1 of 1

IRRADIATION TESTING OF AN ASPHALT-BASED
GROUT VAULT SEALANT

L. R. Bunnell

September 1993

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

MASTER

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED
DATE 11/11/01 BY 60322 UCBAW/ML

SUMMARY

In general, Nokorode 705M^(a) showed only minimal effects from irradiation at the levels calculated for a 300-year lifetime, while in contact with the basic fluids expected in actual use. In no instance was loss of adhesion on concrete or loss of water tightness encountered in this testing. In contrast to simpler materials tested over 30 years ago, the Nokorode showed only small changes in density and virtually no changes in the mechanical properties examined. The much higher dose rate used to perform these tests within a reasonable time presumably amplified all irradiation effects, and nevertheless produced no changes which would make the material obviously unsuitable for its intended use. Although the effects observed were not examined in enough detail to determine the dominant degradation mechanism(s), the material is qualified from an engineering point of view.

(a) Nokorode 705M is produced by Lion Oil Co., El Dorado, Arkansas.

CONTENTS

SUMMARY	iii
1.0 INTRODUCTION	1
2.0 EXPERIMENTAL	3
3.0 RESULTS AND DISCUSSION	6
3.1 DENSITY	6
3.2 TENSILE	10
3.3 CONCRETE ADHESION	12
3.4 WATER TIGHTNESS	13
3.5 NEEDLE PENETRATION TESTS	14
4.0 CONCLUSIONS	15
5.0 REFERENCES	16
ACKNOWLEDGMENTS	16
APPENDIX A - COMPOSITION, DENSITY, AND NEEDLE PENETRATION DATA	A.1

FIGURES

1	Percentage Change in Density of Nokorode 705M as a Function of Irradiation at the Conditions Indicated	7
2	Fracture Stress of Nokorode 705M as a Function of Irradiation at the Conditions Indicated	12
3	Sectional View of the Apparatus used to Evaluate Water Tightness of Membrane Materials	13
4	Percentage Changes in Needle Penetration of Nokorode 705M as a Function of Irradiation at the Conditions Indicated	15

TABLES

1	Exposure Conditions of Specimens	3
2	Gamma Radiation Doses Actually Achieved in Irradiations	5
3	Density Changes in Nokorode 705M	8
4	Gas Analysis Results	9
5	Peak Values of Stress and Strain for Irradiated Nokorode 705M	11

1.0 INTRODUCTION

Based on results of prior evaluations that primarily assessed resistance to exposure in a typical chemical and temperature environment, Nokorode 705M was selected as the leading candidate material for use in lining concrete vaults that will contain cast grout. Grout will be used as a form to immobilize low-level radioactive wastes at the U.S. Department of Energy's (DOE) Hanford Site. Adequate performance in such an application requires that the vault lining provide a water-tight seal, bond well to concrete, resist chemical attack by the basic solutions produced from the hydration of the cement-based grout, and that it be extensible enough to bridge small cracks that may form in the underlying concrete. These factors were considered in the initial evaluation that resulted in the choice of Nokorode. Furthermore, the material must retain all of these properties while in the radiation field generated by the wastes. The asphalt material must function for a minimum of 30 years, consistent with U.S. Environmental Protection Agency and Washington State Department of Ecology Landfill Leachate Monitoring Requirements. The purpose of this work was to irradiate Nokorode 705M at realistic temperatures while in contact with a relevant chemical environment, then test it to determine whether any changes occurred that would make it unsuitable for the intended use.

As a sealant for concrete structures, Nokorode 705M is designed to be used on external surfaces, such as foundations below the soil line. The material is based on an air-blown asphalt to which are added inert mineral fillers, mineral spirits as a solvent, and polybutadiene resin. A second component containing polyisocyanate is mixed with the asphaltic material just before application. The reaction of the polyisocyanate with the polybutadiene resin produces a polymer that improves the mechanical and thermal properties of the asphalt. The resulting sealant is a composite mixture of asphalt and the rubberlike reaction product. It is capable of withstanding fairly large strains before fracture and is stable to over 100°C.

