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IDO-14598
December 1962

THE EFFECT OF RADIATION AND NITRIC ACID-NITRATE SALT
SOLUTION ON SOME NON-METALLIC MATERIALS

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Printed in USA

IDO-14598
AEC Research and Development Report
Chemical Separations Processes
for Plutonium and Uranium
TID-4500 (18th Ed.)
Issued: December 10, 1962

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Contract AT(10-1)-205

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A B S T R A C T

Several plastic materials and one ceramic alumina have been tested for possible use as electrical insulators and spacers in an electrolytic dissolver for processing irradiated nuclear fuels. These were first screened for chemical resistance to the boiling dissolver product solution composed of 1 molar nitric acid and 75 g/l stainless steel. Those which were resistant were then exposed simultaneously to the boiling dissolver product solution and a gamma irradiation field. Values were obtained for the impact strength, compressive strength, and electrical resistivity of the more resistant materials. Those which gave the most favorable performance were: Kynar (polyvinylidene fluoride - Pennsalt Chemicals Corporation) up to 1×10^9 R total dose, Marlex (high density polyethylene - Phillips Petroleum Company) up to 2×10^9 R total dose, G-7 glass fabric-silicone resin laminate (Taylor Corporation) up to 10^{10} R total dose, and ceramic alumina (AP 35 - McDanel Refractory Polcelain Company) to greater than 10^{10} R total dose. If a limited service life is taken into consideration in the design of the equipment, any one of the four more resistant materials should prove acceptable for use as spacers and insulators in an electrolytic dissolver vessel.

NOTICE

The experimental work reported in this document was carried out for the specialized purpose of obtaining information concerning the availability of a radiation and chemically resistant electrical insulating material for use in an electrolytic dissolver for reprocessing spent nuclear fuel. The conclusions as to the serviceability of the materials mentioned are the opinions of the author and apply only to use of the materials in the specific application and environment listed in the report. The fact that some of the materials were judged unacceptable for this specific service does not imply that they are generally inferior.

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	<u>Page</u>
TABLE OF CONTENTS	
ABSTRACT.	3
I. SUMMARY	7
II. INTRODUCTION.	8
III. EXPERIMENTAL PROGRAM.	10
IV. RESULTS	12
V. CONCLUSIONS AND RECOMMENDATIONS	25
ACKNOWLEDGEMENT	27
REFERENCES.	28
APPENDIX I.	29
A. Characteristics of Radiation Source Used in Tests.	29
B. Dosimetry	30
APPENDIX II	30

LIST OF TABLES

Table

1	Comparison of Effects of Boiling Electrolytic Dissolver Solution on Insulator Materials.	13
2	Comparison of Mechanical and Electrical Properties of Insulator Materials Before and After Irradiation in The Presence of Boiling Dissolver Solution	15

LIST OF FIGURES

Figure

1	Proposed ICPP Plant Scale, Basket-Type Electrolytic Dissolver Showing Location of Radiation Source and Plastic Insulating Support and Gaskets.	9
2	Container and Sample Holder for Irradiation of Specimens in Boiling Solutions	12

LIST OF FIGURES
(Continued)

<u>Figure</u>		<u>Page</u>
3	Visual Effects of Irradiation on Marlex	16
4	Visual Effects of Irradiation on Unannealed Kynar	18
5	Visual Effects of Irradiation on Annealed Kynar	18
6	Visual Effects of Irradiation on Ceramic Alumina.	19
7	Visual Effects of Irradiation on G-7 Glass Fabric- Silicone Resin Laminate	20
8	Visual Effects of Irradiation on Kel-F.	21
9	Visual Effects of Irradiation on Saran B115	22
10	Visual Effects of Irradiation on Polystyrene.	23
11	Visual Effects of Irradiation on Polycarbonate.	24
12	Visual Effects of Irradiation on Polypropylene.	24
13	Visual Effects of Irradiation on Penton	25

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I. SUMMARY

Plastic and ceramic materials have been of particular interest as possible materials of construction for equipment in the chemical re-processing of irradiated nuclear fuels. These materials usually possess excellent corrosion resistance and electrical insulation properties. However, their radiation resistance has not been fully evaluated. The development of a chemical process for dissolving stainless steel clad fuel elements by electrolytic dissolution in nitric acid presented a need for such an evaluation. The design requirements for an electrolytic dissolver vessel must include an insulating material to support and separate the anode from the cathode and to serve as gaskets. The material of construction for these insulating spacers, supports, and gaskets must be able to withstand the chemical and radiation environment inside the dissolver.

