NUREG/CR–5231
SAND88–1054

UNLIMITED RELEASE

Cobalt–60 Simulation of LOCA Radiation Effects

Prepared by W. H. Buckalew

Sandia National Laboratories

Prepared for
U.S. Nuclear Regulatory
Commission

When printing a copy of any digitized SAND Report, you are required to update the markings to current standards.

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 2120 L Street, NW, Lower Level, Washington, DC 20555

2. The Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082

3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Office of Information Resources Management, Distribution Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

DISCLAIMER NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, or any of their employees, makes any warranty, expresed or implied, or assumes any legal liability of responsibility for any third party's use, or the results of such use, of any information, apparatus, product or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights.

NUREG/CR-5231
SAND88-1054
RV

Cobalt-60 Simulation of LOCA Radiation Effects

Manuscript Completed: June 1989
Date Published: July 1989

Prepared by
W. H. Buckalew

Sandia National Laboratories
Albuquerque, NM 87185

Prepared for
Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN A1051

ABSTRACT

The consequences of simulating nuclear reactor loss of coolant accident (LOCA) radiation effects with Cobalt-60 gamma ray irradiators have been investigated. Based on radiation induced damage in polymer base materials, it was demonstrated that electron/photon induced radiation damage could be related on the basis of average absorbed radiation dose. This result was used to estimate the relative effectiveness of the mixed beta/gamma LOCA and Cobalt-60 radiation environments to damage both bare and jacketed polymer base electrical insulation materials. From the results obtained, it is concluded that present simulation techniques are a conservative method for simulating LOCA radiation effects and that the practices have probably substantially overstressed both bare and jacketed materials during qualification testing.

TABLE OF CONTENTS

Section	Page
EXECUTIVE SUMMARY	1
1.0 INTRODUCTION	3
2.0 TEST METHODS	4
2.1 Irradiation Facilities	4
2.2 Dosimetry Methods	4
2.3 Test Specimen Analysis	5
3.0 RESULTS	7
3.1 Elongation Results	8
3.2 Tensile Strength Results	9
3.3 Experimental Results Applied to Beta/Gamma Equivalence	12
4.0 DISCUSSION AND CONCLUSIONS	20
REFERENCES	22

LIST OF FIGURES

Figure		Page
1	Calculated Energy Deposition Profiles	6
2	Slab Geometry EPR Elongation Results	9
3	Slab Geometry EPR Elongation: Low Energy Results	10
4	Slab Geometry EPR Tensile Strength Results	11
5	LOCA Beta Particle Average Energy versus Elapsed Time	13
6	LOCA Gamma Ray Average Energy versus Elapsed Time	14
7	LOCA Beta/Gamma Integrated Dose versus Elapsed Time	15
8	LOCA Beta Particle Energy Deposition in a Hypalon-EPR-Copper Composite	18

LIST OF TABLES

Table		Page
1	Absorbed Radiation Dose Estimates	7
2	Gamma Ray Absorbed Dose Estimates	12
3	Beta Absorbed Dose: Hypalon-EPR-Copper Composite	17
4	Gamma Absorbed Dose: Hypalon-EPR-Copper Composite	19
5	LOCA Absorbed Dose Estimates for a Hypalon-EPR-Copper Composite	19

EXECUTIVE SUMMARY

This document is the final account of results obtained and conclusions formulated on the adequacy of isotopic gamma ray irradiators to simulate radiation effects predicted to occur in polymer base electrical insulation and jacketing materials exposed to the mixed radiation environment accompanying a nuclear reactor loss of coolant accident (LOCA).

A preponderance of the data for this report was obtained from NRC-sponsored programs carried out at Sandia. The data base for this program is extensive. Polymer base materials of several compositions and geometries were exposed to both electron beam and Cobalt-60 gamma radiation environments. Radiation variables were electron beam energy and electron beam and gamma ray integrated dose and dose rate. Damage to polymer test specimens was based on changes in material tensile properties, surface hardness, and density. These data were used to establish a correlation between electron beam and Cobalt-60 gamma ray induced damage. It was demonstrated that gamma ray and electron beam radiation damage could be correlated on the basis of absorbed average dose virtually independent of radiation type, electron beam energy, and integrated radiation dose.

Degradation data, for slab samples of polymer materials, obtained from the laboratory simulations were applied to an estimated LOCA radiation environment to determine the adequacy of an isotopic gamma ray irradiator to emulate that environment. Based on electron beam and gamma ray energies averaged over the LOCA event, the following conclusions emerged. In the case of LOCA gamma ray simulation, it appears that the Cobalt-60 irradiator will adequately simulate the LOCA gamma ray effects in polymer base materials. Since beta particle average absorbed dose is strongly dependent on sample thickness, it is difficult to make a general statement concerning beta particle simulation with Cobalt-60 irradiators for a broad spectrum of thickness. Nonetheless, data based on reasonable (1 to 2 mm) thickness insulation samples predict current simulation practices with Cobalt-60 irradiators result in sample overstresses in the range between forty and two hundred percent. Based on these data and calculations, Cobalt-60 irradiators reasonably simulate the effects of LOCA gamma ray radiation damage. However current beta particle dose deposition simulation in discrete insulation and jacket materials with cobalt irradiators probably always results in conservative overtest of samples during qualification testing and evaluation.

Comparable results were obtained for a composite Hypalon-EPR-copper (jacket-insulation-conductor) approximation of a cable configuration. Response of the cable configuration was considered in order to assess the effects of the jacket and conductor components on the dose degradation/enhancement in the insulation region. Depending on the LOCA beta spectrum selected, the beta dose in the EPR region was reduced by a factor of between two and seven when compared to the dose in the Hypalon (jacket) region. On the other hand, gamma dose to the EPR was enhanced

by about twenty percent, by reflection from the copper conductor zone, and was independent of LOCA gamma energy selected.

Finally, estimated dose to the cable configuration from the combined LOCA beta-gamma radiation environment demonstrated that simulation of the LOCA environment with a Co-60 irradiator resulted in over test of both the jacket and insulation components. The degree of overtest was a factor of two for the jacket and a factor of five for the insulation material. As in the case of the response of single materials, results indicate that Cobalt-60 irradiators will adequately simulate LOCA radiation effects in multi-element cable configurations. However the results indicate present practices will probably result in over test of both single and multiple element configurations.

1.0 INTRODUCTION

For some time we have been investigating the effects of electron beam and Cobalt-60 radiation environments on the properties of polymer base electrical insulation and jacketing materials. The immediate purpose of these investigations was to determine if an isotopic gamma ray source could be used to simulate the radiation damage observed to occur in polymer base rubbers subjected to electron beam bombardment. The ultimate goal of this research was to determine the adequacy of isotopic gamma ray irradiators, primarily Cobalt-60 facilities, to simulate the radiation damage predicted to occur in safety related items exposed to loss of coolant accident (LOCA) radiation environments.

During the course of this research project, we investigated the effects of both energy[1,2,3,4] and charge[5] deposition on material response/degradation. The primary focus of this document, however, is limited to reporting the effects of electron/photon energy deposition in polymer base materials. Specifically, it is the intent to demonstrate the link between observed electron and photon induced material response and radiation exposure dose and how these results may be applied to adequately simulate LOCA mixed radiation environments with isotopic (Cobalt-60) gamma ray irradiators. During this program many parameters and their effect on observed radiation damage were considered. For example, the effects of both material and radiation parameters were investigated. Material properties considered were composition, geometry, and thickness. Important radiation parameters were electron beam energy and integrated electron beam and gamma ray exposure dose and dose rate. In the main, consistent results were obtained independent of particle type, material geometry and composition, and radiation parameters. Although the preponderance of data were obtained for ethylene propylene (EPR) rubber in slab configuration, results from those studies will be used to demonstrate the correspondence between material response and radiation type/integrated dose for both EPR slab and Hypalon-EPR-Copper composite configurations.

In what follows, the radiation facilities including dosimetry methods will be briefly described. Also, material test and analysis techniques will be discussed. Methods of relating electron beam and Cobalt-60 gamma ray exposure dose data will be explained. Experimental data obtained from slab geometry will be used throughout. These slab degradation data will then be used in conjunction with calculated LOCA radiation environment estimates[6] to demonstrate equivalence/effectiveness of Cobalt-60 irradiators versus the mixed LOCA radiation environments to induce damage in polymer base electrical insulation and jacket materials. This should address the question of the ability of Cobalt-60 gamma ray irradiators to simulate the complex LOCA radiation environment for qualification testing of safety-related systems and components.

2.0 TEST METHODS

2.1 Irradiation Facilities

The radiation facilities used in these experiments were a variable voltage, variable current electron beam generator (a National Electrostatics PELLETRON) and a Cobalt-60 gamma ray irradiator. The PELLETRON electron beam generator current and voltage capabilities were of sufficient magnitude so that the range of LOCA beta particle energies and dose rates were easily achieved (beam energies between 0.04 and 1.0 MeV and dose rates up to 80 $Gy \cdot s^{-1}$ (29 $Mrad \cdot hr^{-1}$) at the target plane). Since all irradiations were obtained in air, at ambient conditions, the electron beam was extracted from the accelerator through a thin beryllium window and then transported in air to the sample holder. In order to achieve uniform exposures across the test specimens, the electron beam was deflected into a square pattern with a pair of orthogonal magnetic deflection coils mounted inside the accelerator assembly. Additional beam dispersion was obtained as the beam traversed the air gap separating the accelerator assembly from the sample target holder. A more detailed description of the facility is contained in Reference 7.

The gamma irradiation facility (GIF) consists of a dry (ambient air) irradiation cell positioned over a water shielding pool containing the Cobalt-60 array. The array is permanently affixed to an elevator so that it may be raised into the irradiation cell on demand. Gamma dose rate, at the target plane, may be adjusted by either varying the source to target distance or reconfiguring the source array. Source array reconfiguration may consist of changing source array dimensions or number of source pencils in the array. Using these techniques, the gamma dose rate is variable over a wide range with maximum dose rates on the order of 8.3 $Gy \cdot s^{-1}$ (3.0 $Mrad \cdot hr^{-1}$) achievable.