The interactions of gamma rays with polymeric materials are complex, and several results are possible depending on the specific polymer, dose, and

irradiation temperature. Thermoplastic polymers, such as polyethylene, cross-link at low gamma doses (approx. 1 Mrad), becoming harder and melting at a higher temperature. Other changes occur in mechanical properties; stiffness increases and strain-to-failure decreases. Higher doses of around 1000 Mrads produce a brittle, glasslike material that does not possess any detectable crystallinity. Other polymers are stiffened by low-dose gamma irradiation but are degraded by irradiation to very high doses (approx. 10^{10} rads). Although there is some evidence for such competing effects in the work reported here, asphaltic materials are too complex and the data too sparse to make definite conclusions as to mechanisms.

A computer search of the past 40 years' literature^(a) for information on radiation effects on asphaltic materials uncovered only two relevant references (Oglio et al. 1972; Hoiberg et al. 1959); one of these reported work done in support of an application similar to that planned for the grout vaults, so the parameters evaluated were similar to those judged important here. Hoiberg et al. (1959) irradiated asphaltic membrane materials using gamma radiation to a maximum dose of 10^9 rads, with the following results: H_2 and CO_2 evolved; density decreased 14 to 30%; volume and honeycomb structure increased; softening point increased; ductility increased slightly; penetration decreased;^(b) flash point decreased, but weight loss did not increase after heating; asphaltiness and resins increased; and oils decreased. The calculated dose value for a 300-year lifetime at the position of the grout vault liner is 78 Mrads (7.8×10^7 rads). The data of Hoiberg et al. (1959) cover a total dose more than ten times this value, so our data might be expected to show similar but smaller effects of irradiation on the Nokorode material.

(a) The DIALOG system was used, concentrating mainly on Nuclear Science Abstracts, 1948 to present.

(b) This test measures the resistance to penetration by a standard blunt-pointed needle loaded by a defined weight, and is a standard petroleum industry test of heavy hydrocarbons. The standard used was ASTM D5 (1986), "Test Method for Penetration of Bituminous Materials."

2.0 EXPERIMENTAL

Table 1 shows the test matrix, which was taken from the Test Plan written for this work. Several gamma irradiation exposures were planned; the maximum value was that calculated for ten times the minimum 30-year performance period of the membrane. After 300 years, ^{137}Cs has decayed to inconsequential levels. Irradiations were planned for either 90°C, corresponding to that encountered because of the hydration heat of curing grout, or 25°C, corresponding to the long-term average temperature. As shown in the table, more evaluations were done on material irradiated at the higher temperature because of its assumed greater effect on membrane properties. Two environments were used, simulated double-shell slurry feed (DSSF) and pore water. DSSF is a synthetic low-level liquid waste, and pore water is produced by using DSSF as the aqueous component of a grout and subsequently using high pressure to expel the pore fluid from the partially cured grout. DSSF has a pH value of about 12.5, whereas pore water is even more basic at pH 13.2 to 13.3. The compositions of these two solutions are contained in the Appendix, Table A.1.

TABLE 1. Exposure Conditions of Specimens

<u>Sample Type</u>	<u>Environment</u>	<u>Temperature, °C</u>	<u>Target Dose, Mrads</u>	<u>Total Samples</u>
Cup	DSSF	25	0, 78	4
Cup	Pore Water	25	0, 78	4
Cup	DSSF	90	0, 0.152, 8.54, 38.9, 78	10
Cup	Pore Water	90	0, 0.152, 8.54, 38.9, 78	10
Fritted Filter	DSSF	90	0, 38.9	4
Fritted Filter	Pore Water	90	0, 38.9	4
Coated Concrete	DSSF	90	0, 0.152, 8.54, 38.9, 78	10
Coated Concrete	Pore Water	90	0, 0.152, 8.54, 38.9, 78	10
Dogbone	DSSF	90	0, 0.152, 8.54, 38.9, 78	10
Dogbone	Pore Water	90	0, 0.152, 8.54, 38.9, 78	10

Test specimens of Nokorode were evaluated by several different methods. To calculate density, small cups filled with the Nokorode were weighed in air and weighed again when immersed in water. The material in these cups was also tested for penetration using a weighted-needle penetrator, a standard test for asphaltic materials. The Nokorode was applied to fritted glass filters that were pressure tested to determine whether water could be forced through the membrane under the highest hydrostatic pressure likely in use. Discs of concrete representative of the grout vaults^(a) were sprayed with Nokorode to a nominal thickness of 0.060 in., and before and after exposure, were inspected visually for any evidence of adhesion loss. Sheet membrane material 0.060 in. thick, also fabricated by spraying, was tested as dogbone-shaped tensile specimens to evaluate strain-to-failure and tensile strength. Further details of the individual tests are described in Section 3.0.

