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A STUDY OF RESEARCH NEEDS AND PRIORITIES IN RADIOACTIVE WASTE MANAGEMENT

By
Stanley E. Turner
William E. Carson
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February 1984

Work Performed Under Contract No. AC01-82ER30042

Southern Science
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Prepared for

OFFICE OF ENERGY RESEARCH
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SOUTHERN SCIENCE
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PREFACE

This report presents the results of an assessment of long-range research needs in nuclear waste management. The work reported was undertaken at the initiative of the Office of Program Analysis, Office of Energy Research, U S. Department of Energy (DOE). In fiscal 1983, the Office of Energy Research initiated this assessment and several others (in areas such as solar, thermal, photovoltaics, geothermal, and conservation); the purpose of the projects is to aid the Director of Energy Research in determining the health of DOE's research programs.

The intent of the project reported here was to identify additional, basic research necessary in the 1980s and 1990s to develop an adequate scientific data base for nuclear waste management activities likely to be important around the turn of the century. The recommendations resulted from an overview of the entire area of nuclear waste management, not from focused examinations of narrow topics within that area. The suggested research may be the subject of future studies or more intense work by DOE.

The recommendations presented in this report are not accompanied by designations of responsible program offices within DOE. It is anticipated that the contents of the report will be shared with the program offices involved and that those offices will recognize and respond to recommendations within their purviews.

1.0 INTRODUCTION

As part of its mechanism to maintain a healthy research foundation, the Department of Energy, through independent contractors, periodically reviews and evaluates ongoing activities in basic research areas. The purpose of these periodic reviews is to identify, evaluate, and analyze basic research needs and to establish their relative priorities in the context of the overall program. This report presents the results of one such review.

DOE's Office of Energy Research selected the Southern Science office of Black & Veatch, Engineers-Architects, to perform a review of nuclear waste management research and development under U.S. Government contract number DE-AC01-82ER30042. The Statement of Work set forth by DOE to guide the efforts of Black & Veatch in performing the study (review) is as follows:

> "The contractor shall assemble and work closely with a team of approximately 7 to 9 recognized experts representing a cross section of industry, academia, and Government or National laboratories (sic) to review (either at attendance of suitably arranged workshops or other means) the research and development activities underway in the area of nuclear waste management. After considering the team's observations and recommendations, the contractor shall prepare an independent assessment report which would identify research needs, their relative priorities and appropriate options for conducting such research."

The last requirement of the Statement of Work, " . . . identify . . . appropriate options for conducting such research," was later clarified by the statement that DOE did not expect the contractor to define where (in DOE) the recommended work should be done.

The methodology utilized by Black & Veatch to perform the study is described in Section 3.0 of this report. The first task was the selection of individuals to serve on the expert panel (team) specified by DOE in the Statement of Work. The persons selected to constitute the panel were as follows:

PANEL MEMBER	AFFILIATION	EXPERTISE
Dr. Stanley E. Turner, Moderator	Black & Veatch	Reactor Physics - nuclear fuel cycles, fission gas release, hazards evaluation, combustible gas control, criticality safety.
Mr. James L. Buelt	Pacific Northwest Laboratories	Chemical Engineering - vitrification concepts, uranium tailings stabilization, in-situ vitrification of transuranic wastes
Dr. Edward J. Hennelly	Savannah River Laboratory	Physical Chemistry - nuclear energy, nuclear waste management, government reactors, fuel reprocessing, waste immobilization, waste storage.
Dr. Floyd N. Hodges	Pacific Northwest Laboratories	Geology & Geochemistry - nuclear waste repositories, engineered barriers for nuclear waste, repository environment, repository testing.
Dr. Richard K. Lester	Massachusetts Institute of Technology, Associate Professor	Chemical Engineering - waste management economics, waste repository risk analysis, institutional analysis.
Dr. James E. Martin	University of Michigan, Associate Professor	Health Physics (Certified) - radwaste regulations and control programs, radiation risk assessment, measurement and significance of radiation levels.
Mr. William M. Pardue	Battelle Project Management Division	Metallurgical Engineering - nuclear fuels development, high level radioactive waste, repository planning, materials development.

PANEL MEMBER	AFFILIATION	EXPERTISE
Dr. William L. Partain	Consultant	Nuclear Engineering - high level radioactive waste immobilization, instrumentation, safety evaluation, and risk analysis.

As the list of panel members indicates, the experts selected represent a spectrum of organizations; this, in turn, implies a wide range of experience. However, in a subject as broad as nuclear waste management, no panel of reasonable size can be expected to possess a collective expertise that encompasses all possible areas of activity. The panel members' contributions to the study were directed principally toward the technical (and other) areas in which their backgrounds lie, with the foreseen result that certain aspects of nuclear waste management--subseabed disposal, for example--were not considered in detail. The focusing of effort on only a portion of the nuclear waste management program (albeit a very large portion) was, additionally, made necessary by the time and resource constraints imposed by the terms of the contract.

Meetings of the panel were also attended by individuals who were not panel members. These individuals included the DOE Project Officer, persons substituting for panel members who could not be present at a particular meeting, and DOE representatives whose input to the proceedings was deemed desirable. A list of these attendees is given below.

Attendee	Affiliation
Mr. Lorrenzo O. Ricks, Project Officer	Department of Energy
Dr. Wilmer R. Cornman	Savannah River Laboratory
Dr. Michael A. Duffy	Battelle Project Management Division
Dr. George Y. Jordy	Department of Energy
Mr. John F. Kaufmann	Department of Energy
Mr. Ray D. Walton, Jr.	Department of Energy

This report, the end product of the nuclear waste management study performed by Black & Veatch, reflects the consensus of a group of individuals having a diversity of knowledge, experience, and expertise. It should prove useful to DOE in evaluating ongoing research, as well as future research, and in establishing priorities for that research; through distribution within the Department, the report could be an adjunct to other information in planning the directions of long-term research.

The following section (2.0) presents the findings and recommendations of the study, while Section 3.0 contains a discussion of the methodology employed. Appendices A through E give some of the information provided to the panel and also list some of the comments made by the panel during the period preceding the determination of the final recommendations. The reader may find the information in the appendices helpful in understanding the process by which the final recommendations evolved.

2.0 FINDINGS AND RECOMMENDATIONS

The following paragraphs present summaries that reflect, as nearly as practicable, the consensus recommendations of the panel regarding topics for future research in nuclear waste management. The recommendations are consistent with study guidelines, including the general requirement that suggested work be typified by

- future high-risk/high-yield research projects that appear to be of major value in developing information bases in the next decade or so for societal decisions involving all forms of radioactive wastes,

or that such work should reflect

- expansions, reorientations, and scope changes that appear warranted in ongoing research activities in DOE facilities, especially those involving high-level nuclear waste.

Each recommendation is preceded by a background discussion, and the order of appearance of the recommendations does not imply a ranking in terms of relative importance.

2.1 Spent Fuel as a Waste Form

Background. It appears nearly certain that a substantial fraction of the spent fuel discharged from U.S. power reactors will eventually be placed, without reprocessing, in geological repositories. Spent fuel leaching studies have been carried out in Canada (Vandergraaf et al., 1980; Johnson et al., 1980), Sweden (Eklund and Forsyth, 1978), and the U.S. (e.g., Wang and Katayama, 1981). The U.S. research effort should now place more emphasis on spent fuel as a waste form, in view of the changed outlook for the nuclear fuel cycle. The research should be designed to yield insights into the basic mechanisms affecting the long-term stability of spent fuel. Data on the leaching of spent fuel are scant, and are almost non-existent for repository-relevant conditions; therefore, one of the highest research priorities is the determination of the leaching behavior of spent fuel under repository conditions and the development of mechanistic models that will allow prediction of spent fuel behavior over repository time periods. Electrochemically-assisted dissolution studies (made possible by the conducting nature of spent fuel) can be used in fundamental research on spent fuel leaching processes (Wang and Katayama, 1980).

Furthermore, it may be useful to consider whether enough is known about the anticipated performance of spent fuel if disposed of directly (which is under serious consideration), or whether it might be better to alter the spent fuel in some way prior to its disposal. An issue raised by the panel is the absence of studies to answer these basic questions. Most of the DOE effort has addressed the performance of processed waste forms; more data relevant to spent fuel as a disposal medium is needed. Two key questions emerge. Can it be anticipated that spent fuel will retain its integrity for retaining waste constituents after transportation, handling, and emplacement for the long time periods necessary in the repository environment? Would retention be promoted and justified by some type of processing, prior to disposal, to obtain a more stable form and perhaps remove some constituents?

Disposal of spent fuel directly also raises issues regarding its performance throughout a potentially complex management system, especially if (as now appears probable) monitored retrievable storage is a part of the system. Several mode changes appear possible, in particular the use of dry casks for on-site storage, regional sites for monitored retrievable storage prior to transfer to a final repository, and transportation of the spent fuel form. Two factors must be taken into consideration: (1) the performance of the fuel as a waste form in each of these steps, and whether the operations involved in these steps impact the long-term integrity of the fuel once it reaches the geologic repository; and (2) the total system performance of the fuel if it is subjected to the multiple steps of pool storage, dry-cask storage, transportation in several forms (in the same or different containers), final processing for disposal, emplacement, and post-emplacement performance through the period of retrievability (fifty years). The fuel elements may be brittle after removal from the reactor environment and made more vulnerable to leakage by several stages of handling and storage. It is conceivable that a given fuel bundle may be subjected to interim storage for a period of one hundred years or more, and to several processes within that period, and still be expected to meet waste-packaging requirements over a long period of geologic isolation. It is vital, in making decisions and determining data bases for predicting long-term geologic performance, that the impact of several potential handlings of spent fuel be considered. Further, if these handlings may impair planned integrity, remedial processes must be developed to mitigate the possible consequences of that impairment.

It appears that these basic questions are not readily answered and that our current expectations of the performance of spent fuel as a disposal medium are not substantiated with basic data. The answers to these questions remain the responsibility of research programs, some of which are under way; however, there seem to be essential gaps in knowledge that should be closed. On this basis, the following recommendation is made.

