

Energy Deposition in Polymers by Reactor Radiation

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Introduction

In studies involving the irradiation of materials, it is usually important to know the irradiation conditions including the various flux components of the radiation field. When a nuclear reactor is used as radiation source, the flux conditions can be particularly complex since the impinging radiation includes neutrons and photons with a wide, and difficult to determine, energy distribution. It is usually possible, by direct measurement, to determine the thermal neutron flux and the gamma dose rate to which the material is subject. However, the epithermal neutron flux spectrum is not readily available experimentally.

It is the purpose of this paper to discuss experimental results, and pertinent calculations, of energy deposition by reactor radiation in several polymers in terms of basic physical units (ergs per gram-hour). The experimental method is based on the measurement of temperature distribution in a polymer sample located in the given radiation field and at thermal equilibrium. The calculational method is based on an assumed epithermal neutron spectrum using parameters which are empirically determined.¹ If the thermal neutron flux and gamma dose rate are known, a method of estimating the integral epithermal neutron flux can be developed. The energy deposition rate for many polymers in a given radiation field can thus be estimated by measurement of energy deposition rate in one suitably chosen polymer.

The enriched uranium, pool-type reactors at the Pennsylvania State University (PSR) and of Curtiss-Wright (CWR) at Quehanna, Pennsylvania were used in these investigations. The epithermal neutron parameters chosen are assumed to be valid only at the core surface of these reactors (specifically, the CWR).

Experimental

In a sample oriented in a radiation field in a position such that the flux does not vary greatly along

any dimension, the steady state temperature distribution is dependent only on the sample geometry, the thermal conductivity, and the rate of energy deposition, provided that the surface temperature is maintained uniform and constant. For temperature measurement at the center of a finite cylindrical sample with a constant uniform volume heat generation, calculations show that the result will be within 1% of the value of an infinitely long cylinder if the ratio of the length to the radius is greater than eight. In these experiments cylindrical samples were prepared with lengths ranging from 2 to 4 in. for use in experiments, where the samples were to be vertically oriented with axis parallel to the reactor core face. A fine thermocouple wire, with its junction at the specimen center, was inserted axially. Previous experiments indicated that losses along the thermocouple wire could be neglected.

It is well known that the neutron flux gradients are large adjacent to pool-type reactors using light water as reflector. Thus the sample dimensions, and particularly the radius in this case, must be limited if the assumption of uniform energy deposition is to be maintained. Since the flux can change considerably in a 1-cm. distance at some positions the maximum sample radius which can be used is about $1/4$ in. (0.635 cm.). Experiments performed with larger samples yield only qualitative results unless the noncylindrical temperature distribution is taken into account. This severely complicates the calculations.

In Figure 1, a sample is shown in an arrangement designed to maintain temperature control of the sample surface while determining the temperature both at the surface and the center of the sample. The aluminum shield immediately around the sample provides good thermal contact for the surface thermocouples and reduces surface gradients along the sample. Water from a constant temperature source is pumped into an aluminum casing around the shield to provide thermal equilibrium at the

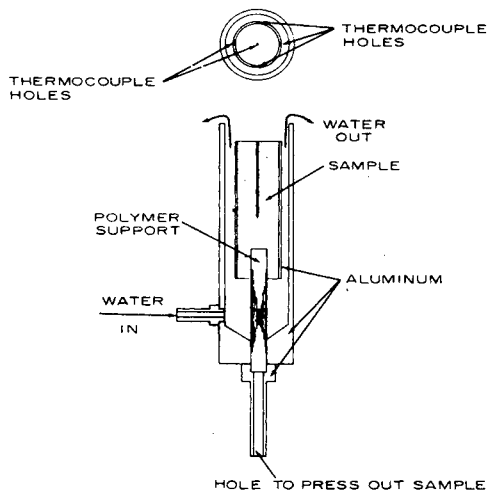


Fig. 1. Sample and temperature control jacket for energy deposition experiments.

