NNA.871113.0030

Scientific Investigation Plan
for
NNWSI WBS Element 1.2.2.2.L

NNWSI Waste Package Environment

Lawrence Livermore National Laboratory

October 30, 1987

L. Ramspott 10-30-87
L D Ramspott, Technical Project Officer

Ronald E. Schultz for 10/30/87
John J Dronkers, Deputy for Quality Assurance

William E. Glassley 10/30/87
William E. Glassley, Task Leader and Technical Area Leader

Carol J. Bruton 10/30/87
Carol J. Bruton, Technical Reviewer

James Blaylock 11/5/87
Project Sponsor Quality Manager

Lester P. Skousen 11/7/87
Project Sponsor

SAIC/T&MSS
NOV 13 1987
CCF RECEIVED

8811070359 87-10-30

102.2
WM-
NH

TABLE OF CONTENTS

SCIENTIFIC INVESTIGATION PLAN FOR THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATION: WASTE PACKAGE ENVIRONMENT

1.0 PURPOSE AND OBJECTIVE

1.1 Purpose of Study

The purpose and objective of the Waste Package Environment task is to establish and characterize the environmental processes affecting the near-field repository host rock after waste package emplacement, as dictated by requirements contained in Section 135 (a) of the NRC Rule 10CFR60 which states, in part:

> Packages of HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.
>
> The design shall include, but not be limited to considerations of the following factors: Solubility, oxidtion/reduction reactions, corrosion, hybriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

These processes, which reflect the perturbation induced in the environment by engineering effects and by the waste package decay heat and radiation, will influence chemical, mineralogical and hydrological features of the environment. The thermal and radiation output of the waste packages will change with time, resulting in an environment in which the chemical, mineralogical and physical attributes may also change through time. To assure that waste package design considerations reflect the characteristics of this evolving environment, it is necessary to determine the range of conditions that may develop in the pre- and post-emplacement waste package environment. To assure that the emplacement configurations do not

compromise the lifetime of the repository or the waste packages, the design of the emplacement configuration must also consider the environmental features. Recognition of these requirements resulted in the development of the following issue and information needs (IN) (taken from the 8/7/86 version of NNWSI information needs):

Issue 1.10 Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the post closure design criteria of 10 CFR 60.135, and (b) provide information to support resolution of the performance issues?

IN 1.10.4 Description of the post-emplacement near-field environment of the waste packages, including the expected range of environmental characteristics under conditions appropriate for the reference emplacement configuration.

It is the purpose and objective of the Waste Package Environment Task to provide information that will be used to resolve this issue. Processes affecting the post-emplacement environment will also influence waste package performance. The activities described below will therefore provide input to waste package performance assessment models.

The proposed environment in which high level radioactive waste would be emplaced is a devitrified, welded, rhyolitic tuff. To establish the nature of effects acting on this material, it is necessary to identify and characterize the processes that will occur during thermal perturbation of the environment in the presence of radiation. Once the processes have been identified that may affect the environment, it will be possible to describe the conditions that could lead to failure of the package and transport of radioactive material away from the emplacement location.

The processes that may occur in the waste package environment reflect the chemical and mineralogical characteristics of the tuff, which are expressed by the minerals that have developed during and after emplacement of the

tuff. The tuff consists of primary minerals, such as sanidine, plagioclase, quartz, biotite, iron-titanium oxides, allanite and zircon, that formed at temperatures in excess of 600°C in a magma chamber prior to eruption of the tuff and secondary minerals, such as cristobalite, quartz, alkali feldspars, and smectite clays that formed during cooling and later alteration of the tuff at temperatures less than 500°C. Available evidence suggests that the rock in the proposed repository horizon has a mean matrix porosity of 14% and a mean water saturation of 65% (Montazer and Wilson, 1984). Fluid, therefore, partially fills the rock pores. Emplacement of waste packages in this environment will modify the thermal and radiation fields experienced by the host rock, and may lead to complex chemical reactions between the near-field fluids and minerals. The unsaturated nature of the host rock and the local hydrological properties of the host rock demonstrate that, for anticipated scenarios, these complex reactions will occur in a humid, vapor-present, liquid-absent condition. However, for some scenarios under unanticipated conditions, saturation of the waste package host rock may occur. Chemical reactions under saturated conditions may differ in magnitude and nature from those that might occur under unsaturated conditions. The reactions that may occur over this range of saturation conditions constitute the chemical processes that must be characterized to meet the purpose and objective of Information Need 1.10.4.

The effects of individual parameters on the reaction process must be evaluated to fully characterize the chemical environment of the waste package. The parameters to be considered in activities are temperature, the ratio of rock surface area to fluid volume, fluid composition, radiation dose and dose rate, and dissolution and precipitation kinetics.

The hydrologic characteristics of the tuff reflect the welding, devitrification, and fracture processes that have occurred after deposition of the tuff. These processes have resulted in development of a rock with a mean matrix porosity of 14% (Montazer and Wilson, 1984) and a fracture density of between 8 and 40 fractures per cubic meter (Scott et al., 1983). The structural location of this horizon 700 to 1400 feet above the local water table (Ortiz et al., 1985), and the local meteorological conditions have resulted in a rock that is 65% saturated (Montazer and Wilson, 1984). Evidence suggests that the net water flux in this unsaturated environment is 1.0 to 2.0 mm/yr upward, although a downward flux of 1.0×10^{-7} to .5 mm/yr may occur as a result of matrix flow (Montazer and Wilson, 1984;

Montazer et al., 1985). The matric potential of the tuff is approximately -112 kPa, which results in negligible fracture flow (Wang and Narasimhan, 1985). The processes that will occur upon emplacement of waste packages in the tuff, and the effect of these processes on the hydrologic characteristics of the tuff, must be established to meet the requirements of Information Need 1.10.4.

Characterization of the processes affecting the hydrologic properties of the tuff at elevated temperatures requires knowledge of the dissolution and precipitation reactions that may influence pore and fracture geometry (i.e., size, shape and roughness), the potential fluid flow pathways under saturated and unsaturated conditions, the influence of fractures on fluid flow and degree of relative saturation, and the relative importance of convective flow coupled with condensation/evaporation phenomena. The parameters that influence these processes, and that will be evaluated in tests, experiments, and numerical simulations are temperature, temperature gradient, relative saturation, dissolution/precipitation kinetics, and fluid composition.

Two broad categories of activities provide the information necessary to characterize the mineralogical, chemical, and hydrological properties and processes that constitute the post-emplacement waste package environment. The first category of activities incorporates laboratory tests, experiments, and numerical geochemical simulations to define the interaction of tuff, water, water vapor, and waste package components in the presence of elevated temperature and radiation fields. Activities described under heading 2.1 fall in this category. These activities will establish the nature of chemical and mineralogical evolution of the waste package environment for anticipated and unanticipated conditions involving various degrees of water saturation. The second category of activities incorporates laboratory tests, experiments and numerical geochemical simulations to establish the hydrologic properties of the tuff under anticipated and unanticipated conditions. This second category of activities will define the range of values of parameters, for anticipated and certain unanticipated conditions, that influence fluid flow processes in the waste package environment. These activities are described under heading 2.2.

1.2 Use of Results

Results from activities identifying mineralogical and chemical changes in the waste package environment will provide input to Information Need 1.10.4, which considers the nature of the emplacement environment, and will contribute to performance assessment goals by establishing the possible range of chemical parameters that may influence radionuclide release and transport. Possible changes in water chemistry and the long-term geochemical behavior of the environment will be used to define the chemical characteristics of the environment of the waste package as needed in Information Need 1.10.4. This information will also define the range of anticipated conditions to be experienced by the waste package, as required by Information Need 1.10.2, and will establish chemical criteria to be used in package design activities, and waste form and metal barrier testing. Numerical geochemical simulations of the long-term geochemical characteristics will be used to establish environmental constraints for performance assessment purposes.

Results from activities concerning the hydrologic properties of the waste package environment will define the flow and transport characteristics that may lead to vapor and/or liquid water interaction with the waste package, and the transport pathways that will influence radionuclide migration from failed waste containers. This information will provide input to waste package performance assessment through evaluation of conceptual models of fluid flow and transport, and by developing functional relationships between the physical and chemical parameters characteristic of the waste package environment and fluid flow models.

2.0 RATIONALE FOR SELECTED STUDIES AND QUALITY ASSURANCE LEVEL ASSIGNMENTS

The activities described below are designed to provide information necessary to characterize the chemical, mineralogical and hydrological properties and processes of the waste package environment for anticipated and certain unanticipated conditions. The quality assurance level assignments (QALA) for each activity, and the section in this document where the activity is described, are presented in Table 1. The quality assurance (QA) level assignments are influenced by the availability of data

for each activity. For those activities in which sufficient data are available to design tests and analyses that can be used in a license application, the activity has been designated QA Level I. Activities designated QA Level III are one of three types. One type of QA Level III activity addresses those instances in which tests and analyses necessary to develop a license application cannot be designed or executed because the current scientific database is insufficient. Examples of such activities are B-20-3 and B-20-10. This type of QA Level III activity will provide information to be used in design and execution of QA Level I activities. The QA Level III data used for this purpose will remain separate from that generated by the new QA Level I activity. A second type of QA Level III activity is designed to provide data necessary for the database of the EQ3/6 geochemical modeling code (Wolery, 1983, 1986), and for establishing protocols for use of the code at Level I. Examples of these QA Level III activities are B-20-6, B-20-7 and B-20-8. The database will be validated using QA Level I activity B-20-11. A third type of QA Level III activity explores analytical or laboratory techniques that have the potential to produce information necessary for license application, but for which insufficient information exists to establish the efficacy of the technique. Activity B-20-12 represents such a situation. This level III activity may lead to QA Level I activities, if it can be demonstrated that the technique under evaluation provides data of sufficient quality and appropriate application. In the QA Level III activities described below, it is noted whether the activity will lead to development of a separate QA Level I activity.

For those instances in which a QA Level I activity is to be developed as a result of information gained from a QA Level III activity, the level I activity will be treated as a new activity. This will require that the new level I activity will be developed and reviewed according to procedures 033-NWMP-P 20.0 (Assigning Levels of Quality Assurance) and 033-NWMP-P 20.1 (Numbering of Activities), and will be subject to all other procedures and requirements described in the NWMP Quality Assurance Program Plan.

Discussion of the rationale for individual activities will be presented in two sections. The first section (Section 2.1) discusses the rationale for activities that identify and evaluate parameters that influence chemical and mineralogical attributes of the waste package environment. The second section (Section 2.2) discusses the rationale for activities that identify and evaluate parameters that influence the hydrologic properties of the waste

package environment.

