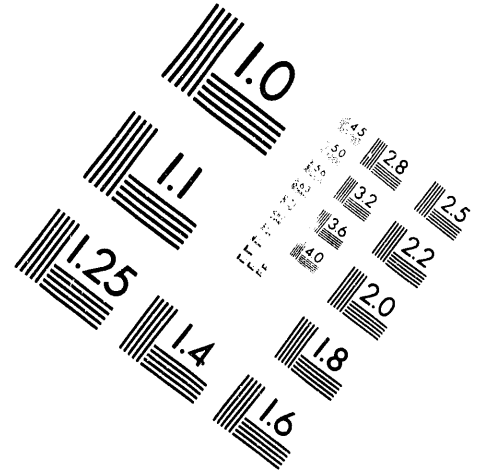
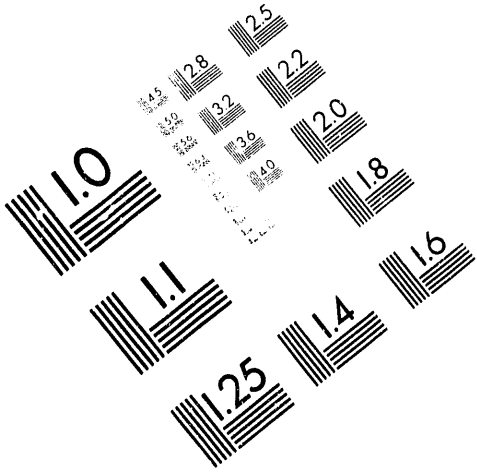




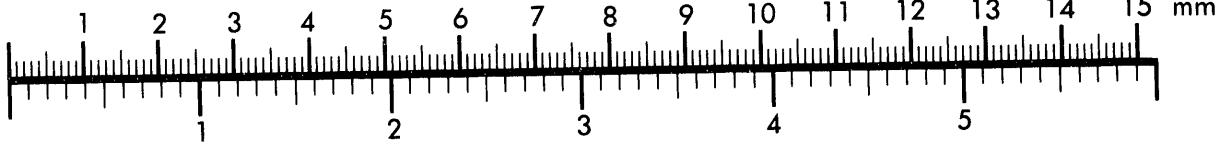
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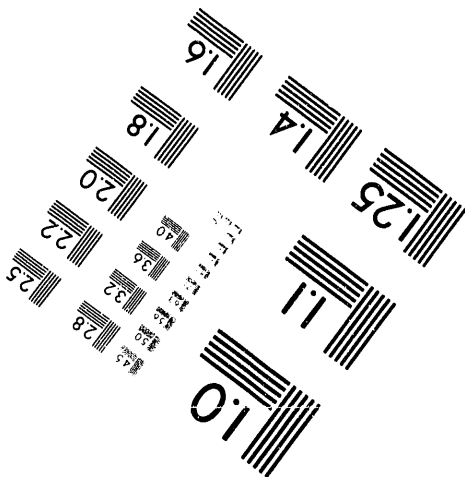
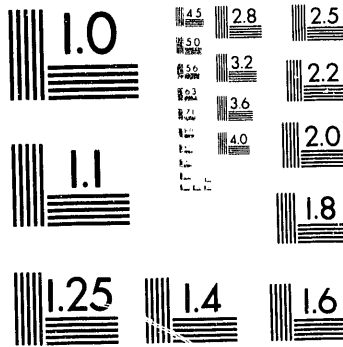
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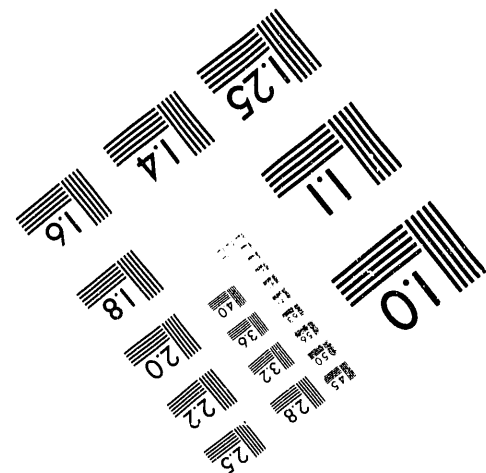
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**DWPF SALTSTONE STUDY: EFFECTS OF THERMAL
HISTORY ON LEACH INDEX AND PHYSICAL INTEGRITY
PART II- FINAL REPORT (U)**

by
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**DWPF SALTSTONE STUDY: EFFECTS OF THERMAL HISTORY ON LEACH
INDEX AND PHYSICAL INTEGRITY - PART II -FINAL REPORT (U)**

SUMMARY

This report summarizes the observations made during the curing and testing of DWPf simulated saltstones which have been cured under isothermal conditions in sealed glass envelopes at temperatures from room temperature to 95°C. This study was performed to evaluate the effect of curing at and around temperatures representing conditions created within large pours of grout.

There appears to be no difference in the leaching resistance of samples cured at the same temperature for varying times to 1 year. Curing at higher temperatures decreases the effective diffusivity of this waste formulation. These results are very encouraging in that leaching resistance for samples near the expected maximum

vault temperature (55°C) show effective diffusion coefficients (Deffective ~10⁻⁸ cm²/sec) that agree with previous work and values that are believed to adequately protect the groundwater.

The isothermal conditions of these tests simulate the nearly adiabatic conditions existing near the centerline of the monolith. However the elevated temperatures due to hydration heat do decrease over long times, which has been simulated by a series (1X) of staged isothermal cures. Since the modeling indicated that it would take nearly two years for emplaced grouts to cool to near ambient temperatures, accelerated (2X) cooling curves were also tested. Specimens cured under these staged-isothermal conditions appear to be no different than specimens cured under isothermal conditions for about the same time at the maximum temperature.

The unexpected generation of nitrous oxide within saltstone, (promoted by the combination of higher temperatures and cure times at such temperatures), create internal stresses which cause fracturing when exposed to leaching conditions. Such fracturing is not considered significant for saltstone emplaced in engineered vaults for disposal.

BACKGROUND

This study was initiated in response to reports from the Hanford Grout program which claimed that their waste forms became seriously less resistant to the diffusive release of salts as a consequence of curing at temperatures representative of adiabatic heating in the pour (>75°C).

Prior experience at SRTC with simulated Hanford salt wastes demonstrated that a much higher adiabatic maximum temperature (chemical hydration heating) was to be expected with their wastes than with SRS wastes. When these chemical heats are combined with the long-term radiolytic heating and thermal isolation of their disposal vault scheme, Hanford expects high grout temperatures to extend well beyond the time of curing where chemical heat is evolved. Our saltstone, on the other hand, has consistently shown more moderate adiabatic heating, <75°C, and has no significant radiolytic thermal input. Nevertheless, centerline temperatures in the vault cells filled with grout can be expected to remain within the range of anticipated adiabatic temperatures for much longer periods than we have investigated previously. This study was designed to investigate the leaching behavior of sodium, nitrate, and chromium ions from specimens subjected to differing thermal histories to demonstrate if any unforeseen degradation of salt retention behavior may result.

METHODOLOGY

Saltstone grouts were mixed from simulated waste salt solution (modified by the addition of 1000 ppm chromium, added as $K_2Cr_2O_7$) and the reference blend of solids consisting of Portland type II cement, ground blast furnace slag, and flyash (see table 1). Portions of the grout were cast into polythene-lined glass curing vials, (to obtain surface characteristics consistent with past studies), which were sealed by glass fusion (to assure no water loss over the thermal exposure period), and placed in thermostatically controlled ovens ($\pm 5^\circ C$). Four sets of nine samples of grout were prepared initially and started their cures at ambient, ($25^\circ C$), and in 3 ovens with mean temperatures of 55, 75 and $95^\circ C$. After periods of 1, 2, 3, 6, and 12 months, samples cured at each temperature were removed, cooled, sectioned (to provide physical examination slices and leach specimens of required dimensions) and subjected to 90 days of leaching under the ANS 16.1 protocol. Other samples were moved sequentially to other ovens set at 10° intervals to simulate modeled cooling curves calculated by A. D. Yu¹ until such time as the modeling predicts a temperature of $<35^\circ C$, whereupon these samples will be cooled to ambient, and treated in the same way as those cured at a constant temperature. A second series of samples were cured at varying temperatures but following a cooling curve that is twice as steep as that modeled by Yu (see figure 1)

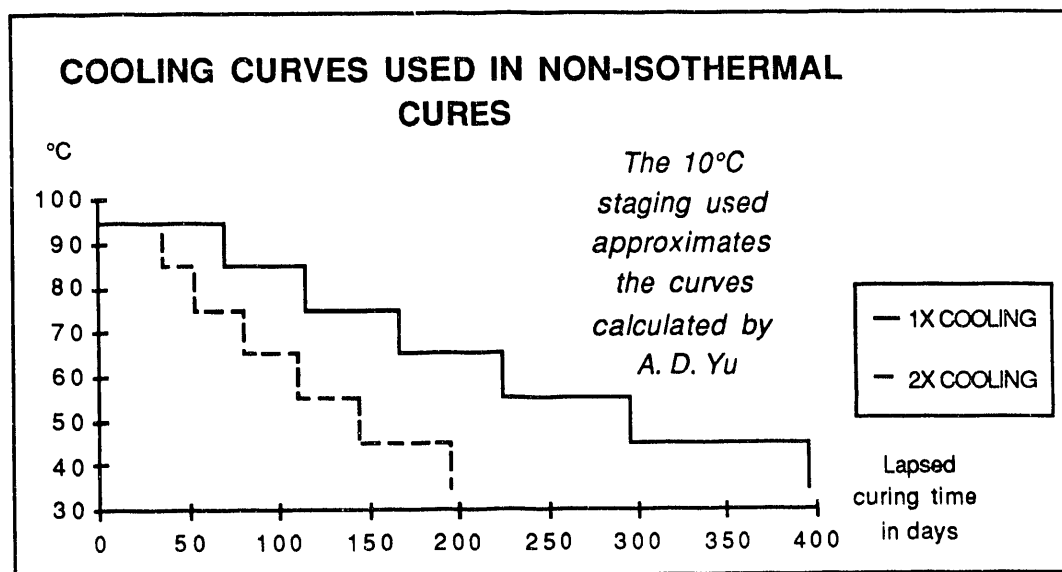


Figure 1 Staged cooling curves used in the non-isothermal curing of saltstone.
Initial temperatures of 55, 75 and $95^\circ C$ were used.

¹ A. D. Yu to W. E. Stevens, "Saltstone Vault Temperature Predictions (U)", IWT-LLW-90-0241, June 7 1990 and WSRC-TR-90-280, July 2, 1990.

