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Department of Energy

Richland Operations Office
WM DOCKET CONTROL CENTER
P.O. Box 550
Richland, Washington 99352

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87-LES-117

Those on Attached List

Ladies and Gentlemen:

SUMMARY OF GEOCHEMISTRY DATA REVIEW RICHLAND, WASHINGTON, JULY 21-23, 1987

The subject Data Review and Summary is attached and provided for your information. Advanced copies of this transmittal were provided earlier to representatives in attendance at the review. Should you require further assistance or clarifications concerning technical aspects of the information provided, please contact Mr. M. J. Furman, of my staff, at (509) 376-7062, or FTS 444-7062.

Sincerely,

John H. Anttonen, Assistant Manager
for Commercial Nuclear Waste

BWI:JMK

Enclosures

WM Record File 101.2 WM Project 10
Docket No. _____
PDR LPDR (B)

Distribution:
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WM Project: WM-10
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WM Record File: 101.2
LPDR w/encl

2594

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SUMMARY OF GEOCHEMISTRY DATA REVIEW
RICHLAND, WASHINGTON, JULY 21-23, 1987

NRC Geochemistry staff and their contractor conducted a geochemistry data review of hydrazine experiments during the week of July 20, 1987. Also attending were representatives of the Yakima Indian Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe.

The objective of the data review was to gain information to formalize the NRC Site Technical Position (STP) on DOE's use of hydrazine in testing. The STP involves assessing the use of hydrazine in experiments to study radionuclide sorption reactions under reducing conditions. DOE-BWI made available data/information in the form of laboratory record books and monthly/annual reports in the following areas of concern:

- o Redox condition or Eh established by the addition of hydrazine
- o Rate of reduction of radionuclides by hydrazine and the identification of radionuclide species
- o Effect of added hydrazine on the pH of test solutions
- o Interactions/interference of hydrazine with sorption reactions and/or with rocks or minerals
- o Interaction of hydrazine with experimental containers, and the stability of hydrazine during tests

These records are clearly identified as for experimental development only, and not to be used in the licensing process. This may be subject to change if these data are subsequently qualified.

Attachment No. 1 presents the list of attendees; Attachment No. 2 presents the agenda for the data review meeting; Attachment No. 3 contains data-related questions which the NRC submitted prior to the meeting; Attachment No. 4 presents a listing of the data (indexes) that were reviewed; Attachment No. 5 is a list of data/information that was or is to be copied and provided to the NRC; Attachment No. 6 contains copies of the Data Clarification questions submitted during the data examination.

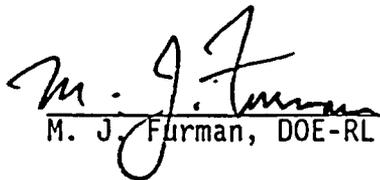
1. Data Review Summary

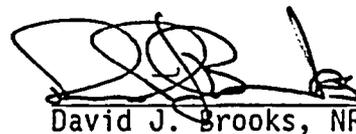
July 21: NRC staff and contractor discussed data review objectives with DOE-BWI. After that, BWI furnished all available data concerning the questions contained in Attachment No. 3 and NRC staff and their contractor spent the day reviewing the available data. At the end of the day, the NRC presented to the DOE a list of data/information to be copied and brought back to HQ.

July 22: NRC staff and their contractor continued the data review. Data clarification questions were submitted by NRC to DOE, and DOE response was made during the final phase of the review meeting. At the end of the review meeting, the NRC presented to DOE an additional list of documents to be copied and shipped to NRC's office in Silver Spring, Maryland. Finally, the NRC staff summarized the meeting activities with DOE-BWI staff during a debriefing meeting.