All irradiation testing was done in the Gamma Testing Facility, 3730 Building. This facility consists of a ⁶⁰Co source at the bottom of a large water-filled tank, plus numerous stainless steel tubes into which test materials can be inserted. The tubes are capped at the bottom to exclude the shielding and cooling water in the tank. The facility has provisions for heating test materials to desired temperatures.

Specimens were contained inside 14-in.-long stainless steel carriers made from 3-in. stainless steel Schedule 40 pipe. A flat cap was welded to one end of the pipe, and the other end was welded to a pipe coupling. The top cap used pipe threads and was provided with a lifting eye, a thermocouple penetration, and a vent line. Two carriers were made; they provided containment for the solutions surrounding the specimens and allowed a thermocouple to be placed at the solution centerline. The carriers were also equipped with an external electrical heater and suitable insulation, and were sized to slide into the irradiation tubes of the gamma facility. After gas pressurization was noted on initial exposures, a vent line was provided to conduct these gases out of the irradiation tank.

(a) Concrete was taken from an actual job-site pour, as called out in Section 03301 of the construction specification B-714-C2.

The gamma irradiation facility has been fairly extensively calibrated, so an estimate of the dose rate at any height in any irradiation tube is available. Calibration values do not include shielding provided by individual experimental hardware, so radiochromic film strips were placed in the carriers along with specimens.^(a) Exposure values determined by this method were lower by 25 to 40% than expected from the source calibration, probably because of attenuation by the thick stainless steel pipe of the carriers and, to a small extent, by the aqueous solutions inside the carriers. Some irradiations were repeated on the basis of these measured dose rates, to more closely approach target exposure values. Table 2 indicates the dose levels achieved

TABLE 2. Gamma Radiation Doses Actually Achieved in Irradiations

<u>Environment</u>	<u>Target Dose, Mrads</u>	<u>Temperature, °C</u>	<u>Minimum/Maximum Dose, Mrads^(a)</u>
Pore	0.152	90	0.150
DSSF	0.152	90	0.086
Pore	8.54	90	8.54
DSSF	8.54	90	4.81
Pore	38.9	90	22.8
DSSF	38.9	90	39.1
Pore	78.0	90	52.4
DSSF	78.0	90	77.9
Pore (Repeat)	78.0	90	78.4
Pore	78.0	25	66.0
DSSF	78.0	25	66.0

(a) Max/min values refer to the range of exposures obtained by reading several dosimeters along the carrier length. A single value represents a single dosimeter, placed at the peak position.

(a) The type 60-00 radiochromic dosimetry film, made by Far West Technology, was calibrated by gamma irradiation to fixed exposure values at the National Institute of Standards and Technology. Documentation was provided in a Report of Calibration, Test 533/234541-85, NBS DB 857/161, XRG-432, April 12, 1985.

in the irradiations measured by the radiochromic strips, compared to the nominal values. For the graphs in this report, the minimum value available from dosimetry was used for conservatism. Thus, specimens were exposed to a dose at least as high as plots indicate and generally no more than 10% higher.

3.0 RESULTS AND DISCUSSION

3.1 DENSITY

The density of Nokorode 705M was determined before and after irradiation, using Archimedes' method. By weighing the asphalt sample and its cup and subtracting the weight of the cup, the sample mass is known. When the sample is weighed immersed in water, it will be buoyed by a force equal to the weight of the water it displaces. The volume of the sample can thus be calculated, after adjusting for the container. Dividing the weight of the Nokorode in air by its volume yields the density. The accuracy of this method, as applied in this work, is about ± 0.01 g/cc. The original density of the Nokorode was measured to be approximately 0.83 g/cc with a standard deviation of 0.02 g/cc in 30 measurements, but extreme values of 0.82 to 0.92 g/cc were measured in isolated cases. Evidently, mixing variations affected the bulk density by influencing the amount of trapped porosity within the samples. The effect of the mixing variations can be eliminated by using the percentage density change resulting from the chemical and radiation exposures. Figure 1 shows the percentage changes in the density of the Nokorode, as a function of irradiation dose, in the two fluids.