An experimental testing program was carried out in order to discover one or more materials which would be suitable as an insulating support and spacer in the boiling (214°F) nitric acid dissolver solution in the presence of the ionizing radiation from the dissolving fuel elements. The dissolver solution at steady-state conditions will be approximately 1M nitric acid with 75 grams per liter of stainless steel metal components as nitrates. The radiation dose rate from a typical APPR fuel element (39 per cent burn up, 100 days cooling time) will be about $5 \times 10^5 \text{ Rep(R) / hr}$ for the basket dissolver design which places the plastic insulating spacers at a distance of only one inch from the fuel surface and two or three inches from the mid-plane of the fuel element. In the case of the solution contact dissolver, in which the insulating material acts as a basket and is in direct contact with the fuel surface, the dose rate may be as high as $2.6 \times 10^6 \text{ R/hr}$.

Four materials, Marlex* polyethylene, Kynar**, ceramic alumina, and G-7*** glass fabric-silicone resin laminate withstood gamma radiation exposure to 10^9 R total dose or greater while immersed in the boiling dissolver product solution. The alumina ceramic and the G-7 laminate remained intact and strong up to 10^{10} R total dose. These materials would be suitable for use as materials of construction in the chemical and radiation environment described above with certain limitations on the service life of the material.

II. INTRODUCTION

The use of plastic materials of construction in the chemical re-processing of nuclear fuels has been discouraged because of the general susceptibility of organic materials to radiation damage. In order to properly evaluate the serviceability of a material in the presence of radiation, it is necessary to test it under actual service conditions. Although results of that type of test are becoming available^(4,5,6,7,8,9), data were not available for design purposes on plastic materials that would be needed for insulating spacers, supports, and gaskets inside the dissolver. Figure 1 shows the location and importance of these insulators in one of the proposed dissolver designs.

The flowsheet design for the electrolytic process calls for a dissolver reagent of 8M nitric acid and a solution in the continuous dissolver (steady state) of 1-3M nitric acid and 75 g/l metal ions (stainless steel components) as nitrates. Service life would be at least one year of continuous duty. The radiation dose rate in a dissolver such as shown in Figure 1 can be $5 \times 10^5 \text{Rep(R)****}$ per hour or higher during operation. Therefore, the basis for one year's service is resistance to 4.4×10^9 R total dose for the insulating spacer nearest the mid-plane of the fuel element. The other spacers and supports and

* Registered trademark of Phillips Petroleum Company for its family of polyolefin resins.

** A vinylidene fluoride resin produced by Pennsalt Chemicals Corp.

*** Produced by Taylor Corporation.

**** See Appendix I for discussion of dosimetry.

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Fig. 1 Proposed ICPP Plant Scale Basket-Type Electrolytic Dissolver Showing Location of Radiation Source and Plastic Insulating Support and Gaskets

the gaskets would receive much smaller dose rates. It is expected that the solution in the dissolver will be boiling.

A program to find a material that would withstand these conditions (i.e., boiling 1M nitric acid - 75 g/l stainless steel components and radiation of 10^9 to 10^{10} R total dose) and still retain physical and electrical properties well enough to serve the purpose was carried out. An initial screening experiment eliminated those materials that were degraded by the boiling solution alone. Those that passed that test still intact were exposed simultaneously to radiation and to the boiling nitric acid solution. The radiation dose rate was accelerated so that 10^9 and 10^{10} R could be reached in a reasonable length of time. The radiation program was carried out at the Materials Testing Reactor (MTR) Gamma Facilities. The materials that were intact after these exposures were submitted for measurement of physical properties.