2.2 Dosimetry Methods

Prior to irradiating any test specimens, both the GIF and PELLETRON radiation fields were characterized on the basis of exposure dose rate and radiation field uniformity. In addition, the PELLETRON output was further characterized as a function of electron beam energy. Beam uniformity and dose rate measurements were obtained by means of thin poly(halo)styrene film. The film responds in a predictable manner to absorbed radiation with the buildup of narrow absorption peaks in the visible (light) spectrum. Film thickness, .005 cm, was sufficiently thin so as to preclude appreciable perturbation to the radiation fields. Lateral dimensions of the film were comparable to that of the rubber test specimens. Thus, detailed spatial dose distributions in the target plane were always acquired. Before using, the thin dosimetry film was characterized on a Cobalt-60 source calibration range. Calibration of the poly(halo)styrene was based on dose determinations obtained with an NBS traceable air ionization chamber so that the film calibration history is also NBS traceable.

2.3 Test Specimen Analysis

Changes in material properties of irradiated test specimens were used as a measure of radiation induced degradation. Parameters analyzed for change were tensile properties, Shore A hardness, and density. Measured changes in surface hardness and density, as functions of integrated radiation exposure dose, were sufficiently small so as to preclude their use as indicators of radiation degradation. Hence, the tensile properties, elongation at break and ultimate tensile strength, were relied on as indicators of radiation damage. Tensile data were obtained with an Instron Model 1000 tensile test machine coupled to an electrical tape extensometer which was clamped to the test specimen. All tensile data were then normalized on the basis of unirradiated material response. Examination of the test data revealed that, of the two, elongation at break was much more sensitive to radiation exposure than ultimate tensile strength. On the basis of sensitivity, more reliance was placed on the elongation results.

The relationship between observed material degradation and measured electron/photon radiation exposure dose is considered in terms of the Bragg-Gray cavity detector which is based on the Bragg-Gray cavity theorem for gamma ray dosimetry. The theorem states that the gamma dose in a large absorbing medium may be determined from the energy deposited by recoil electrons in a small non-perturbing (detector) volume introduced into the absorbing medium provided certain conditions are satisfied. If the conditions are met, the gamma dose to the surrounding medium is determined from the (gamma) recoil electron dose in the detector volume and electron stopping power data for the two media. If the same conditions are met it follows that the inverse is also true, i.e., beta dose can be simulated by gamma ray exposures. Of particular importance is the condition that both the gamma fluence and recoil electron distribution not be perturbed in the detecting/absorbing media. For material thicknesses common in nuclear power plant electrical insulation and jacket applications, attenuation of the gamma fluence will not occur whereas uniform electron beam fluence (therefore dose) throughout the insulation and jacket media is highly unlikely for most electron energy distributions. Examples of typical energy deposition distributions for monoenergetic electrons and Cobalt-60 photons in a polymer material are presented in Figure 1. Since these electron energies span those of LOCA spectra, LOCA beta energy deposition in polymer insulation and jacket material will not be uniform. Nonetheless we proposed, and experimentally verified, that beta-gamma radiation damage equivalence could be based on absorbed dose averaged across the (irradiated) specimen thickness.

In view of the above, tensile data are presented on the basis of absorbed radiation dose for both electron beam and Cobalt-60 exposures. Absorbed dose estimates were obtained with the coupled electron/photon Monte Carlo transport code TIGER.[8] Absorbed dose estimates were obtained for each sample thickness and electron beam energy as well as 1.25 MeV Cobalt-60 gamma rays. Included in the calculations were allowances for beam energy

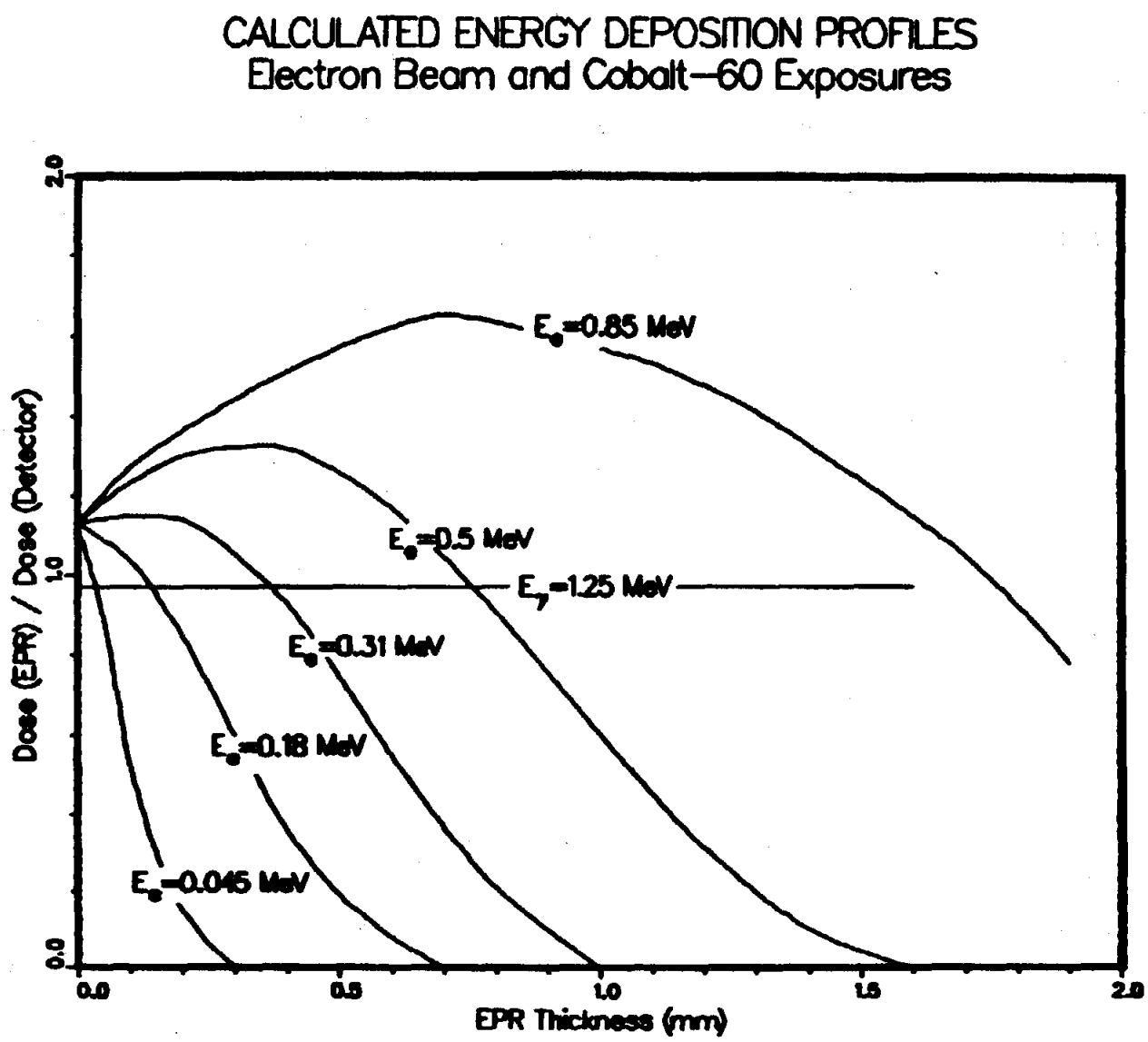

Figure 1. Calculated Energy Deposition Profiles

degradation and direction change due to transport through the air gap, beryllium window, cobalt cladding, etc.

In addition to the energy deposition calculations for test materials, similar absorbed dose estimates were obtained for the thin film dosimetry material. Energy deposition data for the detector material were used to normalize the calculated dose results obtained for the test materials. These indices, calculated material dose/calculated detector dose can be used to estimate specimen absorbed dose from measured or calculated radiation environments. A summary of the TIGER calculations are presented in the following table, Table 1, for all material thicknesses and beam energies.

Table 1

Absorbed Radiation Dose Estimates

Electron/gamma Energy	Absorbed Dose/Exposure Dose Material Thickness		
MeV	1.0 mm	1.5 mm	2.0 mm
0.045 e^-	0.122	0.081	0.061
0.183 e^-	0.42	0.28	0.21
0.31 e^-	0.66	0.44	0.33
0.50 e^-	1.10	0.85	0.63
0.85 e^-	1.50	1.45	1.38
1.25 γ	0.92	0.92	1.01

In the table, beam energies (column 1) are those calculated at the surface of the target area and the tabulated absorbed doses have been averaged over the material thickness. Energy deposition profiles companion to the data of Table 1 are presented in Figure 1. From the figure it may be observed that the ideal condition that describes Bragg-Gray cavities--no beam perturbation across the cavity--cannot be inferred from the electron beam energy deposition profiles.

3.0 RESULTS

3.1 Elongation Results

Material response for the three thicknesses of EPR slab material is presented in Figure 2. In the figure, normalized elongation is plotted as a function of absorbed radiation dose for a fixed exposure dose rate of 5.6 $Gy \cdot s^{-1}$ (2 $Mrad \cdot hr^{-1}$). The solid curve appearing in the plot is a best fit to the electron beam deposition data. The data plot has two notable characteristics. First, the electron beam degradation data exhibits a reasonable trend over the entire range of electron beam energies and target material thicknesses. The plot supports the validity

of basing observed radiation degradation on average absorbed radiation dose for a wide range of electron beam energies and absorbed dose distributions in the irradiated polymer. Second, consider the Cobalt-60 radiation induced damage depicted in the plot by the open and closed square symbols. As may be observed the Cobalt-60 degradation data track well with the electron beam results over the entire range of material thicknesses and absorbed radiation doses. These degradation data are strong evidence that electron/photon radiation damage can be related on the basis of absorbed radiation dose.