Recommendation No. 1. An increased level of research should be undertaken to determine the performance of spent fuel as a waste form in storage, transportation, and emplacement in an interim or repository environment over the short and long term. The possibility that the retention of waste constituents might be enhanced by limited processing, and the optimal level of such processing in terms of cost and risk reduction should be investigated. Research should focus on the following:

- The impact on metal integrity and retention capability of fuel elements for various stages of wet and/or dry storage, transportation, and processing for disposal for periods in the range of one hundred years or so;

- whether waste retention characteristics of spent fuel or a disposal medium would be enhanced with some types of processing prior to emplacement in a repository;

- leachability studies of fuel in short-term storage environments and monitored retrievable storage environments; and

- leachability studies of spent fuel under conditions of the repository environment, accounting for the host rock environment and thermal stresses in such environments.

2.2 Risks of Radioactive Waste - Societal and Technical Factors

Background. The panel discussed this subject in its consideration of Projects B-11 and B-28.* It became apparent that this was an issue broadly applicable to waste management, in that most public and technical issues in the management of radwastes eventually focus on the risks they represent.

Both technical and societal factors are involved in the basic issues of risks associated with radioactive waste. There are also two different time scales: (1) those short-term impacts associated with processing, transporting, and handling of wastes for disposal, and (2) the long-term, futuristic, and largely probabilistic impacts, on future generations, of waste after it is finally disposed. These are intertwined with decisions on sites and geological processes. It is generally a responsibility of technical-program people to interact with a questioning public, whose concerns may involve a matter of policy or may be political in nature.

An impasse over perceived risk acceptability appears almost inevitable, and providing a basis for its resolution is most difficult. Although the U.S. Congress established many policy initiatives in passage of the Nuclear Waste Policy Act of 1982, the directives to DOE were basically technical in nature. Nevertheless, in carrying out the basic technical development program, DOE is continually challenged by a public that demands understanding of

*Throughout this section, alphanumeric project identification refers to the projects so listed in Appendix A.

the risk and justification for it. Neither the Congress, the public, nor any other known entity seems prepared to provide the perspective or guidelines that the technical program should satisfy in the area of risk from radwastes. Because of this deficiency, it is essential that a broad examination of risk be undertaken, not just for radwastes, but for the broad categories of risk that reach society.

Technical factors related to risk appear to be more manageable than societal ones; however, since the technical factors are an essential ingredient of a risk-management decision, it is important that they be well characterized in quantifying risk, its duration, and its magnitude, and in reducing the uncertainty in assessments of that risk. These factors are necessary for understanding risks from all activities in waste management. They are, of course, functions of many specific circumstances, many of which are being addressed in current R&D programs, especially for high-level radwastes and, even more specifically, for defense wastes. An essential element of research is a program to identify those technical areas that represent large uncertainties in the estimation of risks and to conduct studies directed at narrowing the bands of uncertainty of the estimates.

The more difficult aspect involves the societal factors regarding risk, its understanding, and its acceptability; for the most part, these are not well addressed for any energy-production technology, nor, for that matter, for byproducts of a modern technological society (hazardous chemicals, for example). This need is great for high-level radwaste and can soon be expected to increase for other radwastes as well, especially in terms of general public understanding and the goals that the technical community needs to attain in providing an adequate margin of safety for waste management. This generic question could be considered from the standpoint of comparative risk studies with other technologies or with other risks society accepts, but such an approach seems inadequate for addressing the overall issue of how society perceives, addresses, and accepts low-level, long-term, technological risks, no matter what the form.

Panel discussions kept returning to this basic question, with the recognition that society and its governmental institutions (EPA, FDA, OSHA, NRC, etc.) are continually faced with specific questions (a new material, drug, manufacturing process, nuclear power, acid rain, etc.) that must be assessed in evaluating situations or developing solutions to problems that represent risk.

Although the need for a basic set of guidelines for risk acceptability is clear, how to establish these guidelines is not clear. There appears to be a need to try innovative approaches that address society's overall perspective on risk: the various forms in which risk comes to society via our environmental support systems (air, water, food, terrestrial), and what society expects of its legislative and governmental institutions in conducting basic programs to deal with those risks.

The panel believes that the importance of the subject of risk and its acceptability in the development and use of basic energy forms and its difficulty warrants general studies to examine the fundamentals society uses in its perception, understanding, and acceptance of risks. These studies should focus on basic factors, with the development of guidelines for their application to broad categories of risk, which should be stated. The studies should focus on establishing society's mores (not those of selected groups of individuals) for dealing with low-rate, statistical, long-term risks. Innovative approaches involving, for example, public forums, public polls, the study of basic institutions, and the role of ethics should be used in the research.

Recommendation No. 2. Conduct research on the general societal factors basic to risk understanding and acceptability and on the technical factors necessary to risk assessment. In these studies, address the following.

- Optimal approaches for government to use in informing the public of risks for project areas and in receiving guidance from the public on factors necessary for its understanding and acceptance of potential risks that may be involved. Innovative approaches--public forums and polls, for example--should be used, basic institutions and their roles relative to the public should be studied, and the basic principles of ethics and fairness under the law should be examined to determine the responsibility of the government in conducting and regulating programs with respect to risk that may affect current and future generations.

- Evaluation of technical factors basic to risk assessments, and the conduct of studies to narrow uncertainties in those assessments.
- The feasibility of using alternative systems for managing potential widespread risks, such as those involved in the transportation of radioactive wastes; this may provide additional margins of safety and greater public understanding and/or acceptance.

2.3 Surface-Level Migration of Radwaste Constituents

Background. Projects, A-7, A-15, and B-35 address chemical properties of host geologic strata and of the waste package system itself as potentially important in retarding migration of radionuclides. The effects of sorptive agents, complexing agents, precipitation, and physical parameters on migration are also important. This is especially true for LLW, TRU-containing LLW, and U-tailings, where a whole host of media and forms may come together to represent a complex system subject to climatic and physical changes that may promote migration of waste constituents in the near surface environment where these wastes are currently disposed.

The technology for shallow land burial of radwastes has evolved over a number of decades, is in widespread use, and will be used extensively under current policies and plans for disposal of such materials. An important aspect of this use is the regional siting of LLW facilities primarily to serve state disposal requirements from institutions and nuclear-power-related activities. The basic technology is to place materials in geologic media isolated from the shallow ground water tables and to minimize infiltration of water into the site by caps. If such a disposal system can be assumed to stabilize in a few decades, it then amounts to an underground storage vault until radioactive constituents decay to acceptable levels. This system places great reliance on the integrity of liners or natural strata to isolate wastes from ground water and the performance of caps to preclude introduction of a water transport medium into the site to disturb isolation.

A few studies have been performed of liners and caps, most notably for uranium tailings disposal in western arid environments. The results of these studies have been useful for tailings disposal and remediation; however, they have little applicability to eastern and coastal areas where shallow land disposal is likely to exist in the context of developing interstate LLW compacts under the Low-Level Waste Policy Act of 1980. Uranium exploration may occur in such areas and remediation of former Federal sites will be carried out in such areas. There appears to be a need to conduct studies of site performance characteristics, especially liners, in various regions of the nation to develop the basic data necessary to assure isolation of LLW disposed in these areas. This will be essential for the state activities concerned with siting and licensing of such facilities.

For shallow land burial technology, studies should establish, for various regions of the nation, optimal geochemical factors to preclude radionuclide migration, including selection of disposal medium, sorptive properties of packaging or backfill materials, geochemical compatibility of waste forms with liners and surrounding strata, and optimal combinations of these, including potential additives as future tracers, to isolate radwastes. Of particular value would be the development of chemical filters that could be emplaced with liners to absorb materials that may leak.

Due to the extreme importance of cover materials and caps to preclude infiltration of water into shallow land burial sites and to prevent exhalation of gases (e.g., radon), the long-term performance of such cover systems should be studied to discover and evaluate new materials and natural ecosystems to provide optimal cap stability and impermeability. Such ecosystems should be highly dominant and should exclude encroachment of plants or animal life that could otherwise establish roots and burrows to bring water into contact with waste or exhume waste products. Advantage should be taken of past studies conducted by LANL, Pacific Northwest Laboratories (PNL), Rogers & Associates, and Colorado State University for the Uranium Mill Tailings Remedial Action Program (UMTRAP) to extend this approach to other media, waste types, and sections of the country.

One possible high yield research program would involve consideration of extending and developing technologies to vitrify many low-level wastes into a non-leachable solid while providing considerable volume reduction by incineration. This program has two distinct, potential advantages: (1) preserving land space in shallow land burial, while providing a very stable form that would be highly recognizable to future generations that may exhume it intentionally or unintentionally, and (2) concentrating some forms (e.g., spent resins or filters) to a degree that it may be in the interest of public safety, and technically and economically feasible, to dispose of the forms as high-level radwastes. If public concern shifts to shallow land burial (as some members of the panel believe), this may be a very attractive alternative, especially if long-lived components prove to be more significant in siting issues than heretofore recognized. This latter point emphasizes two other aspects of low-level radwaste that may be important: careful assessment of the amount of all long-lived components in LLW, and the potential migration and impact of those components over a period of time consistent with current engineering and maintenance parameters.

The panel believes that a number of issues with regard to LLW and shallow land burial technology warrant attention to maximize the use and acceptance of this technology for managing selected forms of radioactive waste.

> Recommendation No. 3. It is recommended that ongoing and new DOE research in LLW and active mill tailings support the projected licensing requirements of the active mill sites and regional low-level waste burial sites, especially those in the eastern U.S. The research should also provide backup alternatives to waste processing and shallow land-burial trenches. Examples include the following.

- Improvement of the state-of-the-art of liner technology by concentrating on engineered materials that improve the natural sorptive and precipitative properties of natural clays and soils for various regions of the nation;
- evaluation of new cover materials and natural ecosystems to prevent encroachment, intrusion, and infiltration for the long-term; and
- investigations into economic, combined volume-reduction/immobilization processes for low-level radwastes (e.g., vitrification), including consideratiion of the advantages of the European philosophy of storage and recycle of LLW where feasible.

2.4 Decommissioning and Decontamination

Background. Although some decommissioning and decontamination (D&D) of nuclear reactors has occurred, the issue is sure to be of more significance as the currently operating commercial nuclear power plants reach the ends of their useful lives. Options for close-down range from onsite entombment to complete dismantlement, which would produce large amounts of waste products of various types and activity levels. A well-documented Federal policy based on projected risks and costs does not appear to exist. The U.S. Atomic Industrial Forum is thought to be presently sponsoring a small program to investigate costs.