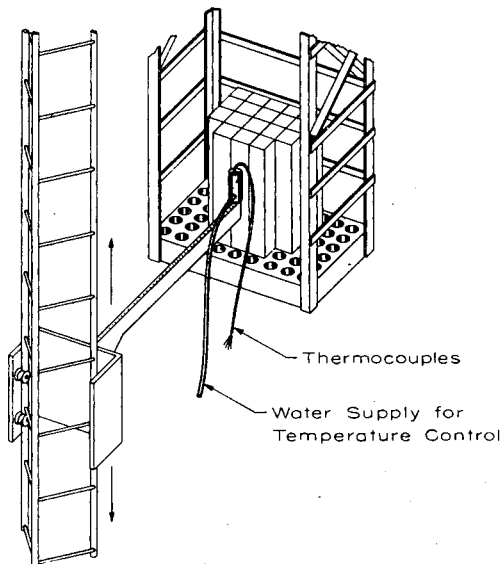


Fig. 2. Illustration showing reactor core and temperature control jacket mounted on arm of instrument bridge tower.

specimen surface. Use of aluminum minimizes residual activity from neutron activation and limits the flux disturbance.

The pin in the bottom of Figure 1 is inserted into a hole in the instrument bridge adapter shown in Figure 2. The adapter, except for the coupling, is constructed of high density polyethylene which closely approximates water for most characteristics important in these investigations. By coupling this to the instrument bridge of either the PSR or CWR, the center of the samples can be accurately placed at any position in front of the face of the core

LOADING 33D

TOTAL FUEL (U-235) = 3.06 KG

CWR

(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
(R)	(F)	(F)	(SR ₂)	(F)	(A)	(F)	(F)	(R)
(R)	(F)	(E)	(F)	(F)	(F)	(RR)	(F)	(R)
(R)	(F)	(F)	(SR ₁)	(F)	(SR ₃)	(F)	(F)	(R)

EXPERIMENTAL CORE FACE

- F = FUEL ELEMENT
- R = REFLECTOR ELEMENT
- SR = SAFETY ROD
- RR = REGULATING ROD
- E = ISOTOPE ELEMENT
- A = ROD ELEMENT (WITHOUT ROD)

PSR

(F)	(F)	(F)	(F)	(F)
(F)	(SR)	(F)	(SR)	(F)
(F)	(RR)	(F)	(SR)	(F)
(F)	(F)	(F)		

EXPERIMENTAL CORE FACE

LOADING 1B

TOTAL FUEL (U-235) = 2.83 KG

Fig. 3. Core loadings used for experiments with the CWR and PSR.

for distances greater than 1 cm. from the face. Core loadings used in these experiments are given in Figure 3 for both reactors.

By using a precision potentiometer and galvanometer, the temperature difference between the sample center and the surface can be determined to about 1/40°C. Since the temperature differential is of the order of a few degrees for most measurements, this accuracy is quite sufficient. At the PSR, the reactor power level was 100 and 200 kw. For nearly all of the experiments at the CWR, the power was maintained at the level of 1 Mw. Based on the temperature gradient across the core, the power level was normalized to account for the decrease in reactor power level with an increase in pool temperature. Reactor control is by radiation sensing elements which are located at some distance from the core. For a given power level, the radiation level (at the detectors) changes with temperature according to the corresponding change in water density.

In order to determine the rate of energy deposition from measurements of the temperature difference ΔT between the center and surface of cy-

lindrical samples, the thermal conductivity k of the material must be known. Thermal conductivity values of the samples tested were not available from polymer suppliers. By direct experimental methods, these were measured along with the respective densities.² The values are given in Table I. Assuming the rate of heat generation

TABLE I
Thermal Conductivities and Densities
of Polymer Specimens^a

Sample	Thermal conductivity k , (cal./cm.-sec.-°C.)	Density d , g./cc.
Polyethylene	6.1×10^{-4}	0.92
Polystyrene	3.3×10^{-4}	1.06
Poly(hexamethylene adipamide)	6.0×10^{-4}	1.15
Polytetrafluoroethylene	5.0×10^{-4}	2.19
Polymerized epoxy resin ^b	4.2×10^{-4}	1.19
Polymerized epoxy resin with filler ^c	12.6×10^{-4}	1.60

^a These values refer to the temperature region of most of the irradiation studies (30–35°C). Values of thermal conductivity were generally measured over the region of 0–100°C.