Candidates for the material of construction narrowed to 4 materials which remained intact to 10^9 R or greater total dose. These were Marlex^{a*}, Kynar^b, alumina ceramic^c, and G-7 glass fabric-silicone resin laminate^d.

III. EXPERIMENTAL PROGRAM

The experimental test conditions were as close as possible to the expected operating conditions. A suitable material would have to be resistant to a boiling 1M nitric acid solution with 75 g/l stainless steel metal components (dissolver product solution) in the presence of radiation of the order of 10^9 R total dose. The properties which were chosen as reference points from which to judge performance were appearance (size and shape), weight change, impact strength, compressive strength and electrical resistivity.

Each material was first put through an initial screening test to determine the chemical resistance to boiling dissolver product solution. This screening test consisted of determining visible defects or weight change after immersion in boiling dissolver product for 96 hours or more. Only those materials that completely withstood the effects of the boiling dissolver product were tested further in the simultaneous exposure to radiation and boiling dissolver product solution.

* See Table 1 for description of materials as identified by superscript letters.

A container was designed and built to hold the test specimens immersed in the dissolver product solution, (See Figure 2). It consisted of a double-walled stainless steel cylinder 7 feet long fitted with a cap through which passed tubes to accommodate the heater and its leads, the thermocouple and its leads, a vent, and a tube to withdraw solution from the container while immersed in the MTR Gamma Facilities canal. Two liters of the dissolver product solution filled the lower 2 feet of the container. The extra five feet of length served as a reflux condenser for the boiling solution. The over-all seven feet allowed the rubber o-ring seal at the top to be above most of the damaging gamma rays. Tests specimens $\frac{1}{2} \times \frac{1}{2} \times 2\frac{1}{2}$ inches for impact strength measurements were suspended from the 1/8-inch-diameter rods attached to the thermocouple well tube. One-inch-diameter by 1-inch-long rod specimens for compression strength measurements were supported between the flat steel plates also anchored to the tube. Extensions to the tubes brought the lead wires and vents through the water to the surface of the canal. A larger version of the container supported 4-inch-diameter x 1/8-inch-thick discs for electrical resistivity test specimens.

The rate of heating was controlled by a variable transformer. Thermocouples were used in connection with a recorder to show that the solution was boiling. An average dose rate of 5×10^6 R/hr could be maintained so that a total dose of 10^9 R could be obtained in 200 hours. (See Appendix I for typical dose rate plot and dosimeter methods). Radiation exposures of 10^8 , 10^9 , and 10^{10} R total dose were given to materials that showed promise of withstanding the exposure.

For the tests over 10^9 R total dose, provisions were made for each material to have its own container and solution to avoid cross-contamination effects. It was found that the acid concentration dropped off drastically after the first two weeks of operation. The acid was consumed mainly by corroding the stainless steel sample holders. Sufficient concentrated (70 per cent) nitric acid was added periodically to bring the acid concentration back to normal. It was found that the acid varied between 0.5M and 1.5M except when fresh acid was not added

Fig. 2 Container and Sample Holder for Irradiation of Specimens in Boiling Solutions

at the regular interval. The acid concentration averaged about $1M$ in the exposures to greater than $10^9 R$ total dose.

IV. RESULTS

Materials were chosen for the initial chemical screening test on the basis of possibly withstanding the chemical environment or for their known radiation resistance. Some of the most corrosion resistant materials such as Teflon have very low radiation resistance, while some of the most radiation resistant plastics such as polystyrene, epoxies, and phenolics have very little chemical resistance to strong oxidizing solutions (10,11,12,13,14).

The list in Table 1 includes those materials which were tested in boiling dissolver product solution. The results of this test ran all the way from complete dissolution to no detectable change. Those that were sufficiently resistant to the chemical test to receive further testing by radiation were, Kel F^e, Marlex^a, Saran B115^f, Kynar^b, and Armalon 4101^g, Polystyrene (Styron)^h, Polycarbonateⁱ, G-7 laminate^d, alumina ceramic^c, and polypropylene^j.