The remaining samples served as spares to be used as needed. The preparation and curing of these grouts were carried out under a QA controlled procedure². The leaching of these cured grouts under the protocols of ANS 16.1³ is covered under a separate QA procedure⁴ (see table 2). Leaching data consists of analyses for sodium, nitrate and chromium for each of the 11 leachant changes and samplings over the 90 day test. The quality parameter sought in this study, the effective diffusion coefficient, D_{eff} , is calculated according to the procedures specified by ANS³ from the fraction leached of the selected analytes. Archival samples were also collected for backup should any one leachate analyze to give statistically improbable results.

The leachate was assayed for sodium, nitrate, and chromium to provide the basis for the determination of the characteristic diffusion index for monovalent cations and anions and to evaluate the effectiveness of the slag as a chemical inhibitor to the migration of dichromate. Analysis of the leachate was performed by SRTC's Analytical Development Section methods: ICP#1500 (sodium), IC#2306 (nitrate), and ICP#1500 (chromium).

TABLE 1

GROUT FORMULATION AND LEACH SPECIMEN PREPARATION

Binder blend:	slag 47.2%	Grout formulation:	
	fly ash 47.2%		binder 53.0%
	type II cement 5.6%		ref. salt solution 47.0%
Dimensions of leach specimen:		Leachant specs:	
	diameter 1.84 in.		volume of leachant 710 ml
	thickness 1.00 in.		depth of leachant 3.1 in.
	avg. weight 73. gms		diameter of vessel 4.07 in.

² E.G. Orebaugh, "Preparation of saltstone and its curing in the study of thermal history during curing on the leach index.(U)", Manual L12.1, Procedure IWT-OP-035, July 24, 1990.

³ American Nuclear Society, Standards Committee, "Measurement of the leachability of solidified low-level radioactive wastes by a short-term test procedure.", ANSI/ANS-16.1-1986, April 14, 1986

⁴ E.G. Orebaugh, "Leaching saltstone specimens to study the effects of thermal history during curing on performance(U).", Manual L12.1, Procedure IWT-OP-034, Rev.1, Sept 5, 1990.

TABLE 2

LEACHING SPECIFICATIONS OF ANS 16.1 PROCEDURE

For cylinders:

Aspect ratios between 0.2 and 5.0, minimum dimension 1 cm., cut or cast surfaces free of macro-voids, i.e. smooth surfaces.

Leaching vessel:

Inert chemically to specimen components and leachant, size suitable to meet spacial clearance requirements, closed to limit evaporative losses.

Spacial requirements:

Leachant volume in ml shall be 10X the numeric value of the surface area in square cms, no more than 2% of the surface area may be occluded by contact with supporting surfaces, must have a minimum depth of leachant at all surfaces no less than the specimens minimum dimension, height or diameter.

Leach intervals:

" 0" an initial 30 sec. rinse	"1" after 2 hours of contact
" 2" after 7 hours of contact	"3" after 24 hours of contact
" 4" after 2 days of contact	"5" after 3 days of contact
" 6" after 4 days of contact	"7" after 5 days of contact
" 8" after 14 days of contact	"9" after 28 days of contact
"10" after 90 days of contact	

OBSERVATIONS

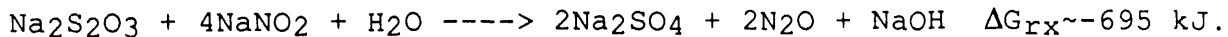
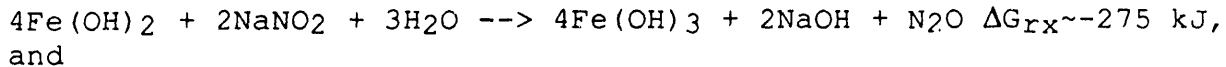
Generation of gases

The execution of the experimental design went without significant deviation for about 9 days, when it was observed that two of the specimens curing in the 95°C oven developed cracked glass envelopes. Over the next couple of weeks all of the 95° envelopes failed or were opened. Many times the only cracking was at the bottom of the sealed vials. Pressurization was not suspected as the glass tubing from which the envelopes were made has a working strength of about 100 psig compared to the maximum pressure of about 14 psig expected from water vapor pressure at 95°C. Microscopic examination of the grout from failed specimens compared to grouts cured at lower temperatures suggested the ingrowth of a possibly expansive phase.

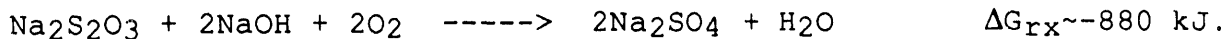
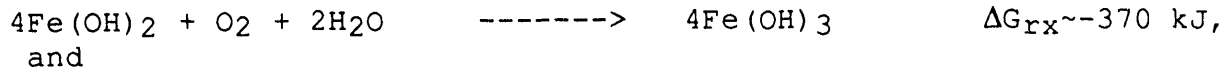
This failure mode suggested a restrained longitudinal expansion. A replacement set of specimens was prepared in which the filling level was limited to below the necking region of the vials to allow longitudinal expansion. However, this set of specimens failed by mass rupture as rapidly as the first. Now we realize that there was a synergistic rupturing in this case by flying debris. Therefore a third set of specimens was prepared for curing at 95° which were cast into 4 oz polythene bottles, over packed in a loose fitting glass envelope, which was then fusion sealed to provide a closed system. Eventually after several weeks of curing these envelopes also began to fail one at a time since they were somewhat isolated from each other.

The cured specimens are removed from the sealed glass envelope after cooling to ambient temperature by breaking the glass with a hammer blow. The "pop" sound upon breaking the rag-wrapped envelope had been thought to result from a negative internal pressure expected from the consumption of oxygen in the enclosed atmosphere. However, as the spontaneous rupturing of the envelopes continued, pressurization was concluded to be the cause of the failure. One of the remaining two intact specimens, having survived 4 months of curing at 95°, was intentionally ruptured in a gas-rack system in a helium atmosphere where accurate measures of volume and pressure could be made. These measurements showed that the internal pressure of gases in the envelope was 112 psia prior to rupture and was developed by 0.052 moles of noncondensable gases. Gas chromatographic and FTIR analysis subsequently showed these gases to be nitrous oxide, N₂O, and residual nitrogen from the original air content. The complete absence of oxygen supported original assumptions that this gas was probably consumed by reductive species in the blast furnace slag used in the solids formulation of the saltstone.

Internal generation of nitrous oxide is undoubtedly resulting from the reduction of sodium nitrite in the DWPF salt solution, by species present in the blast furnace slag used in the formulation of DWPF saltstone. The most energetic reductants are thiosulfate and ferrous ion. The assumed equations and free energy changes are:



The pertinent reactions for the consumption of oxygen in the alkaline saltstone environment are:



Approximately 0.0404 mole of N_2O was generated by the saltstone in the envelope tested. Considering only the reduction of nitrite by thiosulfate as the reductant, the slag need have only 1.6% sulfur as thiosulfate; whereas by $\text{Fe}(\text{II})$, nearly 12%, several times that available in the slag would be required. Thus, it appears likely that all the available thiosulfate and iron has reacted to form the gases observed.

Cracking of the cured grout

All saltstones cured at 95°C were found to be split into shards when they were discovered in the curing oven with their glass envelopes broken. After these grouts were cured in the soft polythene bottles sealed in glass envelopes, the cracking of the grouts could be observed through the intact polythene and glass some 4-6 weeks into the cure. Thus the cracking is not due to dehydration after the glass envelopes failed but is due to internal stresses within fully cured grouts. The cause of this was not apparent until it was determined that gases were being generated internally late in the thermal treatment of the grout.

It should be noted that the observed pressure of about 112 psia within the envelope provides no clue to the maximum internal pressures generated in the saltstone. The porosity of saltstone is mostly filled with pore liquid. Very high capillary pressures prevent the ready escape of gases generated internally. These gases can only escape by solubilization within the pore liquid, diffusive transport to the surface, and evaporation to the gas phase. Because these diffusion limited processes are slow, any rapidly developing internal pressures are likely to expand the

saltstone matrix before diffusive venting of the gases is possible. With the escape of trapped gases near the surface, the surfaces may contract somewhat, causing stress cracking typical of those cured waste forms where internal gas pressure has been observed.

After one month of curing at 95°C, an intact envelope containing uncracked grout was sectioned into leach specimens and subjected to the ANS 16.1 leaching protocol. These specimens spontaneously fractured into ever smaller shards over the first day of contact with deionized leach water. Since it is impossible to estimate the surface area, and the depletion depth due to salt loss rapidly approaches the center line of small shards, no estimation of leach index has been possible with grouts cured at 95°C.

Grout cured at 75°C for 1 month was unfractured when removed from the glass envelopes, but developed radial cracks during the first day of leaching. Additional cracking did not develop and these leach data have been evaluated, correcting for the increased surface area. Duplicate leach wafers cut from the specimen but not subjected to leaching have also cracked radially while stored in a sealed jar. Specimens cured for 3 months had a single longitudinal crack upon opening the envelope, similar to those displayed by 95°C cured specimens early in their cure. The evidence suggests that specimens of grout cured at 75°C do generate lesser quantities of gas over the time of the isothermal curing, but this quantity of internally trapped gas when released by diffusion to either the leachant or the atmosphere does not generate the higher level of tensional stresses seen in the 95°C cured grouts.

To clarify if there is a threshold for the generation of nitrous oxide in these waste forms, grout was cured in a Parr Bomb reactor equipped with pressure gages to indicate the onset and rate of gas generation at different temperatures.

Summary of gas generation in the Parr Bomb reactor

Saltstone was cured in a Parr Bomb reactor, first at 95°C and later at 55°C. Pressures were generated at both temperatures as shown in figure 2. While over 40 psi pressures were generated in the reactor head spaces at 95°C over a 45 day period, only about 17 psi pressure was generated by an identical test cure at 55°C run over about 120 days.

The pressure rises shown in figure 2 suggest that the gases are developed rapidly at 95°C within the saltstone matrix, and escape to the reactor's head space at a linear rate for the first 30 days or so. The decreasing rate of pressure rise after this time suggests that the source pressure is dropping or that the diffusion path way is increasing as the surface gases are lost out

of the saltstone. The latter is the more probable mechanism since diffusion through the pore fluids by the slightly soluble gas is compatible with the known chemistry and physics. The 55°C test data for day 37 appears to break those data trends into two curves. Two curves could be explained if the saltstone gases diffuse out of the top surface of the casting in the reactor during the first period, followed by a shrinking and separation of the saltstone from the glass vessel after about 5 weeks, which creates new surfaces from which gas is again rapidly lost. The maximum pressures observed in either the 55 or 95°C tests are not believed to even approach ultimate pressures, if diffusion is the limiting gas release mechanism. The 95°C test would be expected to generate higher pressures in the reactor head space because nitrous oxide solubility in the alkaline pore solution and the diffusion rates of this gas in pore solutions are highly temperature dependent.