To date, the D&D of nuclear reactors has been done on a case-by-case basis, with the approach depending on a number of technical, policy, and political factors. These past programs have not been designed to yield data essential to the development of a comprehensive D&D policy. The panel notes that the forthcoming dismantlement of the Shippingport reactor offers a rare opportunity to plan and conduct a study that would be invaluable in determining an overall technical policy for the D&D of nuclear power plants utilizing pressurized water reactors. A policy decision has been made to completely remove the facility from the site; if the proper information is obtained, it may be possible to use that information along with data from earlier, different activities, to determine the comparative costs, risks, and benefits of various options.

A program of examining radioactive constituents in the major components of the vessel, primary system, auxiliary systems, and reactor building at Shippingport would be invaluable in establishing the source terms for entombment on the site. It may be of less concern to the public to leave materials intact if they contain only low- to medium-half-lived material rather than to reduce and move those materials elsewhere for disposal (and, in the process, increase the probability for migration). Similarly, the trade-off of occupational exposure versus potential public exposure can be studied and the costs of each of these options determined. It is important that DOE take advantage of the Shippingport dismantlement to study the basic cost/risk factors and to investigate the environmental-versus-occupational exposure possibilites of D&D.

The panel also considered the potential for recycling basic materials and components of D&D activities, citing the approach used by European countries to store and reuse materials and systems that might have otherwise been discarded. This approach requires good data on radioactive constituents and innovative approaches on stockpiling of materials for future use. It may be possible to place some of the materials in the strategic stockpile, with priority for their use developing as national circumstances require. The feasibility of a recovery option for many of the components that may be involved in D&D appears worthy of investigation.

The considerations outlined above lead to the following recommendation.

Recommendation No. 4. Establish a range of options and use the Shippingport facility to determine the risks and costs involved in D&D. Develop specific plans to obtain data to use as a basis for guiding development of performance standards and engineering requirements associated with D&D. Consider in detail the potential recovery of valuable materials and components, the postulated impacts for various regions of the country, the extent and nature of the impacts, and the time periods over which they are most significant.

2.5 Primary Reprocessed Waste Forms

Background. A great deal of work has gone into research on waste glasses at low temperatures and for relatively short time periods; however, less is known about the long-term repository behavior of glass as a waste form. More tests of longer duration, possibly accelerated tests, tests to carefully evaluate the long-term effects of radiation and transmutation, and tests in simulated repository situations are needed.

In examining the subject of repository performance of waste forms, the panel considered the ongoing work represented by Projects A-17 through A-27, which deal basically with the performance of potentially-high-level waste forms in a host of environments. Project A-17, Chemistry and Materials Problems in Energy Production Technologies, develops data on fuel-element integrity up to the point at which the element leaves the reactor environment; this appears necessary to establish the essential features of the fuel-element source term for a high level waste repository. This is augmented by the Radiation Effects in Metals and Ceramic project (A-24) for the periods during and after fuel-element placement in reactor environments. Projects A-18 through A-23 and A-25 through A-27 deal with the basic science required for understanding the behavior of various processed waste forms and, as such, are highly oriented toward defense wastes (understandably so, since this is the only processed waste medium now contemplated).

The data base for quantitative prediction of the long-term leaching behavior of borosilicate glass needs improvement. Of special importance are the processes taking place at the glass-water interface and the structure and properties of the surface layers formed by hydrolytic attack on the glass. The mechanisms and kinetics of layer formation as a function of the glass and aqueous solution compositions, as well as the pH and Eh of the solution, are only partly understood. The stability of the surface layer over the long term needs further study. A better understanding of these issues is basic to developing a model capable of better predicting the long-term leaching behavior of glass.

The impact of radiation fields on the leaching behavior of glass is another area of uncertainty. Most experiments to date have consisted of leaching tests conducted on pre-irradiated glass samples. These experiments generally indicate that radiation damage to the glass structure itself, at the dose levels expected in high-level-waste glass, will not significantly affect the leach rate. However, recent studies suggest that radiolysis of the attacking solution may lead to increases in glass leach rates (Nash et al., 1982). More studies of the effects of radiolysis products on the rate of formation and long-term stability of the surface hydration layer in borosilicate glass are needed.

The data obtained from standard leach tests are not usually applicable to the prediction of waste form performance in repository conditions. This is true, for example, in cases where radionuclide release is solubility-limited; in such cases, the radionuclide concentrations in the liquid layers adjacent to the glass surface will typically be quite different in standard laboratory leaching experiments and under repository conditions. In-situ simulations of repository conditions will provide a suitable medium for verifying these effects.

Ceramic waste forms should be addressed to evaluate their relative advantages and disadvantages. Similar questions would apply to crystalline ceramic waste forms. The interaction of various crystalline ceramic materials with aqueous solutions, the formation of surface alteration layers, and the effect of radiolysis products on these interfacial processes all require systematic study once a typical waste form has been selected.

Another area of research deals with the mechanisms that may induce phase transformations and microstructural changes during the life of the waste form. Microstructural coarsening increases the likely extent of microcracking in ceramic waste forms, which, in turn, increases the available surface area for corrosion. At present, there appears to be little systematic information concerning processes of microstructural coarsening in polyphase ceramics. Here again, more systematic studies of corrosion at interphase boundaries and ordinary grain boundaries in polyphase ceramic systems are needed.

Coated particle waste forms, consisting of glass marbles or crystalline ceramic pellets surrounded by one or more protective layers of chemically-stable material such as pyrolytic carbon, silicon carbide, or aluminum oxide, may have more corrosion resistance than conventional borosilicate glass. A modest research program in this area has been carried out at Pacific Northwest Laboratories, Battelle Columbus Laboratories, and Oak Ridge National Laboratory. The effort should be continued as a longer-term, potentially-high-payoff component of the overall waste package program. Special emphasis should be placed on the development of low-temperature coating techniques. More information is required on the leaching behavior of various coated particle systems under a range of conditions of temperature, Eh and pH, and aqueous solution composition.

Because of the importance of the waste form in the overall performance of a high level waste repository, and the potential advantages that may be offered by ceramic or coated particle waste forms, it is important to address these areas. Therefore, the following recommendation is made.

Recommendation No. 5. Expand research on the performance of primary reprocessed waste form options to include essential tests to assure long-term performance in a repository environment. Particular attention should be given to the following areas.

- The mechanics of leachability of borosilicate glass and ceramics in the high-temperature, high-radiation environment of a geologic repository for long time periods. Special emphasis should be placed on possibilities of carrying out meaningful accelerated testing.

- Long-term effort to develop alternate waste forms, such as crystalline ceramics or multi-barrier coated particles, as candidates for a second-generation waste form for reprocessed commercial waste in the second repository.

2.6 Nuclear Waste Product Migration Studies

Background. In addition to waste form research, a number of other areas of ongoing research appear to need reorientation to develop the detailed data bases necessary for thoroughly understanding the migration of high-level radwaste constituents in repository environments. These involve thermal, geohydrological, geochemical, and other factors with respect to the overall performance of the waste package in a repository. In this context, the panel considered work being done in Projects A-28 through A-69 which, with some exceptions, deal with the basic sciences of migration of waste constituents. A wide range of media are involved, as are various thermal, chemical, and geologic processes that can be expected in a high level waste repository environment. With the exception of the additions and expansions suggested below, these studies seem properly focused; considering the expertise and capabilities of the national laboratories involved, these studies can be expected to yield good, necessary data in the technical areas being pursued. The following background discussions pertain to the areas of canister/overpack materials, thermodynamic factors, and the migration of waste under varying conditions.

Most alloys were developed relatively recently, and there is very little data on their long-term (>50-year) behavior. Testing is needed to determine whether effects such as recrystallization and exsolution may significantly alter the properties of alloys under repository conditions over long time periods. Accelerated testing should be carried out in this area, if possible.

The effects of bacteria on corrosion are unknown. Bacteria can probably survive under repository conditions and iron-metabolizing bacteria are known to exist. Sufficient investigation should be undertaken to permit reasonable evaluation of the importance of bacteria on corrosion. This, of course, could be a site-specific problem.

There is a lack of basic thermochemical data for solution components and particularly for actinides. Sufficient data exist to reasonably model dilute ground waters at 25°C and to make relatively reasonable extrapolations to higher temperatures. The data set for actinides at 25°C is incomplete and at higher temperatures is almost non-existent. The information for brines is particularly inadequate: there is scarcely enough data to allow modeling of brine reactions at 25°C, while at higher temperatures the data base is wholly inadequate.

The solubilities of actinides, as well as the solubility of silica, may be the most important control on their long-term release from whatever waste form is used. Almost all existing data for the solubilities of actinides has been obtained at 25°C in distilled water. There is a strong need for actinide-solubility data in realistic ground waters, particularly in brines, where the effects of other solution components (complexants) can be evaluated. There is also a need to extend these solubility measurements to higher temperatures and to include the effects of radiation (both gamma and alpha) in the tests.

A large amount of work has been done on the modeling of large-scale water migration around and away from a nuclear waste repository. However, virtually no effort has been directed toward the modeling of water migration patterns in the near field (near the waste package). There is a need for modeling to determine how quickly water will initially reach the waste package and how the thermal fields of individual waste packages will affect flows in their vicinities.

Brine inclusions in salt, at least those without gas bubbles, will migrate up a thermal gradient and thus will move toward a waste package placed in salt. Experiments to verify this phenomenon have been carried out with single salt crystals. Models that predict the amount of brine that may reach a waste package give answers that vary from a few to several-thousand liters per waste package. There is a great need for the experimental determination of brine migration in polycrystalline salt samples, where grain boundary effects may be very important, as well as for the determination of the effects of radiation fields (radiolysis) on brine migration.

Usable aquifers and petroleum normally occur in porous media, and, as a result, our understanding of fluid flow through porous media is well developed. However, for many proposed repository rock types, porous flow will not be significant and flow through fractures will be a principal mode of water transport. Fracture flow is very poorly understood; at present, only rudimentary, untested models exist. A small-scale modeling effort is under way at Lawrence Berkeley Laboratory; given the significance of fracture flow in understanding the flow of water around hard rock repositories, a larger effort is definitely needed.