A radiation exposure of $10^8 R$ total dose was given first. Those materials which survived that

TABLE 1
COMPARISON OF EFFECTS OF BOILING ELECTROLYTIC DISSOLVER SOLUTION
ON INSULATOR MATERIALS

Code	Material	Composition	Source	Chem. Resistance 1M HNO ₃ , 75 g/l SS Components
a	Marlex	high density polyethylene	Phillips Pet. Co.	resistant, no wt. loss
b	Kynar	vinylidene fluoride resin	Pennsalt Chemical	resistant, slight wt. gain
c	AP 35	alumina ceramic (99% Al ₂ O ₃)	McDanel	resistant, no wt. loss
d	G-7	glass fabric-silicone resin laminate	Taylor Corp.	resistant, 10% wt. loss
e	Kel-F, KF 3010	chlorotrifluoroethylene	Minn. Mining & Mfg.	resistant, no wt. loss
f	Saran B115	polyvinylidene chloride	Dow Chemical	resistant, some wt. loss
g	Armalon 410L	glass fabric-Teflon laminate	duPont	took up moisture
h	Styron 475	polystyrene	Auburn Plastics	warped
i	Lexan	polycarbonate	General Electric	lost 20% wt.
j	Nalgene	polypropylene	Nalge	no wt. loss
k	Penton	chlorinated polyether	Polymer Corp. of Penn.	very brittle 20% wt. loss (8M HNO ₃)
l	Beetle	urea, cellulose filled	American Cyanamide Company	dissolved
m	Cymel 1077	melamine	American Cyanamide Company	dissolved
n	Catalin	phenolic	Catalin Corp. of America	dissolved
o	Durasite	furan resin	U.S. Stoneware Co.	dissolved
p	CR 39	allyl resin	Columbia Southern Chemical	dissolved
q	Haveg 41	phenolic - asbestos filled	Haveg Industries	disintegrated
r	S 1029	polystyrene	Campco	disintegrated
s	Stycast 2741	epoxy	Emerson & Cuming	disintegrated

exposure intact were exposed to 10^9 R. The four materials that withstood 10^9 R were tested at a higher dose, up to 10^{10} R. Those four materials were G-7 glass fabric-silicone resin laminate, ceramic alumina, Kynar, and Marlex polyethylene. The G-7 laminate and the ceramic alumina were still intact and strong after 10^{10} R total dose. Table 2 lists the values of the mechanical and electrical properties and the effects of radiation for these four materials. The subsequent paragraphs and pictures of specimens give detailed observations of the behavior of each more resistant material.

Marlex^a (polyethylene - Phillips Petroleum Company)

The boiling dissolver solution showed no effect on Marlex in the absence of radiation. After an exposure of 10^8 R at 115°F the only effect was a slight darkening in color. This effect is shown in Figure 3. The lower photo in Figure 3 shows the effects of increased total dosage to 10^{10} R in boiling solution. A comparison can also be made of the effect of higher average acid concentration. The only visual effect of radiation up to 10^9 R total was a darkening in color. However, physical testing showed a loss of impact strength at 10^9 R. See Table 2 for physical properties change.

At about 2×10^9 R total dose the Marlex samples became slightly rubbery but were still quite straight and dimensionally true. From 2×10^9 R on up to 10^{10} R the sample decreased in size, uniformly, by spalling or dissolving or both. By 6×10^9 R exposure the $\frac{1}{2}$ " thick samples had lost $1/8$ " of thickness, by 10^{10} R they had lost $\frac{1}{4}$ ". In the lower photo in Figure 3 the set of samples labelled "acid conc. maintained" was from a run in which periodic acid samples were taken and the acidity maintained at an average of 1.0M. All samples from that run had a crust coating on them as shown by the pair on the right. After peeling off the crust the samples looked as on the left. The crust was composed of about 50 per cent ferric oxide and 50 per cent organic.

Kynar^b (polyvinylidene fluoride resin - Pennsalt Chemical)

The Kynar gained a little weight after 96 hours in the boiling solution but was judged resistant.