Table 1. Quality Assurance Designations For Activities

Activity Number	Title (Section Where Described)	QALA
B-20-1	Two Fluid Phase Flow (Sect. 2.2.2)	III
B-20-2	Single Phase Fluid: Dehydration-Rehydration of Tpt in a Temperature Gradient (Sect. 2.2.1)	I
B-20-3	Hydrothermal Experiments on Vitric, Vitrophyric, and Zeolitized Tuff (Sect. 2.1.3)	III
B-20-4	Hydrothermal Testing of Drillcore from the Repository Horizon (Sect. 2.1.1)	I
B-20-5	Mineral Dissolution and Precipitation Experiments (Sect. 2.1.5)	III
B-20-6	Vadose Water Composition (Sect. 2.1.7)	III
B-20-7	Prediction of Long-Term Rock-Water Interaction Through Computational Simulations of Reactions in Concentrated J-13 Water (Sect. 2.1.8)	III
B-20-8	Modeling of Rock-Water Interaction) (Sect. 2.1.6	III
B-20-9	Hydrothermal Testing of Repository Horizon Material Obtained From the Exploratory Shaft (Sect. 2.1.2)	I

B-20-10	Tests and Experiments of Rock-Water Interaction and Water Chemistry Changes in the Presence of a Radiation Field (Sect. 2.1.4)	III
B-20-11	Validation of EQ3/6 Reaction Path Modeling Code Results (Sect. 2.1.6)	I
B-20-12	Methodology Development and Technique Evaluation (Sect. 2.1.9)	III
B-20-13	Modeling of Rock-Water Interaction to Support License Application (Sect. 2.1.6)	I

2.1 Chemical and Mineralogical Properties

Modeling of the thermal behavior of the waste package near-field environment demonstrates that there will be a rapid increase in temperature immediately after package emplacement (O'Neal et al., 1984). The maximum temperature attained will depend on the nature of the waste emplaced and the repository design, but is expected to be approximately 230° C. The temperature is then expected to slowly decrease over hundreds of years. This thermal behavior will result in development of a dehydration zone surrounding the waste package as water vaporizes and migrates away from the waste package. The rock-water system adjacent to the waste package will experience a thermodynamic drive to attain equilibrium with the new thermal and chemical environment. The thermodynamic drive will be expressed as chemical reactions among the mineral and fluid phases in the environment. Depending upon the extent of reaction, detectable dissolution of host rock primary and secondary minerals may occur, mineral phases may form, and mineral and fluid compositions may change. The extent to which these reactions proceed will depend upon the kinetics of dissolution, precipitation, and diffusion processes. The kinetics that influence reaction progress are, in turn, influenced by temperature, the degree of water saturation, fluid composition, and the ratio of rock surface area to fluid volume. Five activities will evaluate the relationships of these parameters to the chemical and mineralogical evolution of the waste package environment. Three of the activities, described in Sections 2.1.1, 2.1.2, and 2.1.3, examine these relationships under saturated conditions. Activities described in Sections 2.2.1 and 2.2.2 examine these relationships for unsaturated conditions.

Radiation will also influence the chemical and mineralogical evolution of the waste package environment. The principal effects will result from gamma radiation interacting with vapor, water, and rock through ionization processes in the package environment. Neutron radiation will be low, and alpha and beta radiation will not noticeably penetrate the waste package container (Van Konynenburg, 1986). The complex thermal history of the waste package environment requires evaluation of gamma radiation interaction with air-steam and air-water atmospheres, in the presence of tuff and waste package components. Examination of these effects is discussed in Section 2.1.4.

Experiments and tests are insufficient to evaluate all possible conditions the waste package environment may experience. For example, the waste package host rock will experience a continuum of temperatures ranging from ambient through a thermal maximum followed by protracted cooling. Laboratory activities can only evaluate processes that occur at a few discrete temperatures within this continuum. To provide the ability to characterize the waste package environment for all conditions of interest, computer codes that incorporate mathematical descriptions of natural phenomena will be used to numerically simulate the effects of environmentally significant processes. The computer code EQ3/6 will be employed to model rock-water interaction. To enhance use of this code, data must be obtained for dissolution/precipitation kinetics of individual minerals of interest. Section 2.1.5 describes laboratory experiments that will provide data on rates of mineral dissolution and precipitation. Numerical geochemical simulation of rock-water interaction using the EQ3/6 reaction path code is described in Section 2.1.6.

Previous laboratory studies (e.g., Knauss et al., 1985, 1986) have employed ground water obtained from well J-13. Water from well J-13 has been selected as the reference ground water for experimental and test purposes since available data suggests that this ground water may be representative of water that occurs in pores in the repository horizon (Glassley, 1986). To establish the chemistry of vadose water from the repository horizon rock and to evaluate its relationship to well J-13 water, pore water must be extracted from repository horizon rock. Section 2.1.7 describes work that addresses this issue. Section 2.1.8 describes work that incorporates numerical geochemical simulations of rock-water interaction, using vadose water compositions, over a range of environmental conditions not reproduced in the laboratory.

2.1.1 Hydrothermal Testing of Drill Core From the Repository Horizon (QALA I, Activity Number B-20-4)

A series of long-term Quality Assurance Level I tests will be conducted using drill core material recovered from the proposed repository horizon.

These tests will determine the solid phase reaction products that form during interaction of repository level rock with reference ground water at elevated temperatures. The test duration will be ~300 days; tests at different temperatures will be run simultaneously. Tests will be initiated when core material appropriate for this Quality Assurance Level I activity is available.

To examine the effect of temperature on reaction progress and reaction product development, tests will be conducted at temperatures of 90, 150 and 250°C. This temperature range spans that expected for the waste package environment. Although saturation of the waste package environment would not be possible at temperatures significantly in excess of 100°C, tests are planned at temperatures as high as 250°C for three reasons. First, reaction kinetics control the rate of mineral dissolution and growth. Because reaction rate laws are generally exponential functions of temperature, tests conducted at high (>150°C) temperature, where reaction products are better developed, can be used to provide reaction rate relationships at lower temperatures. To establish the functional relationship between temperature and kinetically-controlled reaction progress, it is necessary to establish reaction rates at several different temperatures. Second, the stability fields of reaction product minerals are sensitive functions of fluid composition, temperature, and mineral solid solution effects. Tests limited to temperatures appropriate to a saturated environment would not establish whether reaction product minerals were close to the limits of their stability fields. Third, water confined in the rock pores may exist to temperatures as high as 140°C if venting is restricted (Travis et al., 1984). Such water may interact with the pore walls at elevated temperatures. The tests and experiments at temperatures of 150 and 250°C will provide stability field constraints on the reaction products that may develop in these confined pore volumes.

The effect of the ratio of rock surface area to fluid volume will be established by conducting hydrothermal tests on solid rock wafers and on crushed rock. The large difference in rock surface area in the tests will allow the functional relationship between rock surface area and fluid volume ratio to be determined.

The effect of reaction progress on mineral composition will be established

by post-test analysis of the secondary phases that form. This analysis will establish the relative volume, composition, and mode of occurrence of each secondary mineral. These results will characterize the nature of the reaction product phases and will allow calculation of the reaction stoichiometry that controls the evolution of the chemistry of the coexisting fluid.

The composition of the coexisting fluid will be established through periodic sampling of the fluid in the test apparatus. The fluid composition will evolve as the rock-fluid system approaches equilibrium and will, therefore, be a direct measure of reaction progress and rate of mineral precipitation and dissolution.

The phases in the host rock that dissolve or change in composition during the reaction process will be examined to determine the extent of dissolution of each mineral. Phases will be identified that are the source for elements participating in the development of secondary phases, and that contribute to changes in fluid composition during reaction progress.

The methodology used in this activity is described in Section 3.1.

2.1.2: Hydrothermal Testing of Repository Horizon Material Obtained From the Exploratory Shaft (QALA I, Activity Number B-20-9)

A series of long-term Quality Assurance Level I tests, using rock obtained from the repository horizon during Exploratory Shaft operations, will be conducted under the same conditions as those tests outlined above in Section 2.1.1. These tests will be initiated upon completion of the drill core tests, or when Exploratory Shaft material is available. The test and analytical procedures used in this activity will be identical to those described in Section 2.1.1 and are described in Section 3.1. These tests are necessary to confirm that conclusions and functional relationships developed through the use of outcrop and drill core material are applicable to the actual repository horizon material.

2.1.3: Hydrothermal Experiments on Vitric, Vitrophyric, and Zeolitized Tuff (QALA III, Activity Number B-20-3)

Experiments that examine rock-water interaction involving material from other geologic horizons in the vicinity of the proposed repository horizon will be carried out. Much of this material is vitric, vitrophyric or zeolitized tuff. The experiments will place limits on the number of possible reaction products in the waste package environment by identifying the solid phases produced in hydrothermal reactions in a suite of materials related to, but distinct from, the repository horizon material. The experiments will also establish limits for the range of chemical variation possible for rock-water interaction for the unanticipated condition of rapid fracture flow of fluids into the repository from non-repository horizons. Results of these experiments will be provided to Los Alamos National Laboratory, through reviewed publications and through letter reports, for use in their evaluation of the applicability of natural analogue studies to near-field rock alteration.

As in Section 2.1.1 (Activity B-20-4), the experiments are designed to determine the effect of temperature and the ratio of rock surface area to fluid volume on the kinetics of mineral reaction and the nature of the solid phase reaction products that form during interaction of rock with reference ground water at elevated temperatures. The reaction product phases will be identified and characterized in terms of morphology, relative abundance, and composition. The extent of dissolution of phases in the host rock will be examined to determine the source for elements participating in the development of secondary phases, and to identify the phases contributing to changes in fluid composition during reaction progress. The effect of surface area on reaction kinetics will also be established by comparing the initial ratio of rock surface area to fluid volume, to the extent of reaction. Initial experiments will be conducted at QA Level III, Upon completion of these experiments, a QA Level I activity will be designed using procedures developed in the QA Level III work, if results from further tests are needed.

The methodology used in this activity is described in Section 3.1.

2.1.4: Tests and Experiments of Rock-Water Interaction and Water Chemistry Changes in the Presence of a Radiation Field (GALA III, Activity Number B-20-10)

Studies of rock-water interaction in the presence of a gamma radiation field will be conducted to establish the identity and quantity of solid and dissolved reaction products. Studies of the effect of radiation on water vapor and on J-13 well water will also be done. The purpose of these tests and experiments is to determine the effect radiation will have on the chemical and mineralogical characteristics of the waste package environment.

In the waste package environment, ionizing gamma radiation will interact with the air-steam atmosphere and pore water to form radiolysis products, which may then interact with the rock to influence mineral dissolution and precipitation. The radiolysis products, which are presently poorly known, must be characterized to establish the chemical and mineralogical evolution of the waste package environment through time. The composition of the radiolysis products is a function of temperature and, therefore, will change as the package environment thermally evolves. The following questions are of particular interest and will be addressed by laboratory studies: In a bicarbonate-buffered aqueous solution (such as J-13 water) in contact with air, will formate or oxalate form? Will the nitrite-nitrate ratio change if MnO_2 is present? To what extent will the repository horizon tuff mineralogy buffer the fluid pH, if nitric acid is produced through radiolytic processes? In an air-water system, does nitric acid form in the gas phase and then enter the water, or do nitrogen oxides form in the gas phase, dissolve in the water and react there to form nitric acid? What reactions occur when NO enters water?

The solution that forms during interaction of gamma radiation with the liquid and/or vapor phases in the waste package environment will chemically interact with the repository tuff. The reaction products that develop will be a function of temperature and fluid composition. The rate at which they form will depend upon the kinetics of the reaction process. The progress of chemical reactions and mineralogical changes will be evaluated in experiments and tests in which combinations of an aqueous fluid, tuff, and certain waste package components are present. Periodic sampling and

analysis of the fluid present in these tests and experiments will allow quantitative description of the reaction process, and will provide answers to the questions presented above. Examination of tuff present in the tests and experiments will allow identification of the solid reaction products, and determination of their abundance and composition. The phases originally present in the host rock and package components will be examined to determine their extent of dissolution, and to identify phases that influence fluid composition and contribute to formation of secondary minerals during reaction progress.