^b This material is a bisphenol A based commercial epoxy resin (Shell Chemical Co., Epon 828) catalyzed with 15 parts of *m*-phenylene diamine per 85 parts of resin.

^c This is the same material as b above with 85 parts of fine aluminum powder filler added per 100 parts of resin-catalyst mixture.

throughout the sample is uniform, and the length-to-radius ratio is sufficiently large, the rate of heat generation per unit volume S is given by

$$S = 4k \Delta T/R^2 \text{ cal./sec.-cm.}^3$$

where R is the specimen radius. The rate at which energy is deposited, E_a , is then

$$E_a = 6.02 \times 10^{11} k \Delta T/dR^2 \text{ ergs/g.-hr.}$$

where d is the density.

Results

First, it is of interest to present the results for polyethylene and to compare the results obtained using different nuclear reactors (PSR and CWR). All values of deposited energy will be given in ergs absorbed by the material per gram-hour, per watt of reactor power. By reactor power is meant the power as indicated by the reactor instruments, and this depends upon the calibration by the respective

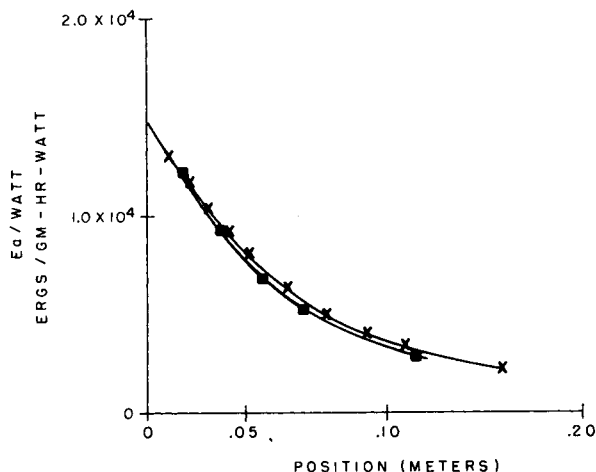


Fig. 4. Measured energy deposition rates for polyethylene as a function of position for the CWR (x) and PSR (■).

reactor staff personnel. Figure 4 shows the relative energy absorption vs. position for identical polyethylene samples in centerline traverses at different reactors (PSR and CWR) having different core loadings (refer to Fig. 3). Reactor power levels were 200 and 1000 kw., respectively, for this test. Inspection of Figure 4 shows that the energy deposited per watt is the same at positions near the core but diverges slightly as one moves away from the core face. This divergence could be due to a different core geometry or to experimental error.

Experiments were also made at the PSR on samples of filled and unfilled polymerized epoxy resin. The results are presented in Figure 5 and compared to those obtained for polyethylene. The filler used in the epoxy samples was atomized aluminum (average diameter 15μ) and was prepared in this case in the ratio of 85 parts filler per 100 parts of resin and catalyst. The commercial resin (Epon 828 of the Shell Chemical Co.) was catalyzed with 15 parts metaphenylene diamine per 85 parts resin. The elemental constituents of these and some other polymers and the relative density of hydrogen atoms are given in Table II.

The total energy deposited in polymers by reactor radiation is dependent on several interactions. For most cases, such as those considered here, the interactions of gamma rays and the scattering of fast neutrons contribute most of the deposited energy. Polyethylene, with a high density of hydrogen atoms (Table II) and a moderate gamma-ray cross section, absorbs a large amount of energy from these two reactions. Polymers with fewer hydrogen atoms per gram, such as the epoxy sam-

TABLE II
Relative Elemental Constituents and Hydrogen Density
for Polymer Test Specimens