In the absence of irradiation, the DSSF and pore water both react with the Nokorode to increase its density, more so at 90°C than at 25°C, see Figure 1. This reaction may be simple diffusion of water into the material. Although density was not measured by Martin (1989), Nokorode increased in weight when exposed to 90°C DSSF, but increased much more when exposed to water at the same temperature. In essentially every case, irradiation caused a decrease in density up to about 7.5% at 90°C and up to 14% at 25°C. The fact that density changes were less at lower temperatures is believed to be due to more rapid product gas escape at the higher temperature. Weight loss

FIGURE 1. Percentage Change in Density of Nokorode 705M as a Function of Irradiation at the Conditions Indicated. Note scale break. Each data point represents density measurements made on a single specimen. The shaded area applies to 90°C data only.

by the specimens during irradiation contributed to the decrease in density, by about 50% in many cases; the rest of the density change was due to volume increases. Table 3 summarizes the results and separates these contributing factors.

The density decreases were much less than those measured by Hoiberg et al. (1959), who indicated that density decreases up to 25.5% were measured in asphalt samples irradiated to 10^7 rads at 20°C. In most of the present work, the asphaltic material was at 90°C, and density decreases at nearly 10^8

TABLE 3. Density Changes in Nokorode 705M

<u>Condition</u>	<u>Percent Weight Change</u>	<u>Percent Density Change</u>
Pore Water, 25°C, 0 Rad	-0.8	+3.4
Pore Water, 25°C, 0 Rad	-0.5	+2.8
DSSF, 25°C, 0 Rad	-0.6	+3.0
DSSF, 25°C, 0 Rad	-0.3	+5.1
Pore Water, 90°C, 0 Rad	-0.7	+8.1
Pore Water, 90°C, 0 Rad	-1.2	+5.4
DSSF, 90°C, 0 Rad	+1.9	+9.0
DSSF, 90°C, 0 Rad	+4.0	+11.0
Pore Water, 90°C, 0.15 Mrad	NA	-0.4
Pore Water, 90°C, 0.15 Mrad	NA	-0.8
DSSF, 90°C, 0.09 Mrad	NA	+0.2
DSSF, 90°C, 0.09 Mrad	NA	+1.6
Pore Water, 90°C, 8.54 Mrad	-3.9	-3.0
Pore Water, 90°C, 8.54 Mrad	-3.6	-3.9
DSSF, 90°C, 4.81 Mrad	-1.9	-3.5
DSSF, 90°C, 4.81 Mrad	-2.1	-3.6
Pore Water, 90°C, 22.8 Mrad	NA	-2.8
Pore Water, 90°C, 22.8 Mrad	NA	-2.9
DSSF, 90°C, 39.1 Mrad	-1.7	-2.8
DSSF, 90°C, 39.1 Mrad	-2.3	-1.8
Pore Water, 90°C, 78.4 Mrad	+1.7	-3.1
Pore Water, 90°C, 78.4 Mrad	-0.7	-6.3
DSSF, 90°C, 77.9 Mrad	-1.0	-3.3
DSSF, 90°C, 77.9 Mrad	+0.6	-2.6
Pore Water, 25°C, 66.0 Mrad	-1.5	-13.6
Pore Water, 25°C, 66.0 Mrad	-1.6	-13.7
DSSF, 25°C, 66.0 Mrad	-1.5	-7.4
DSSF, 25°C, 66.0 Mrad	-1.5	-12.9

rads were much less than seen by Hoiberg. The work of Hoiberg et al. (1959) showed development of many large (approx. 1/4 in.) gas bubbles which produced the volume increases. Scanning electron microscope examination of the Nokorode after irradiation to the highest exposure level showed small (approx. 0.020 in.) gas bubbles, but trapped air bubbles are also present in the as-cast material. No conclusions can thus be drawn about these pores without closer study. While in use, the membrane will be trapped between the wall of the grout vault and the grout, so density changes should be much less than shown in this work, where free expansion was possible. Because of the much lower stiffness of Nokorode compared to concrete or grout, it is unlikely that significant mechanical loading of these structures would result from the volume increase.

