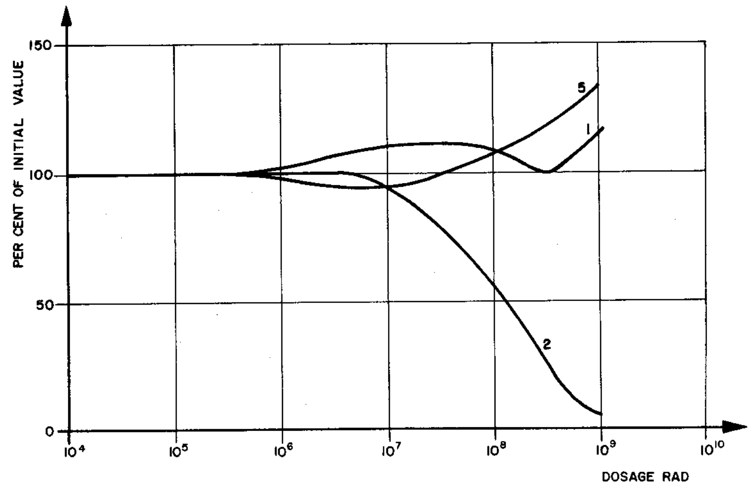
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	133 kg/cm²
2	ELONGATION	250 %
3	SET AT BREAK	3 %
4	COMPRESSION SET	9.5 %
5	STRAIN AT 28 kg/cm²	25 %
6	DUROMETER HARDNESS	75

NITRILE ELASTOMER - BUNA N

Fig. III.69

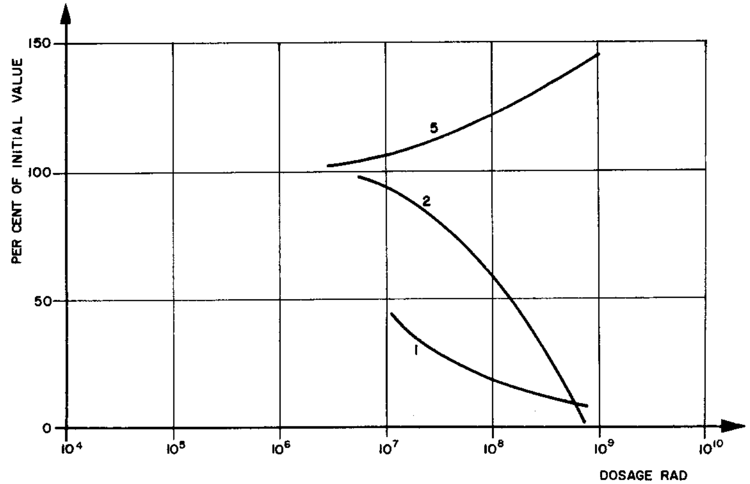


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	220 kg/cm²
2	ELONGATION	320 %
3	SET AND BREAK	kg/cm²
4	COMPRESSION SET	kg/cm²
5	HARDNESS	80 Shore A

SPECIAL NITRILE RUBBER - O-RING

Fig. III.70

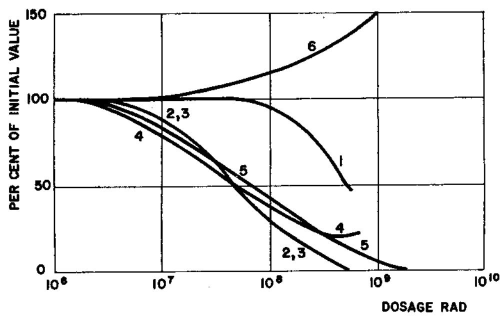
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	410 kg/cm²
2	ELONGATION	530 %
3	SET AND BREAK	kg/cm²
4	COMPRESSION SET	kg/cm²
5	HARDNESS	75 Shore D

POLYURETHANE (CABLE INSULATION)

Fig. III.71

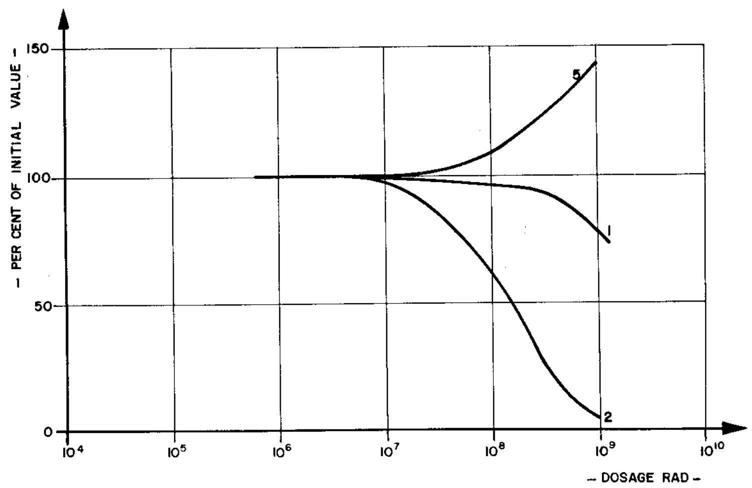


CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	119 kg/cm²
2	ELONGATION	270 %
3	SET AT BREAK	5 %
4	COMPRESSION SET	4.7 %
5	STRAIN AT 28 kg/cm²	28 %
6	DUROMETER HARDNESS	60

S B R ELASTOMER – BUNA S

Fig. III.72

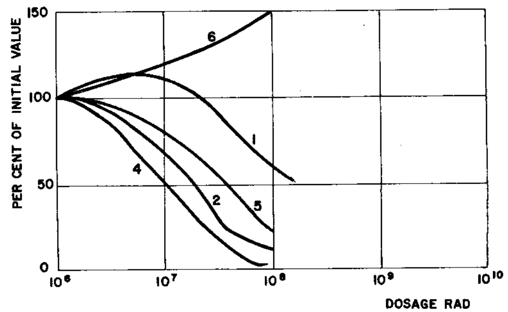
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	135 kg/cm^2
2	ELONGATION	460 %
3	SET AND BREAK	kg/cm^2
4	COMPRESSION SET	kg/cm^2
5	HARDNESS	70 Shore A

SPECIAL SBR - O-RING

Fig. III.73

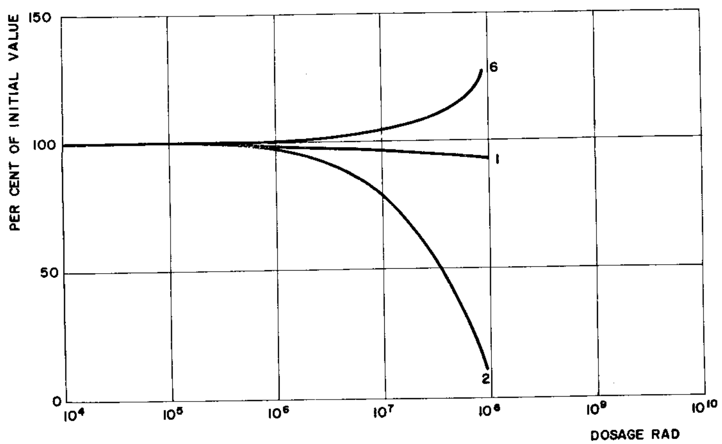


CURVE N°	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	36 kg/cm^2
2	ELONGATION	95 %
3	SET AT BREAK	—
4	COMPRESSION SET	1.4 %
5	STRAIN AT 28 kg/cm^2	3.4 %
6	DUROMETER HARDNESS	60

SILICONE ELASTOMER - DIMETHYL SILOXANE

Fig. III.74

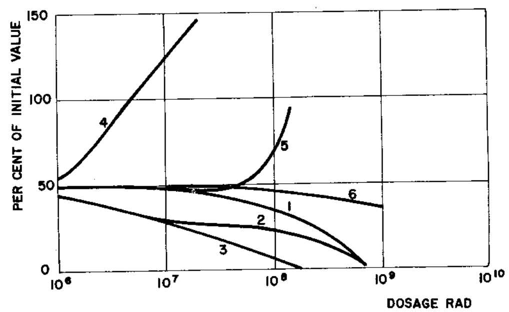
EFFECT OF RADIATION ON MECHANICAL PROPERTIES



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	46 kg/cm²
2	ELONGATION	210 %
3	SET AND BREAK	–
4	COMPRESSION SET	–
5	STRAIN AT 28 kg/cm²	–
6	DUROMETER HARDNESS	63

SILICONE ELASTOMER METHYL PHENYL

Fig. III.75



CURVE Nº	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	56 kg/cm²
2	ELONGATION	162 %
3	SET AT BREAK	3 %
4	COMPRESSION SET	9 %
5	STRAIN AT 28 kg/cm²	26 %
6	DUROMETER HARDNESS	78

THIOKOL ELASTOMER

Fig. III.76

III.3 EFFECT OF RADIATION ON THE ELECTRICAL PROPERTIES

TABLE III.1A EFFECT OF NUCLEAR RADIATION ON VOLUME RESISTIVITY DIELECTRIC STRENGTH AND ARC RESISTANCE OF ORGANIC MATERIALS