The low energy electron behavior prompted further experimental study. From Table 1 it is noted that absorbed radiation dose is strongly dependent on electron beam energy and from Figure 1 we observe that beam penetration depth is also particle energy dependent. Hence the object of this additional experiment was to determine if the decrease in observed degradation was a function of decreased electron penetration or decreased energy deposition per particle. In generating Figure 2 we have assumed that polymer degradation caused by energetic electrons can be determined by averaging the electron absorbed energy across the dimensions of the specimen. However, at some point, the electron energy may be sufficiently low that its penetration depth into the specimen may be limited to the specimen surface region. For these low energies, our analysis model may not be appropriate.

To assess the cutoff energy, below which one cannot assume that degradation is caused by average absorbed energy, we performed the following experiment. For a constant specimen thickness (1.5 mm) we exposed two specimens to the same low energy electron beam. One specimen, however, was irradiated to twice the (air) exposure dose as the other. We then examined the degradation of both specimens. If the specimen degradation were dependent on the average absorbed dose, then the specimen receiving the larger exposure should exhibit a greater degradation than the other specimen and its observed response should track with the data of Figure 2. If however, the degradation were penetration limited, then no difference in material degradation between the slabs should be detected.

This experiment was repeated for several beam energies in the low electron energy region. Figure 3 depicts the experimental results. Although uncertainties in the data are large, it is estimated that for electron energies greater than about 0.18 MeV and sample thicknesses of 1.5 mm, our assumption that polymer degradation can be related on the basis of average absorbed dose is correct.

3.2 Tensile Strength Results

Ultimate tensile strength results are presented in Figure 4. In the figure, ultimate tensile strength is plotted as a function of average absorbed dose. The solid curve is a best fit to the data. From the data it is noted that, for the material used in this study, change in tensile strength is not strongly dependent on absorbed dose. For that reason tensile strength was not used in the beta/gamma equivalence analyses presented here.