It was apparent from container pressurization that gases were produced during irradiation. The gases were sampled by syringe puncture of a Tygon vent line, after overnight flow through a container of silicone oil (to prevent backflow), and analyzed by mass spectrometry. Table 4 lists the results of the analysis.

TABLE 4. Gas Analysis Results

<u>Gas Species</u>	<u>Volume Percent</u>
CO ₂	0.19
Ar ^(a)	7.57
O ₂	70.1
N ₂	12.1
CO	<0.10
He	<0.01
H ₂	9.50
CH ₄	0.10

(a) Argon was used as a purge gas in the irradiation tube, and apparently contaminated the gas sample slightly.

Some hydrogen is produced, as expected in irradiation of a hydrocarbon. The high percentage of oxygen is surprising, however, and might possibly have been produced by radiolysis of the solutions in contact with the specimens. In that case, much more hydrogen would be expected; perhaps the gas is being retained by the Nokorode, by a hydrogenation process. The mechanism leading to the gas composition in Table 4 is not understood, but the hydrogen gas produced is unlikely to be of much consequence because the expected dose rate in actual use is a factor of several thousand less than that used in these accelerated tests. Moreover, the vault liner is much thinner than the bulk Nokorode in the cups. At realistic dose rates, gases should be able to diffuse out of the membrane as they are produced. Because of this factor and the constraint mentioned above, density changes are likely to be less than measured here.

Although our gas sampling showed the presence of hydrogen and oxygen, as also noted by Hoiberg et al. (1959), it may be that the restraint provided by the composite structure in Nokorode 705M is sufficient to prevent large bubbles from forming.

3.2 TENSILE TESTING

Tensile testing was conducted on sheet material nominally 0.060 in. thick, sprayed by Lion Oil Co. After irradiating each piece of sheet material to its specified level, three standard ASTM type C dogbones were cut using a stamping tool. Each specimen was gripped and pulled in a universal testing machine at an extension rate of 2 in./min. A strip-chart recording provided values of force as a function of crosshead travel, and a drop in the force curve at failure enabled failure elongation to be determined. The elongation at failure was used to calculate strain at failure by dividing the elongation by the length of the region of constant cross section, with the assumption that elongation of the enlarged portions of the dogbone shapes could be neglected. Elongation results are the most important for this application and are indicated in Table 5. The elongations were all between 200% and 350%, with no obvious trends caused by irradiation. Table 5 summarizes the tensile testing data and includes both peak stress and strain-to-failure values.

TABLE 5. Peak Values of Stress and Strain for Irradiated Nokorode 705M

<u>Gamma Dose, Mrads</u>	<u>Environment</u>	<u>Average Peak^(a) Stress, psi</u>	<u>Average Peak Strain, Percent</u>
0	Air	219.6	256
0	Pore, 90°C, 41 d	215.8	308
0	DSSF, 90°C, 41 d	275	313
0.158	Pore, 90°C	298.3	293
8.54	Pore, 90°C	320.5	293
22.8	Pore, 90°C	258.8	237
52.4	Pore, 90°C	258.6	279
78.4	Pore, 90°C	277.1	242
0.087	DSSF, 90°C	241.4	274
4.81	DSSF, 90°C	338.4	311
22.8	DSSF, 90°C	292.0	277
77.9	DSSF, 90°C	288.6	245

(a) Values for three specimens were averaged for each value of stress and strain shown here.

The traces of load versus crosshead motion showed typical rubberlike behavior, in that the curves were strongly curved and maximum load occurred just before fracture. Figure 2 shows the trends observed in fracture stress, after correcting for reduction in area at the moment of failure, assuming uniform cross-section reduction and constant volume. This correction is substantial and increases the values of fracture stress by about a factor of three. The plot shows that the tensile strength of the unirradiated Nokorode is about 220 psi (1.5 MPa) and is sharply increased by small values of gamma irradiation in a pore water environment, apparently peaking at less than 10 Mrads. Above 10 Mrads the tensile strength decreases but never drops below the value obtained for nonirradiated specimens. The DSSF results do not indicate the tensile strength peak.

FIGURE 2. Fracture Stress of Nokorode 705M as a Function of Irradiation at the Conditions Indicated. Note scale break.