Tests with waste glass in the presence of iron indicate that the colloids of iron silicate and or iron oxide form as a result of interaction and strongly affect glass leaching by sorbing material leached from the glass. In addition, studies of natural ground waters indicate that iron- and aluminum-bearing colloids are present in most natural ground waters. If colloids can be transported in geological systems, the colloids generated at the waste package may move significant amounts of radionuclides away from the package and cause much higher release rates from the repository. An evaluation of the formation of colloids at the waste package and the geologic transport of colloids (and whatever sorbed material they may carry) is needed.

Canadian studies (at Whiteshell) indicate that bacteria in soils may greatly enhance the transport of plutonium. Bacteria, which are fairly common in geologic systems, produce the elemental sulfur that occurs in the cap rock of gulf coast salt domes; in addition, they can live under extreme condi--tions--for example, in hot springs at the bottom of the Pacific Ocean. Knowledge of the possible effects of bacteria on the transport of radionuclides is practically non-existent, and there is a fairly high need for enough research to allow a meaningful evaluation of this topic.

A number of processes may influence the migration of waste constituents in ways not previously considered. It appears important to include studies of these various processes in the plan for future research.

Recommendation No. 6. It is recommended that DOE support/initiate research, or increase significantly the level of research, to:

- Determine the long-term (>50-year) stability of proposed canister and overpack materials, under repository conditions, through the use of accelerated testing (where possible) and long-term testing;

- develop a thermodynamic data base sufficient to support the performance models required for repository licensing, and place greater emphasis on the determination of radionuclide solubilities under realistic repository conditions;

- develop models of near-field fluid flow in repositories in silicate rocks, and determine the behavior of brine inclusions in the near field of a repository in salt;

- develop field-tested, reliable models that describe the flow of aqueous fluids in fractured rock media; and

- evaluate the importance of colloids and bacterial action in the transport of radionuclides away from the waste package and of bacterial action on the corrosion of metallic barrier materials.

2.7 Statistical Approaches to Waste Management Performance

Background. Statistics is a science largely ignored in nuclear waste reseach, but it is one that can play a role in at least two very important areas. Statistical analyses and approaches may be vital for the licensing process, inasmuch as the "reasonable assurance" required by the NRC will probably end up being some statistical limit on expected waste-package performance (e.g., all of the waste packages in the respository will have zero release for 300 years at the 95% confidence level).

Another area of importance for statistics lies in the evaluation of rock properties and of the long-term behavior of geologic systems. Models that describe repository performance must utilize assumed properties for many cubic miles of rock that can never be sampled or tested. This rock is almost certainly not uniform, and models based on the assumption that it is are likely to suffer severe criticism. It is much more reasonable to use some type of statistical approach (e.g., Kreiging) to evaluate the properties to be expected. Statistical techiques are a realistic way to evaluate the probabilities of disruptive geologic events during the life of the repository. At present, no one can, in any mechanistic way, predict whether or not a major earthquake, volcano, or other catastrophic event will occur at a repository site over the next million years--or even next week.

Recommendation No. 7. It is recommended that DOE undertake a substantial research program to develop the statistical techniques and models necessary for the evaluation of repository and host rock performance. In the case of repository performance, this research should be carried out in conjunction with tests to determine the long-term performance of waste packages and waste-package materials.

2.8 Recommended Implementation Procedure

The preceding recommendations are typically quite broad, each addressing a general area of suggested work. Any overall treatment of a subject as complex and diverse as radioactive waste management research will yield similarly-broad findings. While such findings (and recommendations) should prove to be extremely useful in general planning for the long term, it is important to recognize that the individual recommendations are, in themselves, reasonably complex and that their implementation requires further focusing and perspective to insure proper direction in actual projects.

The concept of the standing committee comes to mind. The use of groups of experts to review and evaluate ongoing programs has proved successful in many instances, with these groups serving as useful adjuncts to the resources available to the managers and planners of large programs.

The collective expertise of the group of experts, or panel, is important. For the study reported here, a group embodying a broad base of knowledge was necessary. For the consideration of a component part of the overall nuclear waste management program, a panel reflecting a narrower range of expertise would be more desirable.

The following recommendation is offered as a suggested form of assistance to DOE in implementing the broadly-defined research needs outlined in the preceding pages of this section.

Recommendation No. 8: It is recommended that expert panels be established to serve as adjuncts to DOE managers and planners in implementing the recommendations made here and in reviewing the progress and direction of specific segments of the overall radioactive waste management research program. The expert panels need not be large, but the collective expertise of the members of each panel should be sufficient to provide insight into the subjects under the purview of the specific panel. Areas in which expert panels might serve DOE well include the following.

- Overall performance of spent fuel as a waste form;

  investigation of technical and societal factors associated with understanding and accepting risks, including transportation and long-term risks from disposal;

- long-term performance of low-level radioactive waste sites, the leachability and migration of water, and alternative approaches for LLW management;

- geoscientific principles involved in geologic repository performance, with special emphasis on thermal effects and geochemical parameters that influence waste migration;

- decommissioning and decontamination; and

- alternative waste forms, with particular emphasis on ceramics and multi-barrier coated particles.

3.0 METHODOLOGY

The plan followed by Black & Veatch to meet the objectives of this study was comprised of four tasks, as follows:

- Select panel members;
- hold panel workshop meetings;
- define research needs and establish priorities; and
- prepare reports.

The first task in implementing the scope of work was the selection of members of the expert panel, whose charge would be to review and assign priorities to current and future research projects. A guideline in the selection of panel members was the DOE desire that industry, academia, and government/national-laboratories be represented by two or more members each. Names and affiliations of the individuals selected to serve on the panel are given in the Introduction (Section 1.0).

The first panel workshop was held September 7 and 8, 1983, for the purposes of orientation, review of DOE project objectives, and discussion of the guidelines that would govern the kinds of research activities to be considered. The DOE guidelines for these research activities included:

- Medium- to long-range time period;
- high risk, high potential yield;
- work not likely done by industry without substantial government support;
- generic rather than single-purpose research; and
- activities related to basic research rather than to applied research or engineering tests.

The panel was asked to review R&D activities, to advise of research needed, and to assign relative priorities to topical areas, with focus on the long range. Each panel member presented a statement of his thoughts regarding long-term research needed to address nuclear waste management goals established for the year 2000.

A chart (matrix) developed by Black & Veatch was used as a base for the panel to build upon and as a guide for discussions during the session. Major subjects reviewed included the following.

Inventory (Waste Generation)

- Need to identify types of wastes and research not adequately addressed
- Recommendation for high-level waste (HLW) R&D using glass form

Interim Storage of HLW and Transuranic (TRU) Waste

- Disposition of TRU waste
- Economic and technical optimization
- Examination of monitored retrievable storage (MRS)

Compaction

- Several approaches discussed
- Combustion Engineering method of putting several bundles into one bundle
- Economics research needed for low-level waste volume reduction and stabilization

Transportation

- More work required in securing public acceptance
- Need to research alternative approaches for HLW

Isolation

- Research needed on long-term behavior of waste forms in terms of heat load effects
- Long-term metal research needed to extend canister life
- Black & Veatch to develop bibliography on long-term backfill, using input from Sandia work

Black & Veatch collected research-activity information for the panel's use in identifying research needs, gaps, and duplicate efforts. The result of this information-collecting activity was a compilation of data on more than 300 recent and ongoing nuclear waste research contracts. The contracts were separated into the following categories.

- Program planning, administration, evaluation, and management;
- licensing, regulations, QA, legal aspects, public education, technical, communication, and human interface;
- waste repository design and testing;
- socioeconomic impact;
- geological projects;
- environmental projects;
- subseabed project; and
- waste package, glass-waste-form leaching.

Information provided in the compilation included the title, sponsor, program schedule, key words, and sponsor contract-designation. Although it was recognized that other agencies sponsor research on radioactive waste, only DOE-sponsored projects were included in this task due to the lack of readily-available information on other projects and the time to consider them.

Panel members were asked to submit recommendations regarding new studies, with priorities, prior to the second panel meeting. This meeting was held November 9 and 10, 1983. The Black & Veatch staff provided each panel member with worksheets covering seventy present research activities and thirty-six future research activities. Initially, Black & Veatch had developed evaluation criteria and a value-engineering methodology for establishing the relative value and priority of research activities, but this technique was deemed too slow to utilize in the limited time available for panel activites. Subsequently, the panel and Black & Veatch agreed on a method that considered the items listed below, as applicable, in a less formal approach than that used in value engineering. These criteria were considered subjectively by each panel member and not prioritized in considering the rank of each research activity.

- Ultimate use and value;
- status of the technology;
- important problems;
- feasibility to complete;
- time required to complete;

- time required to complete;
- cost efficiency;
- level of effort (cost);
- economic competitiveness;
- health & safety;
- regulations;
- public acceptance; and
- national security.

The prinicipal activity at the second panel meeting was the evaluation and assessment of research needs and the establishment of relative priorities.

The third panel meeting was held January 31 and February 1, 1984. At this meeting, the panel discussed its comments on early draft reports (prepared by Black & Veatch and furnished to panel members prior to the third workshop) and, in a page-by-page review of the second draft, specified the final findings and recommendations that it considered to be the result of the workshops.

The third task in implementing the scope of work--define research needs and establish priorities--was a continuing one, extending from the time prior to panel selection, through the panel workshop meetings, and to the preparation of this report.

The fourth task--prepare reports--culminated in the issuance of this report.

The panel used, and developed, a substantial amount of material during the course of the study. A portion of that material is reproduced in appendices to this report; it is included because some of it reveals many additional thoughts of the panel, beyond those conveyed in the body of the report, and because it may prove useful in understanding the processes leading to the development of the final recommendations.

The appendices and their titles are as follows.

Appendix	Title
A	Research Activities Current (A) and Future (B)
B	Research Activity Comments and Discussion
B-1	Comments and Discussion From Panel Meetings or Panel Member Input
B-2	Comments and Discussion for Selected Future Research Activities from Priority Evaluation (B) Worksheets
C	Panel Workshop Handout
D	Sample Priority Evaluation Worksheet
E	Pertinent Reports on Nuclear Waste Management

APPENDIX A

DETAILED EVALUATION OF CURRENT (A) AND FUTURE (B) RESEARCH PROJECTS

This appendix contains tabulations of research activities. Tables A-1 through A-7 present the listings of activities grouped by major scientific areas encountered in radioactive waste management. These listings contain titles of research projects, both current and future, along with a judgment as to sufficiency of research (Yes, Neutral, No) and a priority ranking of activity (High, Medium, Low) by the panel members. Although discussions of the alternate Subseabed Disposal Program, TRU, and LLW took place, specific program evaluations were not covered in these detailed rankings.