A: THERMOPLASTICS

Material	Dose (rad)	Volume resistivity (ohm - cm) ASTM D257	Dielectric strength (kV/mm) ASTM D149	Arc resistance (sec) ASTM D495
ACRYLIC	0	$>10^{15}$		120
	5×10^7	$>10^{15}$		80
	1×10^8	$>10^{15}$		80
CELLULOSE ACETATE	0	$5 \quad 10^{12}$		190
	7×10^7	2×10^{11}		
	2×10^8	2×10^{11}		190
CELLULOSE ACETATE BUTYRATE	0	$>10^{14}$	20	140
	2.5×10^7	5×10^{13}	18	115
	1×10^8	2×10^{12}		85
CELLULOSE NITRATE	0	2×10^{12}	35	22
	9×10^7	1×10^{11}		13
	1.5×10^8		27	
CELLULOSE PROPIONATE	0		20	125
	6×10^6		20	120
	1.3×10^7			110
ETHYL CELLULOSE	0	10^{14}		120
	2×10^7	10^{14}		100
	1.2×10^8	10^{14}		0
POLYVINYLCHLORIDE	0	10^{14}		
	5.3×10^8	10^6		
POLYVINYLCHLORIDE ACETATE	0	$>10^{14}$	43	70
	3×10^7	$>10^{14}$		20
	7.5×10^8	$<10^6$	23	0
POLYVINYLIDENE CHLORIDE	0	2×10^{14}	26	
	3×10^7	7×10^{12}		
	1×10^8	3×10^7		
	2×10^9		8	
POLYCHLOROTRIFLUORO ETHYLENE (PCTFE)	0	$>10^{14}$	25	200
	2×10^8	$>10^{14}$	25	200
POLYTETRAFLUORO ETHYLENE (PTFE)	0	$>10^{15}$	19	300
	4×10^7	4.2×10^{14}		250
	1×10^8	2×10^{14}	12	
POLYAMIDE	0	10^{13}	20	120
	1.5×10^8	10^{13}	20	100
	1×10^9			80
POLYETHYLENE	0	$>10^{15}$	24	130
	7×10^7	$>10^{15}$		130
	9×10^9		21	130
POLYETHYLENE TEREPHTHALATE	0	10^{15}		
	3.6×10^8	10^{12}		
POLYSTYRENE	0	$>10^{14}$		310
	4×10^9	$>10^{14}$		
	5×10^9			26
POLYVINYL FORMAL	0	10^{14}		
	8×10^8	10^{14}		
POLYVINYL CARBAZOLE	0	$>10^{14}$	8	20
	2×10^9	$>10^{14}$	8	20

TABLE III.1B EFFECT OF NUCLEAR RADIATION ON VOLUME RESISTIVITY DIELECTRIC STRENGTH AND ARC RESISTANCE OF ORGANIC MATERIALS

B : THERMOSETS

Material	Dose (rad)	Volume resistivity (ohm - cm) ASTM D 257	Dielectric strength (kV/mm) ASTM D 149	Arc resistance (sec) ASTM D 495
ANILINE - FORMALDEHYDE	0	> 10^{14}	8	20
	3×10^9	> 10^{14}	8	20
MELAMINE - FORMALDEHYDE	0	10^{11}	8	190
	2×10^8	10^{11}	8	130
	2×10^9	10^{11}	8	75
UREA - FORMALDEHYDE	0	2×10^{13}	9	130
	2×10^8		9	120
	2×10^9	10^{11}	9	20
PHENOL - FORMALDEHYDE (UNFILLED)	0	10^{12}	7	5
	2×10^8	10^{12}	7	2
	7×10^8	10^{12}	7	
PHENOL - FORMALDEHYDE (PAPER LAMINATE)	0	3×10^{11}	10	2
	1×10^9	2×10^{12}	9	2
	3×10^9	2×10^{11}		2
PHENOL - FORMALDEHYDE (ASBESTOS FIBRE FILLED)	0	2×10^{10}	6	4
	3×10^9	3×10^{10}	8	4
PHENOL - FORMALDEHYDE (GRAPHITE FILLED)	0		3	
	5×10^9		3	
POLYESTER (UNFILLED)	0	10^{11}	20	63
	8×10^8	6×10^{12}	20	
	2×10^9	> 10^{14}		69
POLYESTER (MINERAL FILLED)	0	> 10^{14}	20	180
	2.5×10^9	> 10^{14}	20	180
	4.5×10^9	3×10^{13}		180
SILICONES (MICA FILLED)	0	10^{14}	10	
	5×10^8	8×10^{11}		
	2×10^9		8	
ALLYLDIGLYCOL CARBONATE	0	> 10^{14}	32	120
	5×10^8	6×10^{13}		120
	2×10^9	> 10^{12}	24	120
FURAN RESIN (ASBESTOS FILLED)	0	10^9	2	4
	3.5×10^9	10^9	2	4

TABLE III.1c EFFECT OF NUCLEAR RADIATION ON VOLUME RESISTIVITY OF ORGANIC MATERIALS

C : ELASTOMERS

Material	Absorbed Dose (rad)	Volume resistivity (ohm – cm) ASTM D257
ACRYLIC RUBBER	0	6×10^{11}
	1.5×10^8	1×10^{11}
	7×10^8	5×10^{10}
BUTYL RUBBER	0	1×10^{12}
	1.5×10^8	1×10^{13}
CHLOROSULFONATED POLYETHYLENE	0	6×10^{13}
	2×10^8	4×10^{12}
	7×10^8	2×10^{13}
NATURAL RUBBER	0	4×10^{14}
	1.5×10^8	1×10^{14}
	7×10^8	1×10^{12}
NEOPRENE	0	2×10^{11}
	1×10^9	2×10^{10}
	2×10^9	1×10^{10}
NITRILE RUBBER	0	10^{12}
	1×10^8	10^{10}
POLYBUTADIENE	0	10^{14}
	3×10^8	10^{10}
	7×10^8	10^9
POLYURETHANE	0	3×10^8
	1×10^8	3×10^8
	1×10^9	3×10^8
S B R	0	10^{14}
	0.5×10^7	10^8
SILICONE RUBBER	0	$> 10^{14}$
	1.5×10^8	10^{14}
	3×10^8	10^{12}
THIOKOL	0	10^{10}
	1.5×10^8	10^{10}
	7×10^8	10^7

TABLE III.1D EFFECT OF NUCLEAR RADIATION ON DIELECTRIC CONSTANT AND DISSIPATION FACTOR OF PLASTICS

ASTM D.150

Material (Trade Name)	Dielectric Constant				Dissipation Factor			
	Frequency = 1 kc		Frequency = 1 Mc		Frequency = 1 kc		Frequency = 1 Mc	
	Before irr.	After irr.	Before irr.	After irr.	Before irr.	After irr.	Before irr.	After irr.
A. THERMOPLASTICS								
ACRYLONITRILE – BUTADIENESTYRENE	2.93	2.96	2.85	2.89	0.0077	0.0071	0.013	0.013
POLYAMIDE	3.94	3.36	3.21	3.11	0.059	0.013	0.036	0.021
POLYETHYLENE (HIGH DENSITY)	2.35	2.32	2.35	2.31	0.000 11	0.000 78	0.000 04	0.000 78
POLYETHYLENE (LOW DENSITY)	2.28	2.29	2.28	2.27	0.000 08	0.001 4	0.000 12	0.000 94
POLYETHYLENE (CARBON FILLED)	2.58	2.61	2.58	2.59	0.000 55	0.001 1	0.001 4	0.002 1
POLYPROPYLENE	2.29	2.25	2.25	2.21	0.000 66	0.002 9	0.000 65	0.001 3
POLYSTYRENE	2.51	2.51	2.53	2.53	0.000 14	0.000 11	0.000 26	0.000 24
POLYVINYLCHLORIDE ACETATE	3.19	3.56	2.97	3.24	0.008 1	0.014	0.013	0.021
POLYVINYL FLUORIDE	3.69	3.46	3.61	3.40	0.0023	0.0089	0.029	0.031
STYRENE BUTADIENE HIGH IMPACT	2.49	2.51	2.49	2.48	0.000 41	0.0018	0.000 88	0.000 85
B. THERMOSETTINGS								
DIALLYL PHTHALATE	4.14	4.29	4.17	4.20	0.014	0.010	0.013	0.013
EPOXY MOULDINGS MINERAL FILLED	8.78	9.50	7.77	7.69	0.046	0.051	0.056	0.041
PHENOLIC ASBESTOS FILLED	10.4	8.31	6.16	5.71	0.15	0.13	0.0046	0.064
POLYETHYLENE TEREPHTHALATE	3.05	3.06	2.95	2.94	0.0022	0.0038	0.012	0.011
POLYAMIDE	3.46	3.50			0.002	0.0029		

The irradiations were carried out in a Van der Graaff accelerator operated with a dose rate of 3×10^8 rad/hr. All the plastics are subjected to a radiation dose of about 1×10^9 rad.