3.3 CONCRETE ADHESION

Concrete cores taken from a specimen representative of the concrete used for the grout vaults were lightly grit-blasted and blown free of loose residue, then sent to Lion Oil for spray application of Nokorode to a nominal thickness of 0.060 in. Specimens were visually judged to be fully adherent when returned from Lion Oil, and all were inspected visually after their irradiation exposures. The first few irradiated specimens were examined at 50X, but the black, nonreflective asphalt made this very unproductive; all remaining examinations were performed visually. Neither blistering nor other indications of adherence loss were noted.

3.4 WATER TIGHTNESS

In order to evaluate whether irradiation would disturb the sealing qualities of the Nokorode, 0.060-in. layers of the material were applied to one side of fritted glass filters. The specimens were irradiated while exposed to the simulated DSSF or pore solutions. Test specimens were then evaluated before and after irradiation, using the fixture shown in Figure 3. During testing, water at pressures to 25 psi was forced against the asphalt material and any leakage was noted visually. It was not possible in all

FIGURE 3. Sectional View of the Apparatus Used to Evaluate Water Tightness of Membrane Materials

instances to keep the basic solutions from contacting the unprotected frits during exposure; when contact occurred, the usual result was complete disintegration of the frit. Basic solutions are more corrosive to glasses than acidic solutions. Several irradiations were repeated as a result of this attack, with better provisions for isolating the glass frit from the solutions. In the case of pore water exposure at 90°C without radiation, the frit was repeatedly destroyed, and no testable specimens were produced. In all remaining tests, the membrane material remained water tight after irradiation and exposure to the two solutions.

3.5 NEEDLE PENETRATION TESTS

While the needle penetration test is an old standard in the petroleum industry for comparing the viscous flow properties of heavy oils, it does not produce a value for viscosity itself. Measurements using the technique were generally quite consistent, exhibiting a standard deviation of no more than 8% in five measurements. Figure 4 shows the results obtained by this method, plotted as percentage increase in penetration versus exposure. Five values before and after irradiation were averaged to produce each point on the plot.

Irradiated Nokorode showed a fairly consistent increase in penetration of about 50%, indicating that the material softened. This increase was not strongly dependent on exposure environment, especially at the highest exposure value. However, the greatest changes occurred when Nokorode was exposed to the solutions but not to irradiation; increases of 50% and 210% were measured at 25° and 90°C, respectively. These increases in penetration correlate with the large increase in strain-to-failure noted for these nonirradiated specimens (see Table 5) and with smaller increases in this property for almost all of the irradiated Nokorode. In DSSF at 90°C and 0.15 Mrad, the change in penetration was nil.

The results plotted in Figure 4 indicate that irradiation tends to harden Nokorode, but the chemical environment (at 90°C) softens it. Hoiberg et al. (1959) reported that the asphaltic materials were hardened by irradiation, but the materials were irradiated in a dry state, not in contact with basic solutions as done here. The end result at high doses is material slightly softened by the combination of chemical environment and irradiation.

39101097.3

FIGURE 4. Percentage Changes in Needle Penetration of Nokorode 705M as a Function of Irradiation at the Conditions Indicated. Note scale break.

The changes in needle penetration as a result of the chemical and radiation exposures were greater than for any of the other properties, but it is impossible to speculate further on the mechanism without more experience in using this method.

4.0 CONCLUSIONS

1. The water tightness of Nokorode 705M and its adherence to concrete were unaffected by the combination of radiation and chemical environment used in this study.

2. The density of Nokorode 705M was decreased by gamma irradiation to doses up to 78 Mrads, to a greater extent at lower temperature. This decrease is unlikely to affect the suitability of the material for the application as planned.
3. The combination of irradiation and chemical environment increased both tensile strength and strain-to-failure of the Nokorode at all doses, with the greatest effect occurring at less than 10 Mrads. These changes would be beneficial for the planned use of the material.
4. The combination of irradiation and chemical environment softened the Nokorode material, as evaluated by needle penetration. The change is unlikely to make the material unsuitable for the intended use as vault liner.

5.0 REFERENCES

Holberg, A. J., C. D. Watson, and G. A. West. 1959. An Evaluation of Asphalt and Other Materials for Lining Radiochemical Waste Storage Basins. ORNL-2508, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Oglio, E. R., J. G. Boone, and J. A. Zenewits. 1972. "Effect of Gamma Radiation on Paving Asphalts," U. S. Nat. Tech. Inform. Serv., 220548/2.

