UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
[formerly National Bureau of Standards]
Gaithersburg, Maryland 20899

October 25, 1989

Mr. Charles Peterson
Technical Review Branch
Division of High-Level Waste Management
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Quarterly Progress Report for April, May, June 1989 (FIN-A-4171-9)

Dear Mr. Peterson:

Enclosed is the April, May, June 1989 quarterly progress report for the project "Evaluation and Compilation of DOE Waste Package Test Data" (FIN-A-4171-9). The financial information is reported separately.

Sincerely,

Charles G. Interrante
Program Manager
Corrosion Group
Metallurgy Division

Enclosures

Distribution:
WM Docket Control Center (1-original)

WM-1
A-417
NH14

Quarterly Letter Report for April, May, June 1989

Published August 1989

(FIN-A-4171-9)

Performing Organization: National Institute for Standards and Technology (NIST)
Gaithersburg, MD 20899

Sponsor: Nuclear Regulatory Commission (NRC)
Office of Nuclear Materials Safety and Safeguards
Washington, DC 20555

TASK 1 -- REVIEW OF WASTE PACKAGE DATA BASE

STATUS OF DATABASE

	Current Month	Previous Month
Number of citations	1108	1086
Number of completed reviews	85	78

Appended to this report are the following Draft Reviews not previously submitted). Comments by the NRC and its contractors are solicited.

1. Chapter 4, "Dissolution of Specific Radionuclides," from "Final Report of the Defense High Level Waste Leaching Mechanisms Program," PNL-5157, August 1984.

2. Ringas, C. and Robinson, F., "Corrosion of Stainless Steel by Sulfate-Reducing Bacteria - Total Immersion Test Results," NACE, Corrosion, Vol. 44(9), September 1988.

3. UCRL-21013, "Summary of Results from the Series 2 and Series 3 NNWSI Bare Fuel Dissolution Tests," November 1987.

As required under Task 1, three outlines of interpretive papers on selected topics were transmitted to the NRC on May 17, 1989. The three outlines covered the following topics.

1. Mechanisms of Environmental Induced Fracture and their Relevance to HLW Containers in the Tuff Environment

2. Mechanisms of Internal Corrosion of Spent Fuel Rods

3. Mechanisms of Localized Aqueous Corrosion of Copper and its Alloys

<u>Status of Recently Listed Reviewable Documents</u>

Reviewable documents are classified as follows: Category 1 documents are currently being reviewed. Categories 2 and 3 are documents that will be entered into the database with citation information and authors abstracts, and the Category 2 documents are flagged "to review when time permits."

Yucca Mountain Project

- 4 Reports currently under review (Category 1).
- 28 Reports to review when time permits (Category 2).
- 0 Reports to file with cross reference(s) to other reports (Category 3).
- 0 Reports identified and not yet categorized.
- 8 Reports received and not yet categorized.

GLASS -- VITRIFIED WASTE FORM

- 1 Reports currently under review (Category 1).
- 4 Reports to review when time permits (Category 2).
- 0 Reports to file with cross reference(s) to other reports (Category 3).
- 0 Reports identified and not yet categorized.

Database searches for the quarter (April, May, June 1989) include Metadex, Engineered Materials Abstract, NTIS, DOE Energy, and Compendex Plus. Examples of the search conducted for each of these databases are in this report (see p. 21).

STATUS OF REVIEWS OF YUCCA MOUNTAIN PROJECT REPORTS

Yucca Mountain Project -- Reports recently identified for review

Two reports have been identified for review. The first is on the release of carbon-14 and the second is on corrosion of the waste container.

Gaseous release of carbon-14, as CO, and CO_2, occurs after the waste canister is breached, and the primary concern of this work is to determine the fraction of ^{14}C, that is in the gaseous state. The results indicate that more C is in a gaseous state before breaching than had been anticipated, resulting in an initial high level of ^{14}C release followed by a low level of release as more gaseous ^{14}C is generated [Konynenburg, 1984].

This report describes a five year program designed to examine the corrosion characteristics and possible failure modes of the waste container materials. The intent is to use short-term electrochemical tests to evaluated long-term performance. The seven tasks are: 1) Review of Problems in Repositories, 2) Potentiodynamic Polarization Studies, 3) Vapor-Phase Corrosion Studies, 4) Pitting Corrosion Studies, 5) Stress-Corrosion Cracking Studies, 6) Studies of Other Failure Modes, and 7) Long-Term Exposure Studies [Beavers, 1989].

1. Konynenburg, Van, R. A., Smith, C. F., Culham, H. W., and Otto, C. H., "Behavior of Carbon-14 in Waste Packages for Spent Fuel in a Repository in Tuff," UCRL-90855, November 1984.

2. Beavers, J. A. and Thompson, N. G., "Container Corrosion in High Level Nuclear Waste Repositories," - Fist Semi-Annual Report/Year 2, September 1988 to February 1988.

Yucca Mountain Project --

Category 1 -- Reports currently being reviewed

1. ANL-88-14, "The Reaction of Glass During Gamma Irradiation in a Saturated Tuff Environment, Part 3: Long-Term Experiments at $1x10^4$ rad/hr," February 1988.

2. WHC-EP-0096 (formerly HEDL-7665), "Initial Report on Stress-Corrosion-Cracking Experiments Using Zircaloy-4 Spent Fuel Cladding C-Rings," September 1988.

3. UCRL-90855, "Behavior of Carbon-14 in Waste Packages for Spent Fuel in a Repository in Tuff," November 1984.

4. Beavers, J. A. and Thompson, N. G., "Container Corrosion in High Level Nuclear Waste Repositories," - Fist Semi-Annual Report/Year 2, September 1988 to February 1988.

Category 1 (continued) - Status of Reviews not yet sent to NRC and WERB

Document No.	Assigned to Reviewer	First Draft Completed	Lead Worker	Program Manager
ANL-88-14	2/17/89		6/30/89	
WHC-EP-0096	2/21/89			
UCRL-90855	4/6/89			
Beavers, 1988	5/11/89			

Category 2 -- Review as time permits (new entries for this reference data file)

None this month.

Category 3 -- File and cross reference

1. UCID-21472, "An Annotated History of Container Candidate Material Selection," July 1988.

OTHER REPORTS ON VITRIFIED WASTE FORM --

Category 1 -- Reports currently being reviewed

1. PNL-5157, "Final Report of the Defense High-Level Waste Leaching Mechanisms Program," August 1984. A summary review that incorporates information given in each of seven previously conducted reviews is currently being written.