The studies will define the chemical processes expected to occur in the immediate vicinity of the waste packages in the presence of ionizing radiation. Initial studies will be conducted at QA Level III. QA Level I tests will be designed using procedures developed in the QA Level III work, if level I data are required.

The methodology used in this activity is described in Section 3.2.

2.1.5: Mineral Dissolution and Precipitation Experiments (QALA III, Activity Number B-20-5)

In rock-water interaction studies the balance between dissolution of reactant phases and the concomitant precipitation of product phases controls fluid composition and rates of chemical reaction. To interpret observed changes in fluid composition and associated development of product mineral phases in rock-water interaction studies, the dissolution kinetics of the phases present in the host rock, and the precipitation kinetics of product minerals phases must be known. Data on the kinetics of dissolution and precipitation of phases of interest is sparse and must, therefore, be obtained through laboratory study. The data collected in such a study will contribute to database development that is necessary for modeling rock-water interaction using the EQ3/6 geochemical simulation computer code.

Dissolution and precipitation studies will be conducted over a range of temperatures and fluid pH in order to determine the sensitivity of the

kinetics to temperature and fluid composition. Phases used in the studies will include the dominant constituents of the devitrified, welded tuff, and the common secondary phases associated with rock-water interaction. Experiments will also be conducted to determine the degree to which vapor-phase dissolution and precipitation will occur under conditions anticipated in the repository environment.

The laboratory studies will be used to identify the mechanisms of dissolution and to determine the rates for the dissolution and precipitation process. This information will contribute to understanding the processes occurring on mineral surfaces during congruent and incongruent dissolution in saturated and unsaturated environments. The phases and structural changes that evolve on mineral surfaces during incongruent dissolution will influence sorption characteristics of the tuff by providing reaction product phases that may interact with fluids transporting radionuclides. Identification of the dissolution and precipitation mechanisms and of the solid reaction products will thus characterize the effects of dissolution on radionuclide retardation.

For each mineral selected for study, dissolution experiments will be conducted over a range of pH values at temperatures of 25 and 70°C. QA Level III vapor phase experiments will also be conducted to determine the magnitude of vapor phase dissolution and precipitation. The analytical results of the experiments will be interpreted using transition state theory, and the results will be incorporated into the EQ3/6 database.

The methodology used in this activity is described in Section 3.3.

2.1.6: Modeling of Rock-Water Interaction (QALA III, Activity Number B-20-8), Validation of EQ3/6 Reaction Path Modeling Code Results (QALA I, Activity Number B-20-11), and Modeling of Rock-Water Interaction to Support License Application (QALA I, Activity Number B-20-13)

The geochemical behavior of the waste package environment over long time periods (tens to thousands of years) will vary as the radiation and thermal fields change through time. Laboratory study is incapable of examining the coupled effects of all possible values and combinations of parameters

significant for the system under consideration. In addition, laboratory studies cannot be directly used to extend the behavior of natural systems studied in the laboratory over periods of months to periods of many years. However, the use of numerical geochemical simulations, in conjunction with judiciously selected tests, can provide the capability to examine effects and processes in natural systems for time periods and chemical conditions not duplicated by experimental studies.

A necessary test of a predictive modeling tool is successful reproduction of completed rock-water interaction experiments and tests. This modeling effort constitutes a part of Activity B-20-8. Numerical simulations, using EQ3/6, of the evolution of rock-water systems have been completed on several hydrothermal studies (Delany, 1985). The efficacy of the modeling approach has been established by duplicating many of the observed changes in fluid composition and mineral development noted in the experiments. In addition, certain limitations in the thermodynamic database relating to precipitation kinetics and standard state data were identified. With completion of the dissolution and precipitation work described in Section 2.1.5, and upon incorporation of new thermodynamic data for clays and zeolites, more accurate modeling of reaction progress is expected.

As new data are incorporated into the database, simulation of the results of hydrothermal studies will be continued. The numerical simulations will be designed to reproduce the same physical conditions, starting materials, and run durations of previously completed hydrothermal experiments. Selected tests and experiments described in Sections 2.1.1, 2.1.2, and 2.1.3 will also be modeled. The results of the numerical simulations will be compared with the hydrothermal experiments and tests to ensure that the models used by the EQ3/6 software to compute fluid composition and solid phase growth and dissolution during reaction progress accurately portray reaction progress.

When results are obtained that accurately describe reaction progress, QA Level I validation of the database will be undertaken as Activity B-20-11. QA Level I laboratory hydrothermal tests not used in previous modeling efforts will be used to validate those portions of the code and database that pertain to hydrothermal reaction progress in the package environment. Tests used in the validation are expected to cover the entire temperature range of laboratory studies, that is 90 to 250°C.

Predicting long-term behavior of the hydrothermal systems by scaling the laboratory experiments to time scales of years, also constitutes a part of Activity B-20-8. Initial results of long-term modeling have been completed and were subject to the same successes and uncertainties observed in the models of hydrothermal experiments. As further code and database development occur, new long-term simulations will be carried out. When the validation for waste package environment applications has been completed (Activity B-20-11), QA Level I long-term simulations will be conducted under Activity B-20-13 to establish the geochemical and mineralogical characteristics of the waste package environment to be used in license application.

The QA Level I activities described for Activity B-20-13 will provide input to Information Need 1.10.4, and will contribute to waste package performance assessment by establishing the composition of fluid in the waste package environment for the anticipated and unanticipated range of repository conditions over the time interval defined by regulatory requirements. The code and database, as validated under Activity B-20-11, will also be used to determine the sensitivity of the geochemical environment to perturbations in individual compositional parameters within the range for which validation was accomplished. Results of this analysis will define limits of variation in the geochemical system that will constrain the input to waste package performance assessment.

The methodology used in this activity is described in Section 3.5.

2.1.7: Vadose Water Composition (QALA III, Activity Number B-20-6)

A series of QA Level III experiments will be conducted to extract pore water from representative devitrified, welded tuff. These experiments will be designed to identify a method that produces fluid representative of that within pores.

Circumstantial evidence exists that the vadose water in the repository horizon is similar in composition to water obtained from well J-13. This

evidence consists of correlations between rock and fluid compositions at Rainier Mesa, which is geologically similar to Yucca Mountain. The similarity in composition between water obtained from the unsaturated zone at Rainier Mesa and water from well J-13 suggests that vadose water within the repository horizon at Yucca Mountain is likely to be similar in composition to well J-13 water. Experimental work must be used to confirm that the vadose water at the repository horizon is, in fact, similar in composition to the reference ground water.

Fluid extraction techniques that have been employed in the past include high pressure compression of core samples, application of high gas pressure to core samples, centrifugation, and pore water displacement (Dropek and Levinson, 1975). Comparisons of extracted fluid composition with available database information will be used to identify a technique that produces uncontaminated fluid. Evaluation of the techniques will be accomplished by comparing analyses of the collected fluid with theoretical models of rock-water interaction and with the limited available data regarding the composition of vadose fluids in equilibrium with the minerals present in the rock. Once an extraction method is selected, a QA Level I activity will be developed in which vadose water will be extracted from core uncontaminated with drilling fluids and from Exploratory Shaft material collected at the repository horizon and analyzed.

The methodology used in this activity is described in Section 3.4.

2.1.8: Prediction of Long-Term Rock-Water Interaction Through Computational Simulations of Reactions in Concentrated J-13 Water (QALA III, Activity Number B-20-7)

Upon obtaining correspondence between the numerical simulations and the hydrothermal tests and experiments, as described in Section 2.1.6, and upon determining the composition of vadose water in the repository horizon material, the behavior of rock-water interaction over time periods of years, in the presence of thermal gradients and vadose water, will be simulated using the EQ3/6 computer code. These simulations will extend the previously described modeling results to systems in which concentrations of the solute species in the vadose water are increased by evaporation. This

activity will evaluate the effects upon rock-water interaction of dehydration/evaporation processes that will occur during the heating of waste package host rock. This activity will also examine the effects of rehydration upon rock-water interaction as the temperature of the host rock decreases after the thermal maximum. These processes are of interest because solute species present in the vadose water may be concentrated as pore fluid evaporates during heating. Precipitation of salts may then occur as the host rock dries. Dissolution of the precipitated salts may occur upon rehydration of the host rock during cooling, at which time solutions more concentrated than the original vadose water may form along the advancing rehydration front. The modeling effort undertaken in this activity will determine the reaction products and fluid compositions expected to form under these dehydration/rehydration scenarios.

The methodology used in this activity is described in Section 3.5.

2.1.9: Methodology Development and Technique Evaluation (QALA III, Activity Number B-20-12)

The laboratory work carried out in this WBS element requires the development of new techniques and procedures for controlling and monitoring multi-phase fluid flow, simultaneous collection of liquid and gas phases, computer-controlled processing and reduction of data, and examining rock-water interaction. In cases where new methods must be developed to obtain information necessary in license application, a research and development effort must be initiated that proves the validity of the new approach. This development work will be constrained to obtain the information required, but must be flexible enough to allow efficient evaluation of proposed or alternative approaches to the technical work. In addition, new technological developments that occur as research progresses can occasionally provide information that was not previously available. When such technological advances occur, they may justify new laboratory activities. Before such activities can become part of a scientific investigation, however, the applicability of the new technology to the problem being considered must be established. Work conducted in this activity would evaluate new techniques and develop the protocol for their use.

The methodology used in this activity is described in Section 3.8.

2.2 Hydrologic Properties

Water transport within tuff of the proposed repository horizon occurs by a combination of vapor transport, water migration through the matrix, and fracture flow (Montazer and Wilson, 1984). The relative importance of each flow mechanism is a function of the bulk saturation, the volume of water transported through the rock, the temperature gradients in the rock, the fracture characteristics, and the permeability of the matrix.

The emplacement of waste packages in the rock will produce a large thermal perturbation. This, in turn, will cause water to vaporize and migrate in the near field and will result in an altered hydrologic regime. There is very little experimental or theoretical information on thermally driven flow in partially saturated rocks. Because water is the main corrosive agent for the metal container and the main agent for the dissolution and transport of radionuclides, laboratory and numerical modeling studies are necessary to characterize fluid flow in the Topopah Spring tuff.

Laboratory studies and accompanying transport calculations will aid in the prediction of the waste package hydraulic environment and will contribute to the calculation of radionuclide release source terms. Understanding the roles that fractures and adjoining matrix blocks play as conduits to liquid and vapor phase transport is of particular importance. This interaction will influence the extent of dry out in the surrounding host rock and the rate at which rewetting can occur as the thermal output of the waste decreases. These processes impact assessment of waste package corrosion mechanisms and rates and will influence transport rates near the waste package after breach of containers.

The hydrologic properties and ambient conditions in the host rock at the repository horizon result in a complex system in which hydrothermal flow and transport in fractures and rock matrix must be considered. The complexity of the near field hydrothermal problem arises from two characteristics of the environment. First, the host rock is partially saturated with approximately 65 percent of the bulk pore volume occupied by water held in the porous matrix by capillary suction (Weeks and Wilson,

1984). Due to the extremely small average pore size in the matrix, capillary suction effects are very pronounced. Second, the host rock is fractured and therefore contains both matrix and fracture porosity and permeability. Experimental evidence indicates that the absolute permeabilities associated with the matrix and fractures differ by at least three orders of magnitude (Lin and Daily, 1984; Daily et al., 1986). Based on empirical evidence and thermodynamic principles, it appears that the characteristic curves, which relate relative permeability and capillary pressure to bulk saturation, differ quite markedly for the respective porosities (Klavetter and Peters, 1986). The sensitivity of the near field hydrothermal response to the characteristic curves in the fractures is of interest because the capillary forces and relative permeability on either side of the fracture/matrix interface will determine whether liquid water is mobile in the fractures under pre-emplacement conditions, as well as when the system is thermally perturbed. Consequently, any near field hydrothermal modeling effort will need to consider the range of variability of the characteristic curves for the fractures.