Sample	Relative constituents	Hydrogen atoms per g.
Polyethylene	C_2H_4	8.6×10^{22}
Polystyrene	C_8H_8	4.6×10^{22}
Poly(hexamethylene adipamide)	$C_{12}H_{22}N_2O_2$	5.8×10^{22}
Polytetrafluoroethylene	C_2F_4	0.00
Polymerized epoxy resin	Resin $C_{21}H_{24}O_4$ (85 parts) Catalyst $C_6H_8N_2$ (15 parts)	4.3×10^{22}
Polymerized epoxy resin with filler	Resin $C_{21}H_{24}O_4$ (85 parts) Catalyst $C_6H_8N_2$ (15 parts) Filler Al (85 parts)	2.3×10^{22}

ples, absorb less energy per gram and thus, as Figure 5 shows, the graph of E_a vs. distance is below that of polyethylene. The variation of gamma dose rate with distance, as measured for this reactor,³ is also given in Figure 5. This variation of dose rate compares well to that given in ref. 4.

It is reasonable to expect that the curves of Figure 5 should tend to approach each other for large distances, and that the value which they attain should be near the value given by the gamma dose rate curve. The decrease in neutron flux with distance

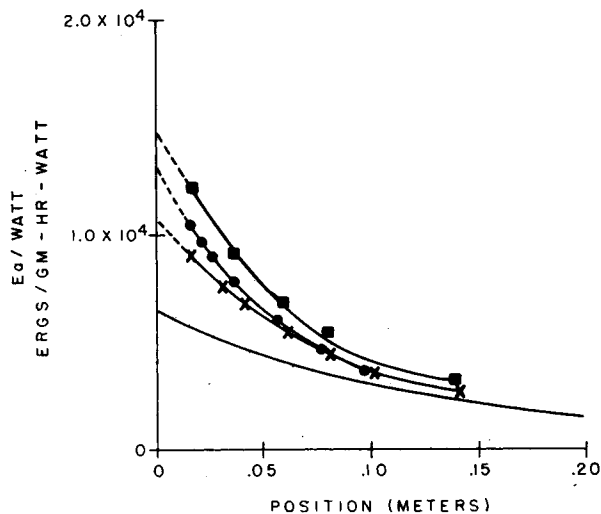


Fig. 5. Measured energy deposition rates for polyethylene and polymerized epoxy resins as a function of distance from the reactor core (PSR): (■) polyethylene, (●) epoxy (85-15-OF), (×) epoxy (85-15-85F), and (—) gamma dose rate.

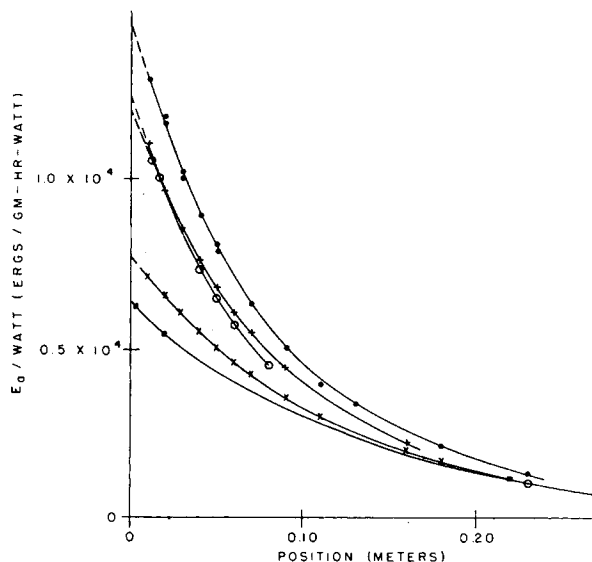


Fig. 6. Measured energy deposition rates for various polymers as a function of distance from the reactor core (CWR): (●) polyethylene, (+) polystyrene, (O) poly(hexamethylene adipamide), (×) polytetrafluoroethylene, and (■) external gamma.

is more rapid than the decrease in the gamma flux and thus, at large distance, the effects of the gamma interactions predominate. The composite interaction probability (energy absorption coefficient) is different for the different polymers and thus their curves should not necessarily be coincident, even for distances where the neutron effects are comparatively negligible. This is largely because of the wide differences in hydrogen content (Table II).