Category 2 -- Review as time permits

None this month.

Category 3 -- File and cross reference

None this month.

TASK 3 -- LABORATORY TESTING

A. Title of Study: Evaluation of Methods for Detection of Stress Corrosion Crack Propagation in Fracture Mechanics Samples.
Principal Investigator: Charles Interrante

April-June 1989:

Data taken in March on Specimen ST8 were analyzed and various changes were made to the code. Examples of the changes follow:

1. The format of the data had to be changed so that the software on the mainframe would be capable of reading the data collected during the test of ST8. Examples of these changes are conversions of fixed point numbers to numbers in scientific notation or dates into elapsed time readings.

2. In order to decrease bias (due to thermal effects) in the measured values of resitance of the test specimen, the polarity should be reversed after every reading. However, the data collected in March contains clusters of data having the same polarity. Therefore, routines, had to be developed to make these clusters of data into one data element for analysis.

3. In May, preliminary data plots were made of various acoustic emissions generated from the test of specimen ST8.

It is expected that this activity will be followed in July and perhaps August by plotting of data; this will permit and lead to further analyses of the data. After that, calibration activities will be conducted with Dr. Clough; and one or more additional test specimens will have to be tested using the modified procedures and calculational routines. The number of staff hours devoted to this work weekly is only about 20 and, with heavy vacation schedules it will be even less during the summer months, so progress may be slow.

B. Title of Study: Effect of Resistivity and Transport on Corrosion of Waste Package Materials.
Principal Investigator: Edward Escalante

April, May, and June 1989

An experiment that measures the diffusion of oxygen through an aqueous solution (containing no sand) has been repeated using a linear diffusion cell in which the electrodes are flat surfaces parallel to each other. This duplication of measurements was carried out to verify that the original data, using spherical an cylindrical electrodes, was valid. The experiment was carried out without any problems, and indeed, verified the earlier results. An advantage to the linear diffusion cell is that the diffusion currents meaured are larger in magnitude, because the area of these electrodes is considerably greater than the spherical or cylindrical electrodes. These measurements may be extended to include a sand environment. In addition, the data from the earlier measurements, terminated in January, are still being evaluated. These data clearly show that corrosion is enhanced by either the increased transport of oxygen and/or the increased electrical (ionic) conductivity of the environment.

C. Title of Study: Pitting Corrosion of Steel Used for Nuclear Waste Storage.
Principal Investigator: Anna C. Fraker

Studies of literature and additional data and specimen analysis in preparation for writing a paper continue. The report that was submitted to NRC earlier will be put in the form of an NIST Internal Report.

D. Title of Study: Corrosion Behavior of Zircaloy Nuclear Fuel Cladding.
Principal Investigator: Anna C. Fraker

April, May and June, 1989 Report

This is a report on continued testing of Zircaloy materials to characterize their corrosion behavior and to establish baseline data. The test of Zircaloy-4 in unconcentrated J-13 water was continued for twenty-five days. The specimen was left in the solution at 22°C and then a cyclic polarization curve was taken at 95°C. This curve did show that changes had occurred as a result of the specimen being exposed to the solution for the extended time, and that some local attack could be present as a result of this extension in exposure time.

During this period, a series of tests was conducted on the "unused" Zircaloy-2 and Zircaloy-4 cladding. Tests included specimens from both the inner and outer surfaces of the tube. Specimens were first cut from the tube (using a diamond saw) and then washed ultrasonnically in acetone, alcohol and water. The specimens were welded individually to an electrical lead that was inserted into a glass tube, and epoxy was applied to shield (from the test solution) all areas except the area of the cut tube to be tested.

Tests were conducted in concentrated J-13 water at 95°C. The tubular (cladding) specimens that had been washed only and had not had the surface polished did not passivate as readily as the earlier tubular specimens that had also received a light mechanical polish. The cyclic polarization curve for the outer surface of the Zircaloy-2 tube showed no hysteresis, and the curve for the inner surface of Zircaloy-2 showed only a small amount of hysteresis. The cyclic polarization curves for the Zircaloy-4 tubing, for both the inner and outer surfaces, showed hysteresis.

Indications are that some crevice corrosion and some pitting do occur with the Zircaloy material, and some or all of the increased current in the return portion of the polarization curve may be a result of these effects. In support of this, a slow scan rate of 0.001 Volt (vs. a Saturated Calomel Electrode, SCE)/second was made and the hysteresis did not disappear. However, contrary to this, observation that pitting and/or crevice corrosion are not always visibly present, and hysteresis does not always occur in these tests. Also, application of the American Society for Testing and Materials (ASTM) method F 746 for determining susceptibility to pitting showed no pitting potential prior to the breakdown potential.

The breakdown potential for this Zircaloy 4 and Zircaloy 2 tubing ranges from +0.300 V to +0.750 V vs. SCE. There is scatter in the data for the tubing, and surface preparation techniques have a strong influence on the results.

Multiple tests were run for all specimens, and data discussed is that which is most representative. Additional tests should be carried out on these materials regarding localized attack.

In all of the polarization tests, the Zircaloy-2 materials usually exhibited corrosion currents approximately one order of magnitude lower than those resulting from the Zircaloy-4 material.

NIST Review of Technical Reports on the High-Level Waste Package for Nuclear Waste Storage

DATA SOURCE

(a) Organization Producing Data

Pacific Northwest Laboratory Operated for the Department of Energy by the Battelle Memorial Institute, Columbus, OH.

(b) Author(s) References, Reference Availability

Mendel, J. E., Compiler
Chapter 4, "Dissolution of Specific Radionuclides," from "Final Report of the Defense High Level Waste Leaching Mechanisms Program," PNL-5157, August 1984.

DATE REVIEWED: 6-15-89

PURPOSE

"Technetium, uranium and the transuranic elements, with their long half lives, are the major radionuclides from the waste that survive well into the 'geological' time period of the repository." Those are elements of greatest significance to the long-term safety of a defense nuclear waste repository." "The sections that follow discuss experimental results on the dissolution of these elements from the MCC reference glass."