The rupturing of the sealed glass envelopes at pressures of around 125 psi suggest that the high internal pressures in the saltstone generated by the nitrous oxide are less than either the yield strength of the cementitious matrix or the capillary suction of the pore solution in the largest of the matrix capillaries. Therefore, the gas must be generated after the saltstone has attained sufficient strength to inhibit swelling and to prevent the attendant stress to the glass envelope. Such swelling would surely stress the glass more than ~ 100 psi (working strength of the glass used to fabricate those envelopes).

Therefore, from the data accumulated it appears that the gas generating reactions begin after the initial set of the saltstone and most probably proceed to completion fairly early in the cure. It is impossible to determine if there is an activation temperature for the gas generating reaction from the Parr bomb reactor experimental set up. The Parr reactor heating jacket was heated proportionally by an electrical current driven by a difference between a thermocouple signal and a reference voltage set to give a null difference at 55 or 95°C. Since the thermocouple was located at the center line of the specimen, exothermic reaction heat can raise the centerline temperature well above the reference temperature, causing the heater to go to zero power until sufficient heat was lost to the surrounding air to bring the centerline temperature back to the vicinity of the set point. This behavior was recorded during the first few hours of operation of the 55°C experiment. After about 2 hours the temperature reached a maximum of 67°C at the centerline before it began to decrease, allowing the controller to maintain a 55±5°C temperature for the 120 day test. This unusual early exothermic behavior is unexplained and inconsistent with adiabatic calorimeter test results.

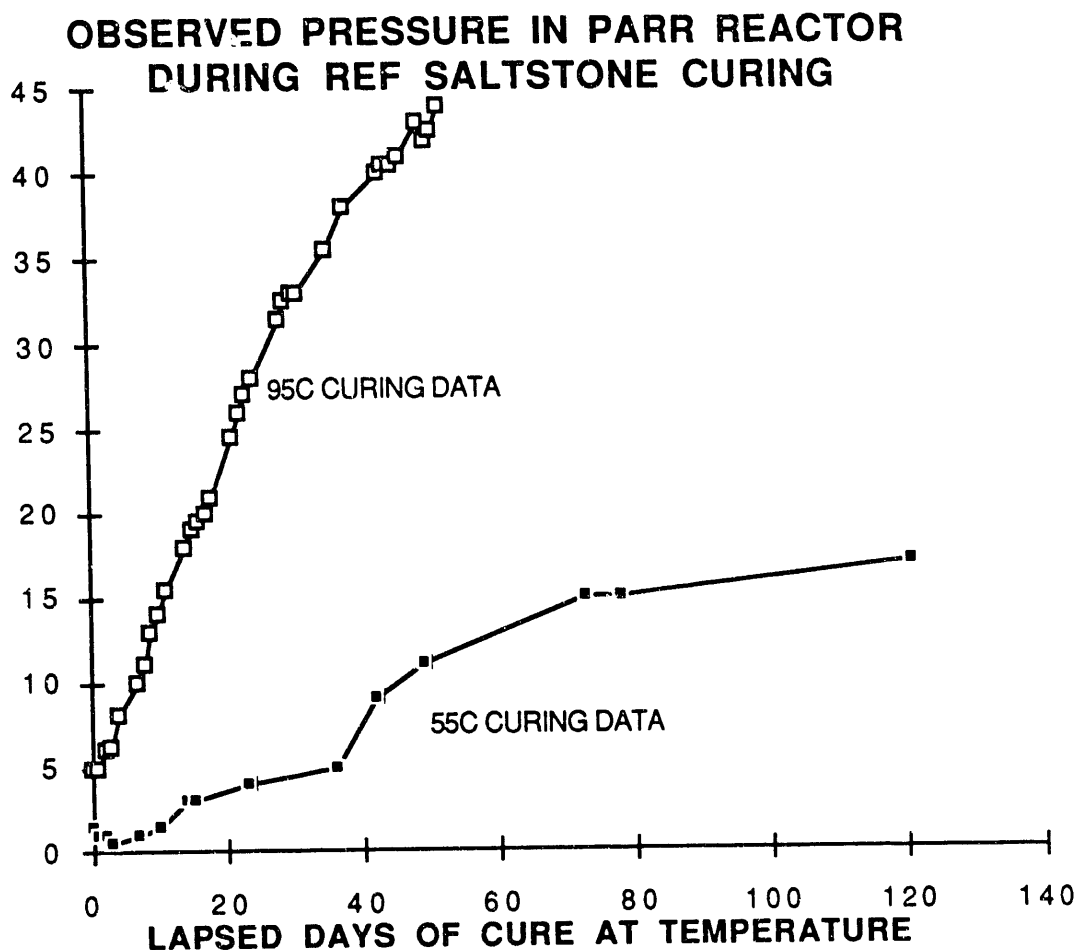


Figure 2 Plot of the observed pressure (PSIG) of gas within the Parr reactor when used to cure the reference saltstone at 55 and 95°C.

Conclusions on gas generation

Nitrous oxide gas generation within Z-area saltstone must be assumed to occur from these test results. The expected temperatures for vault filling are well above 55°C observed here to produce nitrous oxide. Generation of this slightly soluble gas will introduce internal stress in the waste form, but it is not expected to cause expansion of the waste form for the reasons mentioned above. Diffusive release of nitrous oxide from the saltstone can be considered a non-event since the gas is non-toxic, nonflammable and noncorrosive. The fracturing observed upon exposure to leaching conditions should be mitigated by the diffusive release of these gases over the long lifetime of the protective vault. Such mitigation could not be verified by the methodology employed in this study.

RESULTS OF LEACHING TESTS

Summary

The data show no selectivity between sodium and nitrate ion leachability. Chromate leaching remained at low levels for all specimens tested, confirming its precipitation in the grout to a species having very low release potential. The fracturing of leach specimens, when observed, is not instantaneous, allowing valid computation of incremental D_{eff} from leachates collected prior to fracturing. These data have been found to be the same as that observed for specimens cured for shorter times which did not fracture during leaching. The observable increase in the leach index during the 90 day leaching period agrees with the ingrowth of an expansive phase with increasing temperature and time which tightens up the saltstone structure. All leaching tests performed were conducted without incident. No precipitates were ever observed in the leachant and the leachants have never developed any precipitates or colorations.

Data treatment

The effective diffusion coefficient, D_{eff} , and the leach index, LI, were uniformly calculated in an Excel® spread-sheet using the calculational methods specified by ANS 16.1. All analytical data has been entered into these records which in turn have been incorporated into the laboratory notebook dedicated to this study. The leaching parameters calculated from leachate data for sodium and nitrate ions are given in Data Tables 1 - 16. This data was calculated for both fractured and unfractured specimens. While incremental D_{eff} 's calculated from leachates collected after specimen fracturing are invalid, (because the fragments are no longer right cylinders and the surface area to volume ratios no longer pertain) the data collected before fracturing is totally valid. The onset of fracturing is readily apparent when the incremental D_{eff} are plotted vs their leach number by the abrupt increases in the value of D_{eff} .

All calculations in this interim report are based on average specimen dimensions. Actual dimensions and weights of specimens vary so little that their effect would be undetectable in the calculated results.

The results for chromium were all well below that which would be expected if the chromium in the waste were in a water soluble form. The fairly linear relationship between the amount of chromium in the leachate and the leaching period supports the conclusion that the chromium has been precipitated as a species of low solubility. This result assures us that curing at high

temperatures is not deleterious to the fixation of Cr(+6) by the binder formulation designed specifically for this purpose.

Graphical presentation of results

Leaching data are presented differently in the following figures. Figure 3 illustrates data for the fraction of sodium ion leached from specimens cured for 2 months vs the square root of time. Notice that the data for the 25 and 55°C cured specimens are nicely linear, while the data for the 75°C specimens are quite different. This behavior is not strange when one remembers that the 75°C specimens developed cracks shortly after beginning the leaching process. Since they did not develop the same number of cracks, the amount of sodium ion leached from each specimen differed.

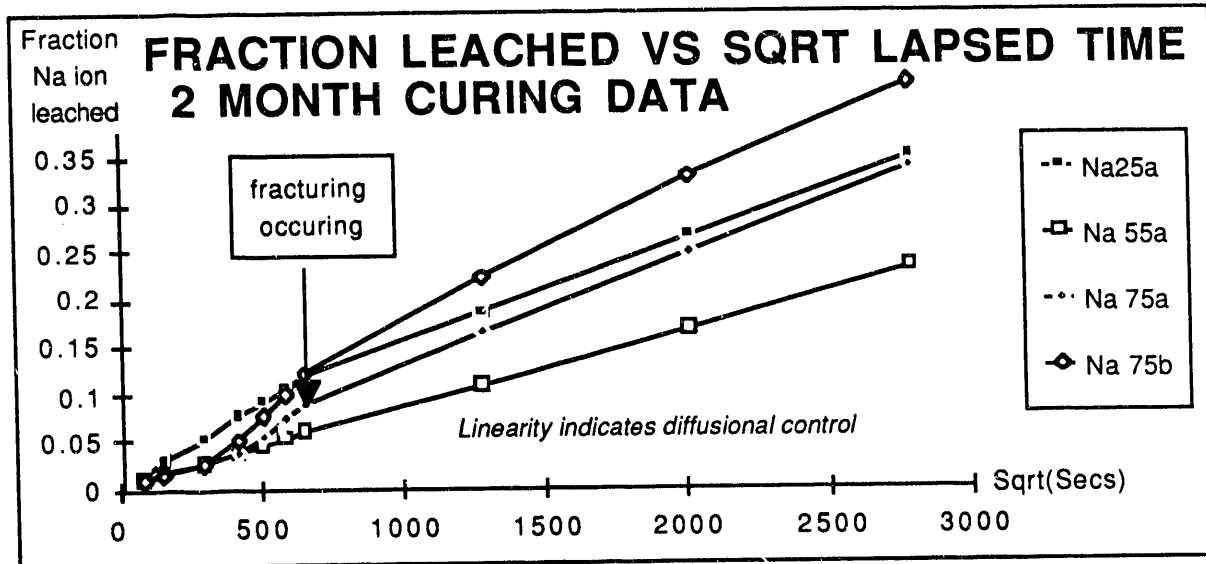


Figure 3 Plot of the fraction sodium leached vs square root of lapsed leaching time should be linear if simple diffusional leaching is occurring.

The lack of strict linearity in the trends of the noncracked specimens is proof that strict diffusional transport of the ions is not occurring. The decrease in the slope of the trends with time suggests that the diffusional path is becoming more restrictive. If solid salts constituted part of the restrictive path way, their dissolution would open up the matrix and cause the curve to increase its slope. Thus the shape of the curve suggests an expansive phase change, most probably a change in hydration of one or more of the insoluble matrix phases.