Table III.1e

Effect of nuclear radiation on the dielectric strength of epoxy resins

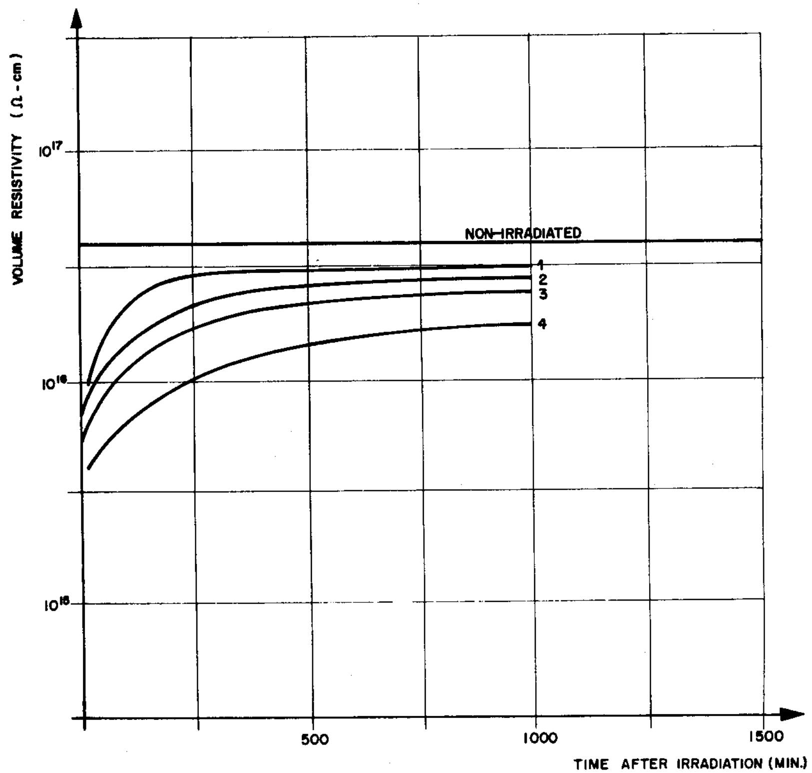
Resin composition	Dielectric strength (kV/mm) versus dose (rad)						
	0	2.3×10^8	5.6×10^8	6.8×10^8	1.2×10^9	1.2×10^9	2.7×10^9
1) Araldite F + MDA	21.2 ± 0.8				17.7 ± 0.8(83.5)		16.1 ± 0.8(76)
2) Araldite F + DADPS	21.4 "				18.5 " (86.5)		17.5 " (82)
3) Araldite F + MA	19.0 "				18.2 " (96)		17.8 " (93.5)
4) Araldite B + AP	18.1 "				17.4 " (96)		14.5 " (80)
5) Araldite F + DPA + TETA	19.6 "	19.5 ± 0.8(100)		16.5 ± 0.8(84)	0		
6) EPN + MA + BDMA	22.5 "		21.0 ± 0.8(93.5)			20.0 ± 0.8(89)	
7) EPN + MDA	19.1 "		20.0 " (105)			18.5 " (97)	
8) TGMD + MA + BDMA	20.1 "		18.7 " (93.5)			18.0 " (90)	
9) TGMD + MDA	23.4 "		23.3 " (100)			25.2 " (108)	

The values in brackets represent the percentage of the initial value.

Table III.1f

Effect of nuclear radiation on the
surface resistivity of epoxy resins

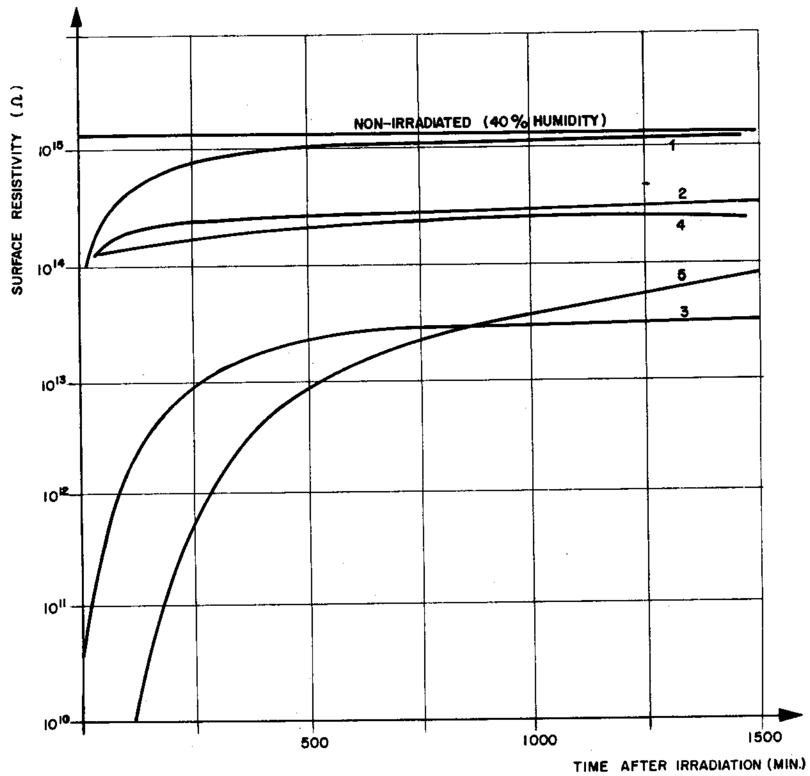
Resin composition	0	1.2×10^9 rad	2.7×10^9 rad
a) Araldite F (CY205) + HT972	2.5×10^{13} Ω	4.5×10^{12} Ω	1×10^{13} Ω
b) Araldite F (CY205) + HY905	1.1×10^{13} Ω	1×10^{12} Ω	6×10^{11} Ω
c) Araldite B (CT200) + HT901	1.7×10^{13} Ω	1×10^{12} Ω	5×10^{8} Ω
d) Araldite B (CT200) + HY906 + X157/2.426	7×10^{12} Ω	7.5×10^{12} Ω	-
e) Araldite D (CY230) + HY951	1.1×10^{12} Ω	-	-
f) Araldite EPN 1.138 + HT972	1.1×10^{13} Ω	-	-
g) Araldite X33-1.020 + HT972	8×10^{12} Ω	-	-



CURVE N°:	DOSE
1	10^6 RAD
2	10^7 RAD
3	3×10^8 RAD
4	10^9 RAD

ARALDITE B + HT 901

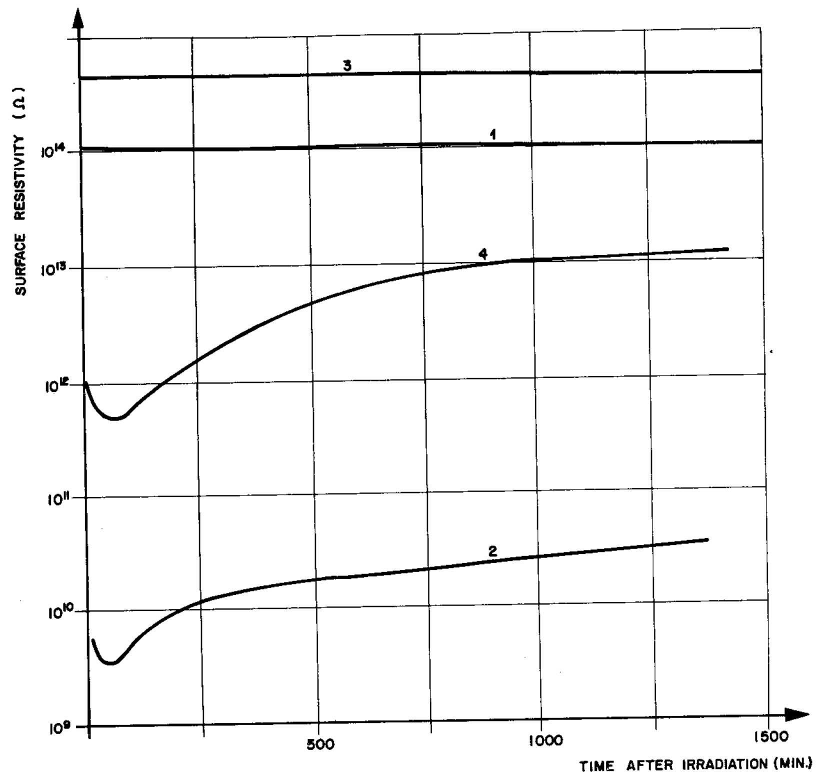
Fig. III.77



CURVE N°:		DOSE
1	IRRADIATION AND TESTING WITH 40% HUMIDITY	10^7 RAD
2	———	10^8 RAD
3	———	10^9 RAD
4	IRRADIATION AND TESTING WITH 65% HUMIDITY	10^8 RAD
5	———	10^9 RAD

ARALDITE B + HT 901

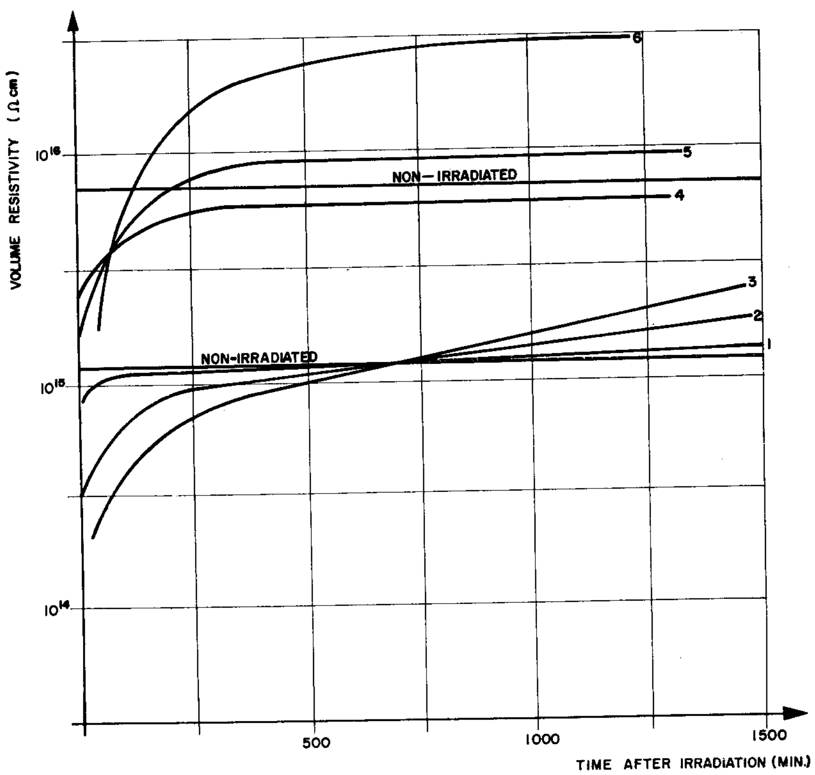
Fig. III.78



CURVE N°:	SYSTEM	DOSE
1	ARALDITE B + HT 901 + 100% ALUMINA HYDRATED	0 RAD
2	———	5 x 10^{8} RAD
3	ARALDITE B + HT 901 + 100% SILICA	0 RAD
4	———	5x 10^{8} RAD