Because the repository horizon is partially saturated, an interconnected gas phase may be assumed to exist and to be at local atmospheric pressure. As the rock mass heats after waste emplacement, pore water will begin to evaporate. This phase change and the lower gas permeability of the matrix, relative to the fractures, will induce a pressure gradient between the matrix and the fracture system. The pressure gradient will result in migration of the vapor phase away from the waste package. Even though many of the fractures within the dehydration zone will not intersect the borehole, the net gas flux in the rock mass may still be directed away from the waste package.

The flow of vapor in the fractures away from the waste packages will result in condensation along the cooler fracture walls. Whether the liquid condensation along the fracture walls will attain water saturations sufficient to result in liquid phase mobility within the fracture, or the liquid condensation will be pulled into the rock matrix by capillary suction gradients must be established. The answer to this question depends on the rate of condensation, capillary suction gradients, and liquid phase permeabilities within the matrix and fractures.

The size of the dried-out region around the waste package is inversely

dependent on the efficiency of the primary mechanism of heat transfer. Where the liquid phase is mobile in the fractures, a highly efficient vapor-liquid counter flow, or "heat pipe", system may be established (Preuss et al., 1984), which may result in a large dried-out zone around the waste package. If the liquid phase in the fractures is immobile, a far less efficient vapor-liquid counter flow system may develop in which the radial inflow of liquid in the matrix is never able to balance the radial outflow of vapor in the fractures, potentially resulting in a smaller dried out zone. Fractures approximately perpendicular to the thermal and hydraulic gradients could further interfere with the vapor-liquid flow system. Within the dehydration zone around the waste package, the only available mechanism of heat transfer is heat conduction, which is far less efficient than the vapor-liquid counter flow "heat pipe" system. Examination of these effects is necessary to characterize the waste package environment hydrologic properties.

To facilitate examination of these processes and effects, two laboratory systems have been developed. One system is designed to study the hydrologic properties of a rock-fluid system containing a single fluid phase, and the other system is designed to obtain hydrologic information for a steam-liquid water-rock system. Section 2.2.1 describes research to be conducted in the single fluid phase system and Section 2.2.2 describes research to be conducted in the two fluid phase system.

The results of these laboratory studies will be used in flow and transport code development and calculations carried out in WBS 2.2.5. The experiment and test design is facilitated through formal involvement of personnel responsible for the flow and transport code development with the personnel responsible for executing the laboratory activities.

2.2.1: Single Fluid Phase; Dehydration-Rehydration of Tpt in a Temperature Gradient (QALA I, Activity Number B-20-2)

Experiments completed to date on single-phase systems under isothermal conditions have established that unfractured samples of Topopah Spring tuff (Tpt) do not change relative permeability or dehydration/rehydration characteristics during repeated heating and cooling cycles. Similar studies (Lin and Daily, 1984; Daily et al., 1986) demonstrate that fractured samples

exhibit a marked decrease in permeability during repeated dehydration and rehydration. After several such cycles, the relative permeability of fractured samples approaches that of unfractured tuff. Computed impedance tomography images (Daily et al., 1986) and scanning electron microscope studies (Lin and Daily, 1984) suggest that permeability changes reflect sealing of fractures. These results imply that significant changes in the hydrologic properties of fractured tuff may occur during the thermal perturbation resulting from emplacement of waste packages.

To evaluate the processes responsible for the change in permeability noted in the fractured samples, a series of QA Level I tests will examine fluid flow properties, relative permeabilities, and dehydration/rehydration characteristics of fractured and intact tuff samples in the presence of liquid water or steam. The samples will be subjected to a thermal gradient, which will be monitored via electrodes attached along the axis of the sample. Computed impedance tomography images will provide a record of the dehydration and rehydration behavior of the samples. Permeability measurements will be made repeatedly to identify changes in fluid migration behavior. Correlation of impedance tomography images with the temperature record will allow identification of onset of "heat pipe" behavior. These results will allow characterization of water saturation distribution as a function of thermal condition, and will define the conditions for which "heat pipe" effects may be expected.

Fractured samples run in these tests will be examined, using scanning electron microscopy and noble gas mass spectrometry, to establish the processes responsible for fracture healing. The scanning electron microscope images will allow characterization of crystal morphology along the fracture surfaces, providing a means of identifying material that occurs in areas where fracture healing has been noted. Noble gas mass spectrometry will be used on samples in which the fluid phase has been spiked with a noble gas. Trapping of the fluid during mineral growth along fracture surfaces can then be recognized by identifying anomalously high concentrations of the spiked element. Through these techniques it will be possible to distinguish between recrystallization and other mechanisms that may be responsible for the fracture healing.

Test results will be modeled using the TOUGH computer code for flow and transport, as outlined in the Scientific Investigation Plan for NNWSI Waste

Package Performance Assessment (WBS 1.2.2.5.L). The numerical simulations will aid in the prediction of the waste package hydrologic properties for conditions not duplicated in the laboratory, and will provide a conceptual model for understanding flow and transport in the fractured and unfractured tuff that constitutes the waste package environment.

Samples of fluid obtained during permeability measurements will be analyzed for dissolved cation and anion species. These analyses, when combined with post-test examination of rock samples and numerical simulations, will provide data regarding reaction progress and reaction processes during fluid flow in saturated and unsaturated conditions. These results will complement those developed in the hydrothermal tests described in Sections 2.1.1, 2.1.2, and 2.1.3, and will define reaction processes occurring in flow-through fractured systems.

The QA level I tests will document the hydrologic properties of rock in a single-phase system using material obtained from drill core and from the repository horizon in the exploratory shaft.

The methodology used in this activity is described in Section 3.6.

2.2.2 Two Fluid Phase Flow (QALA III, Activity Number B-20-1)

Vaporization, vapor migration, and condensation processes along fractures and within the tuff matrix will affect the waste package environment during the period of time when the temperature exceeds ~100°C. As noted in Section 2.2, these processes may result in "heat pipe" or other convection geometries and have the potential to produce concentrations of precipitates in some areas. To evaluate conditions under which such processes might occur in the waste package environment, studies will be initiated of the hydrologic properties of tuff with two fluid phases present.

Experiments and tests will be designed to establish the isothermal hydrologic properties of the near-field rock in the presence of liquid water and steam, followed by experiments and tests in a thermal gradient. Using information gained from the single fluid phase system, tests will be designed that examine the same parameters and system characteristics as

described in Section 2.2.1. Characterization of the two fluid system will thus be facilitated through knowledge gained regarding the behavior of single fluid phase systems. In particular, fracture wetting and suction of fluid into the matrix from fracture walls will be monitored and compared with hydrologic characteristics of intact tuff. This information will contribute to development of conceptual models of fracture flow in the waste package environment.

Samples will be subjected to repeated dehydration-rehydration cycles. Computed impedance tomography images will provide a record of the dehydration and rehydration behavior of the samples. Permeability measurements will be made repeatedly to identify changes in fluid migration behavior. Fractured and unfractured samples will be used in these experiments. Fracture surfaces will be examined for changes in surface characteristics, upon completion of the tests. Fluid will be sampled during permeability measurements as described in Section 2.2.1, with the intent of establishing reaction processes in the two fluid phase environment.

The experiment and test observations will be compared to theoretical predictions and models developed from the TOUGH computer code, or other computer codes that may be appropriate. These numerical simulations will provide the means to identify processes affecting the hydrologic properties of the tuff, and will establish the relative importance of fluid flow and transport pathways for a range of anticipated and unanticipated conditions.

A QA level I activity will be initiated when the fundamental properties of the rock-fluid system and the experimental apparatus are characterized. The QA level I tests will document the two-phase hydrologic properties of repository horizon rock obtained in the exploratory shaft. The level I activity will be established as described in section 2.0.

The methodology used in this activity is described in Section 3.7.

3.0 DESCRIPTION OF EXPERIMENTS, TESTS AND ANALYSES

Described below is the methodology used in the activities outlined above. The activities described in Sections 2.1.1, 2.1.2, and 2.1.3 use the same

technical methods to carry out hydrothermal research. The test descriptions for these activities are combined in Section 3.1.

3.1 Hydrothermal Tests and Experiments

These tests pertain to the hydrothermal studies described in Sections 2.1.1, 2.1.2, and 2.1.3. Details of the hydrothermal study procedures are contained in Knauss et al., (1985, 1986).

Method: Sample material from the appropriate geological horizon is selected for study. If solid reaction products are to be characterized in terms of composition, morphology and abundance after completion of the experiment or test, wafers of the sample are cut, polished on one side, and examined for petrographic characteristics, including identification and modal determination of minerals present. Once characterized, the sample is mounted in an appropriate reaction vessel. If studies of the solid reaction products are not to be undertaken by electron microprobe (EM), crushed tuff is placed in the reaction vessel, rather than using a rock wafer. The effects on reaction kinetics of variable rock surface area to fluid volume ratios can be evaluated by comparing reaction progress rates observed for wafer and crushed tuff studies. Prior to placing the sample in the reaction vessel, rock surface area measurements are made using BET procedures on a split of the sample. Sufficient fluid of the appropriate composition is added to the reaction vessel to last the duration of the test or experiment. The reaction vessel is then sealed and taken to the temperature and pressure appropriate for the test or experiment. The reaction vessel is kept at these conditions for the period of time necessary for the rock-water system to approach equilibrium.

Fluid is periodically extracted from the reaction vessel for chemical analysis. Elements and ionic species analyzed are those that are primary constituents of the reference ground water (well J-13; Glassley, 1986) and the tuff. The sampling schedule is designed to track the rapid changes in fluid composition during the early test and experiment periods, and to monitor the asymptotic approach to steady state concentrations during the later test and experiment periods. Such a sampling schedule makes more efficient the analytical procedures and data analysis.

At completion of the test or experiment, the rock wafer is removed and examined for reaction products in the scanning electron microscope (SEM) and the EM. The abundance, modal proportion, mode of occurrence and composition of reaction products are determined. If crushed rock is used instead of a rock wafer, the material is examined using X-ray diffraction (XRD) and SEM.

Parameters To Be Considered: Controlled parameters are temperature, pressure, and the ratio of rock surface area to fluid volume. Evaluated parameters are fluid composition, reaction rates, and abundance, composition and mode of occurrence of reaction products.

Test Conditions: Tests will be run at temperatures of 90, 150, and 250°C, and at pressures sufficient to maintain water as a liquid phase.

3.2 Hydrothermal Tests and Experiments in the Presence of a Radiation Field

These tests and experiments pertain to studies described in Section 2.1.4.