TABLE 2
COMPARISON OF MECHANICAL AND ELECTRICAL PROPERTIES* OF
INSULATOR MATERIALS BEFORE AND AFTER IRRADIATION
IN THE PRESENCE OF BOILING DISSOLVER SOLUTION

<u>Marlex</u> ^(a)	"as received"	10 ⁸ R dose	10 ⁹ R dose	10 ¹⁰ R dose
Impact strength ft. lb/in. of notch	3.67	3.51	0.54	-
Compressive yield strength, psi	2890	2870	2890	-
Volume resistivity ohm - cm	1.82 x 10 ¹⁶	-	3.3 x 10 ¹¹	-
<u>G-7 Glass Fabric-Silicone Resin Laminate</u>				
Impact strength ft. lb/in. of notch	18.5 ^(d)	25.2	29.7	2.03
Compressive strength psi	49,400 ^(d) 14,500 ^(d')	41,300	35,300 10,300	4,030
Volume resistivity ohm - cm	1.62 x 10 ¹⁶	-	7.36 x 10 ⁷	-
<u>Kynar</u> ^(b)				
Impact strength ft. lb/in. of notch	1.11	0.65	0.81	-
Compressive strength, psi	6210**	6470**	3890**	-
Volume resistivity ohm - cm	2.29 x 10 ¹²	-	4.87 x 10 ⁹	-
<u>AP 35 Ceramic</u> ^(c) <u>Alumina</u>				
Impact strength ft. lb/in. of width	1.53	-	2.13	1.88
Compressive strength psi	104,000	-	131,000	103,000
Volume resistivity ohm - cm	9.55 x 10 ¹⁵	-	9.6 x 10 ¹³	

(a) Registered trade mark of Phillips Petroleum Company, for its family of polyolefin resins.

(b) Polyvinylidene Fluoride Resin from Pennsalt Chemicals Corp.

(c) McDanel Refractory Porcelain Co.

(d) Taylor Corp., LaVerne, California.

(d') Insulation Mfrs. Corp., Chicago, Illinois.

(*) These values are generally the average of three measurements. For additional properties see Appendix II.

(**) Did not show definite fracture. Failed by deforming into disk.

Fig. 3 Visual Effects of Irradiation on Marlex

Two kinds of Kynar were tested, annealed and unannealed. The unannealed specimens were unaffected by exposure to 10^8 R at 115°F in the solution but showed cracks and were warped after 10^8 R at boiling - 214°F . The warping and cracking was even more pronounced after 10^9 R at 214°F . The annealed specimens were intact, straight, and had no cracks after similar exposures. Figures 4 and 5 show the visible effects of radiation on Kynar.

The impact strength for Kynar was low to begin with but it only dropped to about one-half the initial value at an exposure of 10^8 R total dose, then increased slightly after further radiation to 10^9 R total dose. Its compressive strength remained essentially the same up to 10^8 R and then dropped in value after 10^9 R total dose. However, it was still quite strong and tough after 10^9 R total dose. It rapidly deteriorated after 10^9 R total dose so that by the time the samples had reached 2.8×10^9 R exposure in the boiling solution they were completely destroyed.

AP 35 Ceramic Alumina^c (McDanel)

This high density (3.7 g/cc) pure ceramic alumina showed no visible change nor weight loss after exposure to the boiling dissolver product solution. It also withstood the effects of radiation in the presence of the boiling solution up to 10^{10} R total dose. No weight loss occurred, and no dimensional change was observed. Table 2 shows that the impact strength increased with radiation, the compressive strength changed slightly but ended up about equal to the initial value, and the volume resistivities (ohm-cm) decreased by a factor of 100. Figure 6 shows the slight discoloration on the ceramic specimens which was caused mainly by the iron oxides precipitating from the solution.

G-7 Glass Fabric-Silicone Resin Laminate^d

The G-7 laminate is a standard National Electrical Manufacturers Association grade of insulating material for general service. It is manufactured by several companies and samples from three of these companies were tested. Weight loss of up to 10 per cent was experienced after exposure to the dissolver solution and 8M and 16M nitric acid;

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Fig. 6 Visual Effects of Irradiation on Ceramic Alumina

however, essentially no loss of strength was associated with the weight loss. All specimens remained straight, strong, and intact to over 10^9 R; however, only the specimens from Taylor Corporation remained hard and without cracks to 10^{10} R. The other samples became soft and showed incipient delamination after about 6×10^9 R. Figure 7 shows the visible changes after irradiation. The values in Table 2 indicate that the Taylor Corporation G-7 laminate would be useful as an insulator and support up to about 10^{10} R. These results are not too different from those obtained for silicone resin laminate irradiated in air⁽¹⁵⁾.