ARALDITE B + HT 901 + FILLERS

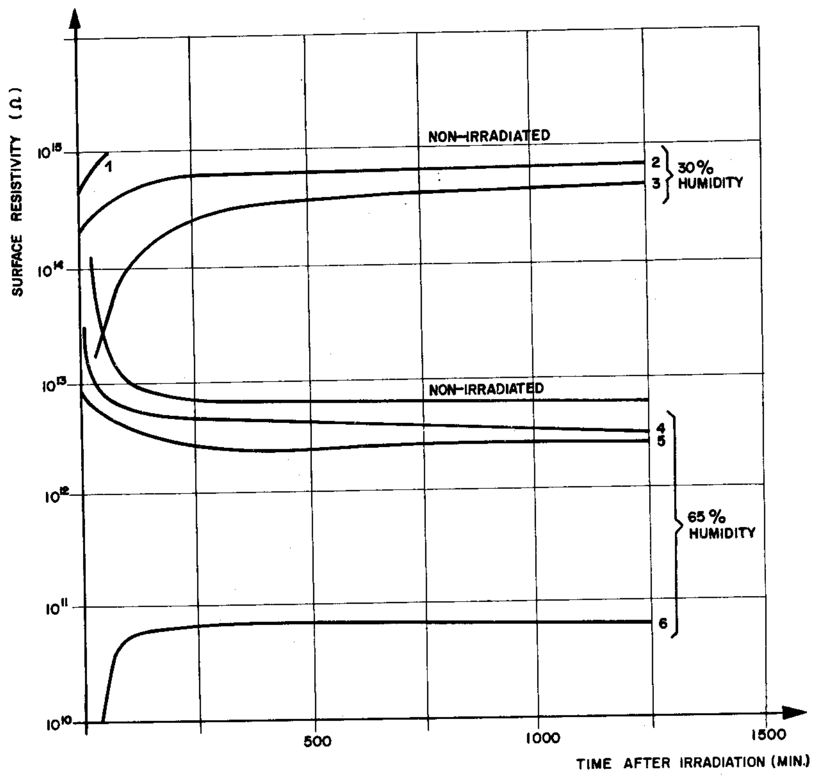
Fig. III.79



CURVE N°:		DOSE
1	ROOM TEMPERATURE CURE	10^7 RAD
2	———	10^8 RAD
3	———	5×10^8 RAD
4	POST CURE 30 mm/90°C	10^7 RAD
5	———	10^8 RAD
6	———	5×10^8 RAD

ARALDITE D + HY 951

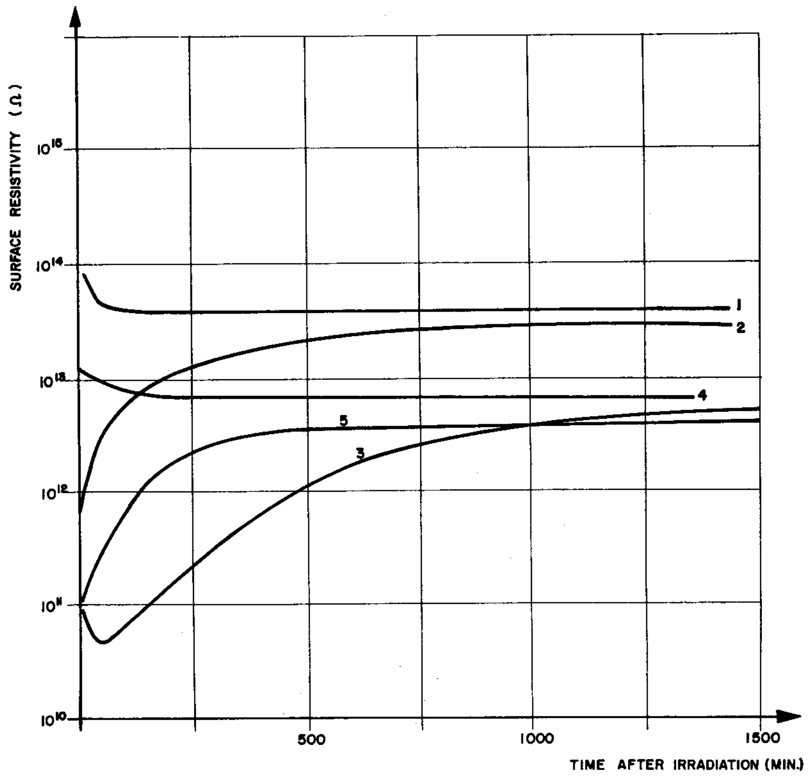
Fig. III.80



CURVE N°:		DOSE
1	IRRADIATION AND TESTING WITH 30% HUMIDITY	10^7 RAD
2	———	10^8 RAD
3	———	5×10^8 RAD
4	IRRADIATION AND TESTING WITH 65% HUMIDITY	10^7 RAD
5	———	10^8 RAD
6	———	5×10^8 RAD

ARALDITE D + HY 951

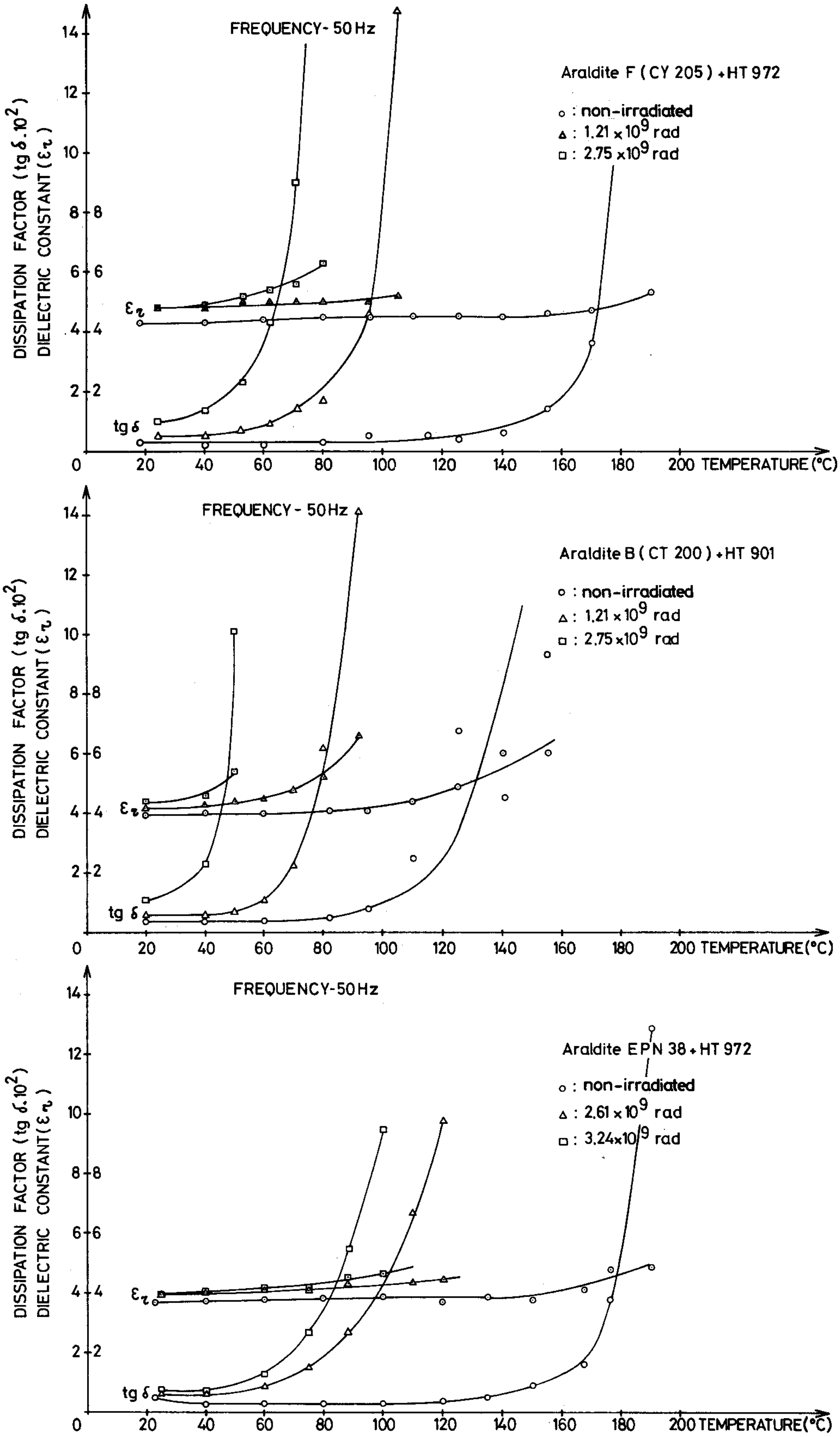
Fig. III.81



CURVE N°:	SYSTEM	DOSE
1	ARALDITE D + HY 951 + 100% ALUMINA HYDRATED	0 RAD
2	———	10^8 RAD
3	———	5×10^8 RAD
4	ARALDITE D + HY 951 + 100 % SILICA	0 RAD
5	———	5×10^8 RAD