Experiments were also carried out with the CWR on several other types of polymers, and the data for these samples are given in Figure 6. In this case, the variation of gamma dose rate with distance, as shown in the figure, is estimated from the references noted. Inspection of the data shows, as before, that polyethylene has the highest energy deposition rate of any of the polymers tested. Second to polyethylene are polystyrene and poly(hexamethylene adipamide), both of which have somewhat less hydrogen atoms per gram than polyethylene (note Table II). Polytetrafluoroethylene, with no hydrogen content, has an energy deposition rate which is only slightly above that of the external gamma dose rate curve of Figure 6 and which closely approaches this curve for large distances. The data also reveal that near the core of the reactor the energy deposition rate for polyethylene is nearly twice that for polytetrafluoroethylene in the same position.

Estimation of Energy Disposition

We discuss here, from a more theoretical point of view, the results given in Figure 6 extrapolated to the reactor core face. By a calculational method based on a simplified radiation spectrum,¹ we estimate the contribution of (a) thermal neutron capture, (b) epithermal neutron elastic scattering, and (c) external gamma interaction, to the total energy deposition. Actually, the only important assumptions regarding the reactor radiation spectrum are imposed on the pithermal neutron energy distribution. It is assumed that the pithermal neutron flux is distributed in energy as:

$$\begin{aligned} \phi(E) &= B/E \Sigma_s^m(E), \text{ for } E_1 < E < E_0 \\ \phi(E) &= cBe^{-aE}, \text{ for } E_0 < E < E_2 \end{aligned}$$

where E is neutron kinetic energy, $\Sigma_s^m(E)$ is the reactor moderator (macroscopic) scattering cross section, B is proportional to the reactor power level, and c , a , E_0 , E_1 , and E_2 are empirically chosen parameters, and are specific to a reactor or reactor type. It is also assumed for the sake of simple integrations that the elastic scattering cross section for all nuclei of interest here vary as

$$\sigma_s^x(E) = \sigma_{s0}^x / (1 + E/e_x)$$

where σ is the microscopic cross section and e_x is a constant characteristic of the isotope. In order to fit the n - p scattering cross section over the entire range of neutron energies (ca. $1/2$ e.v. to 10 m.e.v.), the above expression is used for σ up to $E = E_0$, and above E_0 an exponential dependence on neutron energy is assumed.

As noted above, there are only three significant contributions to the total energy deposition rate E_a . Here they are denoted: E_c , the energy deposited in the sample due to thermal neutron capture (capture gamma interactions within sample and ion recoil or charged particle emission); E_s , the energy deposited by recoil nuclei from epithermal neutron elastic scattering events; and E_g , the energy deposited by the interaction of gamma radiation, the source of which is external to the polymer sample.

With these assumptions and notations, the following expressions can be derived as a slight extension of those given in ref. 1:

$$(1) \quad E_c = 3.47 \times 10^{-3} f_c \phi_{th} \text{ ergs/g.-hr.}$$

where

$$f_c = \frac{1}{A} \sum_x w_x \sigma_c^x (E_x + dF_x R E_{gx})$$

$$(2) \quad E_s = 1.73 \times 10^{-3} f_s \phi_{epi} \text{ ergs/g.-hr.}$$

where

$$f_s = \frac{1}{AJ} \sum_x w_x \sigma_{s0}^x (1 - a_x) e_x K_x$$

$$J = \frac{E_0}{e_m} + \ln \frac{E_0}{E_1} - \sum_{s_0}^m \frac{c}{a} e^{-aE_0}$$

$$K_x = \left(1 - \frac{e_x}{e_m}\right) \ln \left(1 + \frac{E_0}{e_x}\right) + \frac{E_0}{e_m}$$