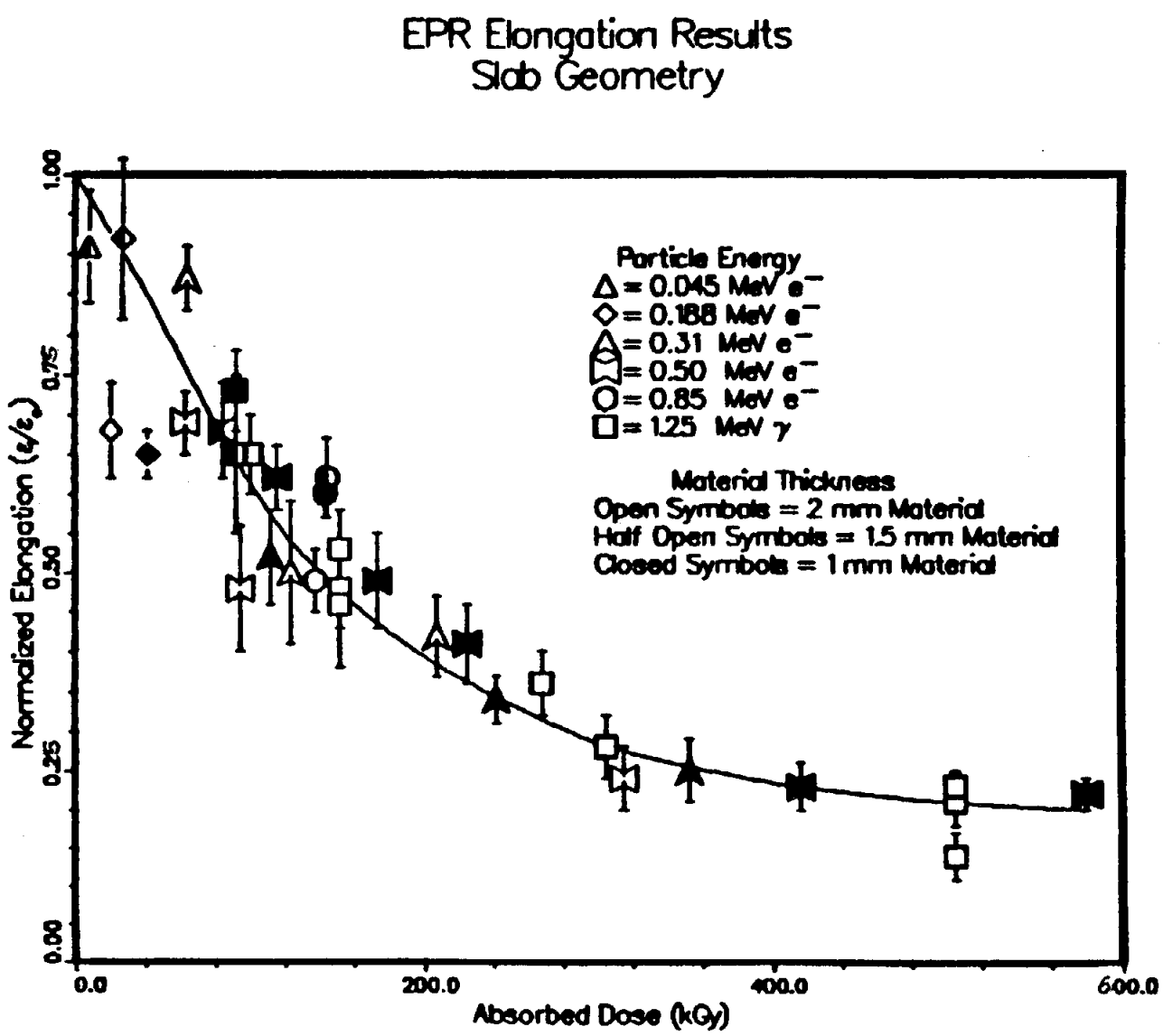

Figure 2. Slab Geometry EPR Elongation Results

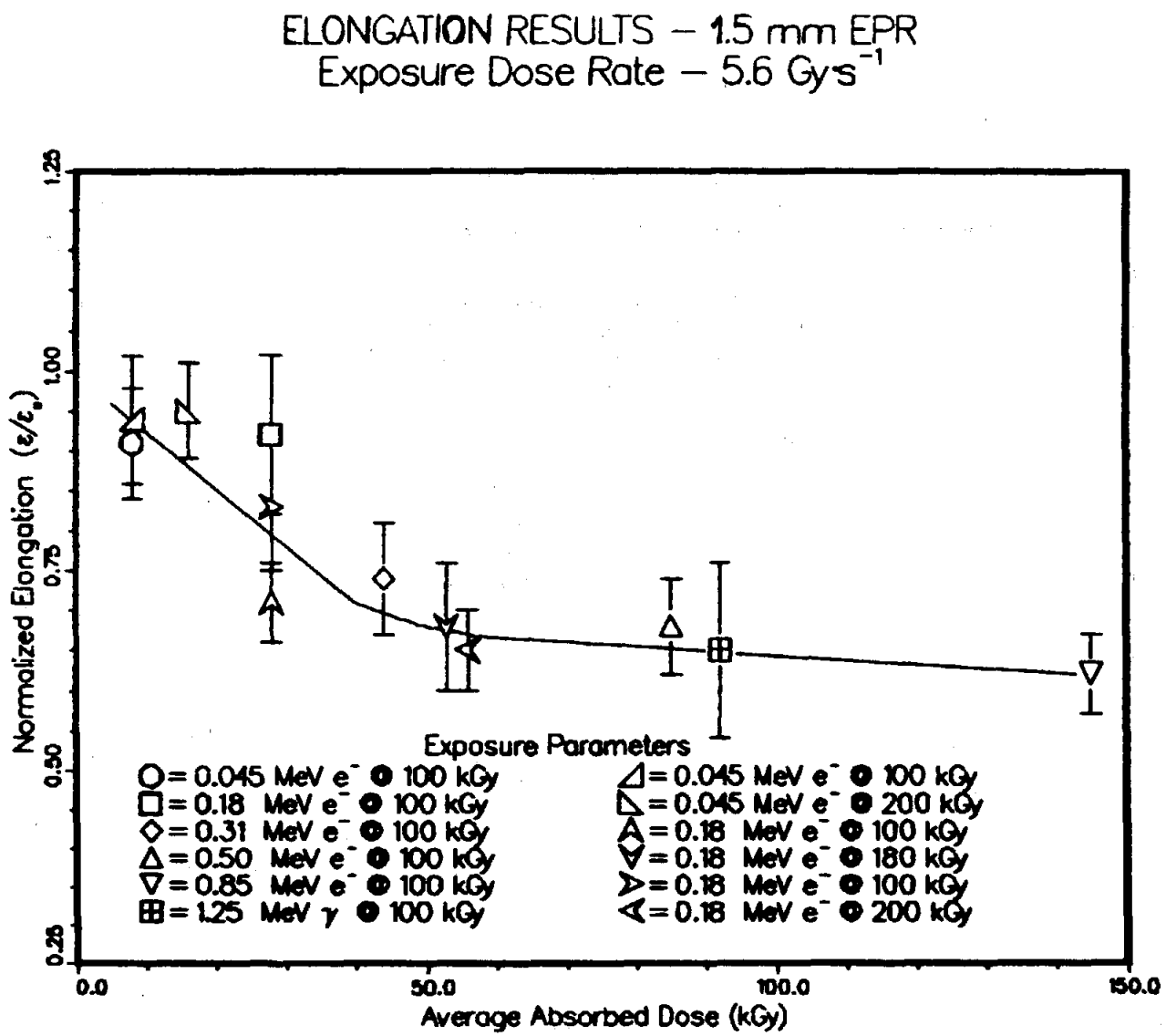

Figure 3. Slab Geometry EPR Elongation: Low Energy Results

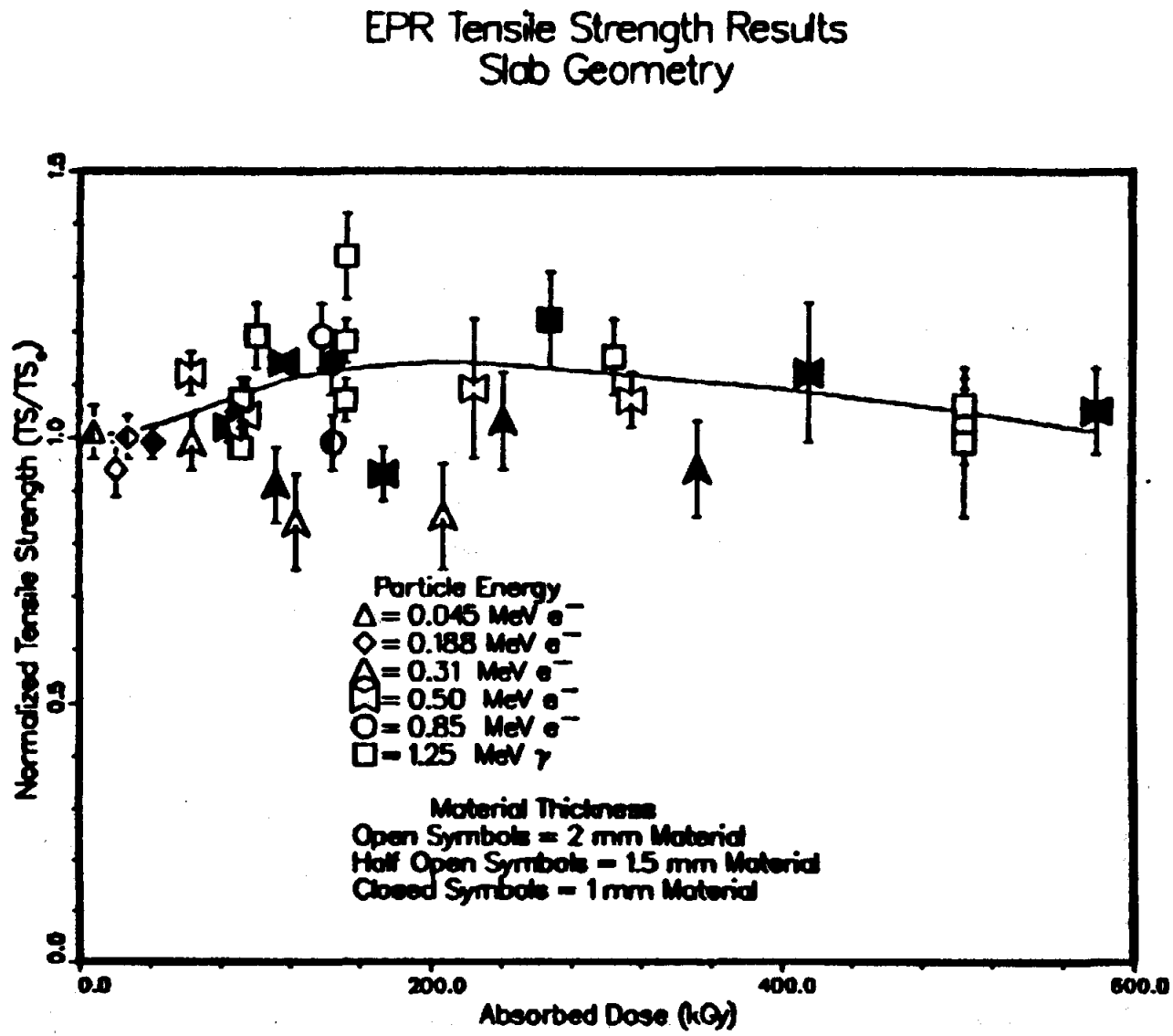

Figure 4. Slab Geometry EPR Tensile Strength Results

3.3 Experimental Results Applied to Beta/Gamma Equivalence

First consider the response of an EPR slab. Use is made of calculated[9] LOCA beta and gamma ray spectra in conjunction with estimates[6] of beta and gamma integrated dose time histories to obtain suitable average energies for this application. Examples of these data from the references are presented in Figures 5, 6, and 7. In Figure 5 the average beta particle energy is plotted as a function of elapsed time from release. Average beta energies were obtained by averaging beta particle number spectra (N(E)), at selected elapsed times from release, over the appropriate energy limits ($\int E\ N(E)\ dE / \int N(E)\ dE$).

It is of interest to note that the electron beam energies used in the effects experiments reasonably well span the range of average energies, between about 1.0 and 0.3 MeV, calculated for the LOCA release. Comparable LOCA gamma ray data are presented in Figure 6. From the figure it may be noted that average gamma ray energies are mainly in the range between 1.0 and 0.4 MeV. Beta and gamma ray integrated exposure doses are plotted as a function of elapsed time from release in Figure 7. From the figures it is observed that beta particle and gamma ray average energies are rather low. For this exercise beta particle and gamma ray average energies at twelve hours following release were assumed to be typical for the entire LOCA event. At this elapsed time the accumulated radiation exposure dose is about 1 MGy (100 Mrad), the average beta energy is approximately 0.3 MeV, and the average gamma energy is about 0.5 MeV.

Next consider the consequences of using Cobalt-60 gamma rays to simulate (average energy) LOCA beta and gamma rays. The suitability of using Cobalt-60 to simulate LOCA gamma environments is investigated first. For this exercise, we consider the equilibrium gamma dose (energy deposition = energy absorption) estimates to be adequate. In the following table the EPR gamma dose is tabulated as a function of gamma ray energy. As discussed earlier, the absorbed dose estimates have been normalized on the basis of detector response (detector response = exposure dose). The tabulated dose estimates span the range of energies estimated for the LOCA gamma environment as well as Cobalt-60.

Table 2

Gamma Ray Absorbed Dose Estimates

Gamma Energy MeV	Absorbed Dose/Exposure Dose
0.3	1.28
0.5	1.06
0.6	1.03
0.9	1.06
1.25	1.05