The project areas were generated through the panel's use of the worksheets (Appendix D) as applied to current research activities (A) and to future research activities (B). These worksheets focused on consideration of the projects in Appendix A. Although this procedure was very useful for identifying the major areas of ongoing and future research activities, the ranking of the individual projects in terms of sufficiency of research and priority was believed to be deficient. This deficiency arises from the fact that, on any given project, a panel member may or may not have been sufficiently knowledgeable to provide a meaningful vote. For this reason, it was determined that the data in this appendix would be used as a scoping tool; the findings and recommendations contained in the body of the report are more representative of panel consensus, even though the areas represented may be broader in scope. It is believed the rankings of individual projects may be of some value to DOE in reviews of study areas, so they are included here. The panel wishes these rankings to carry much less weight than the major findings in the body of the report.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-1 MATERIALS SCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-2		Waste Glass Hydration and Leaching	Neutral	Medium
A-4		System Studies of Glass Ceramics	No	Medium
A-12	X	Research Cask Development	Yes	Medium
A-13	X	Repository Seal-Material Development	Yes	Medium
A-17		Chemistry and Materials Problems in Energy Production Technologies (LBL)	Yes	Medium
A-18		Leaching of Glass and Ceramics (PNL)	No	High
A-19		Los Alamos Equation of State Library	Yes	Low
A-20		The Effect of Self-Irradiation on Stability of Ceramic Nuclear Waste (LANL)	Yes	Medium
A-21		Preparation and Characterization of Research Materials (ORNL)	Yes	Low
A-22		Research and Development - Isotope Research Materials Preparation (ORNL)	Yes	Low
A-23		High Temperature Chemistry and Thermodynamics of Structural Materials (ORNL)	Yes	Low
A-24		Radiation Effects in Metals and Ceramics (PNL)	Yes	Medium
A-25		Sputtering Parameter Influences on Material Structure and Behavior (PNL)	Yes	Low

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-1 MATERIALS SCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-26		Radiation Damage and Environmental Effects in Nuclear Waste Storage Media - University of California-Davis	Yes	Medium
A-27		Structure of Glasses Containing Transition Metal Ions	Yes	Medium
B-4		Test of Complete Waste Package and Migration Behavior	Neutral	Medium
B-5	X	Planning of Long Range Backup Tests	No	Medium
B-9		Ceramic Waste Forms	Neutral	Medium
B-10		Devitrified Glass (Crystalline Ceramic)	No	Low
B-18	X	Redesign the Heat Package	Neutral	Medium
B-22	X	Packaging of Iodine Waste	Yes	Low
B-25		Research Long-Term Metal Corrosion (>30 Years)	No	Medium
B-29	X	Disposal/Immobilization Technology for Newly Emerging or Special Nuclear Wastes	No	Medium
B-30	X	Process Technology for Second-Generation Waste Forms	No	Medium
B-31	X	Material and Engineering Techniques to Prevent Ground Water Contamination From Active Uranium Mill Tailings (Improve Liner Technology)	No	Medium

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A 2 CHEMICAL SCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-5	X	Technical Information on Volume Reduction	No	High
A-13	X	Repository Seal-Material Development	Yes	Medium
B-1	X	Spent Fuel Reprocessing Modification to Affect Waste Properties and Optimize the Waste Treatment System	No	Medium
B-2		TRU Waste Immobilization and Disposal	No	Medium
B-7		Noble and Strategic Metals Recovery	Yes	Low
B-13		Conditioning Intact or Partially Processed Nuclear Fuel	No	High
B-19	X	Develop Vitrification Processes and Other Immobilization Processes Emphasizing Cost and Regulations	No	Medium
B-24		LLW Processing Into a Form That Puts It Into HLW Category	Neutral	Low
B-32	X	Process Research of Combined Volume Reduction and Immobilization Techniques for Low-Level Wastes	No	Medium
B-34	X	Fuel Waste Reprocess Concerns/ Alternatives	No	Medium
B-35		Radionuclide Migration Chemical Aspects	No	High

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-3 GEOSCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY	TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-1	Modification of Backfill Materials Under Repository Conditions	Neutral	High
A-3	Radionuclide Migration (LLW)	Neutral	Medium
A-9	Research Thermal Heat Load and Migration Effects	No	Medium
A-14	Backfill R&D: Reaction to Sustained Heat	Yes	Medium
A-16	Research Potential Crystalline Repositories	No	High
A-28	Trace Element Transport in Geologic Media	Yes	Medium
A-29	Thermochemistry of Geothermal Materials	Neutral	Medium
A-30	Migration of Heavy Element Chemical Species in Geologic Strata	Yes	Medium
A-31	Rock-Water Interactions	Yes	High
A-32	Aqueous Solutions Data Base	Yes	Medium
A-33	Fundamental Studies of Fluid Flow in Fractured Rock	No	High
A-34	Thermodynamics of High Temperature Brines	Yes	Medium
A-35	Thermodynamic Properties of Silicate Liquids	Yes	Medium
A-36	Chemical Transport in Natural Systems	Yes	Medium
A-37	Element Migration and Fixation in Crystalline Rocks	No	High

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-3 GEOSCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY	TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-38	Non-Linear Generation of Acoustic Beams	Yes	Low
A-39	Geochemistry of Technetium & Geochemical Controls on the Redistribution of Multivalent Elements in the Lithosphere	Neutral	Medium
A-40	Thermodynamic Properties of Aqueous Solutions at High Temperatures & Pressures	Yes	Medium
A-40A	Creep Deformation of Rocks	Yes	Medium
A-41	Rock Water Interaction in Geothermal Systems	Yes	Medium
A-42	Cation Size & Coulomb Energy Calculations for the Principal Rock Forming Minerals	Yes	Medium
A-43	Surface Wave Method for Determining Earthquake Mechanisms With Applications to Regional Stress Field Studies	Yes	Low
A-44	Thermodynamics, Kinetics and Transport in Aqueous Electrolyte Solutions	Yes	Medium
A-45	Attenuation and Dispersion in Partially Saturated Rocks	Yes	High
A-46	Diffusion in Silicate Materials	Yes	Medium
A-47	Rock Mechanics	Yes	Medium
A-48	Underground Imaging	Neutral	High
A-49	Interactions of Aqueous Media With Constituents of Natural Formations	Yes	High
A-50	Physical Chemistry of Geothermal Solutions & Materials	Yes	Medium

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-3 GEOSCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY	TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-51	Geochemistry of Crustal Processes at High Temperatures and Pressures	Yes	High
A-52	Chemical Migration by Contact Metamorphism in Granite-Carbonate Rocks	Yes	Medium
A-53	Mechanistic Studies of Trace Constituent Sorption and Migration in Geologic Media	Neutral	High
A-54	Creep Response of NaCl at Low Stresses and Temperatures	Neutral	High
A-55	Clay-Water Interactions	Neutral	Medium
A-56	Rock Deformation in Magma Hydrothermal Systems	Yes	Low
A-57	Silicate, Aluminosilicate & Borosilicate Melts	Yes	Low
A-58	Advective-Diffusion/Dispersion Transport of Chemically Reacting Species	Yes	Medium
A-59	Fluid Transport Properties of Rock Fracture	Neutral	High
A-60	Seismology of Crack Formation	Yes	High
A-61	Micro-Crack Technology	Yes	High
A-62	Mechanism of Zeolite Crystallization and Alteration in Silicate Glasses	Neutral	High
A-63	Hydrothermal Solubility of Uraninite	Yes	High
A-64	Porosity with Fluids	Yes	Low
A-65	Thermally Induced Chemical Migration in Carbonate Rocks	Yes	Medium

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-3 GEOSCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-67		Mechanical & Transport Properties of Rocks	Neutral	Medium
A-68		Opening Mode Crack Growth in Rocks	Yes	High
A-69		Computerized Underground Image Reconstruction	Neutral	Low
B-5	X	Planning of Long Range Backup Tests	No	Medium
B-27	X	Research Sealing of Repository Leaks	No	Medium

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-4 NUCLEAR SCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-15	X	Research on Tailings	No	Medium
B-23		Determine Activities of Many of the Low Level Wastes	Yes	Low
B-26		Research Fuel and Waste Loadings	Neutral	Low
B-36		Reduction of Occupational Radiation Exposures	No	Medium

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-5 BASIC RESEARCH IN ENGINEERING

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-5	X	Technical Information on Volume Reduction	No	High
A-6		Investigate Implementation and Operation of Repositories	Yes	Medium
A-8		Research Retrieval Methods and Exposures (Define the Source)	Neutral	Low
A-10	X	Research Overall System Oriented Toward Economic Criteria to Determine Waste ManAgement System	Yes	Medium
A-11		Risks in Transportation	Neutral	Medium
A-12	X	Research Cask Development	Yes	Medium
A-15	X	Research Tailings	No	Medium
B-1	X	Spent Fuel Reprocessing Modification to Affect Waste Properties and Optimize the Waste Treatment System	No	Medium
B-3		Reactor D&D High Activity Materials	No	Medium
B-6		Operation and Maintenance Effects on Reprocessing and Solidification Building Designs	No	Medium
B-8		On-Line Sampling Instrumentation	No	Medium
B-12		Standardized Shipping Cask Design	Yes	Low
B-14		Procedures and Techniques for Repository Instrumentation Systems	No	Medium
B-17		Investigate Retrieval of Waste to Be Useful Later	Yes	Low

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-5 BASIC RESEARCH IN ENGINEERING

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
B-18	X	Redesign the Heat Package	Neutral	Medium
B-19	X	Develop Vitrification Processes and Other Immobilization Processes Emphasizing Cost and Regulations	No	Medium
B-21	X	Research Disposal of Spent Fuel Assemblies and Handling Abilities	No	High
B-22	X	Packaging of Iodine Waste	Yes	Low
B-27	X	Research Sealing of Repository Leaks	No	Medium
B-29	X	Disposal/Immobilization Technology for Newly Emerging or Special Nuclear Wastes	No	Medium
B-30	X	Process Technology for Second-Generation Waste Forms	No	Medium
B-31	X	Material and Engineering Techniques to Prevent Ground Water Contamination From Active Uranium Mill Tailings (Improve Liner Technology)	No	Medium
B-32	X	Process Research of Combined Volume Reduction and Immobilization Techniques for Low-Level Wastes	No	Medium
B-33	X	Processing Technology for High-Level Waste Glassification	Neutral	Medium
B-34	X	Fuel Waste Reprocess Concerns/ Alternatives	No	Medium

NOTE: "X" indicates multiple listing.