Method: Tests and experiments will be conducted in three parts. Part one will consist of gas phase radiolysis experiments that will characterize the effects of ionizing radiation on the gas phase environment. This work will address issues concerning the composition of the gas phase, and will examine how a steady state composition is attained in this system. The second part of the tests and experiments will examine gas phase corrosion in an irradiated environment. This work will evaluate the chemical processes and effects that occur in an environment containing radiation, a gas phase, and candidate container materials. The third part of tests and experiments will measure open circuit potentials in an irradiated environment for the candidate container materials. This part of the experimental and test program will utilize tuff and J-13 water in the experiments and tests, thus providing information on the chemical effects these materials will have on candidate material corrosion processes. These tests and experiments will be conducted under the Metal Barriers Task, and will follow the procedures and methods described there. The information

gained from these tests and experiments will provide the information necessary to address questions regarding fluid composition in the presence of a radiation field. In addition, tests and experiments that examine the effects of corrosion products on radiolysis products will provide information that identifies the corrosion products, which is necessary information for characterizing the chemical processes affecting the waste package environment.

Samples will be exposed to a range of gamma radiation doses and dose rates in order to address questions posed in Section 2.1.4. In some cases, fluids will be spiked with alpha emitting radionuclides in order to establish the radiolysis reaction path. Samples of liquid and coexisting vapor will be extracted at various times to identify and measure the quantity of radiolysis products, and to establish the evolution of the fluid chemistry as a function of time. At completion of the experiment or test the tuff and/or container material, if present, will be examined by SEM and electron microprobe to identify solid reaction products. Analyses of the liquid and vapor phases will be used to determine the reaction process responsible for generation of the radiolysis products and to identify the reactions that occur between the tuff and/or container material, if present, and coexisting liquid and vapor phases.

Parameters To Be Considered: Controlled parameters are temperature, radiation dose and dose rate, nature of the fluid phase (steam and/or liquid water). Evaluated parameters are fluid composition, and identity, abundance, and composition of reaction products.

Test and Experiment Conditions: Conditions for these tests and experiments will span a broad temperature interval (less than 95°C to less than 250°C). Tests and experiments will use water from well J-13 except for tests which will be used to examine radiolysis products in the absence of dissolved species, in which case distilled water will be used.

3.3 Mineral Dissolution and Precipitation Studies

These experiments pertain to activities described in Section 2.1.5.

Method: The mineral of interest is crushed to a specific size range and

washed thoroughly to remove adhering fine particles. BET surface area measurements are conducted to determine the actual surface area of the material per gram of substance. For experiments at temperatures of 25 and 70°C, the sample is weighed and then placed in small, inert flow-through dissolution cells. Each cell is attached to a fluid stream of known composition, pH, and flow rate. The flow rate is maintained at values less than 1 ml/hour. The cell is placed in a controlled temperature environment for periods of time in excess of two months. For efficient experiment design, numerous cells will be run simultaneously, each at a different fluid pH value. The fluid that passes through the cell is collected and analyzed periodically for the constituent elements of the mineral being considered. The sampling schedule is optimized to provide data readily incorporated into transition state theory. Statistical analysis of the results, interpreted in terms of transition state theory, will be used to model the kinetics of the dissolution process. Experimental protocol for dissolution studies at temperatures in excess of 100°C are still in development.

Precipitation studies will be conducted in closed-loop flow-through systems in which fluid composition is maintained at or above saturation values for the phase of interest. The phase for which precipitation kinetics data will be obtained will be present as crushed and washed material within the flow-through cell. Aliquouts of fluid will be periodically removed and analyzed to evaluate precipitation progress. At the end of the experiment the material in the cell will be weighed and examined by SEM to determine the characteristics of the precipitation process. Precipitation rates will be calculated from the analytical data.

Parameters To Be Considered: Controlled parameters are solution pH, initial solution composition, rate and volume of fluid flow, mineral surface area, and temperature. Evaluated parameters are dissolution or precipitation rate, and solution compositions.

Experimental Conditions: Experiments will be conducted at 25 and 70°C over a pH range of 1 to 12. The conditions for higher temperature runs have yet to be established.

3.4 Composition of Vadose Water

These experiments pertain to studies described in Section 2.1.7.

Method: Evaluation of techniques described in Section 2.1.7 will establish the extraction method to be employed in this activity. Once fluid is extracted from a sample the fluid pH will be measured. Filtered and acidified aliquouts of the fluid will be produced and submitted for cation and anion analysis. The resulting compositions will be evaluated using the EQ3/6 geochemical modeling code to establish the solid phases with which the fluid was in equilibrium. These results will provide a means of evaluating the accuracy of the analyses, and will aid in establishing the relationship between vadose water composition and J-13 water composition. Complete design of these experiments will be accomplished by December 31, 1987 (see Schedule of Test Plan Completion Dates).

Parameters To Be Considered: Evaluated parameter is fluid composition.

Test and Experiment Conditions: Conditions for tests and experiments will depend upon the extraction technique selected, and cannot be specified at this time.

3.5 Geochemical Simulation of Rock-Water Interaction

All numerical geochemical simulations described in Sections 2.1.6 and 2.1.8 will be conducted using the computer code EQ3/6.

Method: Rock-water interaction tests and experiments (Section 2.1.6) are simulated by specifying the mineralogy of the reactant rock material, the surface area of the reactant solid phases, the composition of the water, and the temperature and pressure of the test or experiment. The code uses this description of the initial conditions to compute, as a function of time, the evolving composition of the fluid, the degree of saturation of appropriate mineral phases, and the masses of minerals dissolved and precipitated from solution. The results are then compared to observed test and experimental results to evaluate the accuracy of the modeling effort and to facilitate

interpretation of the test and experiment results.

A similar approach is used for prediction of long-term rock-water interaction in the presence of concentrated solutions (Section 2.1.8), except that input fluid compositions vary as a function of the degree of concentration of dissolved species in the fluid. A matrix of fluid compositions can be constructed which represents the range of fluid compositions expected for anticipated and unanticipated conditions. The range of values of the input parameters will be established after the vadose water composition is known, and after dissolution and precipitation studies are completed that determine the kinetics of the dissolution and precipitation processes.

Validation of the EQ3/6 code and database (Section 2.1.6) over the range of conditions applicable to waste package environment studies will be accomplished by modeling rock-water interaction tests and experiments that were conducted over the full range of temperatures and fluid compositions represented by the laboratory work. Included in this laboratory work will be chemical systems that are similar, but not identical, to the tuff - J-13 water chemical system. Studies that were not used in development and evaluation of the code will be used in the validation effort. The validation effort will focus on those solid phases and aqueous species that enter into the test and experimental studies. Validation of the code database will be accomplished by specifying the mineralogy of the reactant rock material, the surface area of the reactant solid phases, the composition of the water, and the temperature and pressure of the test or experiment being considered. Successful validation will be accomplished when the code reproduces the fluid composition evolution and the abundance of the product minerals, to within tolerances outlined in the test plan for "Numerical Modeling of Hydrothermal Interaction Tests and Experiments". In addition, other natural geochemical systems that are well characterized will be used in the validation effort. The appraoch to be taken for each natural system is currently being developed and will be outlined in the test plan.

Parameters To Be Considered: Controlled parameters are the mineralogy of the reactant rock, the surface area of the reactant solid phases, the composition of the water, and the temperature and pressure. Evaluated parameters are fluid composition and abundance of minerals formed and

dissolved.

Test Conditions: The temperature range for tests will span the range 95°C to 250°C. Pressures will be such as to maintain the fluid in the appropriate state (gas or liquid). The composition of the fluid and solid phases will vary sufficiently to allow a range of chemical systems to be used in the validation exercises.

3.6 Single Fluid Phase System

These tests and experiments pertain to activities described in Section 2.2.1. Further details of the study procedures are contained in Lin and Daily (1984) and Daily et al. (1986).

Method: Experiments in the single phase system will be designed to establish the hydrologic properties of a single phase fluid system in tuff. Fractured and unfractured sample material from the appropriate geological horizon is machined to a right cylinder of appropriate size, fitted with thermocouples and electrodes for the computed impedance tomography, jacketed and placed in a pressure vessel. The sample is then brought to the designed test or experiment conditions. A pressure gradient across the sample drives fluid flow. For isothermal tests or experiments the temperature at which the experiment or test will be conducted is determined by the nature of the fluid (i.e., liquid water or steam) to be used in the study. For tests or experiments in a thermal gradient, the temperature is monitored continuously and is controlled to maintain the predetermined thermal gradient. The permeability of the sample is measured by standard flow tests. During these tests or experiments, fluid samples are collected and analyzed for the primary constituents of the rock and water to evaluate reaction progress. Impedance tomography images are obtained periodically during dehydration and rehydration. Upon completion of the test or experiment, the impedance images are processed, and the permeability measurements and fluid analyses are collated for later interpretation. The sample, if fractured, is removed for SEM, EM and noble gas mass spectrometry studies of surface features, as described in Section 2.2.1.

Parameters Considered: Controlled parameters are temperature, magnitude

of the thermal gradient (if any), fluid state (gas or liquid), pressure differential during fluid flow, duration of dehydration and rehydration cycles, and fluid flow rate. Evaluated parameters are relative permeability, fluid flow pathways, relative saturation, fluid composition, and identity, mode of occurrence and composition of product minerals.

Test Conditions: Temperature and pressure are maintained within the stability fields of liquid water and steam, as appropriate.

3.7 Two Fluid Phase System

These tests and experiments pertain to activities described in Section 2.2.2.

Method: Experiments in the two-phase system will be designed to establish the hydrologic properties of a two-phase fluid system in tuff. The methodology of this activity is similar to that for the single phase system. Fractured and unfractured sample material from the appropriate geological horizon is machined to a right cylinder of appropriate size, fitted with thermocouples and with electrodes for the computed impedance tomography, jacketed and placed in a pressure vessel. The sample is then brought to the designed test or experiment conditions. A pressure gradient across the sample drives fluid flow. The rate of liquid and gas flow is controlled by the test equipment. For tests or experiments in a thermal gradient, the temperature is monitored continuously and is controlled to maintain the predetermined thermal gradient. Relative permeabilities of gas and liquid are monitored according to a predetermined schedule. Samples of fluid (gas and liquid) are collected at the time permeability measurements are made. These samples are submitted for chemical analysis. Impedance tomography images are obtained periodically during dehydration and rehydration. Upon completion of the test or experiment, the impedance images are processed, and the permeability measurements and fluid analyses are collated for later interpretation. The sample, if fractured, is removed for SEM, EM and noble gas mass spectrometry studies of the surface features, as described in Section
2.2.1.

Comparison will be made with results from the single-phase fluid

experiments. The single phase studies will provide data that will constrain interpretations of hydrologic properties in systems containing two fluid phases. The two-phase studies will characterize the tuff-fluid system over the range of conditions anticipated in the post-emplacement waste package environment.

The experimental protocol for the two-phase activities is similar to that for the single-phase activities, with the exception that the ratio of liquid to gas and the respective fluid phase flow rates are additional parameters that require control. These requirements are met by providing separate flow controllers and collecting systems for each fluid phase. Prototype development of these controllers and collecting systems is nearing completion; calibration of the flow and collecting systems is in progress.

Parameters Considered: Controlled parameters are temperature, magnitude of the thermal gradient (if any), volume ratio of gas to liquid, pressure differential during fluid flow, duration of dehydration and rehydration cycles, and fluid flow rate. Evaluated parameters are relative permeability, fluid flow pathways, relative saturation, fluid composition, and identity, mode of occurrence and composition of product minerals.

Test Conditions: The matrix of test conditions is under development.

3.8 Methodological Development and Technique Evaluation

These experiments pertain to activities described in Section 2.1.9.