2. Action Items

- o The NRC will provide a response to the DOE in 30 to 60 days on the data examination. It is expected that this will be essentially a preliminary redraft of the STP.
- o Because several of the considerations that involve the use of hydrazine are inferential, a potential need for further discussion on the future use of hydrazine was identified.
- o The purpose of the July 21-22, 1987, data examination was strictly for clarification. The purpose of any future meetings that may be arranged on this subject will be to discuss interpretations.
- o The two data-clarification questions that were not addressed during the data examination because of the unavailability of investigators will be responded to in writing within the time frame needed to redraft the STP. These are identified in Attachment No. 6 as "Name of Responder: G. S. Barney."

 7/23/87
M. J. Furman, DOE-RL

 23 July 87
David J. Brooks, NRC

NRC DATA EXAMINATION

July 21-22, 1989

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TIN MO	NRC	FTS	427-4693
David Brooks	NRC	FTS	427-4541
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JAMES SHAPLEY (W)	BWIP/LICENSING	FTS	444-9228
Fred N. McDonald	BWIP/Licensing	FTS	444-2786
Richard W. Forester	BWIP / Proj. Office	"	376-2725
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NRC DATA EXAMINATION FOR HYDRAZINE EXPERIMENTS

Date: July 21-22, 1987

Location: 300 Area, 331 Building, Room 69 (3rd floor)

Parties: NRC
State of Washington
State of Oregon
Yakima Indian Nation
Confederated Tribes of the Umatilla Indian Reservation
Nez Perce Tribe

July 21

8:30 a.m. Introductory comments by DOE and NRC

8:45 Meeting Protocol

9:00 Description of hydrazine experiment records

9:15 Data examination

3:15 p.m. Return records to files

3:30 Clarification/questions/responses

July 22

8:30 a.m. Continue data examination

1:00 p.m. Clarification/questions/responses

3:15 Return records to files

3:20 Collection of "Request for Approval" forms

3:30 Summary and discussion as needed

4:30 End of data examination

July 23 Additional time may be made available if requested by the NRC.

NRC DATA REQUEST FOR BASALT-SITE
HYDRAZINE DATA REVIEW

GENERAL:

In addition to the following list of specific data, any other data that would be useful for resolving our concerns should be brought to our attention and made available.

SPECIFIC:

A. NRC Concern 1: Hydrazine can exhibit both reduction reactions and oxidation reactions which have widely different standard potentials. Thus, experimental redox conditions may not reflect site redox conditions.

A1. Issue(s)

- Redox condition or Eh established by the addition of hydrazine.
- Rate of reduction of radionuclides by hydrazine.

A2. Basis For Concern

- Various BWIP publications give Eh values of +0.2, +0.5, and +0.6 volt as representative of air-saturated redox conditions, and Eh values of -0.4 and -0.8 volt as representative of reducing redox conditions with hydrazine present. The reducing tests are at various pH's, temperatures, and hydrazine concentrations (both 0.05 and 0.1 M), so possibly these test parameters are significant in the calculations and account for the different Eh values reported. We do not understand, however, why such a range of Eh values are given in different reports for what seem like equivalent oxidizing rock groundwater systems.

- The concept of representing the redox state of a system by a single Eh value is a strictly hypothetical concept which assumes that all redox reactions are at equilibrium with each other and, therefore, that the concentrations of the reduced oxidized species of the various redox couples can be calculated from a single master variable, the system "Eh". In reality, it is rarely the case that a master Eh can be applied to any geochemical system because all redox couples are seldom simultaneously at equilibrium due to reaction kinetics and activation energy barriers for some reactions. Therefore, if the stated objective of the BWIP work employing added hydrazine is to study the sorption of reduced states of radionuclides such as technetium and neptunium, it cannot be assumed that the reduced species are actually formed solely on the basis of a calculation for some Eh value. Nor can it be assumed, based on information in the chemical literature obtained under other test parameters (e.g., pH, supporting electrolyte, radionuclide concentration), that the radionuclide reduction reactions reported in the literature with hydrazine will actually occur in the rock-groundwater systems of interest.