Figure 4 presents D_{eff} for sodium and nitrate ions calculated for specimens cured for 1 month at ambient (25°C), 55, and 75°C. In this series, the specimens cured at 75°C only developed 2 or 3 radial cracks. As noted in the figure, the surface area used in the calculation of D_{eff} for the 75°C cured specimens was changed during the first day from the geometric surface area of the uncracked specimens to that estimated for the specimen plus the radial cracks as they developed. This procedure "corrected" the slope of the 75°C series and kept the trends in the order established prior to cracking, compared to the 25 and 55°C series. This correction for the cracking of specimens is limited to those having only a few radial cracks where the increase in surface area can be approximated. However successful the correction appears to be, it is not valid by the modeling upon which the calculational procedures are based. Plotting the data on a log scale of time attempts to emphasize the apparent exponential variation of the data with time.

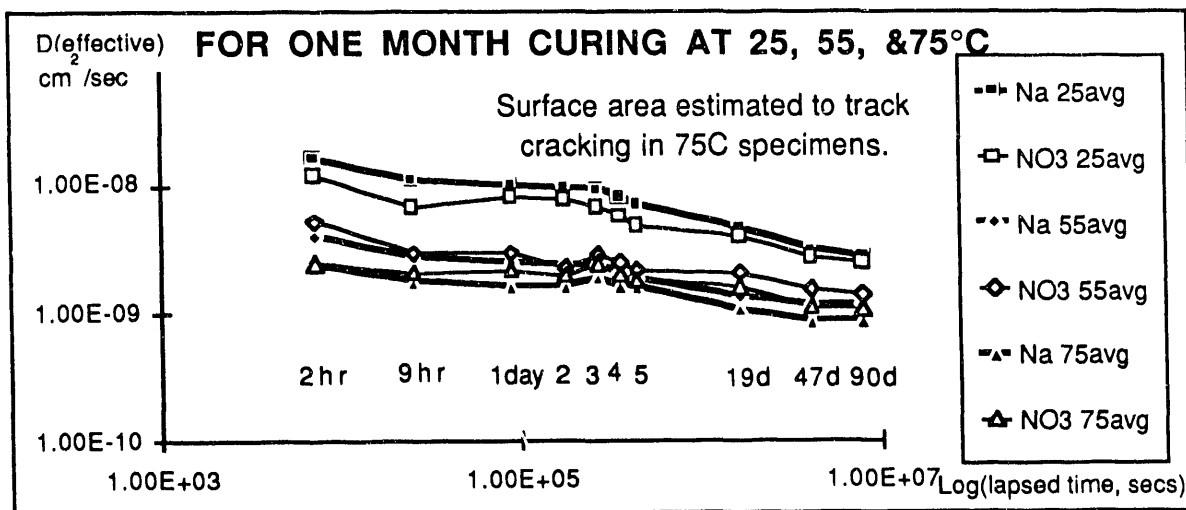


Figure 4 Log plot of the calculated sodium effective diffusion coefficient vs the lapsed leaching time at which the incremental calculation was made.

The following plots (figures 5-8) present the average sodium and nitrate diffusion coefficients for 25 and 55°C cured specimens with different curing times vs the incremental leach number. The data are clearly grouped according to curing temperature but curing time appears to have no clear influence. Even after a year of curing, ambient (25°C) cured specimens were not observed to crack

during the 90 day leaching. However, a year of curing at 55°C was sufficient to cause minor (cleavage via 2 radial cracks and a single radial crack in the duplicate) cracking in the specimens during the 90 day exposure.

The temporary increase in calculated D_{eff} for leach intervals 6 & 7 of specimens cured for 6 months (see figs.5-8) is believed to be due to contamination of the leachate before the analytical samples were collected.

After fracturing of the 55°C - 1 year cured leach specimen has occurred during leaching, the data are clearly abnormal and thus the calculated D_{eff} is not valid. However, even though the surface area was increased many fold by fracturing, and leaching was greatly enhanced, the "calculated" D's are not that badly increased in magnitude.

Figures 9 - 12 attempt to summarize the leaching characteristics of specimens cured under non-isothermal conditions. As with the specimens cured under isothermal conditions there is no difference between cationic and anionic diffusion, little differences in D_{eff} for specimens cured under isothermal and non-isothermal conditions but large differences in the cracking behavior. Comparing figures 9 & 11 it is clear that specimens curing for longer periods at a given temperature develop more stress and crack earlier in the leaching process. The accelerated (2X) non-isothermal cure induces much less stress in specimens, than the modeled cooling curves. Indeed the 2X data shows no sign of cracking, comparable to a 1 month 75°C isothermal cure. This is as one should expect from figure 1 which shows that under the accelerated cure schedule these specimens were held for about 1 month at 75 before being cooled to the 65°C curing stage. Remember that the apparent cracking behavior in the 6 month data at 55°C is believed to be experimental error, as these specimens did not crack during leaching.

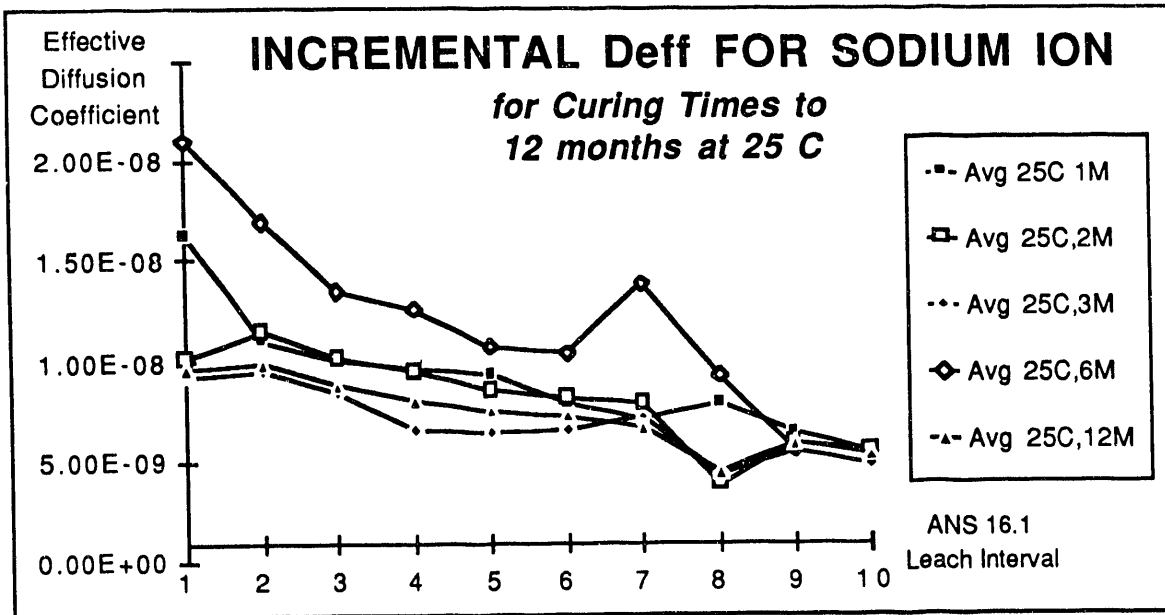


Figure 5 Calculated D-effectives from sodium ion leached at intervals specified by the ANS 16.1 for specimens cured for 1 to 12 months at 25°C. No cracking observed during leaching for any of these specimens.

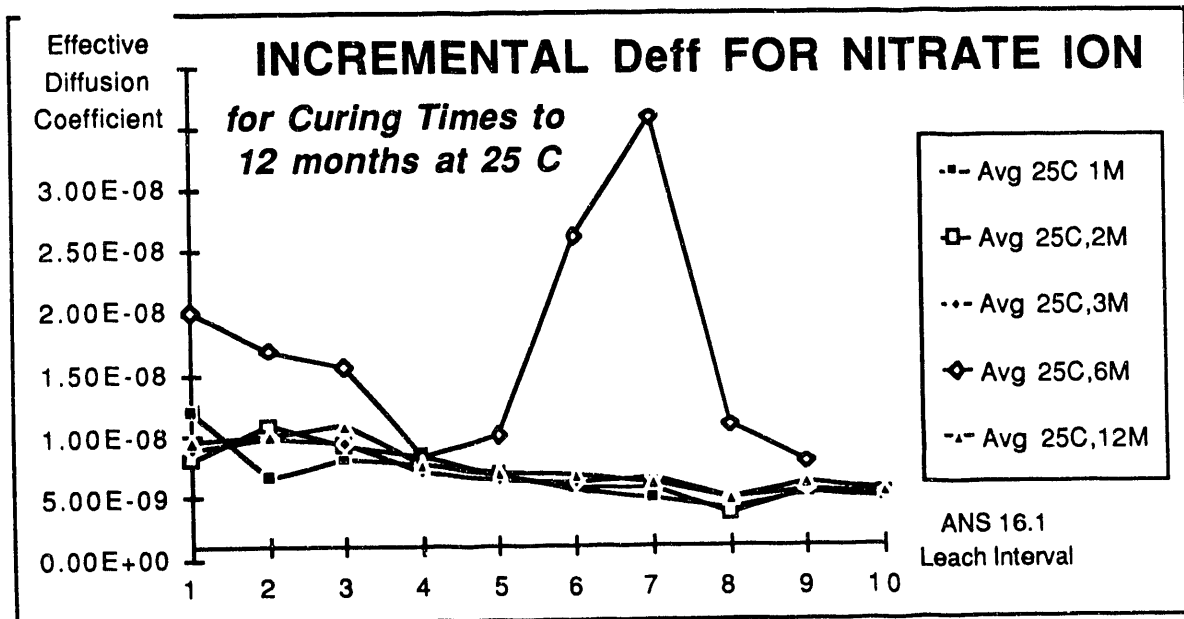


Figure 6 Calculated D-effectives from nitrate ion leached at intervals specified by the ANS 16.1 for specimens cured for 1 to 12 months at 25°C.