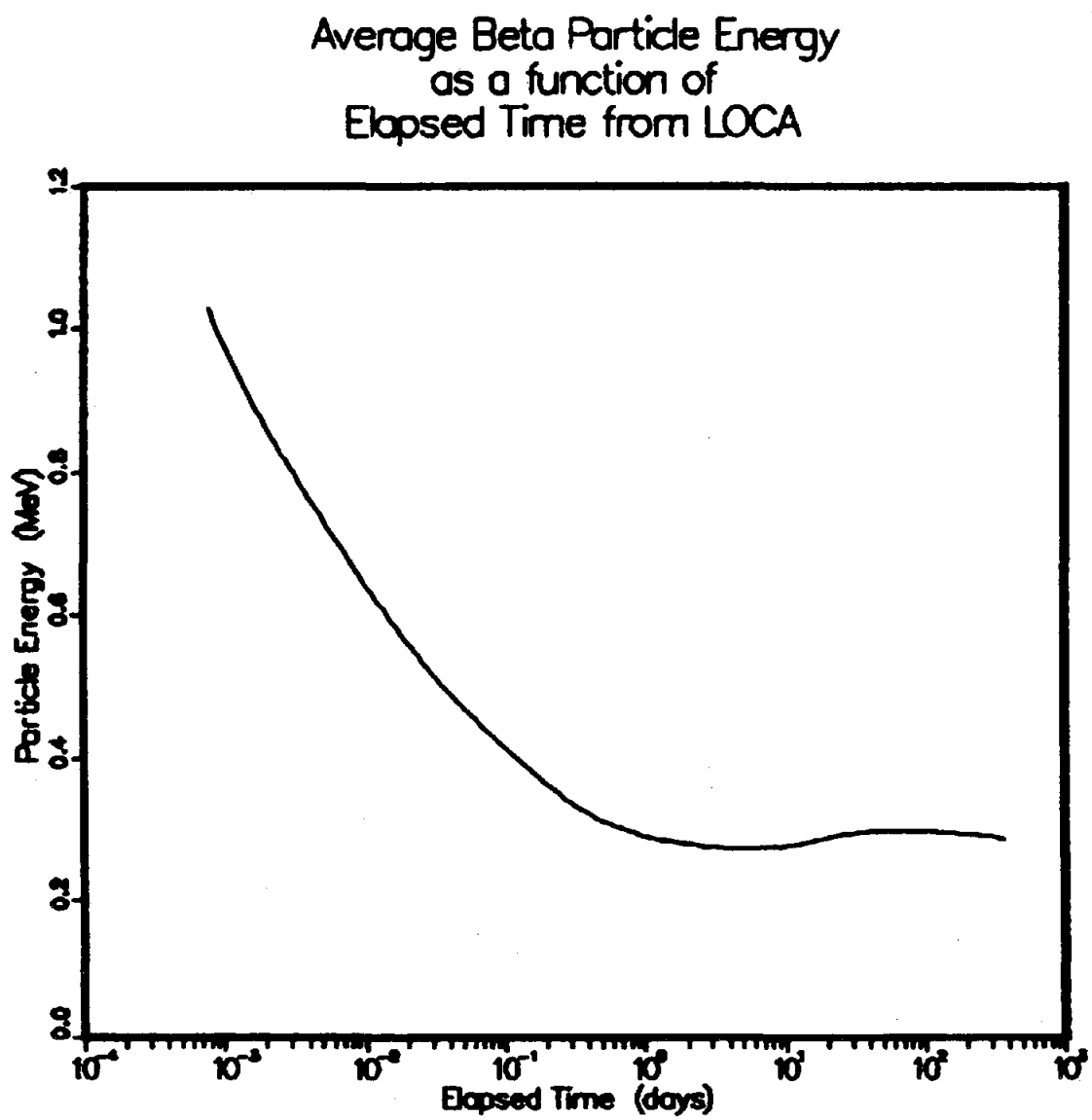

Figure 5. LOCA Beta Particle Average Energy versus Elapsed Time

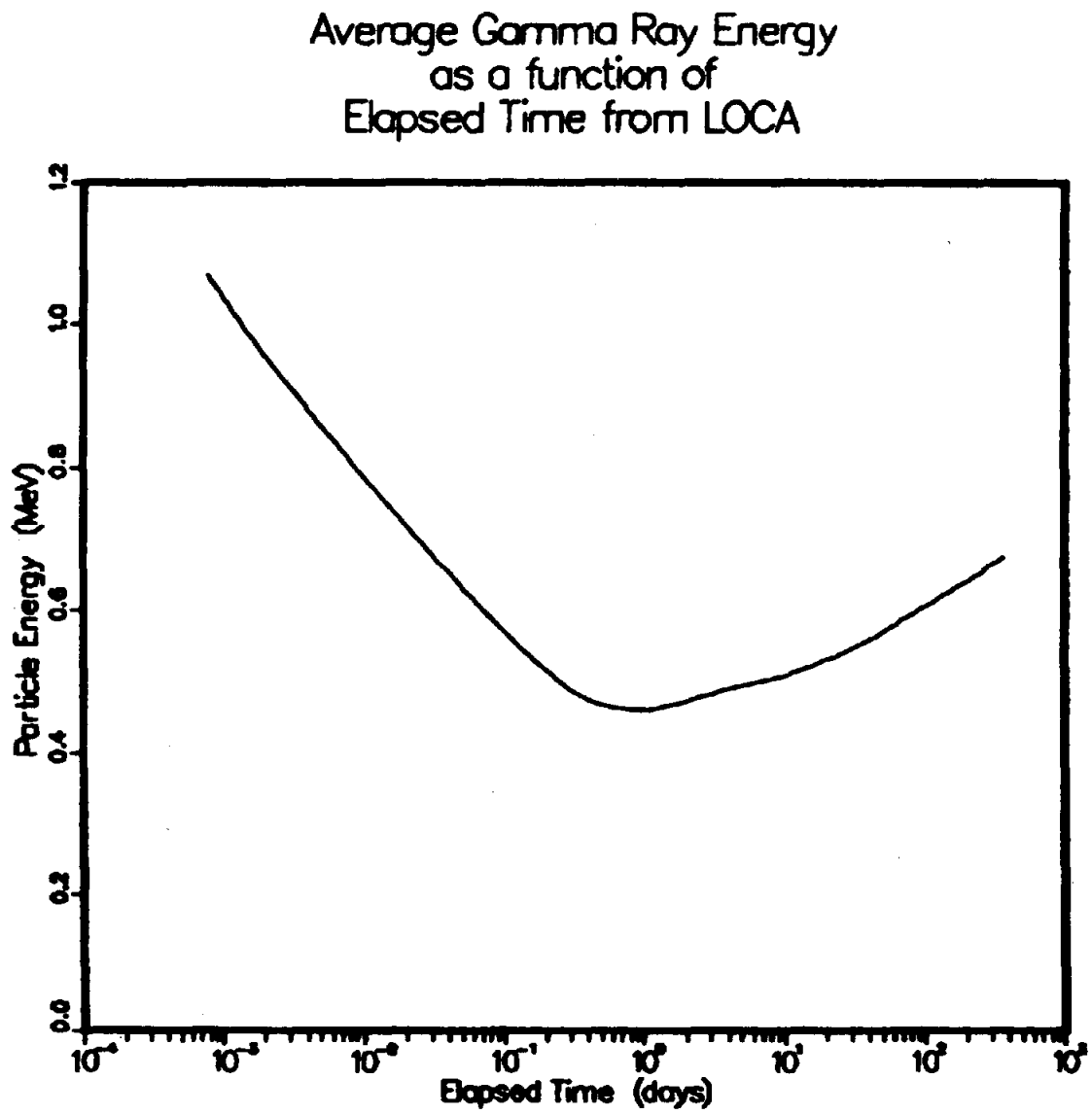

Figure 6. LOCA Gamma Ray Average Energy versus Elapsed Time

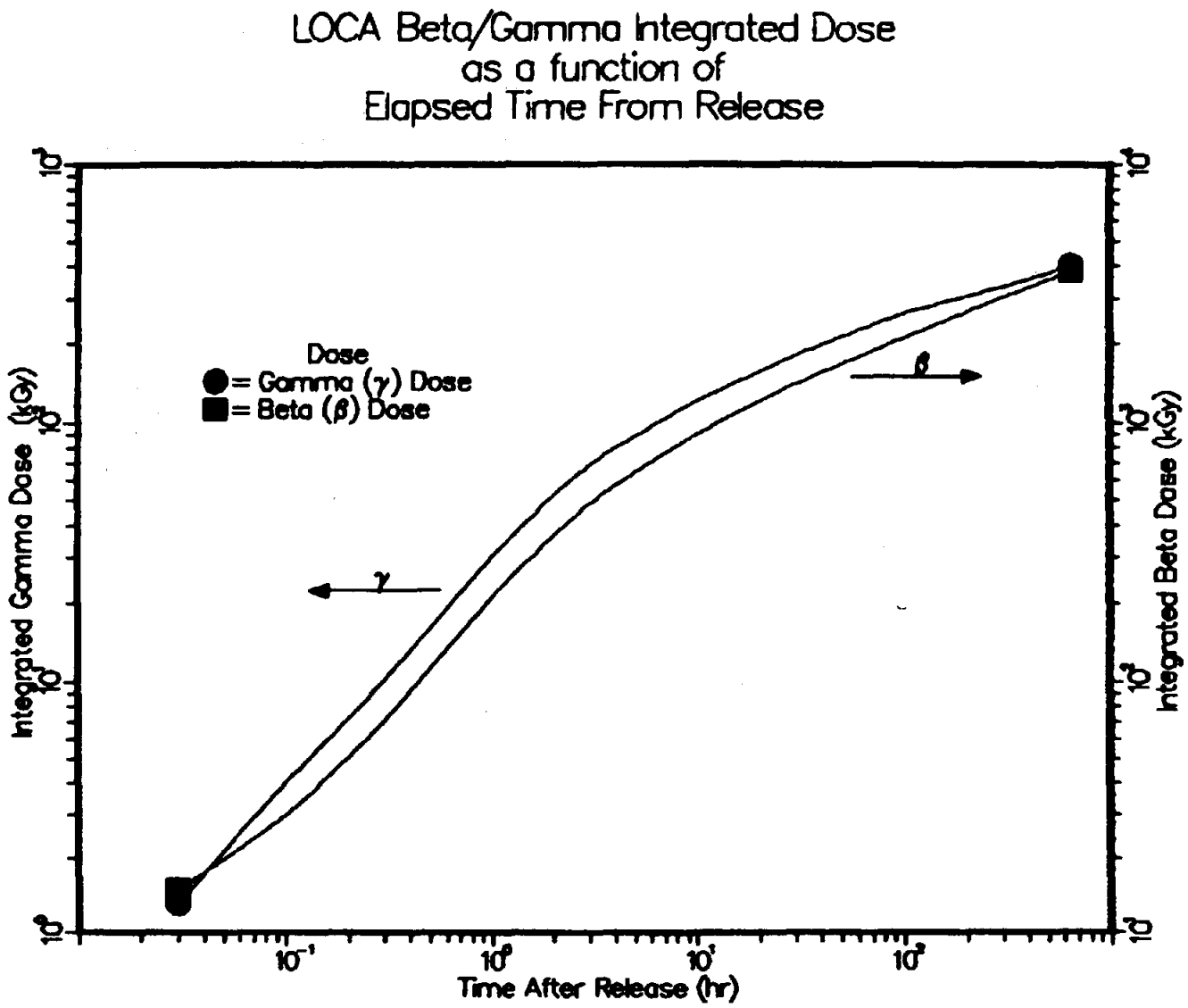

Figure 7. LOCA Beta/Gamma Integrated Dose versus Elapsed Time

Over the range of energies considered, it is noted that the detector response consistently underestimates the equilibrium EPR response by about five percent except at the lowest energy considered where the dose to the EPR is underestimated by about thirty percent. At the lowest energy considered, high atomic number additives in the EPR and not present in the detector composition become a dominant component in the EPR energy absorption. Thus based on an average LOCA gamma energy of about 0.5 MeV, the tabulated results predict that Cobalt-60 simulation of the LOCA gamma environment would result in understress of about five percent. However the spectra used to estimate LOCA average gamma energies all contain a low energy component in the range of 0.3 MeV. When the effects of this low energy component is used to modify the results obtained at 0.5 MeV, the understress is increased from five to approximately nine percent.

Simulation of beta radiation with gamma irradiators is now considered. First attention is directed to the behavior of the average LOCA beta environment energy as a function of elapsed time from release as depicted in Figure 5. From the figure, the average beta particle energy ranges from a maximum of about 1.0 MeV, at the onset of release, to approximately 0.3 MeV at more than twelve hours into the LOCA event. Next examine the absorbed radiation results given in Table 1. In the table note that energy absorption is dependent on both beam energy and sample thickness. This suggests that no single universal gamma to beta damage equivalent conversion factor can be identified. Rather consider the following approach. Assume that the beta energy at 12 hours, 0.3 MeV, is a good approximation for energy deposition for all times. Reexamination of Table 1 reveals that at 0.3 MeV normalized absorbed dose ranges between 0.66 and 0.33 depending on material thickness whereas, again from the table, normalized energy deposition resulting from Cobalt-60 exposure is approximately unity and independent of sample thickness. It it is acknowledged that the thicknesses given in the table are representative of typical insulation and jacket applications then clearly Cobalt-60 irradiation of insulation and jacket specimens will result in overtesting of the materials, as indicated by changes in tensile properties, in the range between 40 and 200 percent. Thinner materials would undergo less over exposure and correspondingly, thicker materials would be subjected to increasing over stressing.