Although the sorption ratio for some radionuclides is observed to be greatly enhanced by the addition of hydrazine, this observation does not unambiguously prove that reduced radionuclide species were formed or that reduced species are more strongly sorbed than oxidized species. For example, the surface of the minerals could be affected or altered by the hydrazine in such a way that the sorption of some radionuclides is affected while others are not. Or, it might be that hydrazine reduces Fe(III) to Fe(II) on or near the mineral surface and that the greatly enhanced concentration of Fe(II) on the mineral surface causes a chemical reaction with some radionuclides to form insoluble products rather than result in sorption of reduced ionic radionuclide species. The processes which control sorption are often quite complex; therefore, it cannot be assumed that observations for one radionuclide (or a small group of radionuclides) can be generalized and applied to other radionuclides.

- The three questions posed by Anttonen (1987) go to the heart of the issue of the appropriateness or applicability of tests employing hydrazine to gather radionuclide sorption data descriptive of the BWIP candidate repository site. These questions are: "... (1) are the reduction reactions fast enough to be useful in these experiments? (2) what are the reaction products? and (3) are the reaction products the same as those expected in a basalt-groundwater environment?"

- In Anttonen (1987), a statement is made that hydrazine reacts rapidly with key radionuclides and maintains the desired lower oxidation states over the course of the sorption reactions. This is an important statement because, if substantiated, it helps justify the use of hydrazine in sorption experiments. In the BWIP publications available to us, we have not seen the results of kinetic experiments which identify the radionuclide species formed by the proposed reactions with hydrazine and the rate at which these are formed. Conclusions about radionuclide reduction and the rate of reduction seem to be based on experimental evidence of increased sorption distribution coefficients for the radionuclides. To some extent, this seems like circular logic; i.e., hydrazine is added because it is expected to reduce radionuclides and increase sorption, thus, when increased sorption is observed after the addition of hydrazine, it is concluded that radionuclide reduction has occurred and that radionuclide reduction is the only significant reaction that has occurred as a result of the addition of hydrazine to the rock-groundwater system.

- Various BWIP publications contain apparent contradictory statements concerning the reaction of hydrazine with selenate anion and the identity of the product formed. Some of the references state that it is reduced to selenium metal, while others state that it remains anionic.

- Hydrazine is reported to react more rapidly with radionuclides than does dissolved oxygen in the rock-groundwater system, thus keeping the radionuclides in the desired reduced state (Barney et al., 1983).

A3. Request for Supporting Data

We would like to review all laboratory procedures, data note books, laboratory records, tables or plots of data, calculational methodology and calculated numbers, computer print-out, records of data analysis and evaluation, and other relevant documentation relating to the following:

- ① - The calculations which were used to obtain the Eh values reported for both oxidizing and reducing redox conditions in the various BWIP sorption experiments.
- ② - Experimental data that substantiates by direct chemical analysis (e.g., spectrophotometry, electrochemistry, laser-induced photoacoustic spectroscopy) that radionuclides stated to be reduced by hydrazine are actually present in the groundwater-rock systems as the lower-valence ionic species identified in Table I of Anttonen 1987.
- ③ - Evidence that answers the questions raised in the last paragraph of the first page of Anttonen (1987) relative to the validity of the experimental methodology employing hydrazine. These questions are: "... (1) are the reduction reactions fast enough to be useful in these experiments? (2) what are the reduction products? and (3) are the reaction products the same as those expected in a basalt-groundwater environment?"
- ④ - The experimental data, other than indirect sorption data, that measured the rate of reaction between hydrazine and radionuclides, and identified the reduced radionuclide species formed as a function of time.
- ⑤ - The experimental data on the rate of reduction of selenate anion by hydrazine in rock-groundwater systems and identification of the selenium-containing compound(s) formed.

- ⑥ - Any experimental data on the relative rates of reaction of hydrazine with radionuclides as compared to the rate of reaction with dissolved oxygen in rock-groundwater systems.

B. NRC Concern 2: Hydrazine hydrate dissociates to release hydroxide ions. Thus, experimental pH conditions may not reflect site pH conditions.