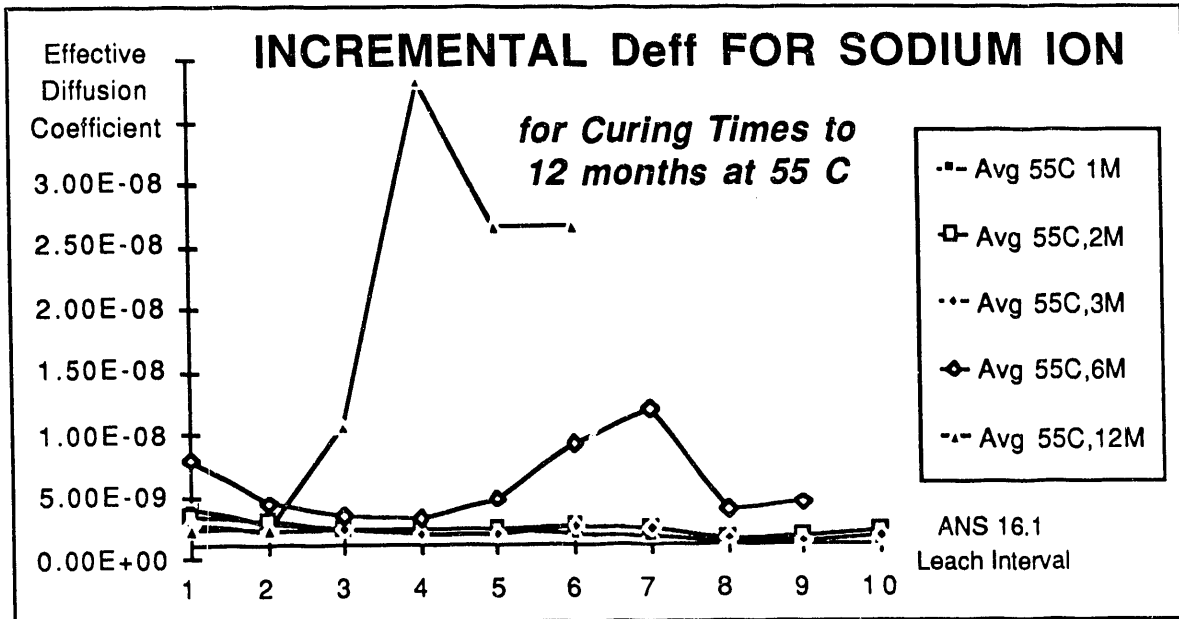


Figure 7 Calculated D-effectives from sodium ion leached at intervals specified by the ANS 16.1 for specimens cured for 1 to 12 months at 55°C. Radial cracking observed during leaching of 12M specimens only.

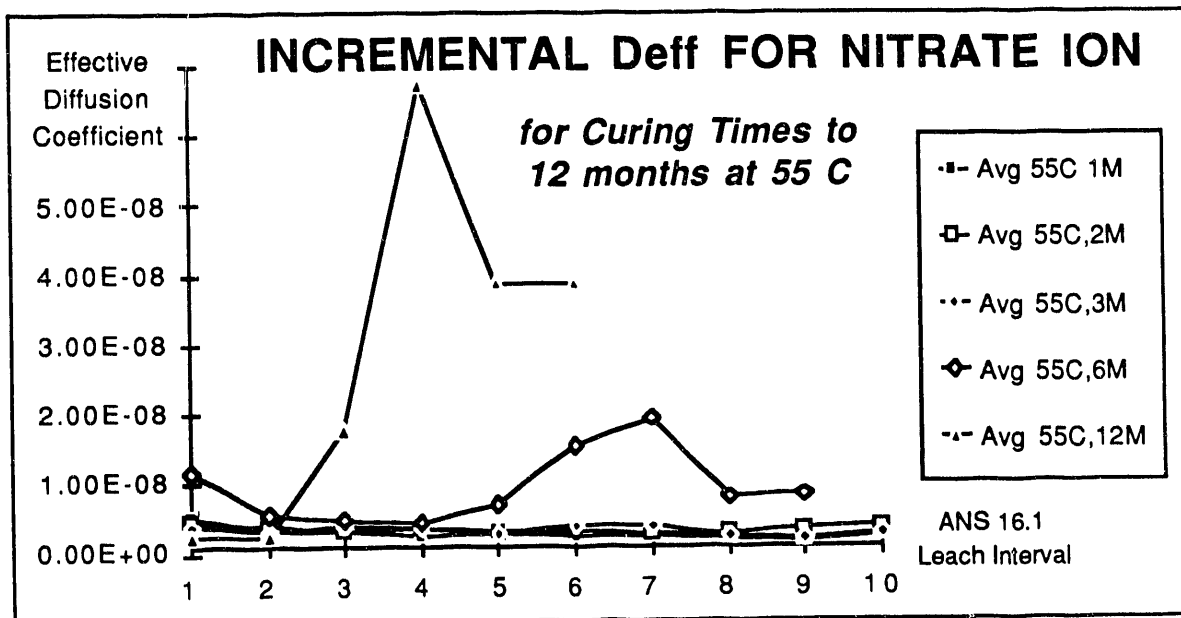


Figure 8 Calculated D-effectives from nitrate ion leached at intervals specified by the ANS 16.1 for specimens cured for 1 to 12 months at 55°C.

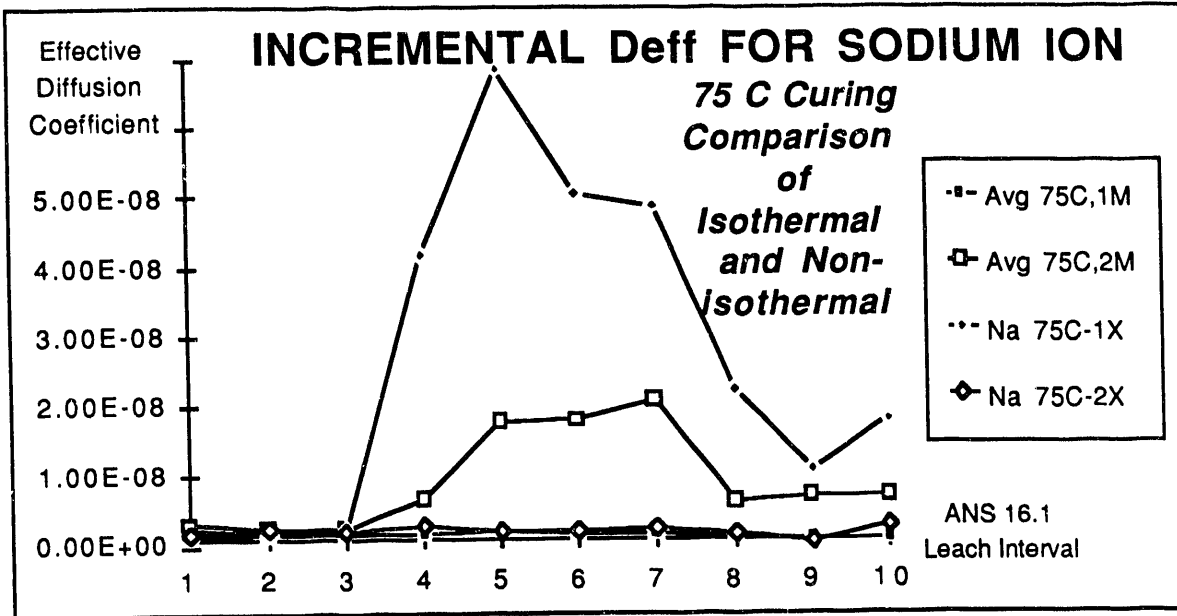


Figure 9 Calculated D-effectives from sodium ion leached at intervals specified by the ANS 16.1 for specimens cured along cooling curves starting at 75°C.

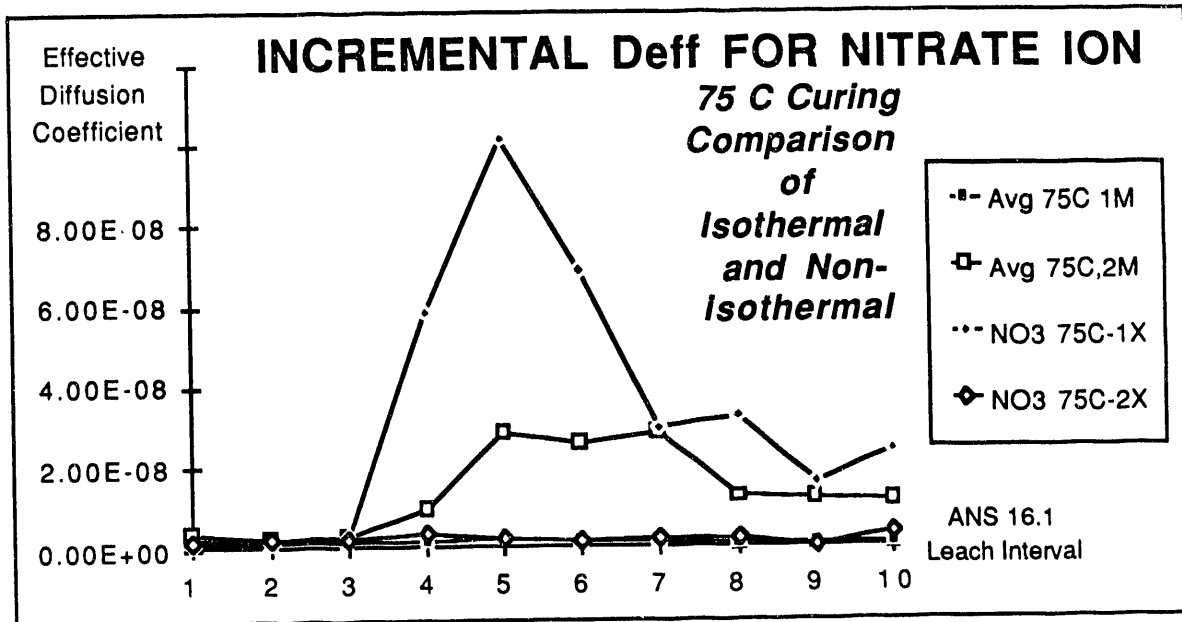


Figure 10 Calculated D-effectives from nitrate ion leached at intervals specified by the ANS 16.1 for specimens cured along cooling curves starting at 75°C.

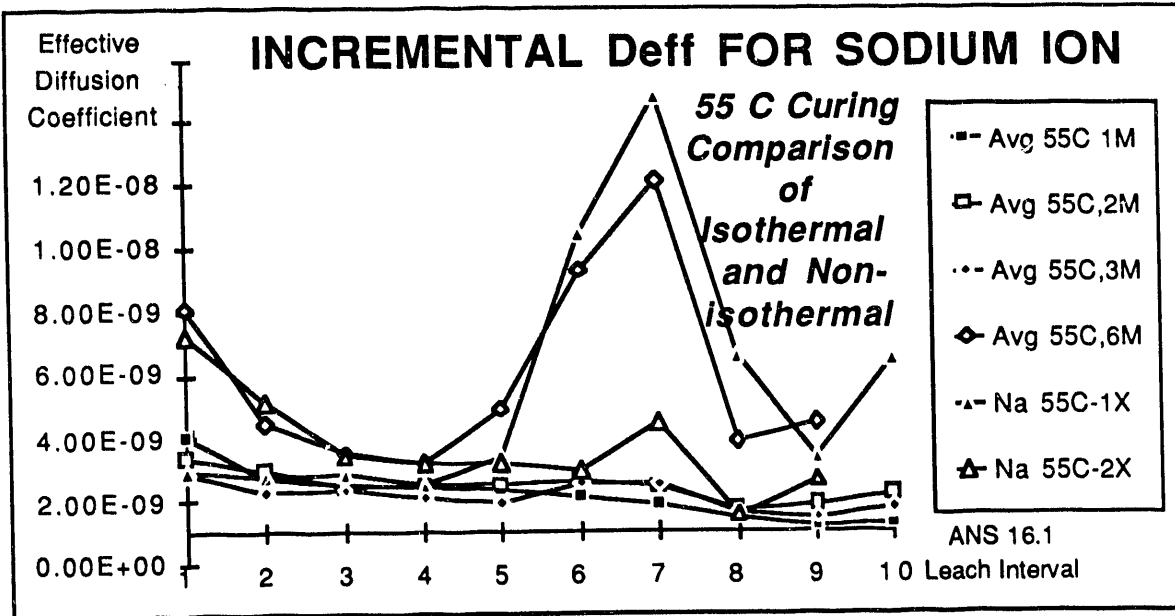


Figure 11 Calculated D-effectives from sodium ion leached at intervals specified by the ANS 16.1 for specimens cured along cooling curves starting at 55°C.