We now consider a composite cable construction with both insulation and jacket materials and overlaying a copper conductor. Reasons for examining this configuration are twofold. First, it is of interest to determine the shielding effects, if any, the jacket may have on the underlying insulation and second, the dose enhancement to the insulation from radiation reflected by the copper conductor should be included in the insulation total dose. Having demonstrated, experimentally, the equivalence of electron and photon radiation damage on the basis of absorbed radiation dose, the response of a jacket-insulation-copper composite was estimated. For this demonstration the dose distribution in a Hypalon-EPR-copper composite was calculated using the TIGER[8] code. Dimensions (thicknesses) of the Hypalon and EPR were identical to those of a jacketed three conductor qualified control cable sample. Hypalon,

EPR, and copper thicknesses were 1.7 mm, .88 mm, and 1.0 mm respectively. In order to assess the effects of high energy, penetrating electrons on the underlying insulation, LOCA beta spectra were used in the calculations rather than monoenergetic approximations to the spectra. Four beta spectra were used in the calculations and spanned the hardest (one minute following release) and softest (four days after release) spectra calculated for the LOCA event. The results of these calculations are presented in Figure 8 and in Table 3. In the figure, absorbed dose (per unit exposure dose) as a function of penetration depth is plotted for the four LOCA beta spectra. Dose deposition in the conductor region was included in the calculation but not presented in the figure. Of interest here is the relatively uniform dose distribution and low absorbed dose in the insulation region.

Table 3 is a presentation of absorbed dose average values tabulated as a function of LOCA beta spectra.

Table 3

Beta Absorbed Dose: Hypalon-EPR-Copper Composite

Spectrum	Accumulated Dose kGy (Mrad)	Absorbed Dose/Exposure Dose Hypalon	EPR	Cu
1 minute	10 (1)	.789	.572	.093
1 hour	100 (10)	.470	.170	.020
12 hour	1000 (100)	.376	.058	.003
4 day	2000 (200)	.325	.048	.002

In the table, spectra denotations are indicative of elapsed time from LOCA release and the dose tabulations are exposure doses accumulated up to those times. Of interest here is the shielding effectiveness of the Hypalon jacket particularly at the later release times when the preponderance of exposure dose is accumulated. During those advanced elapsed times from release (greater than one hour) the absorbed dose ratio of the Hypalon and EPR ranges between about two and seven. Ratios of this magnitude suggest that radiation testing of jacketed insulation materials may have resulted in severe overtest of the insulation component.

Response of the cable composite to a LOCA gamma environment is now considered. The cable response to monoenergetic gamma ray environments, with energies spanning those predicted[9] for the LOCA event, were estimated with the TIGER code. Results of these calculations are tabulated in Table 4 where average absorbed dose for each cable component is tabulated as a function of gamma ray energy. To include the effects of air on photon transport and to provide a measure of dose equilibrium for the Hypalon, a 150 cm air slab was positioned in front of the Hypalon jacket component. As may be noted response of the air slab is included in the tabulation.

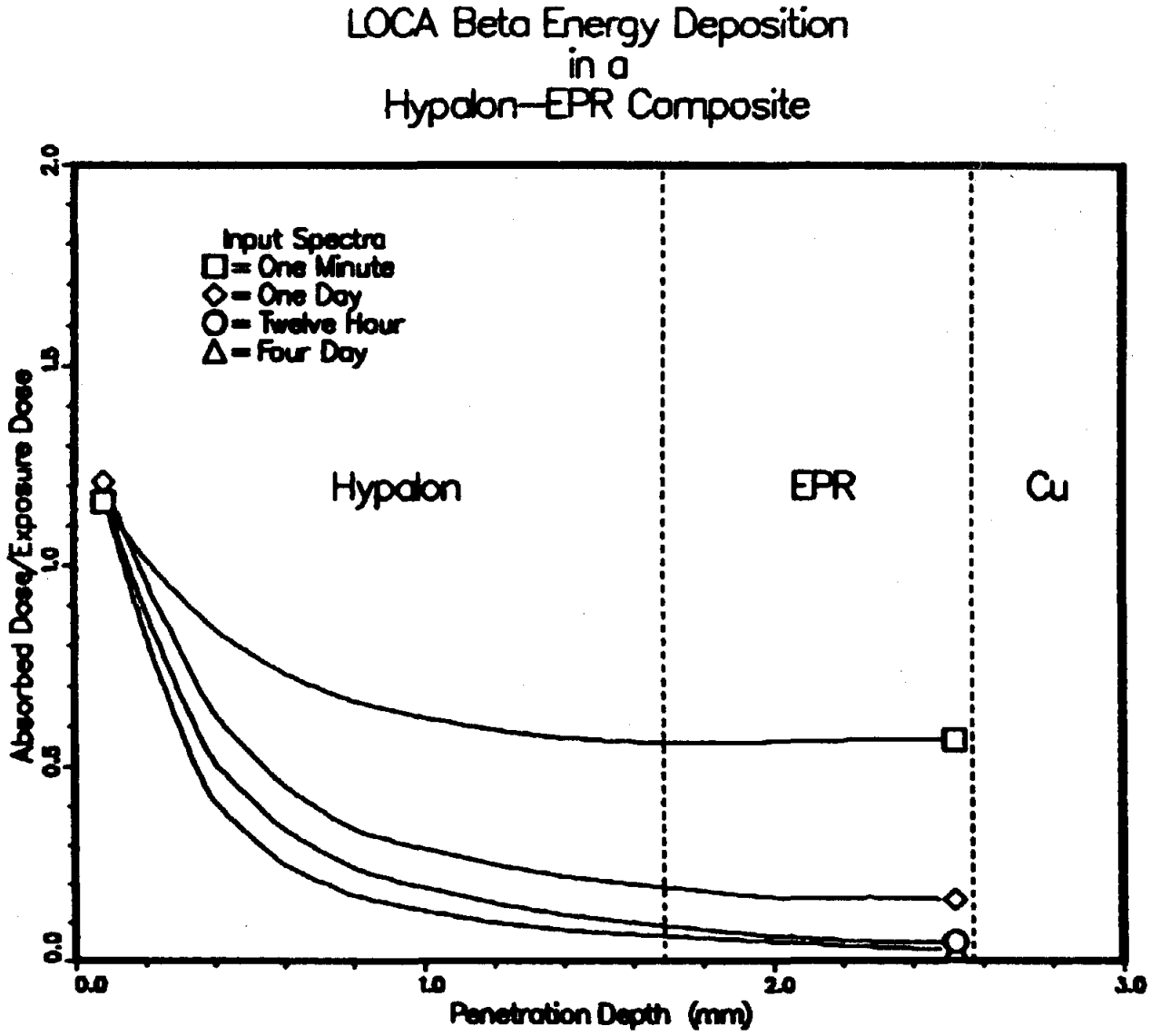

Figure 8. LOCA Beta Particle Energy Deposition in a Hypalon-EPR-Copper Composite

Table 4

Gamma Absorbed Dose: Hypalon-EPR-Copper Composite

Gamma Energy MeV	Absorbed Dose/Exposure Dose Air	Hypalon	EPR	Cu
1.25	.417	.970	1.20	.950
0.90	.648	.988	1.30	1.02
0.60	.801	.990	1.27	.92
0.30	.989	1.080	1.30	1.32

Several items in the table deserve mention. First, the EPR and Hypalon are sufficiently equilibrated to assure their average absorbed doses are independent of the incident gamma ray energy. Second, energy reflected from the copper conductor into the EPR insulation is responsible for an EPR dose enhancement of approximately 25 percent. If it is accepted that exposed cable composites will be in equilibrium with the surrounding air or other environment, then Cobalt-60 will adequately simulate the LOCA gamma ray environment.

The beta and gamma environments have been treated as separate entities. For total absorbed dose estimates, we consider them in combination. The beta/gamma LOCA exposure dose ratio obtained from references 6 and 9 is equal to approximately 7.5. This ratio predicts that 0.88 of the total exposure dose is due to beta radiation and the remaining fraction (.12) is the gamma contribution. In terms of a 2000 kGy (200 Mrad) LOCA radiation exposure, 1760 kGy (176 Mrad) would be due to beta radiation and 240 kGy (24 Mrad) would be due to gamma radiation. We use these results in combination with the beta and gamma absorption data for composites (Tables 3 and 4) and some crude averaging to obtain absorbed LOCA dose estimates for the composite Hypalon EPR configuration. The results of these estimations are presented in Table 5.

Table 5

LOCA Absorbed Dose Estimates for a Hypalon-EPR-Copper Composite

Material	LOCA Dose Beta Dose kGy	LOCA Dose Gamma Dose kGy	Simulator Cobalt-60 Dose kGy	Ratio*
Hypalon	710 (71)	240 (24)	2000 (200)	2
EPR	183 (18)	290 (29)	2400 (240)	5

*Ratio = Co-60 Dose/(Beta Dose + Gamma Dose)

In the table, the numbers appearing in the parenthesis following each dose entry are the dose equivalents in units of megarads. Beta and gamma doses to the materials are listed separately. In addition to the LOCA beta and gamma dose estimates, Cobalt-60 simulation doses for the two cable components are tabulated. The ratio values are a measure of the fidelity of current radiation simulation practices to reproduce the doses in cable components exposed to a LOCA radiation environment. The results of our experiments and calculations, as summarized in Table 5, indicate present radiation simulation practices probably result in overtest of cable components by factors between two and five.

4.0 DISCUSSION AND CONCLUSIONS

This study was initiated to determine the adequacy of isotopic gamma ray irradiators to simulate radiation damage predicted to occur in safety related polymer base materials and components exposed to a LOCA mixed radiation environment. A series of experiments has been performed to investigate the validity of simulating LOCA radiation environments with (isotopic) Cobalt-60 irradiators and to identify the link between observed material damage and radiation type. In these studies,[1,2,3,4] radiation damage, in polymer base electrical insulation and jacket materials, resulting from electron beam and Cobalt-60 gamma ray exposures was investigated to determine which parameters, if any, linked observed radiation damage and radiation type. Investigated were radiation response as a function of material composition and geometry, radiation dose, and radiation type and energy. Changes in elongation at break and ultimate tensile stress were used as measures of radiation-induced response.

Several radiation parameters were investigated for adequacy as links between observed material damage and radiation environments. Based on dosimetry considerations, the logical link between radiation damage and radiation type is, with provisos, average absorbed radiation dose. Briefly in most gamma ray detection systems, detector response is the result of slowing down and stopping recoil electrons in the detector volume. Because of gamma ray penetrability, the distribution of recoil electrons in the detector volume is a good approximation independent of position in the detector. Obviously this is not the case for materials irradiated with electron beams. Hence the factors limiting electron/photon damage equivalence are either sample thickness or electron beam energy.