KEY WORDS

Data analysis, experimental data, theory, supporting data, general corrosion, leaching, solubility, RBS, Eh (platinum electrode), corrosion, SIMS, laboratory, basalt composition, brine, deionized, groundwater, tuff composition, Fe, acidic solution (pH <7), basic (alkaline) solution (pH >7), redox condition, glass (defense waste reference glass), glass (PNL 76-68) leaching, matrix dissolution, technetium release, uranium release, actinide release, iron release, iron effect.

CONTENTS

Text: 55 pages, 52 figures, 7 tables, and 41 reference.

AMOUNT OF DATA

There are 52 figures and 7 tables. The first 6 figures are for the purpose of explaining redox principles and are apparently taken from other publications.

Figures 4.7 to 4.20 involve DWRG glass that has been doped with technetium. Figures 4.7 to 4.11 show extraction data for technetium at pH 1, 3, 7 and 11, at temperatures of 40, 70 and 90°C for periods up to 55 days. Figures 12 through 16 show data on the dissolution of the parent glass at 90°C after 55 days (leach data for glass components at pH 1 and SIMS profiles after reaction in water). Data in figures 4.17 to 4.21 are for reduced and oxidized systems involving pH 1, 3, 7, and 11 at 70°C for 60 days.

Uranium extraction data for DWRG glass are shown in Figures 4.22 through 4.25; the release of uranium "normalized" to boron is recorded for pH 1, 3, 7, and 11 at 90°C up to 30 days.

Extraction of iron plus some alkali elements, apparently from DRWG glass is shown in figures 4.26 through 4.28 for tests at pH 1, up to 30 days at 40°C, 70°C and 90°C.

Neptunium-237 doped DWRG glass was used for generating the data in Figures 4.29 through 4.31. Boron, silicon and sodium release up to 55 days at 90°C are shown for deionized, tuff and basalt waters with and without iron present.

The effect of dissolved silica in silicic acid solutions, as well as in actual groundwater, is shown in Figure 4.32; the extraction of boron from DWRG glass up to 28 days is presented.

Iron effects are shown in Figures 4.33 through 4.36. The release of Si and Ca from glass DWRG for periods up to 28 days when exposed to basalt and tuff waters containing iron at 90°C are shown in Figures 4.33 and 4.34. Figure 4.35 shows similar data for PNL 76-68 glass and figure 4.36 depicts SEM photos of the PNL 76-68 surfaces after test completion.

The release of neptunium-237 from DWRG glass Np doped) is shown in Figures 4.37, a & b, through 4.39, a & b, for deionized water, basalt water and brine at 90°C up to 57 days, with and without iron present.

Figures 4.40, a & b, through 4.42, a & b, show data for release of plutonium-239 from DWRG glass Pu doped) under the same conditions as above for neptunium-237.

Figures 4.43, a & b, through 4.46, a & b, show data for uranium released from the Np- and Pu-doped glasses under the conditions shown in Figures 4.37-4.42 (with the exception of DI water).

Rutherford backscattering spectra of glass surfaces are shown in figures 4.47 through 4.51. They give C, O, Si, Al, Fe and U which remain in DWRG glass after leaching up to 56 days in deionized water at 90°C (figure 4.47) and after leaching 28 days with and without iron in the water figure 4.48). Also shown is Pu and the sum of Nd+Ce+La+Pu in Pu-doped PNL 76-68 glass after exposure to brine and deionized water, with and without iron (figures 4.49 and 4.50).

The solubilities of Pu and Np as they originate from DWRG glass versus the solubilities as they originate from the hydrated oxide compounds are compared at pH 0.5 to 9.5 in Figures 4.51 and 4.52. The solubilities depend on the origins of solid phases since the soluble species can be different.

Table 4.1 shows the values of SA/V [Ed. surface area/volume] that were calculated for the experiments involving a technetium-doped glass sec. 4.3).

Table 4.2 lists the starting and ending pH values for solutions used in the leaching experiments with technetium-doped glass (sec 4.3).

Table 4.3 lists the starting and ending pH values for solutions used in the leaching experiments where uranium was determined sec 4.4).

Table 4.4 shows the composition of tuff, basalt and brine waters used in the leaching experiments where the extraction of neptunium, plutonium and uranium was measured from doped-DWRG glass with and without iron present sec. 4.5.

Tables 4.5-4.7 show respectively the distributions of Np, Pu and U in colloidal form, in solution, on the iron coupon and on the reaction vessel walls after the 56 day test at 90°C in brine, basalt and DI water with and without iron (sec. 4 5 experiments).

TEST CONDITIONS

Crushed glass samples sized from 0.35 to 0.70 mm in the one case specified) were reacted under static conditions that included pH from 1 to 11, temperature from 40°C to 90°C and times up to 75 days. Leach solutions included HCl and NH4OH as well as DI water, basalt water, tuff ground water and salt brine. Nominal SA/V = 10 m^{-1}. Redox potential was not directly measured in the experiments which are the principal subject of this report; the control of redox is however discussed in an introductory section. Control of oxidation conditions was accomplished by conducting the experiments in atmosphere-specific closed capsules or by defining pH. To determine the effect of iron ions, ductile iron coupons were immersed in the leachants.

Materials studied were principally DWRG glasses that had been doped with technetium, uranium,neptunium and/or plutonium. PNL 76-68 glass was used in some experiments relating to leaching of parent glass components and the effect of iron. The specific glass compositions are not given.

UNCERTAINTIES IN DATA

With respect to the data for the technetium-doped glass (sec 4.3), the following comments were made: (1) "the error in counting statistics is about equal to the size of the symbols on the graphs" and (2) error bars for the range of Eh are shown in figure 4.17.

With respect to the data for the extraction of uranium (sec. 4.4), there are comments regarding the drift and difficulty of control of pH.

With respect to the data for the Np, Pu, U doped glass experiments sec 4.5 numerical ranges are shown for the total amount of Np, Pu and U calculated as shown in Tables 4.5 to 4.7. Error bars are also given for the boron release plotted in Figure 4.32.

DEFICIENCIES/LIMITATIONS IN DATABASE

Section 4.5 notes that (1) "a detailed chemical analysis of filterable material and of the iron surface may be required to" determine whether the uranium is precipitating on the iron coupon, and is being subsequently released as iron is corroded, or whether it results from decrease in redox potential in the presence of iron, (2) "obtaining a clear analogy in release behavior... is further complicated by the fact that reactions are obviously continuing", and (3) empirical correlation of chemical similarity... may be fortuitous and should be confirmed...".