Method: The methods to be used will depend upon the technique being developed and evaluated. Laboratory studies will be conducted to ascertain the extent to which the technique will contribute to obtaining information necessary for license application, the reproducibility of the results, the precision of the results, and the ability of the technique to provide results in a timely fashion.

Parameters To Be Considered: The parameters to be controlled and evaluated

will depend upon the technique being considered.

Test Conditions: The test conditions will depend upon the technique being considered.

4.0 APPLICATION OF RESULTS

The compositions of fluids that might interact with the waste package will be defined for anticipated and unanticipated repository conditions. Compositions will be determined from the tests, experiments, and numerical simulations described in Sections 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.6, 2.1.8, 2.2.1, and 2.2.2, as well as from QA Level I activities that develop from the QA Level III activities. Fluid compositions will constrain parameters required to conduct the metal barrier and waste form testing programs, and will also be considered when developing scenarios for the characteristics of the source term, for release rate calculations, and for radionuclide transport models.

Numerical geochemical simulations of hydrothermal tests and experiments will be used as input to performance assessment. These results will constrain the possible chemical evolution of the fluid and gas phases in the near-field environment by establishing the nature and quantity of reaction products and by characterizing the rates of reactions responsible for the development of reaction products. The development of reaction products will influence the degree to which host rock will retard the migration of radionuclides, and is an important parameter in transport considerations.

Numerical geochemical simulations of the fluid flow tests and experiments will establish the hydrologic properties of the fractured tuff for anticipated and unanticipated conditions. Fluid flow pathways will be characterized as a function of thermal conditions and fracture-matrix geometries. In addition, the coupled effects of fluid flow and transport, and mineral-fluid reactions will be determined. The results of these studies will define the near-field environment flow features necessary for development of radionuclide release and transport models.

The information derived from these activities will be used in addressing the

following specific Information Needs:

1.4.2	Material properties of the container material.
1.4.3	Scenarios and models needed to predict the time to loss of containment and the ensuing degradation of the container material.
1.4.4	Estimates of the rates and mechanisms of container material degradation in the repository environment for anticipated and unanticipated processes and events.
1.5.2	Material properties of the waste form.
1.5.3	Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.
1.5.4	Determination of the release rates of radionuclides from the engineered barrier system for anticipated and unanticipated events.
1.10.4	Description of the post-closure near-field environment of the waste packages, including. the expected range of environmental characteristics under conditions appropriate for the reference emplacement configuration.
1.18.1	Rates of dissolution of crystalline and non-crystalline components in tuff.

5.0 SCHEDULE AND MILESTONES

Included below is the schedule for Level I and II milestones for the entire

Waste Package Environment task:

FY 1988

31 July, 1988 - Initiate dissolution studies of smectite clays or zeolites (Activity B-20-5; Sect. 2.1.5). This work will begin upon compositional and structural characterization of the collected minerals. The results of this activity will provide kinetics data necessary for precipitation/dissolution modeling of clays in rock/water interaction studies.

FY 1989

31 August, 1989 - Complete extraction of vadose water from tuff (Activity B-20-6; Sect. 2.1.7). This activity will use rock available from core or the exploratory shaft to demonstrate the water extraction capability of the selected technique.

FY 1990

31 May, 1990 - Initiate modeling of rock/water interaction using concentrated solutions compatible with information available from the vadose water extractions (Activity B-20-7; Sect. 2.1.8). The results of this activity will place limits on the composition and abundance of reaction product minerals that may form during rock/water interaction in systems containing concentrated solutions.

FY 1991

31 May, 1991 - Issue report (M004) on the dissolution behavior of minerals as a function of temperature and pH (Activity B-20-5; Sect 2.1.5). This report will summarize results of all experiments initiated since July, 1986.

30 June, 1991 - Issue report (M008) on the results of fracture flow studies (Activities B-20-1 and B-20-2; Sects. 2.2.1 and 2.2.2). This report will include results of experiments initiated in FY 86 and FY 87.

FY 1992

31 October, 1992 - Provide to waste package performance assessment final waste package environment definition (based on all activities).

FY 1993

31 October, 1993 - Issue final report (M271) on waste package environment. This report will present material to be used in license application (based on all activities).

This schedule assumes that material from the Exploratory Shaft will be available beginning June, 1988. The schedule for milestones M008 and M271 assumes, in addition, that repository horizon material will be available from the Exploratory Shaft by November, 1989.

The dissolution milestone (M004) will provide input to Los Alamos National Laboratory EQ3/6 modeling at the time the draft report is issued.

The fracture flow report will provide input to performance assessment via the milestone M008. Information derived from experiments described in this report will also be provided through scheduled meetings with the performance assessment group, as the information is completed and available.

Because the milestone M271 provides information necessary to define the waste package environment, it is scheduled for completion prior to license application.

6.0 Schedule of Completion Dates For Experiment and Test Plans

A. Hydrothermal Experiments on Vitric, Vitrophyric, and Zeolitized Tuff (Activity B-20-3; Level III)	Dec. 31,'87
B. Hydrothermal Testing of Drillcore from the Repository Horizon (B-20-4; Level I)	Dec. 31,'87
C. Single Fluid Phase: Dehydration-Rehydration of Tpt in a Thermal Gradient (B-20-2; Level I)	Dec. 31,'87
D. Tests and Experiments of Rock-Water Interaction and Water Chemistry Changes in the Presence of a Radiation Field (B-20-10; Level III).	Dec. 31,'87
E. Mineral Dissolution and Precipitation Experiments (B-20-5; Level III)	Dec. 31,'87
F. Two Fluid Phase Flow (B-20-1; Level III)	Dec. 31,'87
F. Vadose Water Composition (B-20-6; Level III)	Jan. 31,'87
G. Modeling of Rock-Water Interaction (Activity B-20-8; Level III)	Mar. 31,'88
H. Prediction of Long-Term Rock-Water Interaction Through Computational Simulations of Reactions in Concentrated J-13 Water (B-20-7; Level III)	Aug. 31,'88

I. Hydrothermal Testing of Repository Horizon Material Obtained From the Exploratory Shaft (B-20-9; Level I) — Aug. 31,'88

J. Validation of EQ3/6 Reaction Path Modeling Code Results (B-20-11; Level I) — Sep. 30,'88

K. Modeling of Rock-Water Interaction to Support License Application (B-20-13; Level I) — Dec. 31,'88

REFERENCES

Daily, W., W. Lin, and T. Buscheck, 1986, Hydrology of Topopah Spring Tuff - Laboratory Measurements. UCRL 94363, Lawrence Livermore National Laboratory, Livermore, CA.

Delany, J.M., 1985, Reaction of Topopah Spring Tuff with J-13 Water: A Geochemical Modeling Approach Using the EQ3/6 Reaction Path Code. UCRL 53631, Lawrence Livermore National Laboratory, Livermore, CA.

Dropek, R.K. and A. Levinson, 1975, Progress Report II Water Extraction From Nevada Test Site Tuffs. TR 75-52. Terra Tek, Inc., Salt Lake City, Utah.

Glassley, W.E., 1986, Reference Waste Package Environment Report. UCRL 53726, Lawrence Livermore National Laboratory, Livermore, CA.

Lin, W., and W. Daily, 1984, Transport Properties of Topopah Spring Tuff. UCRL 53602. Lawrence Livermore National Laboratory, Livermore, CA.

Knauss, K.G., W.J. Beiriger, and D.W. Peifer, 1985, Hydrothermal Interaction of Crushed Topopah Spring Tuff and J-13 Water at 90, 150, and 250°C Using Dickson-Type, Gold-Bag Rocking Autoclaves. UCRL-53630. Lawrence Livermore National Laboratory, Livermore, CA.

Knauss, K.G., W.J. Beiriger, and D.W. Peifer, 1986, Hydrothermal Interaction of Solid Wafers of Topopah Spring Tuff and J-13 Water at 90 and 150°C Using Dickson-Type, Gold-Bag Rocking Autoclaves: 2. Long-Term Experiments. UCRL-53646. Lawrence Livermore National Laboratory, Livermore, CA.

Klavetter, E.A. and R.R. Peters, 1986, Fluid Flow in a Fractured Rock Mass. SAND 85-0855. Sandia National Laboratory, Albuquerque, NM.

Montazer, P. and W.E. Wilson, 1984, Conceptual hydrologic model of flow in the unsaturated zone, Yucca Mountain, Nevada. U.S. Geol. Survey Water

Resources Inv. Rep. 84-4345.

Montazer, P., E.P. Weeks, F. Thomas, S.P. Yarp, and P.B. Hofrichter, 1985, Monitoring the water zone in fractured tuff, Yucca Mountain, Nevada. National Water Well Association Symposium, Denver, CO, November 19-21.

O'Neal, W.C., D.W. Gregg, J.N. Hockman, E.W. Russell, and W. Stein, 1984, Preclosure Analysis of Conceptual Waste Package Designs for a Nuclear Waste Repository in Tuff. UCRL-53595. Lawrence Livermore National Laboratory, Livermore, CA.

Ortiz, T.S., R.L. Williams, F.B. Nimick, B.C. Whittet, and D.L. South, 1985, A Three-Dimensional Model of Reference Thermal/Mechanical and Hydrological Stratigraphy at Yucca Mountain, Southern Nevada. SAND 84-106. Sandia National Laboratory, Albuquerque, NM.

Preuss, K, Y.W. Tsang, and J.S.Y Wang, 1984, Numerical Studies of Fluid and Heat Flow Near High Level Waste Packages Emplaced in Partially Saturated Fractured Tuff. LBL-18552. Lawrence Berkeley Laboratory, University of California, Berkeley, CA.

Scott, R.B., R.W. Spengler, S. Diehl, A.R. Lappin, and M.P. Chornack, 1983, "Geologic Character of Tuffs in the Unsaturated Zone at Yucca Mountain, Southern Nevada," in J.W. Mercer, P.S.C. Rao, and I.W. Marim, eds., Role of the Unsaturated Zone in Radioactive and Hazardous Waste Disposal (Ann Arbor Science, Ann Arbor, MI), p. 289.

Travis, B.J.S., S.W. Hodson, H.E.Nuttal, T.L. Cook, and R.S. Rundberg, 1984, Preliminary Estimates of Water Flow and Radionuclide Transport in Yucca Mountain. LA-UR 84-40 (Rev.). Los Alamos National Laboratory, Los Alamos, NM.

Van Konynenburg, R.A., 1986, Radiation Doses in Granite Around Emplacement Holes in the Spent Fuel Test - Climax (Final Report). UCRL-53580. Lawrence Livermore National Laboratory, Livermore, CA.

Wang, J.S.Y. and T.N. Narasimhan, 1985, Hydrologic Mechanisms Governing Fluid Flow in Partially Fractured, Saturated, Porous Tuff at Yucca Mountain. Sand 84-7202. Sandia National Laboratory, Albuquerque, NM.

Weeks, E.P. and W.E. Wilson, 1984, Preliminary Evaluation of Hydrologic Properties of Cores of Unsaturated Tuff, Test Well USW H-1, Yucca Mountain, Nevada. USGS-WRI-84-4193 Water Resources Investigation Report. U.S. Geol. Survey, Denver, CO.

Wolery, T., 1983, EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: User's Guide and Documentation. UCRL 53414, Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T., 1986, EQ6, A Computer Program for Reaction Path Modeling of Aqueous Geochemical Systems: User's Guide and Documentation. Lawrence Livermore National Laboratory, Livermore, CA, in preparation.