$$+ \sum_{s_0}^m \frac{c}{a} [e^{-aE_0} - ae_x e^{ae_x} I_1(ae_x + aE_0)]$$

$$I_1(b) = \int_b^\infty (e^{-y}/y) dy$$

where $E_g = 83 f_g D$ ergs/g.-hr., where x refers to an atom specie; ϕ_{th} is the thermal neutron flux (cm.⁻² sec.⁻¹); ϕ_{epi} is the integrated epithermal neutron flux (cm.⁻² sec.⁻¹); D is the external gamma dose rate (r/hr.); A is the polymer molecular weight (repeating unit); w_x is the atoms of x per repeating unit of polymer; σ_c^x is the thermal neutron capture cross section (in barns); σ_{s0}^x is the scattering cross section as defined previously (in barns); E_x is the charged particle and/or recoil ion energy (in m.e.v.); E_{gx} is the capture gamma energy (in m.e.v.); $dF_x R$ is the fraction of capture gamma energy deposited in sample of radius R ; d is the polymer density (grams/cc.); e_x is the scattering cross section constant as previously defined; e_m is the scattering cross section constant for reactor moderator atom type; a_x is $[(A_x - 1)/(A_x + 1)]^2$, where A_x is atomic weight of x ; f_g is the ratio of gamma absorption coefficient of polymer to that of air; and E_0 , E_1 , E_2 , Σ_{s0}^m , a , and c are defined by their use in the assumed epithermal neutron spectrum.

The atom species present in the polymers used in measurements at the CWR (Fig. 6) are hydrogen, carbon, nitrogen, oxygen, and fluorine. Table III gives the values obtained for the significant parameters for the naturally occurring isotopic mixtures of each nucleus specie.

For further numerical evaluation we use the reactor characteristics given in Table IV. These values for flux parameters are assumed to be valid in the center of, and adjacent to, the experimental core face of the CWR at 1 Mw. power. It should be noted that the integral epithermal neutron flux ϕ_{epi} is not stated at this point. This quantity is difficult to determine experimentally (or theoret-

TABLE III
Nuclear Parameters for Polymer Constituents

x	a_x	σ_c^x , barns	$\sigma_{s_0}^x$, barns	e_x , m.e.v.	E_x , m.e.v.	E_{gx} , m.e.v.	F_x , cm. ² /g.
H	0.0	0.296	20	0.25	0.00132	2.2	0.031
C	0.72	0.0	4.7	1.2	—	—	—
N	0.75	1.6	10.5	0.0034	0.625	NG ^a	—
O	0.78	0.00013	3.8	∞	1.83	NG	—
F	0.81	0.008	3.5	∞	1.81 ^b	8.23 ^c	0.033

^a Here NG stands for no gamma emission.

^b In the case of F¹⁹, thermal neutron capture results in electron emission. Here, one-third of the maximum electron energy is used for E_x .

^c A 6.60-m.e.v. capture gamma and a 1.63-m.e.v. gamma with electron emission.

cally) and it is one of the purposes of this section to show how, by the present analysis, an estimate can be accomplished.

TABLE IV
Reactor Parameters^a

$\phi_{th} = 2 \times 10^{13}$ cm. ⁻² sec. ⁻¹	$\Sigma_{s_0}^m = 1.34$ cm. ⁻¹
$D = 8 \times 10^7$ r/hr.	$e_m = 0.25$ m.e.v.
$E_0 = 1$ m.e.v.	$a = 0.577$ m.e.v. ⁻¹
$E_1 = 0.4$ e.v.	$c = 22.2$ cm. m.e.v. ⁻¹
$E_2 = 10$ m.e.v.	$J = 47.7$

^a Curtiss-Wright reactor at 1000 kw. except for D which is inferred from measurement at PSR.

TABLE V
Polymer Parameters^a

	Poly-ethylene ^b	Poly-styrene	Poly-(hexa-methylene adipamide)	Poly-tetra-fluoro-ethylene
H ^c (1)	0.00156	0.00312	0.0086	—
(2)	0.0472	0.109	0.324	—
(3)	1040	2080	5720	—
C (1)	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0
(3)	64	256	384	64
N (1)	—	—	2.0	—
(2)	—	—	0.0	—
(3)	—	—	0.74	—
O (1)	—	—	0.00048	—
(2)	—	—	0.0	—
(3)	—	—	139	—
F (1)	—	—	—	0.058
(2)	—	—	—	0.012
(3)	—	—	—	218
f_c	0.00348	0.00864	0.0208	0.0012
f_s	1.65	3.76	1.16	0.118
f_g	1.16	1.07	1.11	1.00

^a All values in this table are in units of barn-m.e.v.