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-6 APPLIED MATHEMATICAL SCIENCES

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY	TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-7	Risk Models to Evaluate Storage Methods	No	High
A-10	Research Overall System Oriented Toward Economic Criteria to Determine Waste Management System	Yes	Medium
B-11	HLW Disposal Comparative Risks Studies	No	Medium

APPENDIX A

RESEARCH ACTIVITIES CURRENT (A) and FUTURE (B)

Table A-7 GENERAL RECOMMENDATIONS

CURRENT (A) or FUTURE (B) RESEARCH ACTIVITY		TITLE OF RESEARCH	SUFFICIENT RESEARCH	PRIORITY
A-11	X	Risks in Transportation	Neutral	Medium
B-15		Inspection and Recovery Operations in Case of Unforeseen Events (Earthquake, etc.)	Yes	Low
B-16		Establishment of Acceptance Criteria for Determination of Adequacy of Nuclear Waste R&D	Yes	Medium
B-20		Research to Answer Public Concerns on Disposal, Risk and Health Factors	No	High
B-21	X	Research Disposal of Spent Fuel Assemblies and Handling Abilities	No	High
B-28		Meaning of Waste Storage to Humans in the Long Range	No	Medium

NOTE: "X" indicates multiple listing.

APPENDIX B

RESEARCH ACTIVITY COMMENTS AND DISCUSSION

APPENDIX B-1

COMMENTS AND DISCUSSION FROM PANEL MEETINGS OR PANEL MEMBER INPUT

The brief statements listed under each of the sciences reflect research activities that may need new or continued research funding. These statements may or may not have been addressed by the expert panel in its second meeting. Many reflect research needs determined by panel members and their colleagues.

APPENDIX B-2

COMMENTS AND DISCUSSION FOR SELECTED FUTURE RESEARCH ACTIVITIES FROM PRIORITY EVALUATION (B) WORKSHEETS

A collection of descriptive statements for some of the future (B) research activities is presented. This information was part of the Priority Evaluation Worksheet data (Appendix C) and was utilized in the second panel meeting.

APPENDIX B-1

COMMENTS AND DISCUSSION FROM PANEL MEETINGS OR PANEL MEMBER INPUT

The brief statements listed reflect research activities discussed in the panel workshops or input provided by the individual panel members. They include research activities that need new or continued research funding. They may not have been evaluated (using the Priority Evaluation Worksheets) by the entire panel.

APPENDIX B-1

COMMENTS AND DISCUSSION FROM PANEL MEETINGS
OR PANEL MEMBER INPUT

MATERIALS SCIENCES

1. Long-range material testing programs--a set-aside percentage of current work level to insure there are no long-range effects that are being overlooked

2. Significant increase in work addressing interim spent fuel storage and geologic disposal of spent fuel

3. Better understanding of leaching processes in glass

4. Better understanding of behavior of crystalline ceramic waste forms

5. Long-term behavior of spent fuel in respository environments

6. Development of multiple-barrier waste forms

7. Conditioning for disposal of spent fuel

8. General long-term, basic materials research--especially in severe environments

9. Mechanisms of release of radionuclides from waste forms

10. System studies of waste form interaction with overpack, backfills and repository host rock under repository environmental conditions

11. Behavioral research of interactions of crystalline ceramic waste forms with environment

12. Investigation of waste form alternatives including different glasses, coatings and matrices

13. Identification and testing of improved waste forms and processes that immobilize special HLW from breeders, laser separation technology and fusion reactor research products that are non-vitrifiable

14. Immobilization technology research for special wastes from breeders, fusion reactors and laser separation

CHEMICAL SCIENCES

1. Recovery of noble and strategic metals from HLW fission products

2. Removal of Cs/Sr from HLW to lower heat generation rate

CHEMICAL SCIENCES (Continued)

3. Removal of TRU elements from TRU wastes to reduce volume

4. Choice optimmization of certain process chemicals to improve fuel reprocessing and waste treatment "system"

5. Chemical aspects of radionuclide migration (sorption, precipitation, effect of complexing agents)

6. Absorbants/immobilizers for more transportable waste nuclides, e.g., technetium, iodine, ruthenium, carbon-14, and neptunium

7. TRU wastes immobilization and disposal

8. Conditioning of intact or partially processed nuclear fuel

9. Advantages/disadvantages of oxidative/reducing waste emplacement environments

GEOSCIENCES

1. Study of beneficial, as well as deleterious, interactions between backfill and waste around HLW containers

2. Radionuclide migration in repository environments

3. Understanding of hydrologic flow in fractured geologic media

4. Planning of tests for long-range backup testing

5. Rock mechanics

6. Interactions of aqueous media with constituents of natural formations

7. Sealing of repositories

8. Remote imaging for outmigration from a repository

NUCLEAR SCIENCES

1. Determination of activities of many of the LLWs

2. Fuel and waste loadings

APPENDIX B-1

COMMENTS AND DISCUSSION FROM PANEL MEETINGS
OR PANEL MEMBER INPUT

BASIC RESEARCH IN ENGINEERING

1. Nuclear waste management system engineering
2. Occupational exposure in new facilities - ideas for mitigation, e.g., robotics
3. Spent fuel reprocessing modification to affect waste properties and optimize the waste treatment system
4. Reactor decommissioning and decontamination of high activity materials
5. On-line sampling instrumentation
6. Standardizing shipping cask design
7. Investigation of retrieval of nuclear waste to be useful later
8. Disposal of spent fuel assemblies and handling abilities
9. Packaging of iodine waste
10. Sealing of repository leaks
11. Disposal/immobilization technology for newly emerging or special nuclear wastes
12. Effort toward combined waste volume reduction and immobilization technologies
13. Improved technology in HLW feeding to vitrification processes
14. Disposal of materials with greater than LLW limits from reactor D&D
15. Improved on-line sampling techniques of radioactive solutions
16. Material and engineering techniques to prevent ground water contamination from active uranium mill tailings (improve liner technology)
17. Economic methods for tritium removal from liquid wastes
18. Remote technology development for waste sorting and D&D for waste handling for D&D activities generally and for remote maintenance of waste processing facilities

APPENDIX B-1

COMMENTS AND DISCUSSION FROM PANEL MEETINGS
OR PANEL MEMBER INPUT

APPLIED MATHEMATICS SCIENCES

1. Interaction of analytical (computer code) and experimental work
2. Comparative risk of HLW in geologic media with other hazards
3. Quality assurance on backup experimental work and analytical models
4. Statistical evaluation of repositories and host rock

GENERAL RECOMMENDATIONS

1. Quality of R&D reports improved--more evidence that past and parallel work has been evaluated, more interpretation of results--and more peer review

2. Emphasis on system studies and risk analyses as a means to identify and focus basic science and as a means of communicating the results of complex scientific studies to scientists in other disciplines and the general public

3. Ongoing scoping studies to insure adequate management of special waste categories and potential waste categories

4. More segregation and decontamination in TRU waste management

5. Evaluation of specific R&D activities, including formation of panels to address specific areas: spent fuel in MRS, spent fuel disposal, HLW forms, LLW volume reduction, etc.

6. Decommissioning and decontamination of commercial power reactors

   - Decommissioning

   - Decontamination for ongoing or replacement reactors

   - Installation at time of construction or refurbishment to aid in future D&D

7. Social aspects of waste management--understanding and improving institutional dynamics

8. Spent fuel volatile fission products removal

9. Inspection and recovery operations in case of unforeseen event (earthquake, etc.)

COMMENTS AND DISCUSSION FROM PANEL MEETINGS
OR PANEL MEMBER INPUT

GENERAL RECOMMENDATIONS (Continued)

10. Establishment of acceptance criteria for regulations/determination of adequacy of nuclear waste R&D (to prevent endless investment beyond acceptable technical, operational, and planning goals of nuclear repositories and related subjects)

11. Emphasis on studies determining the behavior of materials over repository life times

12. Nondestructive assay methods for LLW, TRU, and HLW

13. Nondestructive assay methods for waste forms

APPENDIX B-2

COMMENTS AND DISCUSSION FOR SELECTED FUTURE RESEARCH ACTIVITIES FROM PRIORITY EVALUATION (B) WORKSHEETS

A list of descriptive statements is given for some of the future research activities (B) included on the Priority Evaluation Worksheets.

APPENDIX B-2

COMMENTS AND DISCUSSION FOR SELECTED FUTURE RESEARCH ACTIVITIES FROM PRIORITY EVALUATION (B) WORKSHEETS

B-1 Spent Fuel Reprocessing Modification to Affect Waste Properties and Optimize the Waste Treatment System

Comments:

Alternate reprocessing concept (e.g., non-aqueous) could give HLW having more desirable properties and could affect the quantities of TRU wastes.

Minimize/delete usage of certain process chemicals to improve the "treatability" of the resultant HLW. (Objectives here can vary with the HLW waste form to be used--for example, sodium in solvent wash wastes can be incorporated in HLW glass. But what about its incorporation in other HLW waste forms?) Other examples:

- Use of soluble poison (e.g., Gd) increases the volume of HLW glass, which increases waste disposal costs.

- Use of ferrous sulfamate to partition Pu from U results in the presence of sulfate in HLW, which can be deleterious to HLW glass in high concentrations (and lots of Fe could increase the volume of the glass too).

    - Alternate partitioning agents were proposed for commercial fuel reprocessing plants, but ferrous sulfamate continues to be used in defense fuel reprocessing plants.

Key generalization is that the commercial fuel reprocessing and waste treatment "system" should be better optimized when specific processes are selected.

Process additions

Removal of volatile fission products from spent fuel

- If spent fuel is to be a waste, this could increase the safety of the waste disposal operation. This pretreatment could make it easier to achieve the desired retention factors during reprocessing.