B1. Issue(s)

- Effect of added hydrazine on the pH of test solutions

B2. Basis for Concerns

- Hydrazine is a basic reagent and the addition of N_2H_4 increases the pH of poorly-buffered aqueous solutions such as groundwaters. Anttonen (1987) states that HCl was used to adjust the groundwater pH after the addition of hydrazine in BWIP experiments. In the BWIP publications available to us, only in a footnote to Table I in Barney (1984), and in Barney et al., (1985) are direct references made to the use of HCl to readjust the groundwater pH. Other publications from 1981 through 1984 simply mention the addition of hydrazine.

B3. Data/Information Needed to Review Concern/Issue(s)

We would like to review all laboratory procedures, data notebooks, laboratory records, tables or plots of data, calculational methodology and calculated numbers, computer print-out, records of data analysis and evaluation, and other relevant documentation relating to the following:

- ⑦ - The use of acid (or other methods) to reestablish the pH of the groundwater after the addition of hydrazine.

C. NRC Concern 3: Hydrazine can react with the bicarbonate anion to form the carbamate anion. Thus, the experimental groundwater may no longer be representative of site groundwater conditions.

C1. Issues

None. DOE has presented information that the formation of hydrazine carbamate is unlikely. We concur that little strong evidence exists to support the NRC concern that hydrazine carbamate would form in dilute solutions.

C2. Basis for Concern

- No experiments have been conducted to explore this reaction.

C3. Data Information Needed to Review Concern(s)/Issue(s)

- None. This concern will be evaluated based on existing information/data.

D. NRC Concern 4: Hydrazine is reported to disrupt the mineral structure of clays, and disaggregate rock. Thus the rock/mineral components of the experiments may no longer represent those found under site conditions.

D1. Issues

- Interaction/Interference of hydrazine with sorption reactions and/or with rocks or minerals.

D2. Basis for Concern

- The statement is made in Anttonen (1987) that sorption distribution coefficients are the same for reduced radionuclides whether or not hydrazine is present. The BWIP publications available to us do not contain the results of an experimental investigation comparing radionuclide sorption of species reduced by hydrazine and reduced by other methods. Such information could be important in supporting the validity of the use of hydrazine.

- In the BWIP publications available to us, there is an attempt to differentiate between radionuclide sorption by ion-exchange reactions and sorption by complexation with oxygen ligands on the mineral surface. The first mechanism, ion exchange, seems to be invoked in the cases of radionuclides such as Cs, Sr, and Ra which are not reduced by hydrazine but show decreased sorption in the presence of hydrazine, while the second, complexation, is invoked in the cases of radionuclides such as Pb, Am and Zr which are not reduced by hydrazine and do not show a change in sorption in the presence of hydrazine. It is not clear, from the BWIP publications available to us, how the distinction between ion exchange and surface complexation reactions is being made.

- According to Anttonen (1987), essentially none of the radionuclides considered 'key' are sorbed by ion exchange. This is a potentially important statement. Numerous BWIP publications describe the competition of NH ions with radionuclide sorption of certain ions assumed to be sorbed by an ion exchange mechanism. In the BWIP publications available to us, we have not identified results of an experimental investigation of the sorption mechanism for the key radionuclides.

- The results of a recent investigation of the interaction of hydrazine and soils (Hayes et al., 1982) seem particularly relevant to the issue of hydrazine interaction with sorbing minerals in the BWIP experiments with basalts or interbed materials. The abstract of that report is quoted:

"Studies have demonstrated that at high pH (pH = 8) in the solution phase, colloids catalyze hydrazine degradation. This catalysis is particularly dependent upon the exchangeable metal cations held by the colloids, and exceeds that of equivalent solutions of metal cations alone. Hydrazines can be strongly or weakly sorbed by soil colloids in essentially unchanged forms, or can be irreversibly chemisorbed. Reversible ion-exchange is the main mechanism of hydrazine/clay interaction at low pH (pH = 4). Insoluble iron-and

aluminum-hydrous oxides form on the surface of suitably charged clays at high pH, and these bind large amounts of hydrazines by strong hydrogen-bonding forces and by hydrazination of cationic species. Such binding partially destabilizes hydrazine toward thermal degradation. The results for synthetic goethites resemble those for iron(III) montmorillonite, but interactions are larger per gram of colloid. Reduction of iron(III) to iron(II) occurs, and an iron(II)/hydrazine coordination complex forms which deactivates surfaces at high pH, but is soluble at low pH. Hydrazines react with humic colloids by chemisorption, by ion-exchange, and by hydrazination of strongly polarizing cations. The reactivity of humates is determined by their exchangeable metal cations, and by the pH, which both affect their penetrability and solubility. Clay colloids and goethite react strongly with hydrazines from the vapor phase. Results show that hydrazine can compete well with water for interaction sites. The presence of water also determined the products of thermally induced degradation of sorbate molecules. Preliminary results from whole soil/hydrazine experiments show the large capacity of different soil types for interaction with hydrazine. A copper(II)-treated, aerated soil is highly effective in degrading applied hydrazine."

03. Data/Information Needed to Review Concern/Issue(s)

We would like to review all laboratory procedures, data notebooks, laboratory records, tables or plots of data, calculational methodology and calculated numbers, computer print-out, records of data analysis and evaluation, and other relevant documentation relating to the following:

- ⑧ - The results of any direct comparisons of the sorptions of radionuclides reduced by hydrazine with the sorption of the same radionuclides reduced by other means.
- ⑨ - The results of experimental investigations that differentiate between ion-exchange and surface complexation mechanisms for the sorption of radionuclides which are not reduced by hydrazine.

(10) - The results of experimental investigations which identify the sorption reactions of 'key' radionuclides and establish that they are not sorbed by an ion exchange mechanism.

(11) - The results of studies of the interactions of hydrazine-containing groundwater with basalts or interbed materials to look for reactions between hydrazine and mineral constituents. In particular, studies to see if hydrazine undergoes reversible sorption or is irreversibly sorbed onto clays (or other minerals/materials) which are believed to bind radionuclides by ion exchange processes.

E. NRC Concern 5: The chemistry of basalt rock/groundwater systems seems to be primarily dominated by the rock components. Therefore, reactions leading to radionuclide removal from solution by sorption or precipitation must involve heterogeneous reactions between basalt solid surfaces and radionuclide species in solution. Thus, the addition of hydrazine (or any exogenous reducing chemical) seems likely to result in homogeneous solution reactions involving radionuclides not expected under site conditions.

E1. Issue(s)

- Redox condition of Eh established by the additions of hydrazine

E2. Basis for Concern(s)

Same as DSTP Concern 1.

E3. Data/Information Needed to Review Concern/Issue(s)

Same as DSTP Concern 1.

F. NRC Concern 6: Hydrazine is a very aggressive chemical and reacts with plastics in the experimental apparatus. Thus, extraneous reaction products could complicate the interpretation of experimental data to the

point that the results may no longer represent site conditions or reactions.

F1. Issue(s)

- Interaction of hydrazine with experimental containers, and the stability of hydrazine during tests.

F2. Basis for Concern

- According to Anttonen (1987), there was no evidence for reaction with Teflon, glass, polyethylene, and polypropylene containers. Obviously, use of an inert container is a prerequisite to the successful conduct of any experiment. The results of an experimental investigation to identify suitable containers for radionuclide sorption reactions in rock-groundwater systems containing hydrazine is not in the BWIP publications available to us.
- Much of the earlier BWIP work to measure radionuclide sorption data was conducted in polycarbonate tubes. In at least two BWIP publications (Barney 1982a; Barney 1982b) recommendations were made that the work with selenium, technetium, uranium, and neptunium at 85°C should be repeated due to evidence of hydrazine attack on the containers. We are unable to tell from an examination of the BWIP publications available to us if these experiments were explicitly repeated.
- We have assumed that, following the discovery by BWIP that hydrazine may have reacted with the polycarbonate tubes used in much of the earlier sorption experiments, the earlier data was reexamined and any questionable radionuclide sorption values expunged from the sorption data base. We have not seen reports of such a reevaluation in the BWIP publications available to us.
- The more recent BWIP radionuclide sorption work in the presence of hydrazine has been conducted in a variety of containers. In the BWIP