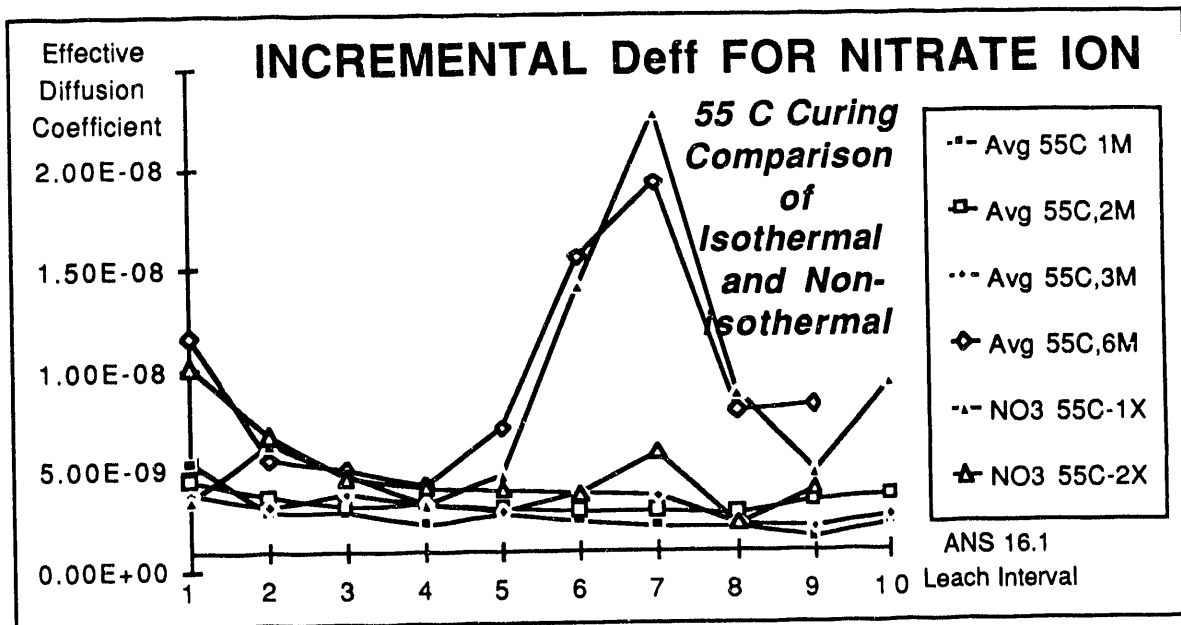


Figure 12 Calculated D-effectives from nitrate ion leached at intervals specified by the ANS 16.1 for specimens cured along cooling curves starting at 55°C.

DATA TABLES

The following tables of data present the incremental effective diffusion coefficient and the leach index as computed from the method given by ANS 16.1. Column 1 provides the identification of the specimen being leached, i.e., 25°C curing, for 1 month, leach number per the ANS procedure.

TABLE 1
DATA FOR SPECIMENS CURED 1 MONTH AMBIENT (~25°C)

	Calc by ANS 16.1(Incremental)		Leach Index	
	$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO ₃ ion
25-1M #0	#N/A	#N/A	0.0	0.0
25-1M #1	1.50E-08	1.03E-08	7.8	8.0
25-1M #2	9.70E-09	4.95E-09	7.9	8.1
25-1M #3	9.10E-09	6.49E-09	8.0	8.2
25-1M #4	9.07E-09	6.84E-09	8.0	8.2
25-1M #5	8.96E-09	6.33E-09	8.0	8.2
25-1M #6	7.68E-09	5.19E-09	8.0	8.2
25-1M #7	6.97E-09	4.45E-09	8.0	8.2
25-1M #8	7.96E-09	3.78E-09	8.1	8.2
25-1M #9	6.16E-09	4.77E-09	8.1	8.2
25-1M #10	5.41E-09	4.39E-09	8.1	8.3
25D-1M #0	#N/A	#N/A	0.0	0.0
25D-1M #1	1.75E-08	1.38E-08	7.8	7.9
25D-1M #2	1.22E-08	8.47E-09	7.8	8.0
25D-1M #3	1.10E-08	9.37E-09	7.9	8.0
25D-1M #4	1.03E-08	8.55E-09	7.9	8.0
25D-1M #5	9.74E-09	7.23E-09	7.9	8.0
25D-1M #6	8.14E-09	5.97E-09	8.0	8.1
25D-1M #7	7.21E-09	5.00E-09	8.0	8.1
25D-1M #8	7.96E-09	4.16E-09	8.0	8.1
25D-1M #9	6.68E-09	5.68E-09	8.0	8.1
25D-1M #10	5.77E-09	5.05E-09	8.0	8.2

TABLE 2
DATA FOR SPECIMENS CURED 1 MONTH AT ~55°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO3 ion
55-1M	#0	#N/A	#N/A	0.0	0.0
55-1M	#1	4.20E-09	5.14E-09	8.4	8.3
55-1M	#2	2.68E-09	2.80E-09	8.5	8.4
55-1M	#3	2.43E-09	2.85E-09	8.5	8.5
55-1M	#4	2.42E-09	2.95E-09	8.5	8.5
55-1M	#5	2.36E-09	2.84E-09	8.6	8.5
55-1M	#6	2.07E-09	2.48E-09	8.6	8.5
55-1M	#7	1.86E-09	2.22E-09	8.6	8.5
55-1M	#8	1.39E-09	2.20E-09	8.6	8.5
55-1M	#9	1.21E-09	1.72E-09	8.7	8.6
55-1M	#10	1.68E-09	2.27E-09	8.7	8.6
55D-1M	#0	#N/A	#N/A	0.0	0.0
55D-1M	#1	3.94E-09	5.46E-09	8.4	8.3
55D-1M	#2	2.78E-09	3.12E-09	8.5	8.4
55D-1M	#3	2.45E-09	3.00E-09	8.5	8.4
55D-1M	#4	2.35E-09	1.64E-09	8.5	8.5
55D-1M	#5	2.33E-09	2.79E-09	8.6	8.5
55D-1M	#6	2.05E-09	2.45E-09	8.6	8.5
55D-1M	#7	1.82E-09	2.14E-09	8.6	8.6
55D-1M	#8	1.34E-09	2.04E-09	8.6	8.6
55D-1M	#9	1.10E-09	1.37E-09	8.7	8.6
55D-1M	#10	1.15E-09	2.27E-09	8.7	8.6

TABLE 3
DATA FOR SPECIMENS CURED 1 MONTH AT ~75°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO ₃ ion
75-1M	#0	#N/A	#N/A	0.0	0.0
75-1M	#1	2.61E-09	2.69E-09	8.6	8.6
75-1M	#2	2.85E-09	2.97E-09	8.6	8.5
75-1M	#3	2.54E-09	2.98E-09	8.6	8.5
75-1M	#4	2.69E-09	3.19E-09	8.6	8.5
75-1M	#5	2.80E-09	3.31E-09	8.6	8.5
75-1M	#6	2.49E-09	2.98E-09	8.6	8.5
75-1M	#7	2.35E-09	2.65E-09	8.6	8.5
75-1M	#8	1.80E-09	2.68E-09	8.6	8.5
75-1M	#9	1.57E-09	1.93E-09	8.6	8.6
75-1M	#10	2.06E-09	2.72E-09	8.6	8.6
75D-1M	#0	#N/A	#N/A	0.0	0.0
75D-1M	#1	2.12E-09	2.21E-09	8.7	8.7
75D-1M	#2	3.35E-09	4.32E-09	8.6	8.5
75D-1M	#3	4.77E-09	7.16E-09	8.5	8.4
75D-1M	#4	4.52E-09	6.11E-09	8.5	8.3
75D-1M	#5	6.28E-09	8.44E-09	8.4	8.3
75D-1M	#6	5.06E-09	6.43E-09	8.4	8.3
75D-1M	#7	5.38E-09	5.97E-09	8.4	8.3
75D-1M	#8	3.31E-09	4.73E-09	8.4	8.3
75D-1M	#9	3.57E-09	5.21E-09	8.4	8.3
75D-1M	#10	3.49E-09	4.70E-09	8.4	8.3

TABLE 4
DATA FOR SPECIMENS CURED 1 MONTH AT ~95°C
(Specimen cracked during leaching)

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO3 ion
95-1M	#0	#N/A	#N/A	0.0	0.0
95-1M	#1	3.65E-09	5.30E-09	8.4	8.3
95-1M	#2	4.23E-09	5.90E-09	8.4	8.3
95-1M	#3	5.75E-09	7.98E-09	8.4	8.2
95-1M	#4	9.08E-09	1.29E-08	8.3	8.1
95-1M	#5	7.28E-09	1.08E-08	8.2	8.1
95-1M	#6	8.50E-09	1.31E-08	8.2	8.1
95-1M	#7	8.49E-09	1.23E-08	8.2	8.0
95-1M	#8	5.19E-09	1.18E-08	8.2	8.0
95-1M	#9	6.16E-09	1.34E-08	8.2	8.0
95-1M	#10	6.56E-09	1.35E-08	8.2	8.0
95D-1M	#0	#N/A	#N/A	0.0	0.0
95D-1M	#1	3.12E-09	4.59E-09	8.5	8.3
95D-1M	#2	3.46E-09	4.88E-09	8.5	8.3
95D-1M	#3	3.26E-09	4.96E-09	8.5	8.3
95D-1M	#4	5.47E-09	8.69E-09	8.4	8.3
95D-1M	#5	6.04E-09	9.12E-09	8.4	8.2
95D-1M	#6	6.77E-09	9.37E-09	8.4	8.2
95D-1M	#7	1.00E-08	1.68E-08	8.3	8.1
95D-1M	#8	3.42E-09	7.96E-09	8.3	8.1
95D-1M	#9	4.35E-09	8.40E-09	8.3	8.1
95D-1M	#10	4.39E-09	8.82E-09	8.3	8.1