APPENDIX B-2

COMMENTS AND DISCUSSION FOR SELECTED FUTURE RESEARCH ACTIVITIES FROM PRIORITY EVALUATION (B) WORKSHEETS

B-2 TRU Waste Immobilization and Disposal

Comments:

Research is needed on TRU waste (immobilization and disposal).

Separation of TRU elements from TRU wastes could reduce the residue requiring repository disposal--another way of saying "decontamination to non-TRU waste." This brings about volume reduction and/or stability enhancement of TRU wastes (cost effectiveness of, based on total system comparison).

B-3 Reactor D&D High Activity Materials

Comments:

Some of the most highly-activated materials from reactor D&D exceed the limits of HLW disposal. These materials must then be disposed of in some other way. There have been some discussions of intermediate-depth burial, but I am not aware of any real significant work on the concept. The only other option that I am aware of is for the material to be treated as remote-handled TRU and to go to repository disposal. Since reactors are to be decontaminated in the near term, this would seem to be a more urgent problem than either HLW or TRU wastes from reprocessing.

B-4 Test of Complete Waste Package and Migration Behavior

Comments:

There is a need for a large-scale facility to test complete waste packages in repository environments and to test migration-type behavior in controlled environments. The currently planned tests are either laboratory-scale or in situ in a repository. In the laboratory, you do not have the scale or time to identify the type of interactions that may occur and to get numbers that can be applied to a real situation. In a repository, you cannot use radioactivity in the early testing phase, nor can you conduct tests of behavior under flooded conditions. Both conditions should be used, since the major concerns are the behavior of actinides under flowing water conditions. This is not a new concept. Others have suggested this concept previously.

B-5 Planning of Long-Range Backup Tests

Comments:

A small percentage of the budget should be reserved for long-range material and geology tests. The specific tests can best be recommended by the researchers involved in these testing programs. Such tests might include the long range (5, 10, 20, 50 years) response of metals, backfills, and waste

B-5 Planning of Long Range Backup Tests (Continued)

forms to a wide range of geothermal waters and conditions. Radionuclide migration would also be addressed in these tests. These tests would serve as a backup to the accelerated testing that is currently done in order to meet the schedule commitments of specific projects. Considering the lead time before substantial amounts of HLW or spent fuel will be disposed of in a geologic repository, the long-range tests will be producing useful data in time to prevent an unforeseen engineering design problem.

B-6 Operation and Maintenance Effects on Reprocessing and Solidification Building Designs

Comments:

Fuel reprocessing plants and HLW solidification plants are designed for remote maintenance with one or two layers of overhead cranes (the canyon concept). As a result, the buildings require very tall load bearing walls that can also provide shielding at heights when a radioactive object is being lifted. R&D in remote operation and maintenance could potentially result in larger "one-story" buildings where equipment is operated and maintained by robotic vehicles that move down lanes between equipment.

B-11 HLW Disposal Comparative Risk Studies

Comments:

More comparative risk studies should be done to compare the risk of HLW disposal in geologic media with a wide range of natural and man-induced hazards (e.g., the coal ash pits, asphalt roads, lead from shotgun shells, lead released from regular gas, natural ore bodies, cadmium plating).

B-12 Standardized Shipping Cask Design

Comments:

Standardized shipping cask design and combination shipping/storage casks should be explored in the recognition that large amounts of spent fuel will soon have to be relocated.

B-16 Establishment of Acceptance Criteria for Determination of Adequacy of Nuclear Waste R&D

Comments:

This will prevent endless investment beyond those acceptable technical, operational, and planning goals of nuclear repositories and related subjects.

APPENDIX B-2

COMMENTS AND DISCUSSION FOR SELECTED FUTURE RESEARCH ACTIVITIES FROM PRIORITY EVALUATION (B) WORKSHEETS

B-29 Disposal/Immobilization Technology for Newly Emerging or Special Nuclear Wastes

Comments:

Some special high-level wastes are beginning to emerge as a result of improved reactor and separation technology. Breeder (and even fusion reactor research and laser separation) technology has developed to the point that special waste streams have been identified that are nonvitrifiable. These waste streams include larger quantities of tritium, metals, and noble gases. Supplemental basic research is required to identify and test improved waste forms and processes that adequately immobilize these wastes in conformance with established criteria.

B-30 Process Technology for Second-Generation Waste Forms

Comments:

I support the current research and development programs on immobilization of high-level wastes in glass. The technology is in the demonstration and implementation phases and is ready for rapid resolution of some of the existing high-level waste problems. However, increased participation by the public may require research into second-generation waste forms that might result in better durability, reduced occupational exposure, lower cost, and reduced volume.

Research into new types of materials is already under way. However, more research is needed in the area of process technology. If the new waste forms center on ceramic waste forms, research into remotely operable and reliable techniques for blending, dry solids handling, containment, maintainability and general safety is necessary. Current ceramic processing technology is not adequate for hot-cell operation. Research is also under way on low-processing-temperature waste forms. Process technology for these waste forms for hot-cell operation is undefined and requires significant long-term research effort.

B-31 Material and Engineering Techniques to Prevent Ground Water Contamination from Active Uranium Mill Tailings

Comments:

The Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission are presently formulating final criteria for the licensing and operation of active uranium mill tailings sites. The proposed criteria identify semi-prescriptive standards in addition to the performance for protecting ground water. The EPA generally establishes these prescriptive standards on

B-31 Material and Engineering Techniques to Prevent Ground Water Contamination from Active Uranium Mill Tailings (Continued)

the basis of currently-available technologies. Present technologies are prohibitively expensive, possibly requiring double layers of synthetic liners. Currently, little, if any, Government-sponsored programs exist to improve the state-of-the-art liner technology. Other technologies should be researched to determine their applicability toward preventing ground water contamination. These technologies should concentrate on sorption, neutralization, and dispersion, as opposed to leachate-barrier technology currently imposed.

B-32 Process Research of Combined Volume Reduction and Immobilization Techniques for Low-Level Wastes

Comments:

With the pending closure of national radwaste burial sites, many nuclear generating plants are looking toward increasing their temporary storage capacity. Because radwaste disposal is so heavily regulated, the Government should be responsible for providing basic research on processes that will reduce the volume for storage and immobilize the wastes for safe transport and disposal. Combination of these technologies is not sufficiently developed for the private sector to invest substantial capital reserves in this area. The DOE should embark on a concerted research effort toward combined volume reduction and immobilization technologies.

B-33 Processing Technology for High-Level Waste Glassification

Comments:

A significant developmental effort is currently under way for immobilization technology for high-level wastes. Programs are funded for the development and testing of glassification technology for both defense and commercially generated wastes. Even so, some research gaps may exist in these programs. These include areas of basic (or applied) research in high-level waste feeding technology and composition sensitivity analyses.

Feeding of high-level wastes to vitrification processes require reliable equipment in high-radiation environments while handling extremely abrasive and corrosive solutions. Current commercial technology is not adequate to meet these requirements and many programs have therefore had to develop their own technologies. Independent, support programs with long term testing of improved feeding technology that can be retrofitted to existing waste vitrification designs should be established. The improved technology, when

COMMENTS AND DISCUSSION FOR SELECTED FUTURE RESEARCH ACTIVITIES FROM PRIORITY EVALUATION (B) WORKSHEETS

B-33 Processing Technology for High-Level Waste Glassification (Continued)

implemented, would reduce occupational exposure while improving the reliability and reducing the overall cost of waste vitrification to the taxpayers and ratepayers.

Another potential area of basic (or applied) research is process sensitivity to variations in compositions. Variations in feed compositions can occur from fluctuations in the reprocessing step, the chemical form of the glass formers, and the homogeneity and relative ratio of these two components in the intermixing step. Support programs designed to perform basic research on determining the effects of composition fluctuations would provide invaluable support to maintaining product quality for the repository and maintaining the integrity of the process equipment. This, again, protects the taxpayers' investment and improves the confidence level in long-term isolation.

B-34 Fuel Waste Reprocess Concerns/Alternatives

Comments:

How to handle the "dissolver solids" (primarily noble metal alloy which doesn't dissolve when the UO_2 does).

How to handle the "process solids" (those which form during storage, concentration, etc., of process solutions).

Chemistry (especially radiation chemistry) of additives that may be used in new waste treatment operations.

B-35 Radionuclide Migration Chemical Aspects

Comments:

Regarding the environmental safety of waste disposal operations, more support for R&D in the chemical aspects of radionucldie migration (sorption, precipitation, effect of complexing agents, etc.) is needed. Earlier level of support in this area has been cut in favor of modeling aspects, the results of which can be no better than the chemical data on which they are based.

APPENDIX C

PANEL WORKSHOP HANDOUT

This appendix contains handout material (Enclosure I) of the second workshop panel meeting held November 9 and 10, 1983.

APPENDIX C

PANEL WORKSHOP HANDOUT

Enclosure I

Instruction Sheet No. 1
Instruction Sheet No. 2
Instruction Sheet No. 3

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG-TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 1

The following evaluation criteria are for use in determining the priorities of research activities on the Priority Evaluation Worksheets.

ULTIMATE USE	COST EFFICIENCY
STATUS OF THE TECHNOLOGY	HEALTH & SAFETY
IMPORTANT PROBLEMS	REGULATION
ECONOMIC COMPETITIVENESS (of systems resulting from research)	TRANSPORTATION
CONTRACTOR CAPABILITY TO COMPLETE	PUBLIC ACCEPTANCE
TIME REQUIRED TO COMPLETE	NATIONAL SECURITY
LEVEL OF EFFORT (cost)	

DOE guidelines for research activities in nuclear waste management are as follows:

Long range;

high risk/high potential payoff;

work not likely done by industry without substantial government support; and

generic rather than specific or single purpose.

Other guidelines are:

a)

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG-TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 2

This Instruction Sheet contains a list of present activities for Priority Evaluation by the panel.