Electron beam and Cobalt-60 gamma ray induced damage in several material compositions and geometry tracked well, reasonably independent of electron beam energy, when plotted as a function of averaged absorbed radiation dose. Results of a study to determine a low electron beam energy cutoff were encouraging. Data from this study predicted electron/photon damage equivalence even in instances where electron range in samples was on the order of one third the sample thickness.

The effect of radiation damage equivalence, based on absorbed radiation dose, on simulating LOCA radiation environments was estimated on the

basis of a LOCA radiation environment defined by Bonzon.[6,9] Using averaged values for the LOCA environment, the adequacy of a Cobalt-60 irradiator to simulate both the beta and gamma LOCA radiation environments was estimated. Based on the estimates, it was calculated that for gamma rays current practices probably under stress test specimens by a few percent. In the case of beta particle simulation, however, current practices result in routine overstress of test specimens. Since energy deposition from electron transport in materials is material thickness/electron energy dependent, it is not possible to generalize conclusions as in the case of gamma ray deposition. However if the range of sample thicknesses used in this investigation is considered typical for most insulation and jacket applications then accepted radiation simulation practices overstress test specimens in a range with limits between 40 and 200 percent.

In the examples cited thus far, the insulation and jacket were not considered as a composite and thus the perturbing effects of adjacent cable components on radiation transmission, absorption, and reflection could not be assessed. When considering beta radiation these effects could be appreciable. We addressed these problems by investigating the response of a Hypalon-EPR-copper composite configuration with dimensions similar to those of a qualified cable sample. The response of this configuration to representative LOCA beta spectra and gamma rays was estimated with the TIGER code. Dose estimates for the composite, based on experimental results and calculations, were consistent with those obtained for components but modified to a degree by the effects of interaction between the cable components. The most notable effects were shielding of the insulation component (EPR) by the Hypalon jacket component and enhancement of the EPR gamma dose by reflection from the copper conductor.

Results for the composite predict that conventional LOCA radiation simulation testing of jacketed cable components will overstress jacket and insulation materials by factors of two and five respectively.

Nonetheless, based on the experimental results obtained, it is concluded that Cobalt-60 irradiators represent a conservative method for simulating the LOCA mixed radiation environments. Polymer base insulation and jacket materials probably have been substantially over stressed during qualification testing. These conclusions are clearly applicable to 2 MGy (200 Mrad) exposures; but, since jacket protection of the insulation cannot be assured at higher dose levels, they may be inappropriate to 10 MGy (1000 Mrad) exposures.

REFERENCES

1. F. J. Wyant, W. H. Buckalew, J. Chenion, F. Carlin, G. Gaussens, P. Le Tutour, and M. Le Meur, U.S./French Joint Research Program Regarding the Behavior of Polymer Base Materials Subjected to Beta Radiation, Volume 1: Phase-1 Normalization Results, NUREG/CR-4530/1 of 3, SAND86-0366/1 of 3, Sandia National Laboratories, Albuquerque, New Mexico, June 1986.

2. W. H. Buckalew, F. J. Wyant, J. Chenion, F. Carlin, G. Gaussens, P. Le Tutour, and M. Le Meur, U.S./French Joint Research Program Regarding the Behavior of Polymer Base Materials Subjected to Beta Radiation, Volume 2: Phase-2a Screening Tests, NUREG/CR-4530/2 of 3, SAND86-0366/2 of 3, Sandia National Laboratories, Albuquerque, New Mexico, September 1987.

3. W. H. Buckalew, J. Chenion, F. Carlin, G. Gaussens, P. Le Tutour, and M. Le Meur, U.S./French Joint Research Program Regarding the Behavior of Polymer Base Materials Subjected to Beta Radiation, Volume 3: Phase-2b Extended Tests, NUREG/CR-4530/3 of 3, SAND86-0366/3 of 3, Sandia National Laboratories, Albuquerque, New Mexico.

4. W. H. Buckalew, First Results from Electron-Electron Damage Equivalence Studies on a Generic Ethylene-Propylene Rubber, NUREG/CR-4543, SAND86-0462, Sandia National Laboratories, Albuquerque, New Mexico, April 1986.

5. W. H. Buckalew, F. J. Wyant, and G. J. Lockwood, Response of Rubber Insulation Materials to Monoenergetic Electron Irradiations, NUREG/CR-3532, SAND83-2098, Sandia National Laboratories, Albuquerque, New Mexico, November 1983.

6. Lloyd L. Bonzon, Radiation Signature Following the Hypothesized LOCA, NUREG 76-6521, SAND76-0740, Sandia National Laboratories, October 1977.

7. W. H. Buckalew, G. J. Lockwood, S. M. Luker, L. E. Ruggles, and F. J. Wyant, Capabilities and Diagnostics of the Sandia Pelletron-Raster System, NUREG/CR-3777, SAND84-0912, Sandia National Laboratories, Albuquerque, New Mexico, July 1984.

8. J. A. Halbleib and W. H. Vandevender, Nuc. Sci. Eng., 57, 94 (1975).

9. L. L. Bonzon and N. A. Lurie, Best-Estimate LOCA Radiation Signature, NUREG/CR-1237, SAND79-2143, Sandia National Laboratories, Albuquerque, New Mexico, January 1980.

DISTRIBUTION

Gulf States Utilities Company
Attn: G. K. Henry
River Bend-NUPE
Main Administration Building
P.O. Box 220
St. Francisville, LA 70775

Commonwealth Edison Company
Attn: D. C. Lamken
P.O. Box 767 Rm. 35 FN West
Chicago, IL 60690

National Technical Systems
Attn: Sonny Kasturi
25 Piermont Drive
Melville, NY 11747

Commonwealth Edison Co.
Attn: R. E. Grams
Room 35 FNW
P.O. Box 767
Chicago, IL 60690

Westinghouse Electric Corp.
Attn: W. C. Gangloff
Water Reactor Division
P.O. Box 355
Pittsburgh, PA 15230

Duke Power Company
Attn: J. E. Thomas
P.O. Box 33189
Charlotte, NC 28242

Bishop Electric
Attn: T. A. Balaska
5 Airport Rd. - Ste. 104
Lakewood, NJ 08701

Northeast Utilities
Attn: R. Luther
P.O. Box 270
Hartford, CT 06141

Chromatic Technologies
Attn: J. S. Pirrong
31 Hayword St.
Franklin, MA 02038

Philadelphia Electric Company
Attn: J. J. Garland
2301 Market Street (S10-1)
P.O. Box 8699
Philadelphia, PA 19101

Fluorocarbon Corporation
Attn: M. Tabbey
1199 South Chillicothe Rd.
Aurora, OH 44202

The Rockbestos Company
Attn: E. D'Aquanno
285 Nicoll Street
New Haven, CT 06511

Department of Chemistry
Attn: J. Tanaka
The University of Connecticut
Storrs, CT 06268

Brand Rex Company
Attn: S. Sandberg
P.O. Box 498
Willimantic, CT 06226

Okonite Company
Attn: J. Lasky
P.O. Box 340
Ramsey, NJ 07446

Kerite Company
Attn: R. Fleming
P.O. Box 452
49 Day Street
Seymour, CT 06483

ITT Suprenant Division
Attn: P. A. McDermott
172 Sterling Street
Clinton, MA 01510

BIW Cable Systems, Inc.
Attn: A. Garshick
65 Bay Street
Boston, MA 02125

Bechtel
Attn: J. Kitchen
12440 East Imperial Highway
Norwalk, CA 90650

Stone and Webster
Attn: K. Petty
245 Summer Street
Boston, MA 02107

JPL/Caltech
Attn: J. W. Winslow
4800 Oak Grove Drive
Pasadena, CA 91109

Naval Research Laboratory
Attn: Frank Campbell
Washington, DC 20361

Electric Power Research Institute
Attn: George Sliter
P.O. Box 10412
3412 Hillview Avenue
Palo Alto, CA 94304

29 Miller Road
Attn: J. B. Gardner
Bethany, CT 06525

University of Connecticut
Attn: M. T. Shaw
Institute of Materials Science
Box U-136
97 North Eagleville Road
Storrs, CT 06268

Washington Public Power Supply System
Attn: J. E. Rhoads
Mail Drop 981 F
3000 George Washington Way
Richland, WA 99352

USNRC
Attn: W. Farmer
5650 Nicholson Lane
Rockville, MD 20852

USNRC
Attn: J. Vora
5650 Nicholson Lane
Rockville, MD 20852

USNRC
Attn: S. Aggarwal
5650 Nicholson Lane
Rockville, MD 20852

USNRC
Attn: D. Sullivan
5650 Nicholson Lane
Rockville, MD 20852

Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Attn: P. E. MacDonald
Idaho Falls, ID 83415

Engineering Technology Division
Brookhaven National Laboratory
Attn: J. H. Taylor
Upton, NY 11973

Pacific Northwest Laboratory
Attn: B. Johnson
Richland, WA 99352

Oak Ridge National Laboratory
Attn: D. Eissenberg
Oak Ridge, TN 37830

Tennessee Valley Authority
Attn: K. Brown
400 West Summit Hill Drive
W11C110
Knoxville, TN 37902

<u>Foreign Distribution</u>

Ansaldo Impianti
Centro Sperimentale del Boschetto
Attn: C. Bozzolo
Corso F. M. Perrone, 118
16161 Genova
ITALY

Ansaldo Impianti
Attn: S. Grifoni
Via Gabirele D'Annunzio, 113
16121 Genova
ITALY

ASEA-ATOM
Attn: A. Kjellberg
Department KRD
Box 53
S-721 04
Vasteras
SWEDEN

ASEA-ATOM
Attn: T. Granberg
Department TQD
Box 53
S-721 04
Vasteras
SWEDEN

ASEA KABEL AB
Attn: B. Dellby
P.O. Box 42 108
S-126 12
Stockholm
SWEDEN

Atomic Energy of Canada, Ltd.
Instrument and Control Branch
Chalk River Nuclear Laboratories
Attn: E. C. Davey
Chalk River, Ontario
CANADA KOJ 1JO