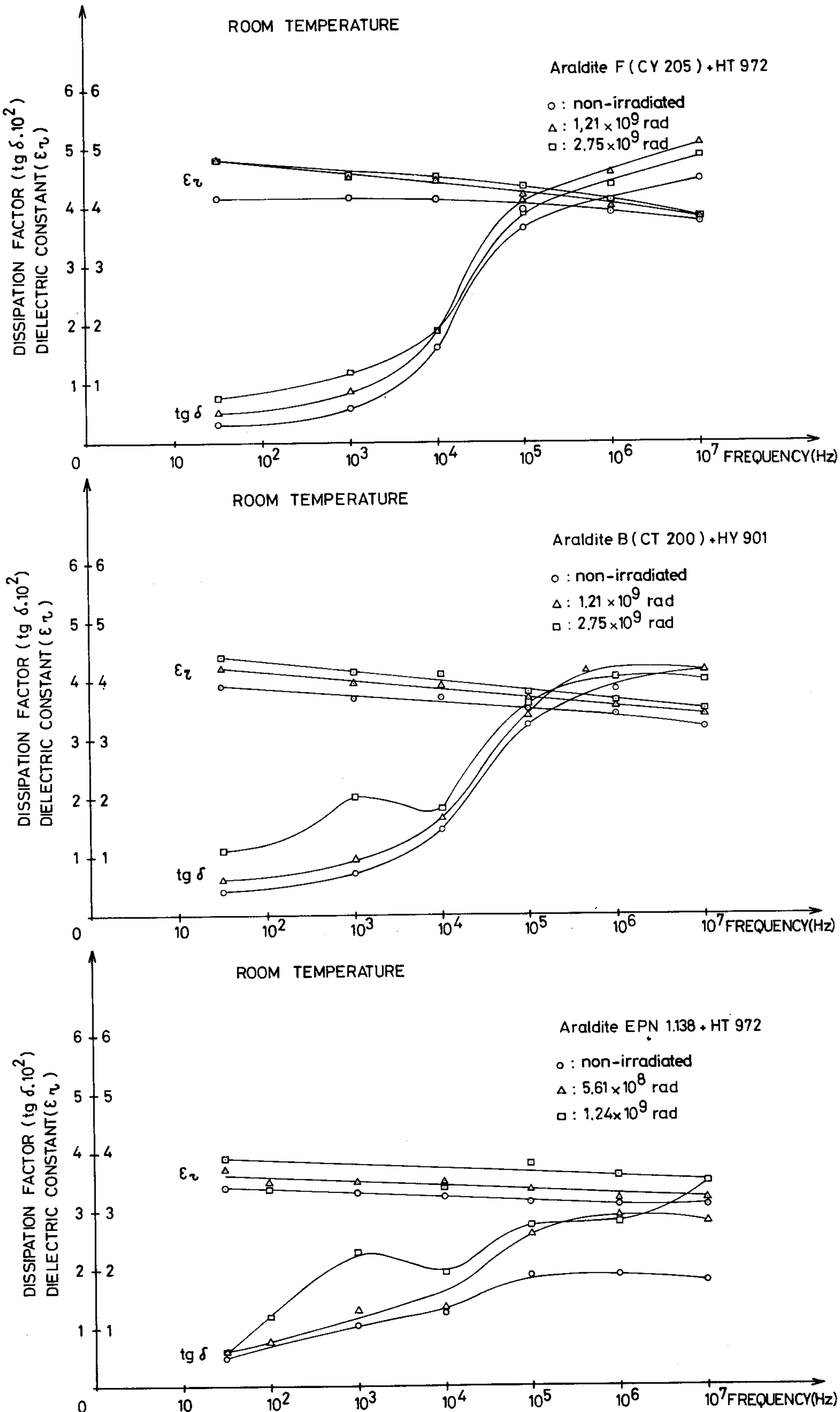
ARALDITE D + HY 951 + FILLERS

Fig. III.82



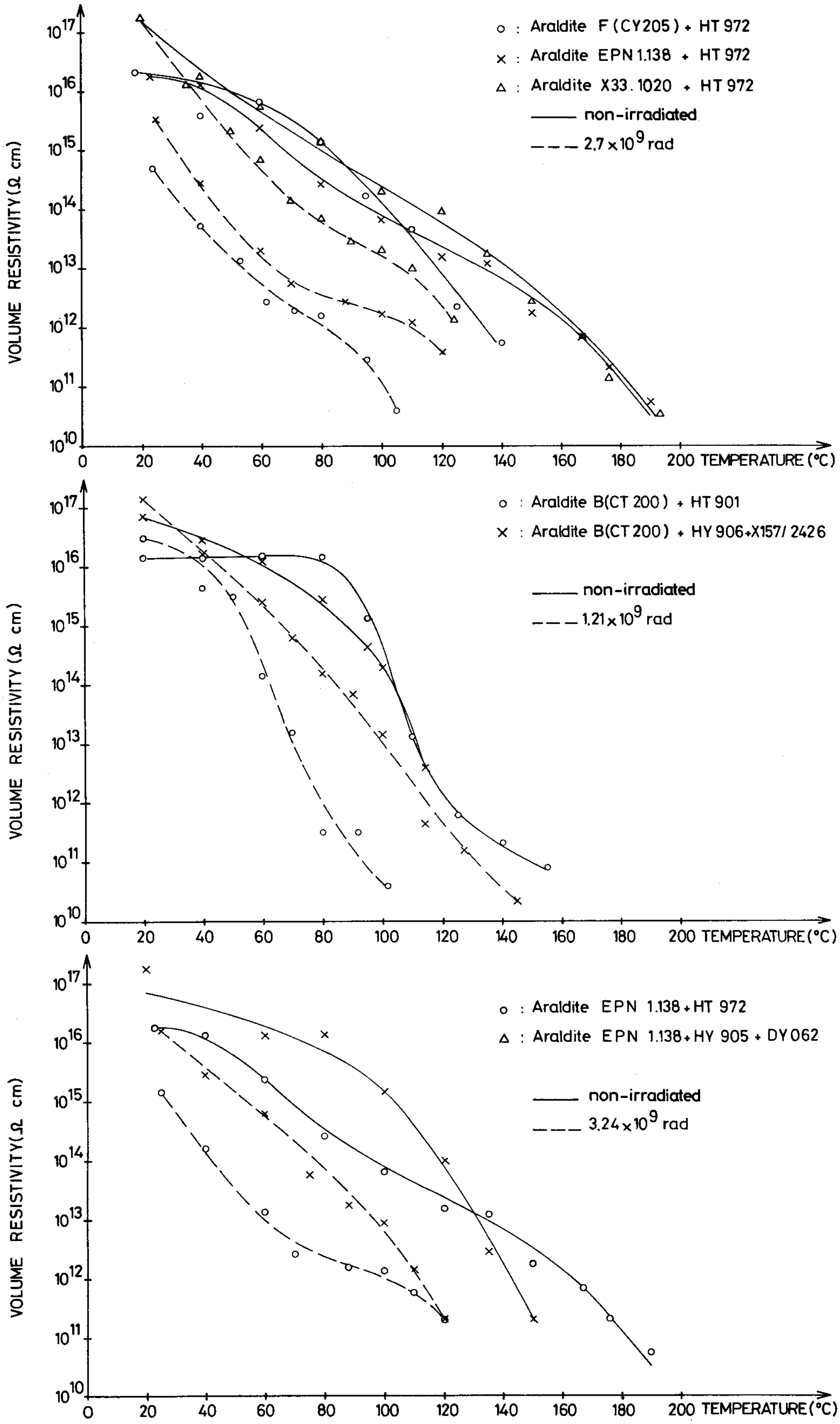
DISSIPATION FACTOR AND DIELECTRIC CONSTANT VS TEMPERATURE FOR IRRADIATED EPOXY RESINS

Fig. III.83



DISSIPATION FACTOR AND DIELECTRIC CONSTANT VS FREQUENCY FOR IRRADIATED EPOXY RESINS.

Fig. III.84



VOLUME RESISTIVITY VS TEMPERATURE FOR IRRADIATED EPOXY RESINS.

Fig. III.85

III.4 EFFECT OF RADIATION ON THE PHYSICAL PROPERTIES

TABLE III.2A PHYSICAL PROPERTIES.
IRRADIATION EFFECT ON WATER ABSORPTION AND SPECIFIC GRAVITY OF POLYMERS : THERMOPLASTICS

Material	Absorbed dose rad $.10^8$	Water absorption %	Specific gravity
ACRYLICS	0 0.4	0.4 0.4	1.19 1.19
CELLULOSE ACETATE	0 0.35	3 4	1.31 1.31
CELLULOSE PROPIONATE	0 0.37	1 1	1.19 1.19
CELLULOSE ACETATE – BUTYRATE	0 0.37	1.1 1.2	1.19 1.19
CELLULOSE NITRATE	0 0.3	1.2 1.2	1.41 1.41
ETHYL CELLULOSE	0 0.42	1.2 1.2	1.13 1.13
POLYVINYLCHLORIDE ACETATE	0 0.15 1.5 15	0.05 0.1 0.4 0.8	1.36 1.36 1.36 1.34
POLYTETRAFLUORO ETHYLENE (PTFE)	0 2	0.04 0.04	2.17 2.23
POLYCHLOROTRIFLUORO ETHYLENE (PCTFE)	0 0.6	0.01 0.01	2.12 2.12
POLYAMIDE	0 5.5 55	1.5 1.5 13	1.142 1.146 1.156
POLYETHYLENE	0 6 60	0.02 0.02 0.03	0.91 0.92 0.96
POLYPROPYLENE	0 0.55 1 5 10		
POLYSTYRENE	0 4 40	0.05 0.07 0.10	1.05 1.05 1.06
POLYVINYL FORMAL	0 0.4 4 40		1.21 1.20 1.17 1.14