ACKNOWLEDGMENTS

The timely cooperation of Lion Oil Co. in fabricating all of the sheet specimens of Nokorode 705M by spraying, the same method planned for use in the field, is gratefully acknowledged. The capable assistance of CR Hymas in performing the experiment is also acknowledged.

Pacific Northwest Laboratory performed the research described in this report. Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

APPENDIX A

COMPOSITION, DENSITY, AND NEEDLE PENETRATION DATA

APPENDIX A

COMPOSITION, DENSITY, AND NEEDLE PENETRATION DATA

TABLE A.1. Composition of Simulated DSSF Waste and Simulated Pore Water

Simulated DSSF Waste		Simulated Pore Water ^(a)	
Species	Concentration, mol/L	Constituent	Concentration, mol/L
Ag	1.50 E-03	HNO ₃	2.91
Al	7.50 E-01	Na ₂ CO ₃	5.38 E-01
Ba	4.54 E-03	NaCl	9.00 E-02
Cl	1.09 E-01	KNO ₃	3.20 E-01
Ca	5.00 E-03	NaAlO ₂	3.85 E-02
SO ₄	5.25 E-02	NaOH	4.51
Fe	2.52 E-02	Na ₂ SO ₄	2.10 E-01
PO ₄	5.95 E-02	NaNO ₂	6.50 E-01
K	2.49 E-01		
OH	2.05 E+00		
F	2.96 E-02		
Mn	5.00 E-02		
Na	5.30 E+00		
B ₄ O ₇	2.43 E-03		
CO ₃	1.50 E-01		
Cr ₂ O ₇	1.11 E-02		
NO ₃	2.49 E+00		
NO ₂	5.00 E-01		
Ni	5.00 E-04		
Zn	2.49 E-02		
TOC	1.29 E-01		

(a) Pore solution was prepared by adding the above constituents to DIW, after first analyzing pore solution prepared as per the text of this report. Some minor ingredients originating from the DSSF were not added as inconsequential.

TABLE A.2. Density Measurements on Nokorode 705M

<u>Environment</u>	<u>Temperature, °C</u>	<u>Dose, Mrads</u>	<u>Original Density, g/cc</u>	<u>Final Density, g/cc</u>
PW	25	0	0.83	0.86
"	"	"	0.84	0.86
DSSF	"	"	0.83	0.85
"	"	"	0.84	0.88
PW	90	"	0.83	0.90
"	"	"	0.83	0.88
PW	"	0.15	0.91 ^(a)	0.91
"	"	"	0.91 ^(a)	0.90
DSSF	"	0.09	0.83	0.84
"	"	"	0.84	0.85
PW	"	8.54	0.83	0.81
"	"	"	0.83	0.79
DSSF	"	4.81	0.83	0.80
"	"	"	0.83	0.80
PW	"	22.80	0.83	0.80
"	"	"	0.82	0.80
DSSF	"	39.10	0.83	0.81
"	"	"	0.83	0.81
PW	"	78.40	0.82	0.79
"	"	"	0.83	0.78
DSSF	"	77.90	0.84	0.81
"	"	"	0.83	0.81
PW	25	66.00	0.83	0.72
"	"	"	0.83	0.71
DSSF	"	"	0.83	0.77
"	"	"	0.83	0.72

(a) Reason for difference unknown; material was from different batch.
PW = pore water.

Note: Values for peak stress and peak strain are contained in Table 5 and are not repeated here.

TABLE A.3. Needle Penetration Results for Nokorode 705M

<u>Environment</u>	<u>Temperature, °C</u>	<u>Dose, Mrads</u>	<u>Ave. Pre-Exposure/Ave. Post-Exposure</u>
PW	25	0	42/63
"	"	"	43/60
DSSF	"	"	42/63
"	"	"	40/63
PW	90	0.15	43/56
"	"	"	39/50
DSSF	"	0.09	41/41
"	"	"	42/40
PW	"	8.54	40/35
"	"	"	41/35
DSSF	"	4.81	39/62
"	"	"	41/60
PW	"	22.80	39/58
"	"	"	38/68
DSSF	"	39.10	42/88
"	"	"	43/87
PW	"	78.40	43/63
"	"	"	42/67
DSSF	"	77.90	40/53
"	"	"	41/56
PW	25	66.00	41/54
"	"	"	41/54
DSSF	"	"	43/54
"	"	"	42/54

PW = pore water.