TABLE 5
DATA FOR SPECIMENS CURED 2 MONTHS AT ~25°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO ₃ ion
25-2M	#0	#N/A	#N/A	0.0	0.0
25-2M	#1	8.43E-09	6.18E-09	8.1	8.2
25-2M	#2	1.13E-08	1.10E-08	8.0	8.1
25-2M	#3	9.93E-09	9.11E-09	8.0	8.1
25-2M	#4	9.68E-09	8.41E-09	8.0	8.1
25-2M	#5	8.89E-09	6.75E-09	8.0	8.1
25-2M	#6	7.82E-09	5.29E-09	8.0	8.1
25-2M	#7	7.56E-09	5.71E-09	8.0	8.1
25-2M	#8	3.64E-09	3.17E-09	8.1	8.2
25-2M	#9	5.68E-09	4.77E-09	8.1	8.2
25-2M	#10	5.41E-09	4.70E-09	8.1	8.2
25D-2M	#0	#N/A	#N/A	0.0	0.0
25D-2M	#1	1.18E-08	9.67E-09	7.9	8.0
25D-2M	#2	1.16E-08	1.04E-08	7.9	8.0
25D-2M	#3	1.04E-08	9.50E-09	7.9	8.0
25D-2M	#4	9.43E-09	8.27E-09	8.0	8.0
25D-2M	#5	8.30E-09	6.87E-09	8.0	8.1
25D-2M	#6	8.52E-09	6.45E-09	8.0	8.1
25D-2M	#7	8.26E-09	6.05E-09	8.0	8.1
25D-2M	#8	4.02E-09	4.05E-09	8.1	8.1
25D-2M	#9	6.16E-09	6.16E-09	8.1	8.1
25D-2M	#10	5.77E-09	5.77E-09	8.1	8.2

TABLE 6
DATA FOR SPECIMENS CURED 2 MONTHS AT ~55°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO_3 ion
55-2M	#0	#N/A	#N/A	0.0	0.0
55-2M	#1	3.30E-09	4.56E-09	8.5	8.3
55-2M	#2	2.75E-09	3.65E-09	8.5	8.4
55-2M	#3	2.14E-09	2.76E-09	8.6	8.4
55-2M	#4	2.22E-09	2.88E-09	8.6	8.5
55-2M	#5	2.23E-09	2.77E-09	8.6	8.5
55-2M	#6	2.36E-09	2.54E-09	8.6	8.5
55-2M	#7	2.21E-09	2.61E-09	8.6	8.5
55-2M	#8	1.72E-09	2.90E-09	8.6	8.5
55-2M	#9	1.95E-09	3.57E-09	8.6	8.5
55-2M	#10	2.27E-09	3.79E-09	8.6	8.5
55D-2M	#C	#N/A	#N/A	0.0	0.0
55D-2M	#1	3.37E-09	4.49E-09	8.5	8.3
55D-2M	#2	3.12E-09	3.65E-09	8.5	8.4
55D-2M	#3	2.70E-09	3.47E-09	8.5	8.4
55D-2M	#4	2.75E-09	3.69E-09	8.5	8.4
55D-2M	#5	2.74E-09	3.40E-09	8.5	8.4
55D-2M	#6	2.85E-09	3.35E-09	8.5	8.4
55D-2M	#7	2.61E-09	3.10E-09	8.5	8.4
55D-2M	#8	1.63E-09	2.59E-09	8.6	8.5
55D-2M	#9	1.81E-09	3.22E-09	8.6	8.5
55D-2M	#10	2.06E-09	3.49E-09	8.6	8.5

TABLE 7
DATA FOR SPECIMENS CURED 2 MONTHS AT ~75°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
75-2M	#0	#N/A	#N/A	0.0	0.0
75-2M	#1	2.97E-09	4.19E-09	8.5	8.4
75-2M	#2	2.26E-09	2.77E-09	8.6	8.5
75-2M	#3	2.25E-09	3.10E-09	8.6	8.5
75-2M	#4	2.60E-09	3.25E-09	8.6	8.5
75-2M	#5	1.05E-08	1.48E-08	8.5	8.4
75-2M	#6	1.29E-08	1.85E-08	8.4	8.2
75-2M	#7	1.41E-08	2.26E-08	8.3	8.2
75-2M	#8	4.43E-09	8.84E-09	8.3	8.1
75-2M	#9	4.77E-09	8.40E-09	8.3	8.1
75-2M	#10	5.05E-09	8.34E-09	8.3	8.1
75D-2M	#0	#N/A	#N/A	0.0	0.0
75D-2M	#1	2.85E-09	3.81E-09	8.5	8.4
75D-2M	#2	2.26E-09	2.77E-09	8.6	8.5
75D-2M	#3	2.12E-09	2.87E-09	8.6	8.5
75D-2M	#4	1.08E-08	1.61E-08	8.5	8.3
75D-2M	#5	2.46E-08	4.27E-08	8.3	8.1
75D-2M	#6	2.29E-08	3.41E-08	8.2	8.0
75D-2M	#7	2.72E-08	3.56E-08	8.1	7.9
75D-2M	#8	9.77E-09	1.65E-08	8.1	7.9
75D-2M	#9	8.99E-09	1.60E-08	8.1	7.9
75D-2M	#10	8.82E-09	1.49E-08	8.1	7.9

TABLE 8
DATA FOR SPECIMENS CURED 3 MONTHS AT ~25°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO3 ion
25-3M	#0	#N/A	#N/A	0.0	0.0
25-3M	#1	9.6E-09	9.87E-09	8.0	8.0
25-3M	#2	9.6E-09	1.02E-08	8.0	8.0
25-3M	#3	8.3E-09	9.50E-09	8.0	8.0
25-3M	#4	6.6E-09	7.09E-09	8.1	8.0
25-3M	#5	6.5E-09	6.30E-09	8.1	8.1
25-3M	#6	6.1E-09	5.99E-09	8.1	8.1
25-3M	#7	7.0E-09	6.49E-09	8.1	8.1
25-3M	#8	4.1E-09	4.87E-09	8.2	8.1
25-3M	#9	5.21E-09	5.68E-09	8.2	8.1
25-3M	#10	4.70E-09	5.41E-09	8.2	8.2
25D-3M	#0	#N/A	#N/A	0.0	0.0
25D-3M	#1	9.0E-09	8.09E-09	8.0	8.1
25D-3M	#2	9.4E-09	9.31E-09	8.0	8.1
25D-3M	#3	8.6E-09	9.24E-09	8.0	8.1
25D-3M	#4	6.7E-09	7.09E-09	8.1	8.1
25D-3M	#5	6.5E-09	6.45E-09	8.1	8.1
25D-3M	#6	7.1E-09	6.52E-09	8.1	8.1
25D-3M	#7	7.3E-09	6.82E-09	8.1	8.1
25D-3M	#8	4.7E-09	4.57E-09	8.1	8.1
25D-3M	#9	5.68E-09	5.68E-09	8.2	8.2
25D-3M	#10	5.05E-09	5.05E-09	8.2	8.2

TABLE 9
DATA FOR SPECIMENS CURED 3 MONTHS AT ~55°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
55-3M	#0	#N/A	#N/A	0.0	0.0
55-3M	#1	3.1E-09	3.66E-09	8.5	8.4
55-3M	#2	2.5E-09	3.15E-09	8.6	8.5
55-3M	#3	2.5E-09	3.87E-09	8.6	8.5
55-3M	#4	2.3E-09	3.24E-09	8.6	8.5
55-3M	#5	2.1E-09	2.86E-09	8.6	8.5
55-3M	#6	3.1E-09	4.48E-09	8.6	8.5
55-3M	#7	3.0E-09	4.21E-09	8.6	8.4
55-3M	#8	1.8E-09	2.59E-09	8.6	8.5
55-3M	#9	1.5E-09	1.99E-09	8.6	8.5
55-3M	#10	1.87E-09	2.72E-09	8.6	8.5
55D-3M	#0	#N/A	#N/A	0.0	0.0
55D-3M	#1	2.6E-09	3.79E-09	8.6	8.4
55D-3M	#2	2.0E-09	3.06E-09	8.6	8.5
55D-3M	#3	2.2E-09	3.68E-09	8.6	8.5
55D-3M	#4	1.9E-09	3.26E-09	8.7	8.5
55D-3M	#5	1.8E-09	2.85E-09	8.7	8.5
55D-3M	#6	2.0E-09	2.94E-09	8.7	8.5
55D-3M	#7	1.9E-09	3.13E-09	8.7	8.5
55D-3M	#8	1.3E-09	2.08E-09	8.7	8.5
55D-3M	#9	1.4E-09	2.15E-09	8.7	8.5
55D-3M	#10	1.68E-09	2.49E-09	8.7	8.5

TABLE 10
DATA FOR SPECIMENS CURED 6 MONTHS AT ~25°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO3 ion
25-6M	#0	#N/A	#N/A	0.0	0.0
25-6M	#1	1.98E-08	2.06E-08	7.7	7.7
25-6M	#2	1.67E-08	1.72E-08	7.7	7.7
25-6M	#3	1.36E-08	1.62E-08	7.8	7.7
25-6M	#4	1.17E-08	1.03E-08	7.8	7.8
25-6M	#5	1.07E-08	9.60E-09	7.8	7.8
25-6M	#6	1.02E-08	4.23E-08	7.9	7.8
25-6M	#7	1.38E-08	5.64E-08	7.9	7.7
25-6M	#8	8.84E-09	1.29E-08	7.9	7.7
25-6M	#9	6.04E-09	7.75E-09	7.9	7.8
25-6M	#10	Leaching time	exceeded no	analysis	attempted
25D-6M	#0	#N/A	#N/A	0.0	0.0
25D-6M	#1	2.21E-08	2.00E-08	7.7	7.7
25D-6M	#2	1.71E-08	1.69E-08	7.7	7.7
25D-6M	#3	1.34E-08	1.50E-08	7.8	7.8
25D-6M	#4	1.35E-08	6.35E-09	7.8	7.9
25D-6M	#5	1.07E-08	1.06E-08	7.8	7.9
25D-6M	#6	1.05E-08	1.02E-08	7.9	7.9
25D-6M	#7	1.38E-08	1.53E-08	7.9	7.9
25D-6M	#8	9.77E-09	8.84E-09	7.9	7.9
25D-6M	#9	5.29E-09	7.75E-09	7.9	7.9
25D-6M	#10	Leaching time	exceeded no	analysis	attempted