TABLE III.2B PHYSICAL PROPERTIES.
IRRADIATION EFFECT ON WATER ABSORPTION AND SPECIFIC GRAVITY OF POLYMERS: THERMOSETS

Material	Absorbed dose rad x 10^8	Water absorption %	Specific gravity
ANILINE FORMALDEHYDE NO FILLER	0 4.5 45	0.1 0.1 0.1	1.21 1.21 1.21
MELAMINE FORMALDEHYDE CELLULOSE FILLER	0 0.75 7.5 75	1 2 1 11	1.46 1.46 1.46 1.20
UREA FORMALDEHYDE CELLULOSE FILLER	0 0.06 0.6 6	1.0 1.0 1.5 20	1.50 1.50 1.50 1.47
PHENOL FORMALDEHYDE GRAPHITE FILLER	0 3.5 35	4.5 4.5 4.5	1.70 1.68 1.68
PHENOL FORMALDEHYDE UNFILLED	0 0.035 0.35 3.5 35	0.3 0.4 0.5 0.8	1.3 1.3 1.3 1.3 powder
PHENOL FORMALDEHYDE LINEN FABRIC LAMINATE	0 0.35 3.5 35	1 1 2 30	1.34 1.34 1.34 0.8
PHENOL FORMALDEHYDE PAPER LAMINATE	0 0.35 3.5 35	1 1 3 80	1.37 1.37 1.36 0.8
PHENOL FORMALDEHYDE ASBESTOS FILLER	0 3.5 35	4.2 4.2 4.2	1.66 1.66 1.66
ALLYLDIGLYCOL - CARBONATE (CR 39)	0 0.037 0.37 3.7 37	0.4 0.4 0.5 1.2 2.8	1.31 1.31 1.31 1.29 1.23
FURAN ASBESTOS FILLER	0 3.5 35	0.8 0.7 1	1.85 1.85 1.85
POLYESTER	0 0.35 3.5 35	0.2 0.2 0.3 0.7	2.22 2.22 2.21 2.18
POLYESTER	0 3.5 35	0.6 0.6 0.8	1.25 1.26 1.21

Table III.2c

Gas evolution of thermoplastics*)

Material	Gas evolved mℓ/g at 10^9 rad	Gas composition
Acrylic polymethyl methacrylate	30-35	H_2, CO, CH_4 (76%)
Cellulose acetate	17-20	
Cellulose acetate butyrate	28-30	
Cellulose propionate	35	
Cellulose nitrate	105-120	
Cellulose ethyl	30-35	
Polyvinylchloride	6-9	HCl, H_2
Polychlorotrifluoroethylene	3.5	
Polyamide	20-25	H_2 (52%), CO (20%), CO_2 (12%), N_2 (8%), O_2 (3%)
Polyethylene	70	H_2 + CH_4 (97%), C_3H_8 (3%)
Polyethylene terephthalate	3-5	
Polypropylene	70-80	
Polystyrene	1-1.5	H_2 (100%)
Poly-α-methyl styrene	1.5-10	
Styrene butadiene plastic	2	
Polyvinyl alcohol	25-40	H_2 (95%), CO (4%), CO_2 (0.6%), CH_4 (0.4%)
Polyvinyl formal	∿ 100	

*) The gas evolution was measured from samples of 0.2 to 0.5 gramme, and the yields presented in the tables are for room temperature and in vacuum.

Table III.2d

Gas evolution of thermosets*)

Material	Gas evolved mℓ/g at 10^9 rad	Gas composition
Aniline formaldehyde	2	
Melamine formaldehyde (cellulose filler)	6-10	
Urea formaldehyde (cellulose filler)	10-17	
Phenol formaldehyde		
No filler	3	
Linen fabric filler	14	
Paper filler	17	
Asbestos	< 0.15	
Graphite	< 0.03	
Polyester	2-40	
Epoxy (Bisphenol A, Novolac/aromatic amine)	2-7	H_2 (90%), CO (10%) and hydrocarbons
Polyphenylene oxide (PPO)		H_2 (98.5%), CO_2 (1.2%), O_2 (0.1%), res. (0.2%)

*) The gas evolution was measured from samples of 0.2 to 0.5 gramme, and the yields presented in the tables are for room temperature and in vacuum.

Table III.2e

Gas evolution of elastomers*)

Material	Gas evolved mℓ/g at 10^9 rad	Gas composition
Acrylic	28	
Butyl	13	
Natural rubber	7	H_2 + CH_4 (95%), CO_2 + C_3H_8 (5%)
Neoprene	2-4	
Nitrile	5-10	NH_3 (8%), H_2 (24%), C_2N_2 (68%)
Polybutadiene	5	H_2 + CH_4 (100%)
Polyisoprene	10	H_2 + CH_4 (95%), CO_2 + C_3H_8 (5%)
Polyisobutylene	17-20	H_2 + CH_4 (95%), CO_2 + C_3H_8 (5%)
Polysulfide	6	
SBR	4	H_2 + CH_4 (80%), CO_2 + C_3H_8 (20%)
Silicone	20	

*) The gas evolution was measured from samples of 0.2 to 0.5 gramme, and the yields presented in the tables are for room temperature and in vacuum.

Table III.3

Radiation stability of organic materials at temperatures above 75°C

Material	Temp. °C	Max. dose (electrical) rad	Max. dose (mechanical) rad
THERMOPLASTICS			
Casein	125-140		2.5×10^7
Polychlorotrifluoroethylene	200	5×10^8	5×10^6
Polyamide	100	5×10^8	2.5×10^8
Polyethylene	85	5×10^9	2.5×10^8
Polystrene	75	5×10^9	5×10^8
Polytetrafluoroethylene	250	2.5×10^9	2.5×10^6
Polyvinlacetate	130	5×10^8	2.5×10^8
Polyvinylcarbazole	150	5×10^9	5×10^8
Polyvinylchloride	85	10^9	5×10^7
Polyvinylformal	130	10^9	5×10^8
THERMOSETTINGS			
Epoxy	130	5×10^9	2×10^9
Furan	120-160	-	3.3×10^9
Melamine formaldehyde:			
cellulose filler	110	-	1×10^8
glass-fibre filler	120	-	1×10^8
Phenol formaldehyde:			
no filler	120	-	1.1×10^7
cellulose filler	120	-	2.6×10^7
mineral filler	175-190	-	3.9×10^9
Polyester:			
no filler	100	-	8.7×10^5
mineral filler	110	-	3.9×10^9
Silicones	150	5×10^9	2.5×10^8
ELASTOMERS			
Butyl	85	5×10^8	5×10^7
Natural rubber	85	8×10^8	10^8
Neoprene	100	1.5×10^9	5×10^8
Polyisobutylene	85	5×10^8	5×10^7
Silicones	125	2×10^9	5×10^7

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Acknowledgements

We wish to thank Drs. R. Resegotti, J.P. Gourber, R. Perin and S. Pichler of CERN Laboratory I for their useful suggestions.

Also, we are very grateful to Drs. K. Goebel and R. Sheldon of Laboratory II who were kind enough to review the draft of this report.

We would also like to express our gratitude to M.W. Say for the preparation of the diagrams and to the Scientific Typing Service for the typing and presentation of this document.

APPENDIX I

A. THERMOPLASTICS

FAMILY NAME	CHEMICAL NAME	TRADE NAME
Acetals	Polyacetal	Alkon Celson Delrin Durathon Ertacetal Hostaform C
Acrylics	Acrylic resin	Acnyloid Acronal Acrysol Altuglas Bonoplex Diakon Lucite Oroglas Perspex Plexidur Plexiglas Terplex Zetafin
	Polyacrylonitrile	Dolan Dralon Orlon
Cellulosics	Cellulose esters	Acetophane Bexoid Cellidor Cellit Cellophane Forticel Lactophane Plastacele Pyraline Rhodanite Tenite butyrate Triacel Xylonite
	Ethyl cellulose	Ethocel
Halogenated polymers	Polyvinylchloride	Agilide Astralit Bakelite Benvic Carina Darvic Ekavyl Exon Flexon Geon Hostalit Igelit Koroseal Lucovyl Marvinol Opalon

Halogenated polymers (cont.)	Polyvinylchloride (cont.)	Pliovic
		Polytherm
		Saran F
		Sicron
		Solvic
		Somoplas
		Trulon
		Tygon
		Ultron
		Vestolite
		Vinidur
		Vinnal
		Vinoflex
		Vinylite
		Vipla
		Vybac
		Welvic
	Polyvinylfluoride	Tedlar
	Polytetrafluoroethylene (PTFE)	Algoflon
		Diaflon
		Fluon
		Fluorlon
		Halon
		Hostaflon TF
		Hydeflon
		Polyflon
		Soreflon
		Teflon
		Tetran
	Polychlorotrifluoroethylene (PCTFE)	Fluorothene
		Hostaflon
		Kel F
		Trithene
	Polyvinylidene chloride	Diorit
		Ixan
		Saran
		Velon
		Vestan
	Polyvinylidene fluoride	Kynar
Phenoxy resins	Phenoxy	Bakelite
Polyamides	Polyamide	Akulon
		Capran (film)
		Dederon
		Dyxyl
		Ertalon
		Grilon
		Nailonplast
		Nomex (aromatic)
		Nylon
		Orgamid
		Perlon L
		Rilsan
		Trogamid
		Ultramid
		Vestamid
		Zytel
Polycarbonates	Polycarbonate	Campco C119
		Lexan
		Makrolon
		Merlon
		Sustonat

Polyolefines	Polyethylene	Agilene Alathon (high pressure) Alkathene Bakelite Carlona Dylan Hifax Hostalen G Lupolen Marlex Orizon Polydur Polythene Rayolin Vestolen
	Polypropylene	Bakelite Carlona P Daplen Herculon Hostalen PPH Meraklon Moplen Pro-fax Propathene Tenite Tortulen P Trolen P
	Ionomer resin	Surlyn
Polyethylene terephthalate	Polyethylene terephthalate	Arnite Dacron Ertalyte Melinex Mylar Terylene Trevira
Polyphenylene oxides	Polyphenylene oxide	Alphalux 400 Ertaphenyl Noryl PPO
Polysulfones	Polysulfone	Bakelite
Styrene polymers	Polystyrene	Abcolite Afcolene Ampacet Bakelite Bextrene Carinex Cellofoam Dowexso Dylene Gedex Hostyren Lacqrene Lorkalene Lustrex Monsanto Polystyrol Styrex Styron Styropor