There is further comment that there are (1) "several cautionary aspects..." that "....complicate any attempt to reliably use radionuclide solubility data to predict actual steady-state concentrations of radionuclides released from glass waste forms" and (2) "direct tests on glass waste forms" should be done.

There are several cautionary aspects regarding the assumption that steady-state radionuclide concentration observed in long-term tests on glass waste forms will correspond directly to measured solubilities of radionuclide-bearing solids. The first is that the actual radionuclides-bearing solids that form upon alteration of glass are typically not simple oxide and or hydroxides used in solubility studies. The second is that the steady-state concentration may be due to a state of dynamic balance between the kinetics of dissolution and precipitation, for solid components, and it is not due to a true thermodynamic equilibrium. The third is that the thermodynamics data are typically obtained from the solutions, which are quite different from the groundwater and may contain both increased concentrations and number of ionic species.

CONCLUSIONS OF AUTHOR

The conclusions drawn from the summary and the content are as follows:

"The dissolution behavior of technetium, uranium, neptunium and plutonium from defense waste reference glass was studied. The effect of Eh on the leaching behavior of technetium was found to be significant because the valence states have different solubilities." However, "the equilibrium redox conditions were found to pertain only at the extreme upper and lower ends of the Eh, that is, near the upper and lower stability limits of water."

"The dissolution of Tc from the waste glass under oxidizing conditions followed a mixed linear-parabolic kinetics and was strongly influenced by the initial pH of the solution. Dissolution of Tc was slowed by several orders of magnitude under highly reducing conditions."

"The form of the transuranic leached from waste glass was found to be at least partially associated with colloidal-sized particles (held on a 1.8 nm filter) in almost all tests. With deionized water leachant, the leached transuranic were almost totally filtered out; but with brine leachants the transuranic passed through the filter, showing that soluble species were dominant. Simulated groundwater leachants tended to exhibit an intermediate behavior."

COMMENTS OF REVIEWER

The summary does not seem to completely reflect the material content, neither in terms of scope of experiments reported nor in terms of conclusions reached. e.g. The effect of iron, which is the focus of much of the experimental work, is not mentioned in the "summary" although there is considerable experimental work and commentary. Nor is there any statement in the summary such as the one in section 4.1 to the effect that "The extent to which these effects can be described quantitatively and incorporated into rate equations is still open."

The experimental data is contained in sections 4.3, 4.4 and 4.5. It is often difficult to understand the variables associated with the data, since it appears that they derive from different experiments that sometimes have very little in common. It appears that the base glasses used for the experiments were either DWRG or PNL 76-68, although this is not clear, and the specific compositions are not available in the body of the report. For instance, (1) the glass size was 0.35 ~ 0.70 nm in one case and -100 mesh in another case, (2) tests on Tc was performed at SA/V = 0.29 and 0.47 m^{-1} while other actinides was tested at SA/V = 10 m^{-1}, and (3) the majority of the test durations were 60 days while 75 days' tests were also used.

In the course of review, some specific comments regarding experimental conditions or assumptions arose as indicated below:

(1) Re: the assumption (Table 4.1) that crushed glass grains are spherical and that the surface area can be calculated on this basis... This reviewer notes that such grains are not spherical; they generally present as much as 2X the surface presented by a sphere of the same mesh.

(2) Re: the attribution of the decrease of Tc reaction rates with time to a "diffusive barrier layer" (p. 4.9) as shown in figures 4.8-4.10... This reviewer notes at least three other causes: the change in pH (documented in table 4.2) the change in surface are of crushed glass as it is corroded away and the diminishment of available Tc until it is close to the vanishing point.

(3) Re: the data in section 4.3 with respect to U extraction which is "normalized" to boron extraction rates...This reviewer notes that such a statement seems to imply some fundamental reaction phenomenon of which he is unaware. There is a reference in the first paragraph of section 4.4.2 to the fact that such a rationale "..shown in Chapter 1..", but there is no Chapter 1 in this document.

(4) Many of the rate changes shown in data for U in section 4.4 may also be due to the causes cited above in item 2.

APPLICABILITY OF DATA TO LICENSING
[Ranking: key data ( ), supporting data (x)]

(a) Relationship to Waste Package Performance Issues Already Identified

2.3.2, 2.3.2.1, 2.3.2.1.1, 2.3.2.1.2, 2.3.2.3; All relate to dissolution and radionuclide release from the waste form.

(b) New Licensing Issues

(c) General Comments on Licensing

DRAFT

NIST Review of Technical Reports on the High Level Waste Package for Nuclear Waste Storage

DATA SOURCE

(a) Organization Producing Data

Dept. of Metallurgy, Univ. of Witwatersrand, 1 Jan Smuts Ave., Johannesburg, 2001 South Africa

(b) Author(s), Reference, Reference Availability

Ringas, C. and Robinson, F. P. A.
"Corrosion of Stainless Steel by Sulfate-Reducing Bacteria--Total Immersion Test Result,"
Corrosion Engineering, 44, (9), 671-678, 1988.

DATE REVIEWED: 6/9/89

PURPOSE

Tests were conducted over a four month period to "unequivocally show that sulfate reducing bacteria (SRB) could cause corrosion of stainless steels".

KEY WORDS

Corrosion, mild steel, 304 stainless steel, 316L stainless steel, microscopy, weight change, laboratory, bacteria culture medium, microbial corrosion.

CONTENT

There are nine pages of text and figures, and six references are given. There are twenty four figures showing the test vessel and scanning electron micrographs of mild steel and several stainless steel surfaces after various stages of corrosion by SRB. There are two tables. One table shows the weight loss for all of the alloys studies after exposure to specific bacteria strains. The other table shows pit density counts for the various specimens.

AMOUNT OF DATA

There are 26 figures (micrographs) and 2 tables.

TEST CONDITIONS

Specimens which had been ground through 120 SiC grit paper were washed and passivated in 40% HNO_3 for one h before testing. Other specimens for crevice corrosion tests were clamped together with rubber bands between two teflon washers. Specimens were sterilized in an autoclave at 120°C for 15 min prior to being placed in four two liter flasks. Three of the flasks contained bacterial cultures and the fourth was sterile growth medium that was used as the control. Specimens were observed only at the end of the test and special care was taken for necessary medium additions to avoid contamination. Specimens were removed at the end of the test, cleaned with a nylon brush and distilled water, weighed and then observed in the stereomicroscope at 15X and in the scanning electron microscope (SEM). Specimens included 3CR12, 3CR12A, 3CR12B, AISI 409, AISI 430, Sandvik 1802, AISI 304L, AISI 316L, AISI 316, Mild Steel. Strains of SRB were 8303, 8312 and a mixed strain.