Kel-F^e, KF 3010 (chlorotrifluoroethylene - Minnesota Mining & Mfg. Co.)

Kel-F suffered no damage in the boiling solution in the absence of radiation. However, after 10^8 R exposure the specimens showed deep cracks at both 115°F and boiling - 214°F. Cracking and spalling became more severe with increased dosage.

Fig. 7 Visual Effects of Irradiation on G-7 Glass Fabric-Silicone Resin Laminate

The "as-fabricated" specimen was translucent, pale brownish pink in color. After 10^8 R at 115°F the specimens had turned pastel green. After 10^8 R at boiling and also at higher dosages, the samples were a deep brownish red, still translucent. Figure 8 shows these visible effects.

Saran B115^f

Saran B115 is a polyvinylidene chloride resin made by Dow Chemical Company. After boiling for 96 hours in the dissolver solution the Saran had darkened and lost a little weight but was judged resistant. Figure 9 shows the successive visible damage to the samples with increased exposure to heat and to radiation. After 10^8 R in the boiling solution the specimens were still straight and intact with severe bleaching on the surface. Another series of samples failed before 4.4×10^8 R by becoming brittle, porous, and spalling. At that point testing was discontinued because it was judged unsatisfactory for service in the proposed electrolytic dissolver. No physical properties tests were made.

Fig. 8 Visual Effects of Irradiation on Kel-F

Fig. 9 Visual Effects of Irradiation on Saran B115

Polystyrene^{h,r}

Two formulations of polystyrene were tested. One furnished by Auburn Plastics, the other by Campco. Styron 938^h gray rod and Styron 475^h-6034 ivory sheet furnished by Auburn Plastics Company withstood 96 hours in the boiling nitric acid solution with only slight warping and a dose of 10^9 R caused severe warping, pitting, and dissolution. These effects are shown in Figure 10.

The samples of Campcolite S1029^r polystyrene furnished by Campco became severely warped, swollen, and partly disintegrated during exposure of 96 hours in the boiling dissolver solution and therefore were not subjected to radiation testing.

Polycarbonateⁱ (Lexan-General Electric)

The samples of Lexan polycarbonate retained their strength but suffered 37 per cent weight loss after 168 hours exposure to 8M nitric

Fig. 10 Visual Effects of Irradiation on Polystyrene acid. A radiation dose of 10^8 R produced a brittleness and darkened the specimens although they were still transparent. A dose of 10^9 R caused swelling, cracking, severe embrittlement, and general disintegration, as can be seen in Figure 11.

Nalgene PR^j (polypropylene Nalge)

Polypropylene can withstand the chemical environment with no damage, but a 10^8 R dose of radiation causes severe cracks and discoloration. These two effects can be seen in Figure 12.

Penton^k (chlorinated polyether)

Exposure to 8M nitric acid bleached the material and left it very brittle. Exposure to the simulated dissolver product solution plus radiation to a dose of 10^8 R produced cracks and brittleness but caused very little color change. See Figure 13.

Fig. 11 Visual Effects of Irradiation on Polycarbonate

Fig. 12 Visual Effects of Irradiation on Polypropylene

Fig. 13 Visual Effects of Irradiation on Penton

Irradiation Container Corrosion

The extremely corrosive, oxidizing (nitric acid-chromiumVI) solution nearly destroyed the 347 stainless steel sample holder after about 3000 hours at the boiling point ($\sim 221^{\circ}\text{F}$). A residue consisting of iron, chromium (18 per cent), and nickel (8 per cent) deposited on the specimens and also accumulated in the bottom of the container as a heavy black sludge.