Styrene polymers (cont.)	Polystyrene (cont.)	Terluran Trolitul Vestyron
	Acrylonitrile-butadiene-styrene copolymer	Abson Blendex Cycolac Kralastic Lustran Novodur Royalite Tybrene
	Styrene-acrylonitrile copolymer	Luran Rhodorsil
Vinyl polymers	Polyvinylacetate	Elvazet Emultex Gelva Movolith Propiofan Rhodopas Vinavil Vinnapas Vinylite A
	Polyvinylalcohol	Aleothex Elvanol Gelvatol Mowiol Polyviol Rhodoviol Vinarol Vinavinol Vinylon
	Polyvinylbutyral	Butacite Saflex
	Polyvinylformal	Formvar
	Polyvinylcarbazole	Luvican Polectron

B. THERMOSETTINGS

CHEMICAL NAME	TRADE NAME
Aminoplasts	Acrolite Albamite Casco resins Cibanite Cymel Formica Gabrite Melmac Melox Resimene Synvarol Urox
Casein resin	Ameroid Erinoid Gansolite
Epoxy resins	Araldite Cardura Devcon Epiall Epikote Epon Epophen Epoxylite Lekutherm 3M
Furan resin	Duralon
Phenolic	Caladene Catalin Durez Durite Haveg Karbate Marblette Micarta Phenolite Pliophen Resinol Resinox Resocel Resofil Rosite 2000 Synvaren Synvarite Tufnol Varcum
Polyester	Alkyldale Aropol Atlac Catabond Ceapren Crystic

Polyester (cont.)	Dacron Dapon Desmodene Dynapol Ervalkyd Gabraster Glidpol Hetron Laminac Leguval Marco MR Paraplex Plaskon Pleogen Selectron Silmar Vibrathane Vibrin Vulcaprene
Polyimide	Kapton (film) Vespel
Polyurethane	Desmodur, Desmophen Durethane Estane Igamid U Perlon Sodethane Solithane Texin
Silicone resin	Covisil D.C. resins Dow corning Silopren Sylgand Union carbide

APPENDIX II

THERMOPLASTICS AND THERMOSETTINGS

(A)

TRADE NAME	CHEMICAL NAME
ABCOLITE	Polystyrene (PST)
ABSON	Acrylonitrile butadiene styrene (ABS)
ACETOPHANE	Cellulose acetate
ACROLITE	Urea formaldehyde
ACRONAL	Acrylic resin
ACRYLOID	Polyacrylester
ACRYSOL	Polyacrylester
ACRYTEX	Polyacrylacid
AFCOLENE	Polystyrene
AGILENE	Polyethylene
AGILIDE	Polyvinylchloride
AKULON	Polyamide
ALATHON	High-pressure polyethylene
ALBAMIT	Melamine formaldehyde
ALEOTHEX	Polyvinylalcohol (PVA)
ALGOFLON	Polytetrafluoroethylene (PTFE)
ALKATHENE	Polyethylene
ALKON	Polyacetal
ALKYLDALE	Polyester
ALPHALUX 400	Polyphenylene oxide (PPO)
ALTUGLAS	Acrylic resin
AMEROID	Casein resin
AMPACET	Polystyrene
ARALDITE	Epoxy resin
ARNITE	Polyethylene terephthalate
AROPOL	Polyester
ASTRALIT	Polyvinylchloride (PVC)
ATLAC	Polyester

(B)

TRADE NAME	CHEMICAL NAME
BAKELITE	Polyvinylchloride, polyethylene, polypropylene, polystyrene, phenoxy, polysulfone
BENVIC	Polyvinylchloride
BEXOID	Cellulose acetate
BEXTRENE	Polystyrene
BLENDEX	Acrylonitrile butadiene styrene (ABS)
BONOPLEX	Polymethacrylester
BUTACITE	Polyvinylbutyral
BUTOFAN	Copolymer butadiene styrene

(C)

TRADE NAME	CHEMICAL NAME
CALADENE	Phenolic
CAMPCO C119	Polycarbonate
CAPRAN (film)	Polyamide 6
CARDURA	Epoxy resin
CARINA	Polyvinylchloride
CARINEX	Polystyrene
CARLONA	Polyethylene
CARLONA P	Polypropylene
CASCO RESINS	Urea formaldehyde, phenolic
CATABOND	Polyester
CATALIN	Phenolic
CEAPREN	Polyester
CELLIDOR	Cellulosics
CELLIT	Cellulosics
CELLOFOAM	Polystyrene
CELLOPHANE	Cellulosics
CELSON	Polyoxymethylene
CIBANITE	Aniline formaldehyde
COVISIL	Silicone
CR 39	Diallyl-polycarbonate
CRYSTIC	Polyester
CYCOLAC	Acrylonitrile butadiene styrene (ABS)
CYMEL	Melamine formaldehyde

(D)

TRADE NAME	CHEMICAL NAME
DACRON	Polyethylene terephthalate
DAPLEN	Polypropylene
DAPON	Polyester
DARVIC	Polyvinylchloride
D.C. RESINS	Silicone
DEDERON	Polyamide
DELRIN	Acetal
DESMODENE	Polyester
DESMODUR	Polyurethane
DESMOPHEN	Polyurethane
DEVCON	Epoxy resin
DIAFLON	Polytetrafluoroethylene (PTFE)
DIAKON	Polymethylmethacrylate
DIORIT	Polyvinylidenechloride
DOLAN	Polyacrylonitrile
DOW CORNING	Silicones
DOWEXSO	Polystyrene (sulfonated)
DRALON	Polyacrylonitrile
DURALON	Furan resin
DURATHON	Polyacetal
DURETHANE	Polyurethane
DUREZ	Phenolic
DURITE	Phenolic
DYLAN	Polyethylene
DYLENE	Polystyrene
DYNAPOL	Polyester
DYXYL	Polyamide

(E)

TRADE NAME	CHEMICAL NAME
EKAVYL	Polyvinylchloride
ELVANOL	Polyvinylalcohol
ELVAZET	Polyvinylacetate
EMULTEX	Polyvinylacetate
EPIALL	Epoxy resin
EPIKOTE	Epoxy resin
EPON	Epoxy resin
EPOPHEN	Epoxy resin
EPOXYLITE	Epoxy resin
ERINOLD	Casein resin
ERTACETAL	Polyacetal
ERTALON	Polyamide
ERTALYTE	Polythylene teraphthalate
ERTAPHENYL	Polypheylene oxide
ERVALKYD	Alkyd resin
ESTANE	Polyurethane
ETHOCEL	Ethyl cellulose
EXON	Polyvinylchloride

(F)

TRADE NAME	CHEMICAL NAME
FLEXON	Polyvinylchloride
FLUON	Polytetrafluoroethylene (PTFE)
FLUORLON	Polytetrafluoroethylene (PTFE)
FLUOROTHENE	Polychlorotrifluqroethylene (PCTFE)
FORMICA	Melamine-formaldehyde
FORMVAR	Polyvinylformal
FORTICEL	Cellulosics

(G)

TRADE NAME	CHEMICAL NAME
GABRASTER	Polyester
GABRITE	Urea formaldehyde
GANSOLITE	Casein resin
GEDEX	Polystyrene
GELVA	Polyvinylacetate
GELVATOL	Polyvinylalcohol
GEON	Polyvinylchloride
GLIDPOL	Polyester
GRILON	Polyamide

(H)

TRADE NAME	CHEMICAL NAME
H Film and HT Film	Polyimide
HALON	Polytetrafluoroethylene (PTFE)
HAVEG	Phenolic
HERCULON	Polypropylene
HETRON	Polyester
HIFAX	Polyethylene
HOSTAFLON	Polychlorotrifluoroethylene (PCTFE)
HOSTAFLON TF	Polytetrafluoroethylene
HOSTAFORM C	Polyoxymethylene
HOSTALEN G	Polyethylene
HOSTALEN PPH	Polypropylene
HOSTALIT	Polyvinylchloride
HOSTYREN	Polystyrene
HYDEFLON	Polytetrafluoroethylene (PTFE)

(I)

TRADE NAME	CHEMICAL NAME
IGAMID U	Polyurethane
IGELIT	Polyvinylchloride
IXAN	Polyvinylidene chloride

(K)

TRADE NAME	CHEMICAL NAME
KAPTON (film)	Polyimide
KARBATE	Phenolic
KEL F	Polychlorotrifluoroethylene (PCTFE)
KOROSEAL	Modified polyvinylchloride
KRALASTIC	Acrylonitrile butadiene styrene (ABS)
KYNAR	Polyvinylidene fluoride

(L)

TRADE NAME	CHEMICAL NAME
LACQRENE	Polystyrene
LACTOPHANE	Cellulosics
LAMINAC	Polyester
LAROMIN	Polyamine
LEGUVAL	Polyester
LEKUTHERM	Epoxy resin
LEXAN	Polycarbonate
LORKALENE	Polystyrene
LUCITE	Polymethyl methacrylate
LUCOVYL	Polyvinylchloride
LUPOLEN	Polyethylene
LURAN	Styrene acrylonitrile (SAN)
LUSTRAN	Acrylonitrile butadiene styrene (ABS)
LUSTREX	Polystyrene
LUVICAN	Polyvinylcarbazole

(M)