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

- 12 DOE/Office of Scientific and
Technical Information

C. Frank, EM-50
DOE Office of Technology
Development
Trevion-II
12800 Middlebrook Rd.
Germantown, MD 20874

- 4 DOE Office of Waste Operations
Trevion-II
12800 Middlebrook Rd.
Germantown, MD 20874
ATTN: J. A. Coleman, EM-35
M. W. Frei, EM-34
H. Harmon, EM-32
J. E. Lytle, EM-30

J. C. Haugen
DOE Chicago Operations Office
9800 South Cass Avenue
Argonne, IL 60439

F. Bazan
Lawrence Livermore National
Laboratory
University of California
P.O. Box 808
Livermore, CA 94550

- 5 Westinghouse Savannah River
Company
Savannah River Site
Aiken, SC 29808-0001
ATTN: C. A. Langton
R. M. Wallace
E. Wilhite
E. Stevens
M. Hay

M. Fuhrmann
Brookhaven National Laboratory
Upton, NY 11973

T. C. Johnson
Nuclear Regulatory Commission
MS-623SS
Washington, DC 20555

M. McFadden
DOE Albuquerque Operations
Office
P.O. Box 5400
Albuquerque, NM 87115

R. M. Neilson, Jr.
EG&G
P.O. Box 1625
Idaho Falls, ID 83415

- 3 Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37831
ATTN: T. M. Gilliam
E. W. McDaniel
R. D. Spence

E. B. Peacock
Wastech, Inc.
P.O. Box 1213
Oak Ridge, TN 37831-1213

D. M. Smith
University of New Mexico
Chemical and Nuclear
Engineering Department
Albuquerque, NM 87131

No. of
Copies

FOREIGN

A. Atkinson
Atomic Energy Research
Establishment
HARWELL
Didcot
Oxfordshire, OX 11 ORA
UNITED KINGDOM

L. P. Buckley
Atomic Energy of Canada Ltd.
Chalk River, Ontario K0J 1J0
CANADA

P. Cote
Environment Canada
Canada Centre for Inland
Waters
Burlington, Ontario L7R 4A6
CANADA

R. Dayal
Ontario Hydro
800 Kipling Ave.
Toronto, Ontario M8Z 5S4
CANADA

C. L. Farmer
Atomic Energy Establishment
WINFRITH
Dorchester, Dorset DT2 8DH
UNITED KINGDOM

ONSITE

3 DOE Richland Operations Office

K. W. Bracken, R3-72
R. Carreon, R3-74
G. H. Sanders, R3-74

No. of
Copies

18 Westinghouse Hanford Company

K. W. Bledsoe, R4-03
K. C. Burgard, R4-03 (5)
W. T. Gretsinger, R4-01
P. F. Kison, S6-12
S. C. Klimper, S6-12
R. J. Murkowski, R4-02
R. E. Potter, H4-68
E. F. Riebling, R4-03
S. H. Rifaey, S6-12
R. K. Sanan, R4-05
D. J. Tedeschi, S6-12
J. E. Van Beek, R3-27
G. F. Williamson, R4-01
A. K. Yoakum, S4-43

33 Pacific Northwest Laboratory

C. R. Allen, P7-43
R. P. Allen, P8-10 (5)
C. M. Anderson, K7-34
L. M. Bagaasen, P7-19
K. A. Blanchard, P7-18
L. K. Fetrow, P8-44
B. M. Johnson, K1-78
C. T. Kincaid, K6-77
H. E. Kjarmo, K2-22
D. K. Kreid, K1-22
R. O. Lokken, P8-37
J. Luey, P7-34
K. R. Martin, P7-39
K. H. Pool, P8-44
W. A. Ross, P7-41
P. A. Scott, P7-19
R. J. Serne, K6-81
J. H. Westsik, Jr., P7-19 (5)
G. A. Whyatt, P7-19
Publishing Coordination
Technical Report Files (5)

**DATE
FILMED**

11 / 30 / 93

END