TABLE 11
DATA FOR SPECIMENS CURED 6 MONTHS AT ~55°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
55-6M	#0	#N/A	#N/A	0.0	0.0
55-6M	#1	7.09E-09	9.97E-09	8.1	8.0
55-6M	#2	4.09E-09	5.23E-09	8.3	8.1
55-6M	#3	3.24E-09	4.58E-09	8.3	8.2
55-6M	#4	3.00E-09	3.96E-09	8.4	8.3
55-6M	#5	4.55E-09	6.59E-09	8.4	8.2
55-6M	#6	8.59E-09	1.38E-08	8.3	8.2
55-6M	#7	1.18E-08	1.85E-08	8.3	8.1
55-6M	#8	4.16E-09	7.96E-09	8.3	8.1
55-6M	#9	4.25E-09	7.75E-09	8.3	8.1
55-6M	#10	Leaching time	exceeded no	analysis	attempted
55D-6M	#0	#N/A	#N/A	0.0	0.0
55D-6M	#1	9.08E-09	1.33E-08	8.0	7.9
55D-6M	#2	4.75E-09	5.69E-09	8.2	8.1
55D-6M	#3	3.73E-09	5.34E-09	8.3	8.1
55D-6M	#4	3.37E-09	4.63E-09	8.3	8.2
55D-6M	#5	5.25E-09	7.53E-09	8.3	8.2
55D-6M	#6	9.98E-09	1.72E-08	8.3	8.1
55D-6M	#7	1.23E-08	1.99E-08	8.2	8.0
55D-6M	#8	3.58E-09	7.96E-09	8.2	8.1
55D-6M	#9	4.59E-09	8.73E-09	8.2	8.1
55D-6M	#10	Leaching time	exceeded no	analysis	attempted

TABLE 12
DATA FOR SPECIMENS CURED 6 MONTHS AT ~75°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
75-6M	#0	#N/A	#N/A	0.0	0.0
75-6M	#1	1.05E-08	1.82E-08	8.0	7.7
75-6M	#2	1.03E-07	2.00E-07	7.5	7.2
75-6M	#3	1.50E-07	1.86E-07	7.3	7.1
75-6M	#4	8.40E-08	1.98E-07	7.2	7.0
75-6M	#5	8.90E-08	2.09E-07	7.2	6.9
75-6M	#6	9.14E-08	2.10E-07	7.2	6.9
75-6M	#7	9.09E-08	2.20E-07	7.1	6.8
75-6M	#8	4.94E-08	1.34E-07	7.2	6.8
75-6M	#9	2.07E-08	5.17E-08	7.2	6.9
75-6M	#10	Leaching time	exceeded no	analysis	attempted
75D-6M	#0	#N/A	#N/A	0.0	0.0
75D-6M	#1	1.11E-08	1.97E-08	8.0	7.7
75D-6M	#2	1.60E-07	2.47E-08	7.4	7.7
75D-6M	#3	1.23E-07	2.80E-07	7.2	7.3
75D-6M	#4	9.29E-08	1.45E-07	7.2	7.2
75D-6M	#5	9.66E-08	1.52E-07	7.1	7.1
75D-6M	#6	9.88E-08	1.57E-07	7.1	7.1
75D-6M	#7	1.04E-07	1.68E-07	7.1	7.0
75D-6M	#8	5.78E-08	1.12E-07	7.1	7.0
75D-6M	#9	2.48E-08	4.15E-08	7.2	7.0
75D-6M	#10	Leaching time	exceeded no	analysis	attempted

TABLE 13
DATA FOR SPECIMENS CURED 12 MONTHS AT ~25°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
25-12M	#0	#N/A	#N/A	0.0	0.0
25-12M	#1	1.04E-08	1.11E-08	8.0	8.0
25-12M	#2	1.03E-08	1.05E-08	8.0	8.0
25-12M	#3	8.86E-09	1.04E-08	8.0	8.0
25-12M	#4	8.00E-09	7.47E-09	8.0	8.0
25-12M	#5	7.59E-09	7.35E-09	8.0	8.0
25-12M	#6	7.47E-09	6.67E-09	8.1	8.1
25-12M	#7	6.79E-09	6.20E-09	8.1	8.1
25-12M	#8	4.38E-09	4.77E-09	8.1	8.1
25-12M	#9	5.68E-09	6.16E-09	8.1	8.1
25-12M	#10	5.41E-09	5.41E-09	8.1	8.1
25D-12M	#0	#N/A	#N/A	0.0	0.0
25D-12M	#1	8.97E-09	8.01E-09	8.0	8.1
25D-12M	#2	9.52E-09	9.60E-09	8.0	8.1
25D-12M	#3	8.68E-09	1.10E-08	8.0	8.0
25D-12M	#4	8.03E-09	7.87E-09	8.1	8.0
25D-12M	#5	7.47E-09	6.63E-09	8.1	8.1
25D-12M	#6	7.24E-09	6.81E-09	8.1	8.1
25D-12M	#7	6.71E-09	6.26E-09	8.1	8.1
25D-12M	#8	4.73E-09	4.94E-09	8.1	8.1
25D-12M	#9	6.16E-09	6.16E-09	8.1	8.1
25D-12M	#10	5.41E-09	5.41E-09	8.1	8.2

TABLE 14
DATA FOR SPECIMENS CURED 12 MONTHS AT ~55 & 75°C

		Calc by ANS 16.1(Incremental)		Leach Index	
		$D_{eff}(\text{Na ion})$	$D_{eff}(\text{NO}_3 \text{ ion})$	via Na ion	via NO ₃ ion
55-12M	#0	#N/A	#N/A	0.0	0.0
55-12M	#1	2.47E-09	2.75E-09	8.6	8.6
55-12M	#2	2.92E-09	3.15E-09	8.6	8.5
55-12M	#3	1.32E-08	2.36E-08	8.3	8.2
55-12M	#4	2.86E-08	4.72E-08	8.1	8.0
55-12M	#5	2.66E-08	3.88E-08	8.0	7.9
55-12M	#6	2.90E-08	3.95E-08	7.9	7.8
55D-12M	#0	#N/A	#N/A	0.0	0.0
55D-12M	#1	2.19E-09	2.15E-09	8.7	8.7
55D-12M	#2	2.05E-09	1.83E-09	8.7	8.7
55D-12M	#3	8.02E-09	1.17E-08	8.5	8.4
55D-12M	#4	4.78E-08	8.68E-08	8.2	8.1
75-12M	#0	#N/A	#N/A	0.0	0.0
75-12M	#1	1.10E-08	6.44E-09	8.0	8.2
		#N/A		# #	# #
75D-12M	#0	#N/A	#N/A	0.0	0.0
75D-12M	#1	1.76E-08	1.03E-08	7.8	8.0

TABLE 15
DATA FOR SPECIMENS CURED UNDER PROGRAMED TEMPERATURE
CHANGES STARTING AT 55°C.

NOTE: The 1X curing rates approximate the cooling curves calculated by A.D. Yu for the anticipated rates of vault loading assuming reaction heats sufficient to yield the initial (maximum) temperature. The accelerated, 2X, curing rates allow only half the 1X time interval at each 10°C temperature stage.

	Calc by ANS 16.1(Incremental)		Leach Index	
	<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
mold#17				
55-1X #0	#N/A	#N/A	0.0	0.0
55-1X #1	2.93E-09	3.52E-09	8.5	8.5
55-1X #2	2.82E-09	6.30E-09	8.5	8.3
55-1X #3	2.85E-09	4.77E-09	8.5	8.3
55-1X #4	2.44E-09	3.30E-09	8.6	8.4
55-1X #5	3.34E-09	4.73E-09	8.5	8.4
55-1X #6	1.04E-08	1.40E-08	8.4	8.3
55-1X #7	1.48E-08	2.26E-08	8.4	8.2
55-1X #8	6.55E-09	8.84E-09	8.3	8.2
55-1X #9	3.37E-09	4.92E-09	8.4	8.2
55-1X #10	6.45E-09	9.23E-09	8.3	8.2
55-2X #0	#N/A	#N/A	0.0	0.0
55-2X #1	7.26E-09	1.01E-08	8.1	8.0
55-2X #2	5.10E-09	6.66E-09	8.2	8.1
55-2X #3	3.41E-09	4.58E-09	8.3	8.2
55-2X #4	3.18E-09	4.16E-09	8.3	8.2
55-2X #5	3.18E-09	4.03E-09	8.4	8.3
55-2X #6	2.95E-09	3.81E-09	8.4	8.3
55-2X #7	4.43E-09	5.81E-09	8.4	8.3
55-2X #8	1.56E-09	2.26E-09	8.4	8.3
55-2X #9	2.60E-09	3.96E-09	8.5	8.3

TABLE 16
DATA FOR SPECIMENS CURED UNDER PROGRAMED TEMPERATURE
CHANGES STARTING AT 75°C.

NOTE: The 1X curing rates approximate the cooling curves calculated by A.D. Yu for the anticipated rates of vault loading assuming reaction heats sufficient to yield the initial (maximum) temperature. The accelerated, 2X, curing rates allow only half the 1X time interval at each 10°C temperature stage.

		Calc by ANS 16.1(Incremental)		Leach Index	
		<u>D_{eff}(Na ion)</u>	<u>D_{eff}(NO3 ion)</u>	<u>via Na ion</u>	<u>via NO3 ion</u>
mold #18					
75-1X	#0	#N/A	#N/A	0.0	0.0
75-1X	#1	1.38E-09	1.34E-09	8.9	8.9
75-1X	#2	1.65E-09	1.71E-09	8.8	8.8
75-1X	#3	2.32E-09	3.12E-09	8.8	8.7
75-1X	#4	4.15E-08	5.89E-08	8.4	8.3
75-1X	#5	6.86E-08	1.01E-07	8.2	8.1
75-1X	#6	5.04E-08	6.90E-08	8.0	7.9
75-1X	#7	4.86E-08	3.02E-08	7.9	7.9
75-1X	#8	2.22E-08	3.31E-08	7.9	7.8
75-1X	#9	1.09E-08	1.64E-08	7.9	7.8
75-1X	#10	1.80E-08	2.48E-08	7.9	7.8
mold #22					
75-2X	#0	#N/A	#N/A	0.0	0.0
75-2X	#1	1.74E-09	1.83E-09	8.8	8.7
75-2X	#2	2.28E-09	2.45E-09	8.7	8.7
75-2X	#3	1.85E-09	2.58E-09	8.7	8.6
75-2X	#4	2.55E-09	3.54E-09	8.7	8.6
75-2X	#5	1.80E-09	2.27E-09	8.7	8.6
75-2X	#6	1.91E-09	2.20E-09	8.7	8.6
75-2X	#7	2.34E-09	2.54E-09	8.7	8.6
75-2X	#8	1.61E-09	2.40E-09	8.7	8.6
75-2X	#9	6.12E-10	9.05E-10	8.8	8.7
75-2X	#10	2.60E-09	3.65E-09	8.7	8.6

QA STATEMENT

The data and observations upon which this report is based, were collected under the guidance of the Task Technical and QA Plan⁵

⁵ E. G. Orebaugh, "Thermal Effects Study ...(U)", WSRC-RP-90-599, (Task Technical and QA Plan)

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and referenced procedures, and recorded in a laboratory notebook, WSRC-NB-90-222. The calculations were made on MicroSoft Excel[®] spread-sheets, copies of which are reduced and attached to the laboratory notebook, WSRC-NB-90-222, which acts as the primary repository for all data of this study.

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