UNCERTAINTIES IN DATA

None given.

DEFICIENCIES/LIMITATIONS IN DATABASE

None given.

CONCLUSIONS OF THE AUTHOR

"These total immersion tests results .... show that stainless alloys are susceptible to microbial corrosion.

The actual mechanism of corrosion is complex and includes the establishing of differential aeration cells and the generation of sulfur species such as H_2S.

... all the alloys suffered higher weight losses in the bacterial cultures than in sterile medium because of the metabolic end products of the bacteria.

The resultant corrosion manifested itself in two forms, namely intergranular corrosion and pitting.

A distinctive shiny surface was produced on mild steel. giving a pickled and etched appearance.

AISI 304L stainless steel is unsuitable in active sulfate reducing bacteria environments (SRB), and even AISI 316L experienced distinct pitting and intergranular corrosion initiation.

Alloys high in sulfur are inferior to low sulfur alloys in active SRB environments."

COMMENTS OF THE REVIEWER

This study was conducted under good conditions for the growth of sulfate reducing bacteria (SRB) and under less favorable conditions for the materials to attain or maintain corrosion resistance. The tests were conducted in an oxygen free environment and in a bacterial growth medium; conditions that enhance bacterial growth but that can degrade metal passivity. It is possible that conditions in the nuclear waste storage repository in locations where SRB attack would be a problem could be similar or related to the conditions of these tests, especially with regard to the absence of oxygen. SRB would not be expected to be a problem in the oxygenated environment of the planned Yucca Mountain Nevada tuffacious rock repository, but oxygen could be absent or depleted in crevices, cracks and similar areas. These conditions would need to be determined and additional tests should be run to determine whether the "worst case" situation described in this paper would actually occur.

The experiments described in this paper appear to have been conducted carefully, and the results, that all of the alloys studied are susceptible to attack by the SRB, should not be ignored. The ranking of materials studied in terms of decreasing pit density is Sandvik > mild steel > AISI 409 SS > 3Cr12A > 3Cr12B > 3Cr12 > AISI 304L SS > AISI 316L SS > AISI 316 SS. Results in the weight loss data were less striking, but the Sandvik suffered the greatest loss (8 mg/cm^2) and the 316 SS had the lowest weight loss (2.62 mg/cm^2).

<u>APPLICABILITY OF DATA TO LICENSING</u>

[Ranking: key data ( ), supporting (X)]

(a) Relationship to Waste Package Performance Issues Already Identified

2.2.4.4 Will microbes affect corrosion of the waste package container, and if so, how?

(b) New Licensing Issues

(c) Comments Related to Licensing

DRAFT

NIST Review of Technical Reports on the High Level Waste Package for Nuclear Waste Storage

DATA SOURCE

(a) Organization Producing Data

Westinghouse Hanford Company, Pacific Northwest Laboratories, Richland, WA. For the NNWSI Project, U.S. DOE.

(b) Author(s), Reference, Reference Availability

Wilson, C. N.
"Summary of Results from the Series 2 and Series 3 NNWSI Bare Fuel Dissolution Tests,"
UCRL-21013, PNL-SA-15207 and HEDL-SA-3731A, November 1987.

DATE REVIEWED: 6/25/89

PURPOSE

"Tests have been conducted at Westinghouse Hanford Company in support of the NNWSI Project Waste Package Task at Lawrence Livermore National Laboratory to study the dissolution behavior of spent fuel in groundwater under NNWSI-relevant conditions." "Although spent fuel specimens in defected and undefected cladding were tested in both Series 2 and Series 3, only results from the bare fuel tests are discussed in this paper."

KEYWORDS

Experimental data, leaching, x-ray diffraction, solution analysis (not specified), laboratory, air, J-13 water, Cl, Fe, Ca, Cr, K, Mg, Na, Ni, Si, F, NO_3, SO_4, HCO_3, fuel rod segment irradiated in HBR and Turkey Point PWR, ambient temperature, dynamic (flow rate given) 40 l/year, high temperature, spent fuel (PWR), ^{241}Am, ^{137}Cs, ^{129}I, ^{239}Pu, ^{240}Pu, ^{99}Tc, ^{134}C, ^{90}Sr, ^{14}C, ^{223}Rn, radionuclide release, leaching (spent fuel).

CONTENTS

This paper consists of 11 pages containing abstract, 8 figures, 3 tables, and the following content

CONTENTS	NUMBER OF PAGES
Introduction	0.5
Test Description	1.0
Results and Discussion	7.0
Principal Observations and Conclusions	0.5

AMOUNT OF DATA

There are 8 figures and 3 tables. One figure shows the experimental set-up and several other figures show concentration versus time (15 to 34 months) for uranium (U, plutonium ($^{239+240}Pu$), americium (^{241}Am) and technicium (^{99}Tc). One table shows ^{14}C and ^{129}I in solution at the end of Cycle I (~200 days)

TEST CONDITIONS

Materials: Bare Spent Fuel
Specimen Preparation: "Specimens prepared from fuel rod segments irradiated in the H. B. Robinson (HBR) and Turkey Point pressurized water reactors."
Environments: "The Series 2 tests were conducted in NNWSI reference J-13 well water using unsealed fused silica vessels under ambient air (253°C) hot cell conditions. The Series 3 tests were similar to the Series 2 tests except that the Series 3 tests were conducted in sealed 304L stainless steel (304 in cycle 1) vessels at 853°C (one Series 3 test was run at 253°C)."

UNCERTAINTIES IN DATA

Not stated.

DEFICIENCIES/LIMITATIONS

"Based on a water flux of about 40 l/year per 3140 Kg UO_2," "the data appear quite favorable for meeting the 0.1 Ci/MTHM EPA 10,000-year cumulative release limits for ^{239}Pu, ^{240}Pu and ^{241}Am with a high degree of conservatism."

"^{99}Tc releases greater than 1 part in 100,000 per year could occur for some time from saturated failed waste packages."

"The data did not indicate that ^{129}I was released to the atmosphere in the Series 2 tests."