TRADE NAME	CHEMICAL NAME
MAKROLON	Polycarbonate
MARBLETTE	Phenolic
MARCO MR	Polyester
MARFOAM	Polyurethane
MARLEX	Polyethylene
MARVINOL	Polyvinylchloride
MELINEX	Polyethylene terephthalate
MELMAC	Melamine formaldehyde
MELOX	Melamine formaldehyde
MERAKLON	Polypropylene
MERLON	Polycarbonate
MICARTA	Phenolic
MONDUR	Isocyanates
MONSANTO	Polystyrene
MOPLEN	Polypropylene
MOWILITH	Polyvinylacetate
MOWIOL	Polyvinylalcohol
MYLAR	Polyethylene terephthalate
3M	Epoxy resin

(N)

TRADE NAME	CHEMICAL NAME
NAILONPLAST	Polyamide
NOMEX YARN	Polyamide (aromatic)
NORSOLENE	Coumarone resin
NORYL	Polyphenylene oxide
NOVODUR	Acrylonitrile butadiene styrene (ABS)
NYLON	Polyamide

(O)

TRADE NAME	CHEMICAL NAME
OPALON	Polyvinylchloride
ORGAMID	Polyamide
ORIZON	Polyethylene
ORLON	Polyacrylonitrile
OROGLAS	Polymethacrylester
OXIDWACHS	Polyethyleneglycol

(P)

TRADE NAME	CHEMICAL NAME
PARAPLEX	Polyester
PARYLENE N, C, D	Parylene
PENTON	Chlorinated polyether
PERLON	Polyurethane
PERLON L	Polyamide
PERSPEX	Polymethyl methacrylate
PHENOLITE	Phenolic
PHOTEX	Polyacrylacid
PLASKON ALKYD	Polyester
PLASTACELE	Cellulose acetate
PLEOGEN	Polyester
PLEXIDUR	Polymethyl methacrylate
PLEXIGLAS	Polymethyl methacrylate
PLEXILEIM	Polyacrylacid
PLIOVIC	Polyvinylchloride
PLYOPHEN	Phenolic
POLECTRON	Polyvinylcarbarzole
POLYDUR	Polyethylene
POLYFLON	Polytetrafluoroethylene
POLYOX	Polyethylene
POLYSTYROL	Polystyrene
POLYTHENE	Polyethylene
POLYTHERM	Polyvinylchloride
POLYVIOL	Polyvinylalcohol
PPO	Polyphenylene oxide
PROFAX	Polypropylene
PROPATHENE	Polypropylene
PROPIOFAN	Polyvinylacetate
PYRALINE	Cellulose nitrate

(R)

TRADE NAME	CHEMICAL NAME
RAYOLIN	Polyolefin
RESIMENE	Melamine formaldehyde
RESINOL	Phenolic
RESINOX	Phenolic
RESOCEL	Phenolic
RESOFIL	Phenolic
RHODANITE	Cellulose acetate
RHODOPAS	Polyvinylacetate
RHODORSIL	Styrene acrylonitrile (SAN)
RHODOVIOL	Polyvinylalcohol
RILSAN	Polyamide
ROSITE 2000	Phenolic
ROYALITE	Acrylonitrile butadiene styrene (ABS)

(S)

TRADE NAME	CHEMICAL NAME
SAFLEX	Polyvinylbutyral
SARAN	Polyvinylidene chloride
SARAN F	Polyvinylchloride
SELECTRON	Polyester
SICRON	Polyvinylchloride
SILMAR	Polyester
SODETHANE	Polyurethane
SOLITHANE	Polyurethane
SOLVIC	Polyvinylchloride
SOMOPLAS	Polyvinylchloride
SOREFLON	Polytetrafluoroethylene
STYREX	Polystyrene
STYROFOAM	Polystyrene
STYRON	Polystyrene
STYROPOR	Polystyrene
SURLYN	Ionomer resin
SUSTONAT	Polycarbonate
SYLGAND	Silicone
SYNVAREN	Phenolic
SYNVARITE	Phenolic
SYNVAROL	Urea formaldehyde

(T)

TRADE NAME	CHEMICAL NAME
TEDLAR	Polyvinylfluoride
TEFLON	Polytetrafluoroethylene
TEFLON FEP	Copolymer of hexafluoropropene and tetrafluoroethylene
TENITE	Polypropylene
TENITE BUTYRATE	Cellulose acetate butyrate
TERLURAN	Styrol polymer
TERPLEX	Polymethacrylester
TERYLENE	Polyethylene terephthalate
TETRAN	Polytetrafluoroethylene
TEXIN	Polyurethane
TORTULEN P	Polypropylene
TREVIRA	Polyethylene terephthalate
TRIACEL	Cellulose acetate
TRITHENE	Polychlorotrifluoroethylene
TROGAMID	Polyamide
TROLEN P	Polypropylene
TROLITUL	Polystyrene
TRULON	Polyvinylchloride
TUFNOL	Phenolic
TYBRENE	Acrylonitrile butadiene styrene (ABS)
TYGON	Polyvinylchloride

(U)

TRADE NAME	CHEMICAL NAME
ULTRAMID	Polyamide
ULTRON	Polyvinylchloride
UNION CARBIDE	Silicone resin
UROX	Urea formaldehyde

(V)

TRADE NAME	CHEMICAL NAME
VARCUM	Phenolic
VELON	Polyvinylidene chloride
VESPEL	Polyimide
VESTAMID	Polyamide
VESTAN	Polyvinylidene chloride
VESTOLEN	Polyethylene
VESTOLITE	Polyvinylchloride
VESTYRON	Polystyrene
VIBRATHANE	Polyester
VIBRIN	Polyester
VINAROL	Polyvinylalcohol
VINAVIL	Polyvinylacetate
VINAVINOL	Polyvinylalcohol
VINIDUR	Polyvinylchloride
VINNAPAS	Polyvinylacetate
VINNOL	Polyvinylchloride
VINOFLEX PC	Polyvinylchloride
VINYLITE A	Polyvinylacetate
VINYLITE	Polyvinylchloride
VINYLON	Polyvinylalcohol
VIPLA	Polyvinylchloride
VISCOSE	Cellulosics
VYBAK	Polyvinylchloride

(W)

TRADE NAME	CHEMICAL NAME
WELVIC	Polyvinylchloride

(X)

TRADE NAME	CHEMICAL NAME
XYLONITE	Cellulosics

(Z)

TRADE NAME	CHEMICAL NAME
ZETAFIN	Polyethylacrylate
ZYTEL	Polyamide

APPENDIX III

ELASTOMERS

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
Acrylics	Polyacrylate	Acrylon Angus HR, SH Cyanocryl Hycar Lactaprene Paracril OHT Precision acrylics Thiacril Vyram
Butyl GRI	Isobutylene-isoprene	Bucar butyl Enjay butyl Hycar I.I. rubber Oppanol B Petro-Tex butyl Polysar butyl Precision butyl Vistanex MM
EPR	Ethylene propylene	Angus KR APK C 23 Dutral N Enjay EPR Nordel Olethene Royalene
Fluoroelastomers	Vinylidene fluoride hexafluoropropylene	Angus VA, SV Fluorel Precision fluoro Viton
	Fluoro-silicone	Precision fluoro silicone Silastic LS 53
	Trifluorochloro-ethylene-vinylidene-fluoride	Kel F
Hypalon	Chlorosulphonated polyethylene	Angus HN Hypalon Precision hypalon
Natural rubber	Natural polyisoprene	Coral DPR Natsyn Okolite Shell isoprene Trans P.R.
Neoprene GRM	Chloroprene	Angus G Neoprene Okoprene Perbunan C Precision neoprene Sovprene U.S. rubber neoprene

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
Nitrile; Buna N; G.R.A; N.B.R.	Acrylonitrile-butadiene	Angus DS, WR, FR, LR, E, P
		Butacril
		Butraprene
		Chemigum
		Chemivic
		FR-N
		Herecrol
		Hycar OR
		Parker Nitrile
		Perbunan
		Polysar Krynao
		Precision Nitrile
		Royalite
		Tylac
Polybutadiene; Buna; S.K.A.	Butadiene	Ameripol CB
		B R rubber
		Budene
		Cisdene
		Diene
		Duradene
		Duragen
		Polysar tacktene
		S.K.B.
		Texus synpol EBR
		Trans 4 or cis 4
Polyisoprene synthetic	Synthetic polyisoprene	Ameripol SN
		Coral
		DPR
		Natsyn
		Philprene
		Shell IR
		Trans PIP Cariflex
Polyurethane	Diisocyanate-polyester or polyether	Adiprene
		Chemigum XSL
		Conathene
		Contilan
		Cyanoprene
		Desmodur
		Desmolin
		Disogrin
		Elastocast
		Elastolan
		Elastothane
		Estane
		Genthane
		Guidfoam
		Lamigom
		Mearthane
		Microvon
		Multrathane
		Pagulan
		Phoenolan
		Polyvon
		Precision urethane
		Roylar
		Solithane
		Texin
		Vorylen
		Vulcaprene
		Vulkollan

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
SBR, Buna S, GRS; SKB	Styrene-butadiene	Ameripol Angus R.G. ASRC Polymers Butaprene S Carbonix Cariflex Chemigum IV Copo Darex Duradene Flosbrene FR-S Gen-flow Gentro Hycar OS, E, TT Krylene Kryflex Navgapol Naugatex Philprene Plioflex Pliolite S Pliotuf Polysar S S Polymers Solprene Synpol Tylac
Silicone	Polysiloxane	Angus SIL. SIS Arcosil Cohrlastic Fairprene General Electric SE HW Parker silicone Rhodorsils RTV Silastene Silastic Union carbide K.Y.
Thiokol GRP	Organic polysulfide	Alkylene polysulfide F.A. polysulfide rubber Perduren Precision thiokol S.T. polysulfide rubber Thioplasts Vulcaplas
Vinylpyridine	Butadiene-2-methyl-5-vinyl pyridine	Philprene