V. CONCLUSIONS AND RECOMMENDATIONS

The combination of radiation damage and chemical attack in the electrolytic dissolver will limit the useful life of plastic components. There is some finite period after which the plastic part will have to be replaced. Ceramic materials are much more resistant to radiation damage. The ceramic material tested during this program was also completely resistant to the corrosive chemical environment.

Kynar^b would be suitable for use as an insulating support in an electrolytic dissolver if its service life were limited to a radiation dose of 10^9 R or less. Its properties of strength and electrical resistivity were essentially constant over that range. One disadvantage is that when it fails it loses shape and strength completely.

Marlex^a appears to be satisfactory up to about 2×10^9 R. Although its impact strength drops sharply at about 1×10^9 R, it is still stronger than some plastics are without radiation damage. Even though at 2×10^9 it becomes rubbery, it is still intact, straight, and dimensionally stable.

The G-7 laminate^d will probably stand up in service to 10^{10} R. Its impact strength is outstanding up to 10^9 R total dose, and it is almost as strong at 10^{10} R as Marlex is to begin with. Even though its electrical resistivity drops by a factor of 10^8 by the time it has received 10^9 R, it is still a better insulator than stainless steel by a factor of $\sim 10^{13}$. It fails by delamination.

The AP 35 alumina^c has the greatest mechanical strength (compression and tensile) of all materials tested and showed the least damage due to radiation or chemicals. It is more brittle initially than Marlex or G-7 but changes much less than either of them and finished the test at 10^{10} R as strong as or stronger than they did.

It would appear that any of the four materials would be suitable for service in the electrolytic dissolver under a radiation dose rate of 5×10^5 R/hr. Under those conditions the Kynar could be expected to last about 2.8 months, the Marlex 5.5 months, the G-7 and AP 35 alumina 28 months of continuous service.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the work of C. E. May who performed some of the chemical resistance tests, R. D. Fletcher who designed the irradiation sample holders and containers and provided guidance and suggestions for the program, and A. M. Holman and operators who gave assistance and watched the equipment at the MTR Gamma Facilities.

The author also wishes to acknowledge the help of the suppliers of the materials tested, many of which were supplied free of charge.

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APPENDIX I

A. Characteristics of Radiation Source Used in Tests

The radiation source for the tests was made up of clusters of MTR or ETR fuel elements. These clusters were placed around a rectangular column which was filled with water. The sample holder container was lowered into the water-filled column. Fuel elements which had been removed from the reactor immediately after shutdown and placed in the cluster around the column gave very high initial readings of dose rate. The dose rate decayed rapidly at first and then more slowly. Figure 14 shows the effect on dose rate and total dose of replacing cooled fuel elements with fresh elements for a typical exposure period. For a further discussion of MTR fuel elements as radiation sources see W. C. Francis and L. L. Marsden, Experimental and Theoretical Values of the Gamma Decay Dose Rate and Heating from Spent MTR Fuel Elements, IDO-16247, (1956).

Fig. 14 Dose Rate and Accumulated Total Dose vs Time for a Typical Irradiation Test

B. Dosimetry

The dose rate and the total dose have been reported in rep(R). The exposure of the specimens was determined by the standard dosimetry methods used at the MTR Gamma Facility. At regular intervals an air ionization chamber was inserted in the space normally occupied by the sample holder. A high voltage was impressed across the chamber and the current flow was read from a milliammeter. This was then converted to rep/hr and reported as the instantaneous dose rate. The sum of products of the average dose rate between readings and the number of hours between readings was reported as the total dose received.

In calculating the expected dose rate to a plastic material in the dissolver, the rep was used as the unit of radiation and was taken as 93 ergs/gram.

APPENDIX II

ADDITIONAL INFORMATION FROM MANUFACTURER'S LITERATURE FOR FOUR MOST RESISTANT MATERIALS TESTED

<u>Material</u>	<u>Tensile Strength, psi</u>	<u>Specific Gravity</u>	<u>Water Absorption</u>	<u>Hardness</u>
Marlex	4,250	0.95	< .01%	Rockwell R30-R50
Kynar	7,000	1.76	.04%	Shore D 80
G-7	23,000	1.88	.4 %	Rockwell M1001
AP 35	35,000	3.7	.00%	9 (mohs)

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