publications available to us, we have not seen an explanation of the rationale for the use of different containers.

- Hydrazine is well known to be unstable and decompose in the presence of many materials, although pure solutions of hydrazine in water may be stable for long periods of time. The decomposition of hydrazine may be catalyzed by the presence of many different materials. The BWIP publications available to us do not contain reports of analyses of the hydrazine concentration of the groundwater solutions, or analyses for hydrazine concentration after completion of the sorption experiments. Proof that the hydrazine did not decompose during the experiments seems important because the hydrazine in the groundwater establishes the redox condition or Eh value. Recent work (Hayes et al., 1982) showed that hydrazine decomposes in the presence of soil constituents, and that this decomposition is catalyzed by the presence of metal cations. The decomposition is also thermally accelerated.

F3. Data/Information Needed to Review Concern/Issue(s)

We would like to review all laboratory procedures, data notebooks, laboratory records, tables or plots of data, calculational methodology and calculated numbers, computer print-out, records of data analysis and evaluation, and other relevant documentation relating to the following:

- (12) - The experiments which established that Teflon, glass, polyethylene, and polypropylene containers do not interact with hydrazine in groundwater solutions, or that the containers do not affect the hydrazine-radionuclide reactions over the times employed in the longest sorption experiments at room temperature or evaluated temperatures.
- (13) - The repeated experiments, as recommended in BWIP publications, of the tests with selenium, technetium, uranium, and neptunium in hydrazine-containing rock-groundwater systems at 85°C conducted in polycarbonate tubes.

⑭ - The review and analysis of the hydrazine work conducted in polycarbonate tubes to determine which sorption data was unaffected by the experimental apparatus, and thus the data could be kept in the sorption data base, and which sorption data was expunged from the data base due to either evidence that reaction with the experimental apparatus may have invalidated the data or uncertainty over the validity of the sorption data due to use of polycarbonate tubes and the possibility of reactions with the container.

⑮ - The experimental rationale and demonstration of resistance to attack by hydrazine which supports the use of a wide variety of containers (serum bottles, polyethylene bottles, Wheaton serum bottles, Teflon PFA vials with screw caps) reported in recent (1983 and later) BWIP publications.

⑯ - The results of hydrazine analyses which demonstrated that hydrazine was stable and did not decompose due to reaction with the containers and other test components in the rock-groundwater mixtures at room temperature or elevated temperatures over the times employed in the longest sorption experiments.

⑰ - The laboratory procedure and records/data for the various tests that support Figure 1, and Table III and VII presented in Barney 1983; Figure 1, and Table III and VII, presented in Barney 1984; Figure 1 and 3, and Table 2 and 7 presented in Barney 1982a; and Figure 1 and 3, and Table 2 and 7 presented in Barney 1982b.

References

Anttonen (1987) - Letter (87-LES-27) and attachment from J.H. Anttonen, Hanford Operations Officer, U.S. Department of Energy, Richland, WA, to J.J. Linehan, Division of Waste Management, U.S. Nuclear Regulatory Commission, Washington, DC, February 23, 1987.

Barney (1982a) - G.S. Barney, Radionuclide Sorption of Columbia River Basalt Interbed Materials, RHO-BW-SA-198 P, Rockwell Hanford Operations, Richland WA, May 1982.