Atomic Energy of Canada, Ltd.
Attn: S. Nish
1600 Dorchester Boulevard West
Montreal, Quebec
CANADA H3H 1P9

Atomic Energy Research
Establishment
Attn: S. G. Burnay
Building 47, Division M.D.D.
Harwell, Oxfordshire
OX11 ORA
ENGLAND

Bhabha Atomic Research Centre
Health Physics Division
Attn: S. K. Mehta
BARC
Bombay-85
INDIA

British Nuclear Fuels Ltd.
Attn: W. G. Cunliff, Bldg. 334
Springfields Works
Salwick, Preston
Lancs
ENGLAND

Brown Boveri Reaktor GMBH
Attn: R. Schemmel
Postfach 5143
D-6800 Mannheim 1
WEST GERMANY

Bundesanstalt fur Materialprufung
Attn: K. Wundrich
Unter den Eichen 87
D-1000 Berlin 45
WEST GERMANY

CEA/CEN-FAR (41)
Department de Surete Nucleaire
Service d'Analyse Fonctionnelle
Attn: M. Le Meur (40 copies)
J. Henry
B.P. 6
92260 Fonetnay-aux-Roses
FRANCE

CERN
Laboratorie 1
Attn: H. Schonbacher
CH-1211 Geneve 23
SWITZERLAND

Canada Wire and Cable Limited
Power & Control Products Division
Attn: Z. S. Paniri
22 Commercial Road
Toronto, Ontario
CANADA M4G 1Z4

Centro Elettrotecnico
Sperimentale Italiano
Research and Development
Attn: Carlo Masetti
Via Rubattino 54
20134 Milan
ITALY

Commissariat a l'Energie Atomique
Attn: G. Gaussens (10 copies)
J. Chenion
F. Carlin
ORIS/LABRA (12)
BP N° 21
91190 Gif-Sur-Yvette
FRANCE

Commissariat a l'Energie Atomique
CEN Cadarche DRE/STRE
Attn: J. Campan
BP N° 1
13115 Saint Paul Lez Durance
FRANCE

Conductores Monterrey, S. A.
Attn: P. G. Murga
P.O. Box 2039
Monterrey, N. L.
MEXICO

Electricite de France (2)
(S.E.P.T.E.N.)
Attn: H. Herouard
M. Hermant
12, 14 Ave. Dubrieroz
69628 Villeurbarnie
FRANCE, Paris

Electricite de France (2)
Direction des Etudes et Recherches
Attn: J. Roubault
L. Deschamps
1, Avenue du General de Gaulle
92141 CLAMART CEDEX
FRANCE

Electricite de France (3)
Direction des Etudes et Recherches
Les Renardieres
Attn: Ph. Roussarie
V. Deglon
J. Ribot
Boite Postale n° 1
77250 MORET SUR LORING
FRANCE

Energia Nucleare e delle
Energie Alternative
CKE Casaccia
Attn: A. Cabrini
1-0060 Rome
ITALY

EURATOM
Commission of European Communities
C.E.C. J.R.C
Attn: G. Mancini
21020 Ispra (Varese)
ITALY

FRAMATOME (2)
Attn: G. Chauvin
E. Raimondo
Tour Fiat - Cedex 16
92084 Paris La Defense
FRANCE

Furukawa Electric Co., Ltd.
Hiratsuka Wire Works
Attn: E. Oda
1-9 Higashi Yawata - 5 Chome
Hiratsuka, Kanagawa Pref
JAPAN 254

Gesellschaft fur Reaktorsicherheit
(GRS) mbH
Attn: Library
Glockengasse 2
D-5000 Koln 1
WEST GERMANY

Health & Safety Executive
Attn: W. W. Ascroft-Hutton
Baynards House
1 Chepstow Pl, Westbourne Grove
London W2 4TF
ENGLAND

ITT Cannon Electric Canada
Attn: B. D. Vallillee
Four Cannon Court
Whitby, Ontario L1N 5V8
CANADA

Imatran Voima Oy (2)
Electrotechn. Department
Attn: B. Regnell
K. Koskinen
P.O. Box 138
SF-00101 Helsinki 10
FINLAND

Institute of Radiation Protection
Department of Reactor Safety
Attn: L. Reiman
P.O. Box 268
00101 Helsinki 10
FINLAND

ISMES S.p.A. (2)
Attn: A. Castoldi
M. Salvetti
Viale G. Cesare, 29
24100 Bergamo
ITALY

Japan Atomic Energy Research Institute
Attn: N. Tamura
K. Yoshida
T. Seguchi
Takasaki Radiation Chemistry (3) Research Establishment
Watanuki-machi
Takasaki, Gunma-ken
JAPAN

Japan Atomic Energy Research Institute
Attn: Y. Koizumi
Tokai-Mura
Naka-Gun
Ibaraki-Ken
319-11
JAPAN

Japan Atomic Energy Research Institute
Osaka Laboratory for Radiation Chemistry
Attn: Y. Nakase
25-1 Mii-Minami machi,
Neyagawa-shi
Osaka 572
JAPAN

Kalle Niederlassung der Hoechst AG
Attn: Dr. H. Wilski
Postfach 3540
6200 Wiesbaden 1,
WEST GERMANY
Biebrich

Kraftwerk Union AG
Department R361
Attn: I. Terry
Hammerbacherstrasse 12 + 14
D-8524 Erlangen
WEST GERMANY

Kraftwerk Union AG
Section R541
Attn: W. Siegler
Postfach 1240
D-8757 Karlstein
WEST GERMANY

Kraftwerk Union AG
Attn: W. Morell
Hammerbacherstrasse 12 + 14
Postfach 3220
D-8520 Erlangen
WEST GERMANY

Motor Columbus
Attn: H. Fuchs
Parkstrasse 27
CH-5401
Baden
SWITZERLAND

National Nuclear Corporation (2)
Attn: A. D. Hayward
J. V. Tindale
Cambridge Road, Whetstone
Leicester LE8 3LH
ENGLAND

NOK AG Baden
Beznau Nuclear Power Plant
Attn: O. Tatti
CH-5312 Doettingen
SWITZERLAND

Norsk Kabelfabrik
Attn: C. T. Jacobsen
3000 Drammen
NORWAY

Nuclear Power Engineering Test Center
Attn: K. Takumi
6-2, Toranomon, 3-Chome
Minato-ku, #2 Akiyana Bldg.
Tokyo 105
JAPAN

Ontario Hydro (2)
Attn: R. Wong
B. Kukreti
7000 University Avenue
Toronto, Ontario
CANADA M5G 1X6

Oy Stromberg Ab
Helsinki Works
Attn: P. Paloniemi
Box 118
FI-00101 Helsinki 10
FINLAND

Radiation Center of Osaka Prefecture
Radiation Application-Physics Division
Attn: S. Okamoto
Shinke-Cho, Sakai
Osaka, 593
JAPAN

Rappinl
ENEA-PEC
Attn: Ing. Ruggero
Via Arcoveggio 56/23
Bologna
ITALY

Rheinisch-Westfallscher
Technischer Uberwachunge-Vereln e.V
Attn: R. Sartori
Postfach 10 32 61
D-4300 Essen 1
WEST GERMANY

Sydkraft
Southern Sweden Power Supply
Attn: O. Grondalen
21701 Malmo
SWEDEN

Technical University Munich
Institut for Radiochemie
Attn: Dr. H. Heusinger
D-8046 Garching
WEST GERMANY

UKAEA
Materials Development Division
Attn: D. C. Phillips
Building 47
AERE Harwell
OXON OX11 ORA
ENGLAND

United Kingdom Atomic Energy Authority
Safety & Reliability Directorate
Attn: M. A. H. G. Alderson
Wigshaw Lane
Culcheth
Warrington WA3 4NE
ENGLAND

Waseda University
Department of Electrical Engineering
Attn: Y. Ohki
3-4-1 Ohkubo, Shinjuku-ku
Tokyo 160
JAPAN

1200	J. P. VanDevender
1234	G. J. Lockwood
6400	D. J. McCloskey
6410	D. A. Dahlgren
6419	L. D. Bustard
6419	M. J. Jacobus
6419	M. P. Bohn (15)
6429	K. D. Bergeron
6512	F. J. Wyant
6524	F. V. Thome
8524	J. A. Wackerly
3141	S. A. Landenberger (5)
3151	W. I. Klein

NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-5231
SAND88-1054

2. TITLE AND SUBTITLE

Cobalt-60 Simulation of LOCA Radiation Effects

3. DATE REPORT PUBLISHED

MONTH	YEAR
July	1989

4. FIN OR GRANT NUMBER

A1051

5. AUTHOR(S)

W. H. Buckalew

6. TYPE OF REPORT

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION – NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Sandia National Laboratories
Albuquerque, NM 87185

9. SPONSORING ORGANIZATION – NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

The consequences of simulating nuclear reactor loss of coolant accident (LOCA) radiation effects with Cobalt-60 gamma ray irradiators have been investigated. Based on radiation induced damage in polymer base materials, it was demonstrated that electron/photon induced radiation damage could be related on the basis of average absorbed radiation dose. This result was used to estimate the relative effectiveness of the mixed beta/gamma LOCA and Cobalt-60 radiation environments to damage both bare and jacketed polymer base electrical insulation materials. From the results obtained, it is concluded that present simulation techniques are a conservative method for simulating LOCA radiation effects and that the practices have probably substantially overstressed both bare and jacketed materials during qualification testing.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

loss of coolant accident (LOCA)
Cobalt-60 gamma ray irradiators
radiation effects

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

(This Page)

Unclassified

(This Report)

Unclassified

15. NUMBER OF PAGES

16. PRICE

NRC FORM 335 (2-89)

★U.S. GOVERNMENT PRINTING OFFICE:1989-241-590:00139

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL FOURTH-CLASS RATE
POSTAGE & FEES PAID
USNRC

PERMIT No. G-67