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Two Fluid Phase Flow
B-20-1

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The purpose of this activity is to determine whether reproducible results on Two Phase Flow in Tpt can be obtained using the Two-Phase Flow apparatus. If reproducible results can be obtained, then procedures will be developed to upgrade this activity from an experiment to a test.

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 5/14/87		[signature] for J. Dronkers 5/14/87	
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
[signature] 5/15/87		[signature] 5/15/87	
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/7/87		[signature] 11/6/87	
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Two Fluid Phase Flow

ACTIVITY NO.: B-20-1
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ____

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0	Yes	033-NWMP-R 3A.0 Rev. 4
	3B.0	No	Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL		Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS		No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS		Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS		No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES		No	Good scientific & engineering practices apply
10.0 INSPECTION		No	Good scientific & engineering practices apply
11.0 TEST CONTROL		Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP		No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.		No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.		No	Good scientific & engineering practices apply
19.0 SOFTWARE QA		No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Single Fluid Phase: Dehydration-Rehydration of Tpt in a Temperature Gradient
B-20-2

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: This activity provides hydrologic data to be used in license application. The activity provides laboratory data on the hydrologic properties of a single fluid phase in tuff for conditions expected in the waste package environment.

Level of Quality Assurance _____I_____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature]	5/14/87	[signature] for J. Dronkers	5/14/87
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
Jesse L. Yow Jr.	5/15/87	[signature]	5/15/87
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature]	11/5/87	James Blaylock	11/6/87
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Single Fluid Phase: Dehydration-Rehydration of Tpt in a Tempera
Gradient
ACTIVITY NO.: B-20-2
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL W
DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21,
and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM #4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev. 1 033-NWMP-P 5.1 Rev. 0; 033-NWMP-P 5.2 Rev. 0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	Yes	033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	Yes	033-NWMP-R 9.0 Rev. 0
10.0 INSPECTION	Yes	033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R 12.0 Rev. 0 033-NWMP-R 12.2 Rev. 0
13.0 HANDLING, STOR. & SHIP.	Yes	See attached sheet.
14.0 INSP. TEST & OPER. STAT.	Yes	033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	Does not apply: use is made of only operating systems, utilitie and databases.

Procedures that apply to QA Element 13.0

033-NWMP-R 13.0 Rev. 0

033-NNWSI-P 8.2 Rev. 0

033-NNWSI-P 8.4 Rev. 0

033-NNWSI-P 11.5 Rev. 0

033-NNWSI-P 11.6 Rev. 0

033-NNWSI-P 12.4 Rev. 0

033-NNWSI-P 12.5 Rev. 0

033-NNWSI-P 13.1 Rev. 0

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Hydrothermal Experiments on Vitric, Vitrophyric, and Zeolitized Tuff B-20-3

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L NNWSI Waste Package Environment

Additional Comments: This activity will provide information on mineral-fluid characteristics for rocks different from the Tpt. This information will be used to evaluate the results of natural analogue studies completed at Los Alamos National Laboratory, and will provide qualitative constraints on phase relationships of significance for Tpt rock-water interaction.

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

5/14/87	for J. Dronkers 5/14/87
Task Leader Date	NWMP Deputy Program Leader for QA Date
5/15/87	5/15/87
NNWSI Deputy Leader Date	NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/4/87	11/6/87
Project Sponsor Date	Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Hydrothermal Experiments on Vitric, Vitrophyric, and Zeolitized Tuff

ACTIVITY NO.: B-20-3
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____III____

CITE "YES" ITEM ON LOGIC DIAGRAM ____________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4.0 Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS	No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES	No	Good scientific & engineering practices apply
10.0 INSPECTION	No	Good scientific & engineering practices apply
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good scientific & engineering practices apply
19.0 SOFTWARE QA	No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Hydrothermal Testing of Drill Core from the Repository Horizon
B-20-4

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: This activity will provide information on the chemical characteristics and mineralogical properties resulting from rock-water interaction, for conditions applicable to unanticipated events in the waste package environment. These data will be used in license application.

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 5/14/87		[signature] for J. Daskers 5/14/87	
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
[signature] 5/15/87		[signature] 5/15/87	
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/2/87		James B. Blanford 11/6/87	
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Hydrothermal Testing of Drill Core from the Repository Horizon

ACTIVITY NO.: B-20-4
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM #4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev. 1 033-NWMP-P 5.1 Rev. 0 033-NWMP-P 5.2 Rev. 0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	Yes	033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	Yes	033-NWMP-R 9.0 Rev. 0
10.0 INSPECTION	Yes	033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R 12.0 Rev. 0 033-NWMP-P 12.2 Rev. 0
13.0 HANDLING, STOR. & SHIP.	Yes	See attached sheet
14.0 INSP. TEST & OPER. STAT.	Yes	033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE	No	Use is made of operating systems, utilities, and databases only

Procedures that apply to QA Element 13.0

033-NWMP-R 13.0 Rev. 0	
033-NNWSI-P 8.1 Rev. 0	(Crushed samples)
033-NNWSI-P 8.2 Rev. 0	(Catalogue procedure)
033-NNWSI-P 8.3 Rev. 0	(Core wafers)
033-NNWSI-P 8.4 Rev. 0	(Sample labeling & tracking)
033-NNWSI-P 11.2 Rev. 0	(Carbonate analysis)
033-NNWSI-P 11.3 Rev. 0	(Rocking autoclave)
033-NNWSI-P 11.4 Rev. 0	(XRD)
033-NNWSI-P 11.5 Rev. 0	(IC)
033-NNWSI-P 11.6 Rev. 0	(ICP)
033-NNWSI-P 12.2 Rev. 0	(Calibration) (already listed)
033-NNWSI-P 12.3 Rev. 0	(Datalogger)
033-NNWSI-P 12.4 Rev. 0	(Pressure transducers)
033-NNWSI-P 12.5 Rev. 0	(Thermocouples)
033-NNWSI-P 12.6 Rev. 0	(pH)
033-NNWSI-P 13.1 Rev. 0	(J-13 Water)

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Mineral Dissolution and Precipitation Experiments
B-20-5

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The data generated in this activity will be used for developing kinetics information applicable to the EQ3/6 Database.

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature]	5/14/87	[signature] for J. Donkus	5/14/87
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
[signature]	5/15/87	[signature]	5/15/87
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature]	11/7/87	James B. Blaylock	11/6/87
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Mineral Dissolution and Precipitation Experiments

ACTIVITY NO.: B-20-5
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS	No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES	No	Good scientific & engineering practices apply
10.0 INSPECTION	No	Good scientific & engineering practices apply
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good scientific & engineering practices apply
19.0 SOFTWARE QA	No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Vadose Water Composition
B-20-6

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: This activity will provide information on vadose water extraction techniques. It will provide the database necessary for later development of procedures for a Level I activity that will accomplish vadose water extraction of waste package environment rock, if necessary.

Level of Quality Assurance ______III______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

5/14/87		5/14/...	
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
5-15-87		5/15/87	
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/3/87		11/6/87	
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Vadose Water Composition

ACTIVITY NO.: 8-20-6
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA _____III_____

CITE "YES" ITEM ON LOGIC DIAGRAM __________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS	No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES	No	Good scientific & engineering practices apply
10.0 INSPECTION	No	Good scientific & engineering practices apply
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good scientific & engineering practices apply
19.0 SOFTWARE QA	No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Prediction of Long-Term Rock-Water Interaction through Computational Simulations of Reactions in Concentrated J-13 Water
B-20-7

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: This activity will provide information regarding changes in fluid composition and rock mineralogy for concentrated J-13 water, using the EQ3/6 Code. The purpose of this activity is to guide tests and experiment planning.

Level of Quality Assurance ____III____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 5/14/87	[signature] for J. Dronkers 5/14/87
Task Leader — Date	NWMP Deputy Program Leader for QA — Date
Jesse L. Yow Jr. 5-15-87	[signature] 5/15/87
NNWSI Deputy Leader — Date	NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/7/87	James Blaylock 11/6/87
Project Sponsor — Date	Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Prediction of Long-Term Rock-Water Interaction through Computati[onal]
Simulations of Reactions in Concentrated J-13 Water

ACTIVITY NO.: B-20-7
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ______ III ______

CITE "YES" ITEM ON LOGIC DIAGRAM ______________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS	No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES	No	Good scientific & engineering practices apply
10.0 INSPECTION	No	Good scientific & engineering practices apply
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good scientific & engineering practices apply
19.0 SOFTWARE QA	No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Modeling of Rock-Water Interaction
B-20-8

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: This activity will update modeling results of hydrothermal experiments using the EQ3/6 Code. As new data become available, from ongoing and planned experiments and tests, and as new solid solution models are incorporated into the code, earlier modeling results will be refined.

Level of Quality Assurance ____III____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

5/14/87
Task Leader Date

for J. Doakes 5/14/87
NWMP Deputy Program Leader for QA Date

5-15-87
NNWSI Deputy Leader Date

5/15/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/9/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Modeling of Rock-Water Interaction

ACTIVITY NO.: B-20-8
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____III____

CITE "YES" ITEM ON LOGIC DIAGRAM ______________________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS	No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES	No	Good scientific & engineering practices apply
10.0 INSPECTION	No	Good scientific & engineering practices apply
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good scientific & engineering practices apply
19.0 SOFTWARE QA	No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Hydrothermal Testing of Repository Horizon Material Obtained from the Exploratory Shaft
B-20-9

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The purpose of this activity is to provide data regarding the chemical and mineralogical characteristics of rock-water interaction for repository horizon material obtained in the Exploratory Shaft. These data will be used in license application, in conjunction with results from activity B-20-4, to define the chemical and mineralogical environment of the waste package, for conditions when liquid water is present.

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 5/14/87
Task Leader Date

[signature] 5/14/8
NWMP Deputy Program Leader for QA Date

[signature] 5-15-87
NNWSI Deputy Leader Date

[signature] 5/15/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/7/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Hydrothermal Testing of Repository Horizon Material Obtained fro the Exploratory Shaft

ACTIVITY NO.: B-20-9
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 1E, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM #4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev. 1 033-NWMP-P 5.1 Rev. 0; 033-NWMP-P 5.2 Rev. 0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	Yes	033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	Yes	033-NWMP-R 9.0 Rev. 0
10.0 INSPECTION	Yes	033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R 12.0 Rev. 0 033-NWMP-R 12.2 Rev. 0
13.0 HANDLING, STOR. & SHIP.	Yes	See attached sheet.
14.0 INSP. TEST & OPER. STAT.	Yes	033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	Use is made of operating systems, utilities, and databases only

Procedures that apply to QA Element 13.0

033-NWMP-R 13.0 Rev. 0	
033-NNWSI-P 8.1 Rev. 0	(Crushed samples)
033-NNWSI-P 8.2 Rev. 0	(Catalogue procedure)
033-NNWSI-P 8.3 Rev. 0	(Core wafers)
033-NNWSI-P 8.4 Rev. 0	(Sample labeling & tracking)
033-NNWSI-P 11.2 Rev. 0	(Carbonate analysis)
033-NNWSI-P 11.3 Rev. 0	(Rocking autoclave)
033-NNWSI-P 11.4 Rev. 0	(XRD)
033-NNWSI-P 11.5 Rev. 0	(IC)
033-NNWSI-P 11.6 Rev. 0	(ICP)
033-NNWSI-P 12.2 Rev. 0	(Calibration) (already listed)
033-NNWSI-P 12.3 Rev. 0	(Datalogger)
033-NNWSI-P 12.4 Rev. 0	(Pressure transducers)
033-NNWSI-P 12.5 Rev. 0	(Thermocouples)
033-NNWSI-P 12.6 Rev. 0	(pH)
033-NNWSI-P 13.1 Rev. 0	(J-13 Water)

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Tests and Experiments of Rock-Water Interaction and Water Chemistry Changes in the Presence of a Radiation Field
B-20-10

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The purpose of this activity is to place constraints on the chemical characteristics and processes expected in the waste package environment. This information will be used to design tests at QA Level I, when sufficient data are available for those tests.