Barney (1982b) - G.S. Barney, FY 1981 Annual Report Radionuclide Sorption on Basalt Interbed Materials, RHP-BW-ST-35 P, Rockwell Hanford Operations, Richland, WA, October 1982.

Barney (1983) - G.S. Barney, Radionuclide Sorption and Desorption Reactions with Interbed Materials from the Columbia River Basalt Formation, RHO-BW-SA-291 P, Rockwell Hanford Operations, Richland, WA, March 1983.

Barney (1984) - G.S. Barney, "Radionuclide Sorption and Desorption Reactions with Interbed Materials from the Columbia River Basalt Formation," pp. 3-23 in Geochemical Behavior of Disposed Radioactive Waste, eds., G.S. Barney, J.D. Navratil, and W.W. Shulz, ACS Symposium Series 246, American Chemical Society, Washington, DC, 1984.

NRC DATA REQUEST FOR BASALT-SITE HYDRAZINE DATA REVIEW

NRC Concern 1

- (1)
 - a. Notebook BNW 3535, page 27
 - b. $\text{AgCl} + e^- \rightleftharpoons \text{Ag}^+ + \text{Cl}^-$, reference electrode potential = 222 mV, Handbook of Chemistry and Physics, 1977, page D141.
- (2), (3), (4)
 - a. Unreported ^{99}Tc and other radionuclide extraction data
 - b. Technetium-Iron Oxide Reactions Under Anaerobic Conditions: A Fourier Transform Infrared, FTIR Study. R. I. Haines, T. T. Vandergraaf and D. G. Owen; September 1986, AECL-9172.
 - c. Basalt-Radionuclide Sorption/Solubility Studies for the Engineered Barriers Department, Basalt Waste Isolation Project: FY 1986 Progress Report. L. L. Ames, J. E. McGarrah, B. A. Walker and T. L. Ehlert-Long, March 1986, pages 8-16, Figures 7, 8, 9.
 - d. October 1983 Monthly Report, page 2, Table 2
 - e. Status Report on the Evaluation of XPS and XRD Methods for Characterizing Sorbed and Precipitated Radionuclides. J. W. Shade and L. S. Dake, July 1986.
- (5)
 - a. February 1983 Monthly Report, page 1, attached XRD data
 - b. Notebook BNW 3535, pages 68-72.
- (6)
 - a. Radionuclide Solubility and Sorption Studies on Basalt FY 1983 Annual Report. L. L. Ames, J. E. McGarrah and B. A. Walker, November 1983.
 - b. BNW Notebooks Numbered 3535, 3636, 5019, 5020, 5423, 5424.

NRC Concern 2

- (7) We (PNL) did not readjust groundwater pH after addition of hydrazine.

NRC Concern 4

- (8)
 - a. April 1982 Monthly Report, pages 3 and 4, Figure 4, 5, Table 3.
 - b. Notebooks BNW 5019, pages 80, 129, BNW 5020, pages 73, 88.

- c. Notebook BNW, pages 45-49.
- d. Technetium and Actinide Sorption on Magnetite and Hematite. J. W. Shade, June 1986.
- e. Letter Report L2D3P-86-2, October 21, 1985.

(9)

- a. Solubility of Selected Radionuclides in the Basalt-Groundwater System at 60°C, Interim Report. L. L. Ames, J. E. McGarrah and B. A. Walker, May 1983, pages 50-65.
- b. Notebook BNW 5424, pages 28, 29, 38, 39.

(10)

- a. June 1982 Monthly Report, pages 1-3, Tables 1 through 8, Figures 1 through 3.
- b. Notebook BNW 5019, pages 96-101.
- c. November 1981 Monthly Report, pages 4-6, Tables 5 and 6.
- d. Notebook BNW 5019, pages 21-25.
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- j. Notebook 5019, pages 131, 137, 138, 124, 126, 128
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(11), (16)

- a. December 1981 Monthly Report, pages 3-5, Table 6.

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(12), (15)

- a. October 1981 Monthly Report, page 1, Table 1.