CONCLUSIONS OF AUTHOR

1. Actinide concentrations generally saturated, and often decreased, during test cycles.

2. Uranium concentrations tended towards about 1 to 2 μg/ml in the Series 2 tests and about 0.1 to 0.4 μg/ml in the Series 3 tests, with the lowest concentrations observed in the 853°C Series 3 tests.

3. Formation of a Ca-Si-U containing secondary phase identified as uranophane was observed in the 853°C Series 3 tests.

4. Activities of the three major alpha emitting actinides ^{241}Am, ^{239}Pu, and ^{240}Pu dropped below a pCi/ml in the 853°C Series 3 tests, which are favorable data for meeting release requirements for these important radionuclides.

5. After an initial fast release at the beginning of Cycle 1, continuous preferential releases of ^{99}Tc and ^{137}Cs occurred with the rates of release greater at 853°C than at 253°C. Continuous release of these soluble radionuclides is thought to result primarily from dissolution of fission product phases which segregate to the grain boundaries during irradiation.

6. Relatively high C-14 activities were measured in the Series 3 tests and in the TP-3-85 test in particular. Much of the ^{14}C released in the unsealed Series 2 tests may have been lost to the atmosphere as CO_2. The data did not indicate that ^{129}I was released to the atmosphere in the Series 2 tests.

COMMENTS OF REVIEWER

1. This report provides us with important data regarding the release of various radionuclides from spent fuel, assessing the government rules met by NRC or EPA.

2. In assessing the EPA or the NRC rules of radionuclides release, it is recommended that the tested flow rate, 40 l/year, be clarified to be of a typical repository condition and how to show the present data could be changed if the tests were performed at realistically lower flow rates.

3. The precipitates filtered may need to be clarified not to be contributing to any of the government rules from NRC or EPA.

4. The potential involvement of oxidation during the experiment needs to be ruled out in drawing conclusions on the performance of waste packages under the repository conditions. Such oxidation may come from the fuel sectioning and from the time of test cycle change.

RELATED REPORTS

1. C. N. Wilson, "Results from Cycles 1 and 2 of NNWSI Series 2 Spent Fuel Dissolution Tests," HEDL-TME 85-22, Hanford Engineering Development Laboratory, Richland, WA, May 1987.

2. C. N. Wilson and H. F. Shaw, in Scientific Basis for Nuclear Waste Management X, edited by J. K. Bates and W. B. Seefeldt (Materials Research Society Symposium Proceedings 84, Materials Research Society, Pittsburgh, PA, 1987) pp. 123-130.

3. J. O. Barner, "Characterization of LWR Spent Fuel MCC-Approved Testing Material ATM-101," PNL-5109, Pacific Northwest Laboratory, Richland, WA, June 1984.

4. R. B. Davis and V. Pasupathi, "Data Summary for the Destructive Examination of Rods G7, G9, J8, I9 and H6 from Turkey Point Assembly B17," HEDL-TME 80-85, Hanford Engineering Development Laboratory, Richland, WA, April 1981.

APPLICABILITY OF DATA TO LICENSING
[Ranking: key data ( ), supporting data (x)

(a) Relationship to Waste Package Performance Issues Already Identified

2.3.2.1.2 What are the rates of dissolution associated with the potential waste form dissolution mechanisms?

(b) New Licensing Issues

(c) Comments Related to Licensing

AUTHOR ABSTRACT

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project is studying dissolution and radionuclide release behavior of spent nuclear fuel in Nevada Test Site groundwater. Specimens prepared from pressurized water reactor (PWR) fuel rod segments were tested for multiple cycles in J-13 well water. The Series 2 tests were run in unsealed silica vessels under ambient hot cell air (253°C) for five cycles for a total of 34 months. The Series 3 tests were run in sealed stainless steel vessels at 253°C and 853°C for three cycles for a total of 15 months. Selected summary results from Series 2 and Series 3 tests with bare fuel specimens are reported.

Actinide concentrations tended to saturate and then often decreased during test cycles. Uranium concentrations in later test cycles ranged from 1 to 2 µg/ml in the Series 2 tests versus about 0.1 to 0.4 µg/ml in Series 3 with the lowest concentrations occurring in the 853°C tests. Formation of a calcium-uranium-silicate phase identified as uranophane in the 853°C Series 3 tests is thought to have limited uranium concentration in these tests. Americium-241, Pu-239 and Pu-240 activities measured in filtered solution decreased to less than 1 pCi/ml in the 853°C tests. Preferential release of fission products Cs, I, Sr and Tc, and activation product C-14, was indicated relative to the actinides. Tc-99 and Cs-137 activities measured in solution after Cycle 1 increased linearly with time, with the rate of increase greater at 853°C than at 253°C. Continuous preferential release of soluble fission products is thought to result primarily from the dissolution of fine particles of fission product phases concentrated on grain boundaries.

SDI006, UD 8909, SER. DD016

File(s) searched:

File 6:NTIS - 64-89/ISS09
(COPR. 1989 NTIS)

Sets selected:

Set	Items	Description
1	4	WASTE(W)PACKAGE?
2	8	CANISTER?
3	59	CORROSION
4	17	LEACHING
5	102	GLASS
6	9	VITRIFICATION
7	172	S3-S6/OR
8	3	HIGH(W)LEVEL(W)WASTE?
9	136	RADIOACTIVE(W)WASTE?
10	8	NUCLEAR(W)WASTE?
11	3	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
07apr	22:36EST	PR 11/5/1-25 (items 1-3)

Total items to be printed: 3

2733
Open R.

SDI032, UD 8905, SER. DD022

File(s) searched:

File 32:METADEX 66-89/MAY
(Copr. 1989 ASM International)

Sets selected:

Set	Items	Description
1	4	HIGH()LEVEL()WASTE? ? OR RADIOACTIVE()WASTE? OR NUCLEAR()WASTE?
2	1920	STEEL? ? OR ZIRCALOY? ? OR TITANIUM? ? OR COPPER
3	2	1*2
4	0	ANNA FRAKER, 223, B-254, X6009

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
13apr	06:52EST	PR 3/5/1-25 (items 1-2)

Total items to be printed: 2

SDI103, UD 8907, SER. DD017

File(s) searched:

File 103:DOE ENERGY - 83-89/APR(ISS07)

Sets selected:

Set	Items	Description
1	8	WASTE(W)PACKAGE?
2	3	CANISTER?
3	161	CORROSION (1974 DEC)
4	34	LEACHING (1974 DEC)
5	90	GLASS (1974 DEC)
6	11	VITRIFICATION (1974 DEC)
7	277	S3-S6/OR
8	11	HIGH(W)LEVEL(W)WASTE?
9	189	RADIOACTIVE(W)WASTE?
10	19	NUCLEAR(W)WASTE?
11	3	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

22

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
15apr	22:37EST	PR 11/5/1-25 (items 1-3)

Total items to be printed: 3

SDI006, UD 8910, SER. DD016

File(s) searched:

File 6:NTIS - 64-89/ISS10
(COPR. 1989 NTIS)

Sets selected:

Set	Items	Description
1	5	WASTE(W)PACKAGE?
2	6	CANISTER?
3	62	CORROSION
4	20	LEACHING
5	145	GLASS
6	9	VITRIFICATION
7	216	S3-S6/OR
8	7	HIGH(W)LEVEL(W)WASTE?
9	251	RADIOACTIVE(W)WASTE?
10	95	NUCLEAR(W)WASTE?
11	3	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

23

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
20apr	08:49EST	PR 11/5/1-25 (items 1-3)

Total items to be printed: 3

SDI293, UD 8905, SER. DD023

File(s) searched:

File 293:Engineered Materials Abs 86-89/May
(Copr. 1989 ASM INTERNATIONAL)

Sets selected:

Set	Items	Description
1	8	HIGH()LEVEL()WASTE? ? OR RADIOACTIVE()WASTE? OR NUCLEAR()WASTE?
2	169	STEEL? ? OR ZIRCALOY? ? OR TITANIUM? ? OR COPPER
3	0	S1*S2
4	0	ANNA FRAKER, 223, B-254, X6009

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
27apr	06:20EST	PR 3/5/1-25 (no items to PRINT)

24

Total items to be printed: 0

SDI103, UD 8908, SER. DD017

File(s) searched:

File 103:DOE ENERGY - 83-89/MAR(ISS08)

Sets selected:

Set	Items	Description
1	5	WASTE(W)PACKAGE?
2	11	CANISTER?
3	196	CORROSION (1974 DEC)
4	34	LEACHING (1974 DEC)
5	103	GLASS (1974 DEC)
6	13	VITRIFICATION (1974 DEC)
7	323	S3-S6/OR
8	8	HIGH(W)LEVEL(W)WASTE?
9	160	RADIOACTIVE(W)WASTE?
10	14	NUCLEAR(W)WASTE?
11	4	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
01may	13:51EST	PR 11/5/1-25 (items 1-4)

Total items to be printed: 4

SDI006, UD 8911, SER. DD016

File(s) searched:

File 6:NTIS - 64-89/ISS11
(COPR. 1989 NTIS)

Sets selected:

Set	Items	Description
1	3	WASTE(W)PACKAGE?
2	3	CANISTER?
3	55	CORROSION
4	20	LEACHING
5	100	GLASS
6	6	VITRIFICATION
7	164	S3-S6/OR
8	6	HIGH(W)LEVEL(W)WASTE?
9	124	RADIOACTIVE(W)WASTE?
10	6	NUCLEAR(W)WASTE?
11	1	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

26

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
05may	03:46EST	PR 11/5/1-25 (items 1-1)

Total items to be printed: 1

SDI103, UD 8909, SER. DD017

File(s) searched:

File 103:DOE ENERGY - 83-89/APR(ISS09)

Sets selected:

Set	Items	Description
1	1	WASTE(W)PACKAGE?
2	5	CANISTER?
3	195	CORROSION (1974 DEC)
4	50	LEACHING (1974 DEC)
5	141	GLASS (1974 DEC)
6	9	VITRIFICATION (1974 DEC)
7	367	S3-S6/OR
8	7	HIGH(W)LEVEL(W)WASTE?
9	203	RADIOACTIVE(W)WASTE?
10	19	NUCLEAR(W)WASTE?
11	3	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
12may	14:48EST	PR 11/5/1-25 (items 1-3)

Total items to be printed: 3

SDI032, UD 8906, SER. DD022

File(s) searched:

File 32:METADEX 66-89/June
(Copr. 1989 ASM International)

Sets selected:

Set	Items	Description
1	3	HIGH()LEVEL()WASTE? ? OR RADIOACTIVE()WASTE? OR NUCLEAR()WASTE?
2	1939	STEEL? ? OR ZIRCALOY? ? OR TITANIUM? ? OR COPPER
3	2	1*2
4	0	ANNA FRAKER, 223, B-254, X6009

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
15may	13:18EST	PR 3/5/1-25 (items 1-2)

28 **Total items to be printed: 2**

SDI006, UD 8912, SER. DD016

File(s) searched:

File 6:NTIS - 64-89/ISS12
(COPR. 1989 NTIS)

Sets selected:

Set	Items	Description
1	2	WASTE(W)PACKAGE?
2	3	CANISTER?
3	41	CORROSION
4	16	LEACHING
5	143	GLASS
6	2	VITRIFICATION
7	190	S3-S6/OR
8	1	HIGH(W)LEVEL(W)WASTE?
9	99	RADIOACTIVE(W)WASTE?
10	13	NUCLEAR(W)WASTE?
11	2	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
19may	17:58EST	PR 11/5/1-25 (items 1-2)

Total items to be printed: 2

SDI008, UD 8904, SER. DA016

File(s) searched:

File 8:COMPENDEX PLUS - 70-89/APR Copr. Engineering Info
Inc. 1989)

Sets selected:

Set	Items	Description
1	1	WASTE(W)PACKAGE?
2	4	CANISTER?
3	161	CORROSION
4	24	LEACHING
5	326	GLASS
6	8	VITRIFICATION
7	509	S3-S6/OR
8	1	HIGH(W)LEVEL(W)WASTE?
9	14	RADIOACTIVE(W)WASTE?
10	3	NUCLEAR(W)WASTE?
11	0	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
21may	21:03EST	PR 11/5/1-20 (no items to PRINT)

Total items to be printed: 0

SDI293, UD 8906, SER. DD023

File(s) searched:

File 293:ENGINEERED MATERIALS ABS 86-89/JUN
(Copr. 1989 ASM INTERNATIONAL)

Sets selected:

Set	Items	Description
1	3	HIGH()LEVEL()WASTE? ? OR RADIOACTIVE()WASTE? OR NUCLEAR()WASTE?
2	183	STEEL? ? OR ZIRCALOY? ? OR TITANIUM? ? OR COPPER
3	1	S1*S2
4	0	ANNA FRAKER, 223, B-254, X6009

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
24may	09:00EST	PR 3/5/1-25 (items 1-1)

31 **Total items to be printed: 1**

SDI103, UD 8910, SER. DD017

File(s) searched:

File 103:DOE ENERGY - 83-89/APR(ISS10)

Sets selected:

Set	Items	Description
1	5	WASTE(W)PACKAGE?
2	3	CANISTER?
3	118	CORROSION (1974 DEC)
4	29	LEACHING (1974 DEC)
5	124	GLASS (1974 DEC)
6	18	VITRIFICATION (1974 DEC)
7	267	S3-S6/OR
8	10	HIGH(W)LEVEL(W)WASTE?
9	142	RADIOACTIVE(W)WASTE?
10	23	NUCLEAR(W)WASTE?
11	1	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

32

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
27may	16:13EST	PR 11/5/1-25 (items 1-1)

Total items to be printed: 1

SDI006, UD 8913, SER. DD016

File(s) searched:

File 6:NTIS - 64-89/ISS13
(COPR. 1989 NTIS)

Sets selected:

Set	Items	Description
1	6	WASTE(W)PACKAGE?
2	3	CANISTER?
3	54	CORROSION
4	18	LEACHING
5	106	GLASS
6	9	VITRIFICATION
7	166	S3-S6/OR
8	13	HIGH(W)LEVEL(W)WASTE?
9	94	RADIOACTIVE(W)WASTE?
10	8	NUCLEAR(W)WASTE?
11	3	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

33

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
01jun	19:21EST	PR 11/5/1-25 (items 1-3)

Total items to be printed: 3

SDI032, UD 8907, SER. DD022

File(s) searched:

File 32:METADEX 66-89/July
(Copr. 1989 ASM International)

Sets selected:

Set	Items	Description
1	2	HIGH()LEVEL()WASTE? ? OR RADIOACTIVE()WASTE? OR NUCLEAR()WASTE?
2	1889	STEEL? ? OR ZIRCALOY? ? OR TITANIUM? ? OR COPPER
3	1	1*2
4	0	ANNA FRAKER, 223, B-254, X6009

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
10jun	16:27EST	PR 3/5/1-25 (items 1-1)

Total items to be printed: 1

SDI008, UD 8905, SER. DA016

File(s) searched:

File 8:COMPENDEX PLUS - 70-89/MAY Copr. Engineering Info Inc. 1989)

Sets selected:

Set	Items	Description
1	0	WASTE(W)PACKAGE?
2	2	CANISTER?
3	168	CORROSION
4	12	LEACHING
5	303	GLASS
6	6	VITRIFICATION
7	478	S3-S6/OR
8	1	HIGH(W)LEVEL(W)WASTE?
9	8	RADIOACTIVE(W)WASTE?
10	2	NUCLEAR(W)WASTE?
11	1	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
12jun	00:04EST	PR 11/5/1-20 (items 1-1)

Total items to be printed: 1

SDI103, UD 8911, SER. DD017

File(s) searched:

File 103:DOE ENERGY - 83-89/MAY(ISS11)

Sets selected:

Set	Items	Description
1	6	WASTE(W)PACKAGE?
2	12	CANISTER?
3	159	CORROSION (1974 DEC)
4	24	LEACHING (1974 DEC)
5	128	GLASS (1974 DEC)
6	17	VITRIFICATION (1974 DEC)
7	302	S3-S6/OR
8	8	HIGH(W)LEVEL(W)WASTE?
9	186	RADIOACTIVE(W)WASTE?
10	38	NUCLEAR(W)WASTE?
11	5	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

36

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
17jun	14:11EST	PR 11/5/1-25 (items 1-5)

Total items to be printed: 5

SDI293, UD 8907, SER. DD023

File(s) searched:

File 293:ENGINEERED MATERIALS ABS 86-89/JULY
(Copr. 1989 ASM INTERNATIONAL)

Sets selected:

Set	Items	Description
1	2	HIGH()LEVEL()WASTE? ? OR RADIOACTIVE()WASTE? OR NUCLEAR()WASTE?
2	232	STEEL? ? OR ZIRCALOY? ? OR TITANIUM? ? OR COPPER
3	0	S1*S2
4	0	ANNA FRAKER, 223, B-254, X6009

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
22jun	06:24EST	PR 3/5/1-25 (no items to PRINT)

37 **Total items to be printed: 0**

SDI008, UD 8906, SER. DA016

File(s) searched:

File 8:COMPENDEX PLUS - 70-89/JUNE Copr. Engineering Info
Inc. 1989)

Sets selected:

Set	Items	Description
1	0	WASTE(W)PACKAGE?
2	3	CANISTER?
3	120	CORROSION
4	27	LEACHING
5	265	GLASS
6	6	VITRIFICATION
7	406	S3-S6/OR
8	2	HIGH(W)LEVEL(W)WASTE?
9	21	RADIOACTIVE(W)WASTE?
10	4	NUCLEAR(W)WASTE?
11	0	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
22jun	21:51EST	PR 11/5/1-20 (no items to PRINT)

Total items to be printed: 0

SDI006, UD 8914, SER. DD016

File(s) searched:

File 6:NTIS - 64-89/ISS14
(COPR. 1989 NTIS)

Sets selected:

Set	Items	Description
1	4	WASTE(W)PACKAGE?
2	6	CANISTER?
3	74	CORROSION
4	14	LEACHING
5	171	GLASS
6	6	VITRIFICATION
7	239	S3-S6/OR
8	3	HIGH(W)LEVEL(W)WASTE?
9	136	RADIOACTIVE(W)WASTE?
10	15	NUCLEAR(W)WASTE?
11	2	(S1 OR S2) AND S7 AND (S8 OR S9 OR S10)
12	0	ANNA FRAKER RM. B-106 BLDG. 223 X6009
13	0	JILL RUSPI

39

Prints requested ('*' indicates user print cancellation) :

Date	Time	Description
23jun	08:53EST	PR 11/5/1-25 (items 1-2)

Total items to be printed: 2