A - PRESENT RESEARCH ACTIVITIES

A-1 Modification of Backfill Materials Under Repository Conditions

A-2 Waste Glass Hydration and Leaching

A-3 Radionuclide Migration (LLW)

A-4 System Studies of Glass Ceramics

A-5 Need Technical Information on Volume Reduction

A-6 Investigate Implementation and Operation of Repositories

A-7 Risk Models to Evaluate Storage Methods

A-8 Research Retrieval Methods and Exposures--Define the Source

A-9 Research Thermal Heat Load and Migration Effects

A-10 Research Overall System Oriented Toward Economic Criteria to Determine Waste Management System

A-11 Risks in Transportation

A-12 Research Cask Development

A-13 Repository Seal-Material Development

A-14 Backfill R&D: Reaction to Sustained Heat

A-15 Research Tailings

A-16 Research Potential Crystalline Repositories

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG-TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 2 (Continued)

These additional current research activities are reported in one of the two following documents:

1) DOE/ER-0143/1 - Materials Sciences Programs, Fiscal Year 1983 (September 1983)

2) DOE/ER-0163 - DOE/OBES/GeoSciences Initiative on Radioactive Waste Isolation in Mined Repositories (May 1983)

These are additional present activities for Priority Evaluation by the panel.

A-17 Chemistry and Materials Problems in Energy Production Technologies (LBL)

A-18 Leaching of Glass and Ceramics (PNL)

A-19 Los Alamos Equation of State Library

A-20 The Effect of Self-Irradiation on Stability of Ceramic Nuclear Waste (LANL)

A-21 Preparation and Characterization of Research Materials (ORNL)

A-22 Research and Development - Isotope Research Materials Preparation (ORNL)

A-23 High Temperature Chemistry and Thermodynamics of Structural Materials (ORNL)

A-24 Radiation Effects in Metals and Ceramics (PNL)

A-25 Sputtering Parameter Influences on Material Structure and Behavior (PNL)

A-26 Radiation Damage and Environmental Effects in Nuclear Waste Storage Media - University of California-Davis

A-27 Structure of Glasses Containing Transition Metal Ions

A-28 Trace Element Transport in Geologic Media

A-29 Thermochemistry of Geothermal Materials

A-30 Migration of Heavy Element Chemical Species in Geologic Strata

A-31 Rock-Water Interactions

A-32 Aqueous Solutions Data Base

A-33 Fundamental Studies of Fluid Flow in Fractured Rock

A-34 Thermodynamics of High Temperature Brines

A-35 Thermodynamic Properties of Silicate Liquids

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 2 (Continued)

A-36 Chemical Transport in Natural Systems

A-37 Element Migration and Fixation in Crystalline Rocks

A-38 Non-Linear Generation of Acoustic Beams

A-39 Geochemistry of Technetium & Geochemical Controls on the Redistribution of Multivalent Elements in the Lithosphere

A-40 Thermodynamic Properties of Aqueous Solutions at High Temperatures & Pressures

A-40A Creep Deformation of Rocks

A-41 Rock Water Interaction in Geothermal Systems

A-42 Cation Size & Coulomb Energy Calculations for the Principal Rock Forming Minerals

A-43 Surface Wave Method for Determining Earthquake Mechanisms with Applications to Regional Stress Field Studies

A-44 Thermodynamics, Kinetics and Transport in Aqueous Electrolyte Solutions

A-45 Attenuation and Dispersion in Partially Saturated Rocks

A-46 Diffusion in Silicate Materials

A-47 Rock Mechanics

A-48 Underground Imaging

A-49 Interactions of Aqueous Media with Constituents of Natural Formations

A-50 Physical Chemistry of Geothermal Solutions & Materials

A-51 Geochemistry of Crustal Processes at High Temperatures and Pressures

A-52 Chemical Migration by Contact Metamorphism in Granite-Carbonate Rocks

A-53 Mechanistic Studies of Trace Constituent Sorption and Migration in Geologic Media

A-54 Creep Response of NaCl at Low Stresses and Temperatures

A-55 Clay-Water Interactions

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 2 (Continued)

A-56 Rock Deformation in Magma Hydrothermal Systems

A-57 Silicate, Aluminosilicate & Borosilicate Melts

A-58 Advective-Diffusion/Dispersion Transport of Chemically Reacting Species

A-59 Fluid Transport Properties of Rock Fracture

A-60 Seismology of Crack Formation

A-61 Microcrack Technology

A-62 Mechanism of Zeolite Crystallization and Alteration in Silicate Glasses

A-63 Hydrothermal Solubility of Uraninite

A-64 Porosity with Fluids

A-65 Thermally Induced Chemical Migration in Carbonate Rocks (1)

A-66 Thermally Induced Chemical Migration in Carbonate Rocks (2)

A-67 Mechanical & Transport Properties of Rocks

A-68 Opening Mode Crack Growth in Rocks

A-69 Computerized Underground Image Reconstruction

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG-TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 3

This Instruction Sheet contains a list of future activities for Priority Evaluation by the panel.

B - FUTURE RESEARCH ACTIVITIES

B-1 Spent Fuel Reprocessing Modification to Affect Waste Properties and Optimize the Waste Treatment System

B-2 TRU Waste Immobilization and Disposal

B-3 Reactor D&D High Activity Materials

B-4 Test of Complete Waste Package and Migration Behavior

B-5 Planning of Long Range Backup Tests

B-6 Operation and Maintenance Effects on Reprocessing and Solidification Building Designs

B-7 Noble and Strategic Metals Recovery

B-8 On-Line Sampling Instrumentation

B-9 Ceramic Waste Forms

B-10 Devitrified Glass (Crystalline Ceramic)

B-11 HLW Disposal Comparative Risk Studies

B-12 Standardized Shipping Cask Design

B-13 Conditioning Intact or Partially Processed Nuclear Fuel

B-14 Procedures and Techniques for Repository Instrumentation Systems

B-15 Inspection and Recovery Operations in Case of Unforeseen Events (Earthquake, etc.)

B-16 Establishment of Acceptance Criteria for Determination of Adequacy of Nuclear Waste R&D

B-17 Investigate Retrieval of Waste to Be Useful Later

B-18 Redesign the Heat Package

B-19 Develop Virification Processes and Other Immobilization Processes Emphasizing Cost and Regulations

B-20 Research to Answer Public Concerns on Disposal, Risk and Health Factors

B-21 Research Disposal of Spent Fuel Assemblies and Handling Abilities

B-22 Packaging of Iodine Waste

B-23 Determine Activities of Many of the Low Level Wastes

APPENDIX C

PANEL WORKSHOP HANDOUT

LONG-TERM RESEARCH NEEDS
NUCLEAR WASTE MANAGEMENT

INSTRUCTION SHEET NO. 3(Continued)

B-24 LLW Processing Into a Form That Puts it Into HLW Category

B-25 Research Long-Term Metal Corrosion (>30 years)

B-26 Research Fuel and Waste Loadings

B-27 Research Sealing of Repository Leaks

B-28 Meaning of Waste Storage to Humans in the Long Range

B-29 Disposal/Immobilization Technology for Newly Emerging or Special Nuclear Wastes

B-30 Process Technology for Second-Generation Waste Forms

B-31 Material and Engineering Techniques to Prevent Ground Water Contamination From Active Uranium Mill Tailings

B-32 Process Research of Combined Volume Reduction and Immobilization Techniques for Low-Level Wastes

B-33 Processing Technology for High-Level Waste Glassification

B-34 Fuel Waste Reprocess Concerns/Alternatives

B-35 Radionuclide Migration Chemical Aspects

B-36 Reduction of Occupational Radiation Exposures

APPENDIX D

SAMPLE PRIORITY EVALUATION WORKSHEET

This appendix contains a sample Priority Evaluation Worksheet. Sheets were prepared for current (A) and future (B) research activities and were utilized by the expert panel in the second workshop meeting.

APPENDIX D

SAMPLE PRIORITY EVALUATION WORKSHEET

PRIORITY EVALUATION WORKSHEET FOR DOE RESEARCH ACTIVITIES

A. Research Activity ______________________ No. ____

Comments: ______________________

B. Sufficient Research -- Yes/No (Circle One)

Comments: ______________________

C. If "No," Specify Description of Additional Research Needed: ______________________

D. Options for Performing Needed Research:

1) Potential Performers: ______________________

2) Cost: ______________________

3) Year of Start and Duration: ______________________

E. Priority -- High / Medium / Low (Circle One)

NAME OF PANEL MEMBER: ______________________ 11/83

APPENDIX E

PERTINENT REPORTS ON NUCLEAR WASTE MANAGEMENT

This appendix lists a number of pertinent reports on activities related to nuclear waste management.

APPENDIX E

PERTINENT REPORTS ON NUCLEAR WASTE MANAGEMENT

Report Number	Title
PNL-4250-3	Nuclear Waste Management Semi-Annual Progress Report October 1982 through March 1983
DOE/ER-0145/1	Summaries of Physical Research in the Geosciences September 1983
DOE/ER-0144/1	Summaries of FY 1983 Research in the Chemical Sciences
DOE/ER-0143/1	Materials Sciences Programs - Fiscal Year 1983
SAND83-1387	The Subseabed Disposal Program: 1983 Status Report
	Q&A - Nuclear Power and the Environment
DOE/NE-0017/2	Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics
DOE/TIC-11033	Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository
DOE/TIC-11207	Status of Technology Isolating High-Level Radioactive Wastes in Geologic Repositories
	BES Initiative FY 1980-89 Radioactive Waste Disposition US DOE - OBES
	Scientific Needs of the Technology of Nuclear Waste Containment - Division of Materials Science U.S DOE by the University of Illinois
	A Study of the Isolation System for Geologic Disposal of Radioactive Wastes - 1983

GENERAL REFERENCE REPORTS

ONWI-110	Standardized Repository and Encapsulation Facility Cost Estimates for Comparative Evaluation and Pricing Study
ONWI-65	Alternative Waste Disposal Concepts An Interim Technical Assessment

APPENDIX E

PERTINENT REPORTS ON NUCLEAR WASTE MANAGEMENT

Report Number	Title
GENERAL REFERENCE REPORTS (Continued)	
ONWI-19 (Rev. 1)	National Waste Terminal Storage Program Office of Nuclear Waste Isolation Technical Program Plan
DOE/NE-0008	Nuclear Waste Management Program Summary Document
ONWI-19	National Waste Terminal Storage Program Office of Nuclear Waste Isolation Technical Program Plan
ONWI-24	Assumptions and Ground Rules Used in Nuclear Waste Projections and Source Term Data
	Summaries of FY 1980 Research in the Nuclear Sciences