^b Based on polymer unit given in Table II under relative constituents.

^c For the three number groups: (1) is $w_x \sigma_c^x E_x$, (2) is $w_x \sigma^x F_x R d E_{gx}$, and (3) is $w_x \sigma_{s_0}^x (1 - a_x) e_x K_x$.

By using the CWR parameters of Table IV it is now possible to evaluate the various quantities which depend on the polymer constitution and the radiation spectrum. The significant polymer parameters are listed in Table V for the four polymers considered here.

For polyethylene, the experimental result for E_a as extrapolated to the reactor core face can be used to obtain an estimate for ϕ_{epi} . Per watt of reactor power,

$$E_a(C_2H_4) = E_c + E_g + E_s$$

$$E_a(C_2H_4) = 0.012 \times 10^4 + 0.77 \times 10^4 +$$

$$0.00143 \phi_{epi} \text{ ergs/g.-hr.}$$

From Figure 6, $E_a(C_2H_4)$ is estimated to be 1.5×10^4 ergs/g.-hr./w. at the core face. The calculated value of ϕ_{epi} is then 5.0×10^6 per watt of reactor power. With this epithermal neutron flux, E_a is calculated for the remaining three polymers and results compared with those illustrated in Figure 6. The tabulation appears in Table VI.

The close agreement of calculated and experimental results for polytetrafluoroethylene at the core surface should be expected. An experimental measurement of gamma dose rate at the core surface was, indeed, used to calculate E_g , and for this nonhydrogenous polymer the relative contribution of E_c and E_s are small. For the other polymers, the experimental and calculated results are in good agreement. Examination of the contributions of E_c , E_s , and E_g illustrates the previously mentioned importance of proton (or light nuclei) recoil due to epithermal neutron scattering. The thermal neutron interactions are insignificant in contributing to the total energy deposition rate, except for cases where the nitrogen density of a polymer is high. For instance, even in poly(hexa-methylene adipamide), where the nitrogen abun-

TABLE VI
Comparison of Experimental and Calculated Results for Energy Deposition Rate^a

Polymer	E_c	E_s	E_g	E_a , calc.	E_a , expt.
Polyethylene	0.01×10^4	0.72×10^4	0.77×10^4	$1.5^b \times 10^4$	1.5×10^4
Polystyrene	0.01×10^4	0.41×10^4	0.71×10^4	1.2×10^4	1.2×10^4
Poly(hexamethylene adipamide)	0.07×10^4	0.50×10^4	0.74×10^4	1.3×10^4	1.2×10^4
Polytetrafluoroethylene	0.004×10^4	0.051×10^4	0.66×10^4	0.74×10^4	0.77×10^4

^a Units of energy deposition are ergs/g.-hr.-w. of reactor power.

^b Normalized to this value.

dance is low (Table II), the value of E_c (Table VI) is much higher than for the other polymers where no nitrogen is present. Thus in polymers where the nitrogen density is somewhat higher than in poly(hexamethylene adipamide), the contribution of E_c could be of the same order of magnitude as E_g or E_s .

Summary

For the hydrocarbon and fluorocarbon polymers, the experimental results indicate that the energy deposited by reactor radiation is strongly dependent upon the hydrogen density. This is expected because of the high neutron scattering cross section and the energy decrement which are characteristic of hydrogen (H^1). In investigating the dependence of the energy deposition upon hydrogen density, polymers with decreasing hydrogen concentrations, including polytetrafluoroethylene with no hydrogen content, can be used as specimens to establish the dose rate contributions of the flux components. From these, one can predict the energy deposition rate for many other polymers under the same conditions. The data, when analyzed and compared to independent gamma dose rate measurements, also indicate that only fast neutron scattering collisions and interactions with gamma rays produced from external sources are important in contributing to the energy deposition rate in these polymers.

The data reported here permit an evaluation of the calculations presented in a previous paper concerning the rate of energy deposition in polyethylene. The extension of these calculations permits some other pertinent observations. Since the polymer constituents generally vary much more in chemical configuration and relative abundance than in elemental specie, the extension of the calculations to other polymers is reasonably valid. Comparison of experimental results with the calculated results for the various polymers used permits further relative confirmation. This is based, however, on establishing a value for the integral

fast flux from one polymer such as polyethylene. From these calculations and the use of polymers with varying hydrogen content a method of epithermal neutron flux and gamma dose rate estimation is possible. The relative ease with which thermal equilibrium temperature distribution measurements can be performed makes it possible to obtain rather rapidly epithermal neutron and gamma flux field measurements compared, for instance, to epithermal neutron measurements by other methods such as isotope activation. It must be noted, however, that the estimates depend on the assumed epithermal neutron spectrum and suffer from the unknowns therein. However, the measurements by energy deposition experiments permit the polymer physicist to directly measure the integral fast neutron dose in the material and to compare it with other doses. In such cases it is often more important to know the total energy deposited rather than the neutron flux spectrum as this must be further analyzed by calculation to determine the effect produced by this flux in interacting with constituents of the material.

It would further appear from our studies that the reporting of flux and dose conditions for radiation effects in polymers should be in terms of the basic physical units such as ergs/gram. This type of reporting, combined with the other pertinent descriptions of the irradiation conditions, would permit better comparison of results from one investigator to another.

The experimental method used in this investigation is also suggested for possible use in determining thermal conductivity of polymers. There is little data in the literature concerning conductivity of polymers, but recently new investigations have been reported.^{5,6} In such investigations, the thermal conductivity could be determined by measuring the temperature distribution in samples which are subject to an internal heat source, such as nuclear reactions, and maintained at thermal equilibrium.

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Synopsis

The temperature distribution in small polymer samples has been used to determine the rate of energy deposition by nuclear reactor radiation as a function of distance from the reactor core. Polyethylene, polystyrene, poly(hexamethylene adipamide), polytetrafluoroethylene, and polymerized epoxy resin were employed as specimen materials. The results for some of these are compared to calculated values based on a simplified radiation spectrum. The values are in good agreement, and it is thus suggested that the calculational method is valid for estimating the integral epithermal neutron flux and the relative energy deposition in different polymers.

Résumé

La distribution de température dans les petits échantillons de polymère a été utilisée en vue de déterminer la vitesse de déposition de l'énergie par les radiations d'un réacteur nucléaire en fonction de la distance au noyau du réacteur. Le polyéthylène, le polystyrène, le polyhexaméthylène adipamide, le polytétrafluoroéthylène et les résines époxy polymérisées ont été utilisés comme matériaux tests. Les résultats pour certains de ceux-ci sont comparés aux valeurs calculées sur la base d'un spectre de radiations simplifié. Les valeurs sont en bon accord et de ce fait on admet que la méthode de calcul est valable pour l'estimation de l'intégrale épithermique du flux de neutrons et de l'énergie de déposition relative dans les différents polymères.

Zusammenfassung

Die Temperaturverteilung in kleinen Polymerproben wurde zur Bestimmung der Geschwindigkeit der Energieanhäufung durch Reaktor-Kernstrahlung als Funktion des Abstandes vom Core des Reaktors verwendet. Polyäthylen, Polystyrol, Polyhexamethylenadipamid, Polytetrafluoräthylen und polymerisierte Epoxyharze wurden als Versuchsmaterial eingesetzt. Die Ergebnisse an einigen von diesen Proben werden mit Werten verglichen, die auf Grund eines vereinfachten Strahlungsspektrums berechnet wurden. Die Werte zeigen eine gute Übereinstimmung und es ist daher anzunehmen, dass die Berechnungsmethode zur Ermittlung des integralen, epithermalen Neutronenflusses und der relativen Energieanhäufung in verschiedenen Polymeren anwendbar ist.

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