Level of Quality Assurance ____III____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 5/14/87 Task Leader Date	[signature] for J. Dronkers 5/14 NWMP Deputy Program Leader for QA Date
[signature] 5-15-87 NNWSI Deputy Leader Date	[signature] 5/15/87 NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/7/87 Project Sponsor Date	James Blaylock 11/6/87 Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Tests and Experiments of Rock-Water Interaction and Water Chemistry Changes in the Presence of a Radiation Field

ACTIVITY NO.: B-20-10
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____III____

CITE "YES" ITEM ON LOGIC DIAGRAM ________________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS	No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES	No	Good scientific & engineering practices apply
10.0 INSPECTION	No	Good scientific & engineering practices apply
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good scientific & engineering practices apply
19.0 SOFTWARE QA	No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Validation of EQ3/6 Reaction Path Modeling Code Results
B-20-11

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The purpose of this activity is to validate the EQ3/6 Database and Code results for the range of conditions appropriate to the waste package environment. Validation must be completed before activity B-20-13 can be completed.

Level of Quality Assurance _____I_____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 5/12/87
Task Leader Date

R. E. Schwartz for J. Dronkers 5/14/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 5-15-87
NNWSI Deputy Leader Date

L. Ramspott 5/13/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/2/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Validation of EQ3/6 Reaction Path Modeling Code Results

ACTIVITY NO.: B-20-11
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM #4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev. 1 033-NWMP-P 5.1 Rev. 0; 033-NWMP-P 5.2 Rev. 0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	Yes	033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	Yes	033-NWMP-R 9.0 Rev. 0
10.0 INSPECTION	Yes	033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R 12.0 Rev. 0 033-NWMP-R 12.2 Rev. 0
13.0 HANDLING, STOR. & SHIP.	Yes	See attached sheet.
14.0 INSP. TEST & OPER. STAT.	Yes	033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	Yes	033-NWMP-R 19.0 Rev. 0

Procedures that apply to QA Element 13.0

033-NWMP-R 13.0 Rev. 0	
033-NNWSI-P 8.1 Rev. 0	(Crushed samples)
033-NNWSI-P 8.2 Rev. 0	(Catalogue procedure)
033-NNWSI-P 8.3 Rev. 0	(Core wafers)
033-NNWSI-P 8.4 Rev. 0	(Sample labeling & tracking)
033-NNWSI-P 11.2 Rev. 0	(Carbonate analysis)
033-NNWSI-P 11.3 Rev. 0	(Rocking autoclave)
033-NNWSI-P 11.4 Rev. 0	(XRD)
033-NNWSI-P 11.5 Rev. 0	(IC)
033-NNWSI-P 11.6 Rev. 0	(ICP)
033-NNWSI-P 12.2 Rev. 0	(Calibration) (already listed)
033-NNWSI-P 12.3 Rev. 0	(Datalogger)
033-NNWSI-P 12.4 Rev. 0	(Pressure transducers)
033-NNWSI-P 12.5 Rev. 0	(Thermocouples)
033-NNWSI-P 12.6 Rev. 0	(pH)
033-NNWSI-P 13.1 Rev. 0	(J-13 water)

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Methodology Development and Technique Evaluation
B-20-12

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The purpose of this activity is to provide for technique and methodology development and evaluation for potentially useful but technically unproven test and experiment protocols. This activity is necessary to allow examination of new approaches to developing data useful in defining the waste package environment.

Level of Quality Assurance ______III______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature]	5/14/87	[signature] for J. Dronkers	5/14/87
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
Jesse L. Yow Jr.	5-15-87	[signature]	5/15/87
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature]	11/7/87	James Blaylock	11/6/87
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Methodology Development and Technique Evaluation

ACTIVITY NO.: B-20-12
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0	Yes	033-NWMP-R 3A.0 Rev. 4
	3B.0	No	Good scientific & engineering practices apply
4.0 PROC. DOC. CONTROL		Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS		No	Good scientific & engineering practices apply
7.0 CTL OF PUR MATERIALS		No	Good scientific & engineering practices apply
8.0 I.D. & CTL OF MATERIALS		No	Good scientific & engineering practices apply
9.0 CONTROL OF PROCESSES		No	Good scientific & engineering practices apply
10.0 INSPECTION		No	Good scientific & engineering practices apply
11.0 TEST CONTROL		Yes	033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP		No	Good scientific & engineering practices apply
13.0 HANDLING, STOR. & SHIP.		No	Good scientific & engineering practices apply
14.0 INSP. TEST & OPER. STAT.		No	Good scientific & engineering practices apply
19.0 SOFTWARE QA		No	Good scientific & engineering practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Jesse L. Yow, Jr.
Bill Glassley
Ron Schwartz
Virginia Oversby

Name(s) and Number(s) of Activity: Modeling of Rock-Water Interaction to Support License Application
B-20-13

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.2.L
NNWSI Waste Package Environment

Additional Comments: The purpose of this activity is to provide numerical simulations of the chemical conditions to be expected in the waste package environment as a function of time and changing physical conditions. This information will be used to describe the chemical and mineralogical evolution of the waste package environment through time periods required by regulations. This information will be used in the license application.

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature]	5/14/87	R. E. Schwartz for J. Dronkers	5/14/87
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
Jesse L. Yow, Jr.	5-15-87	[signature]	5/15/87
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature]	11/4/87	James Blaylock	11/6/87
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Modeling of Rock-Water Interaction to Support License Application

ACTIVITY NO.: B-20-13
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM #4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 Yes 3B.0 No	033-NWMP-P 3A.0 Rev. 4 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev. 1 033-NWMP-P 5.1 Rev. 0; 033-NWMP-P 5.2 Rev. 0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	No	No purchase of hardware is necessary
9.0 CONTROL OF PROCESSES	No	No purchase of hardware is necessary
10.0 INSPECTION	No	No purchase of hardware is necessary
11.0 TEST CONTROL	No	No purchase of hardware is necessary
12.0 CTL OF M & T EQUIP	No	No hardware is used in this activity
13.0 HANDLING, STOR. & SHIP.	No	No hardware is used in this activity
14.0 INSP. TEST & OPER. STAT.	No	No hardware is used in this activity
19.0 SOFTWARE QA	Yes	033-NWMP-R 19.0 Rev. 0

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.2.3.1

NNWSI Glass Waste Form Testing

Lawrence Livermore National Laboratory

Revision 0
Manuscript date 1/15/87

L. D. Ramspott, Technical Project Officer	Date 1-15-87
J. J. Dronkers, Deputy for Quality Assurance	Date 1-15-87
Virginia M. Oversby, Technical Area Leader	Date
Roger D. Aines, Task Leader	Date
William L. Bourcier, Technical Reviewer	Date
Project Sponsor Quality Manager	Date
Project Sponsor	Date 1-23-87

Table of Contents

* * * * *

List of Acronyms

ANL	Argonne National Laboratory
CFR	Code of Federal Regulations
CUA	Catholic University of America
DWPF	Defense Waste Processing Facility
LLNL	Lawrence Livermore National Laboratory
MCC	Materials Characterization Center, Pacific Northwest Laboratories
NNWSI	Nevada Nuclear Waste Storage Investigations
PNL	Pacific Northwest Laboratories
SCP	Site Characterization Plan
SOP	Standard Operating Procedure
SRL	Savannah River Laboratory
WCP	Waste Compliance Plan
WPAS	Work Package [Proposal and] Authorization System
WQR	Waste Qualification Report
WVDP	West Valley Demonstration Project

1.0 Purpose and Objectives

1.1 Regulatory Requirements

The purpose of glass waste form testing is to determine the rate of release of radionuclides from breached glass waste containers. This information will be used to qualify glass waste forms with respect to the release requirements of 10 CFR 60.113, and it will be the basis of the source term from glass waste for repository performance assessment modeling. This information will also serve as part of the source term in the calculation of cumulative releases after 100,000 years in the site evaluation process required by 10 CFR 960.3-1-5. It will also serve as part of the source term input for calculation of cumulative releases to the accessible environment for 10,000 years after disposal, to determine compliance with the EPA regulation (40 CFR 191.13). The glass waste form testing scientific investigation directly addresses the following information needs.

(From the 8/07/86 NNWSI Project Issues Hierarchy)

Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release as required by 10 CFR 60.113?

- 1.5.1 Waste package design features that affect the rate of radionuclide release.
- 1.5.2 Material properties of the waste forms.
- 1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.

Through input to the above information needs, this investigation will also provide data used to resolve information needs 1.5.4 and 1.5.5, and issues 1.1, 1.9, 1.10, and 1.11.

The glass waste form testing scientific investigation structure closely parallels the information needs listed above. Information about the waste forms which is provided by the producer is accumulated and evaluated (1.5.1); the waste form is tested, properties are determined, and mechanisms of degradation are determined (1.5.2); and models providing long-term evaluation of release rates are designed and tested (1.5.3). As part of this investigation, there are three studies identified in the Site Characterization Plan, Chapter 8; these three studies correspond to the three information needs listed. The study under information need 1.5.2 is further subdivided into three areas of study. The titles and SCP designations of each study and their incorporated activities are given in Section 1.2.

1.2 Glass Testing Activities Grouped by SCP Studies

* Integrate Glass Waste Form Information - (SCP, information need 1.5.1, activities 1.5.1.1.2 and 1.5.1.1.3)

  D-20-25 Integrate Glass Waste Form Information Provided by Waste Producers
  D-20-26 Integrate Waste Package and Repository Design Information

* Characterization of the Glass Waste Form - (SCP, information need 1.5.2, study 1.5.2.2 and incorporated activities)

  Leach Testing of Glass

  D-20-27 Conduct Unsaturated Testing of WVDP and DWPF Glass
  D-20-28 Conduct Static Leach Testing of WVDP and DWPF Glass

  Materials Interactions Affecting Glass Leaching

  D-20-29 Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test
  D-20-30 Parametric Studies of WVDP and DWPF Glass Using Static Leaching Methods
  D-20-31 Studies of Glass Surface Layers and Precipitates
  D-20-32 Studies of Geochemical Interactions
  D-20-33 Studies of Scale Factor in Glass Leaching
  D-20-34 Development of Licensing Database for Glass Waste Form Materials Interactions

  Coordinate Testing With Waste Producers

  D-20-35 Coordinate Testing with WVDP
  D-20-36 Coordinate Testing with DWPF/SRL

* Glass Release Modeling - (SCP, information need 1.5.3, study 1.5.3.4)

  D-20-37 Generate Models for Release from Glass
  D-20-38 Screen Data for Incorporation in Release Model
  D-20-39 Validate Glass Release Model

1.3 Information Flow

The goals of glass waste form testing are: to provide accurate data and models concerning glass leaching in the repository under anticipated and unanticipated conditions, and to ascertain that there is adequate information to assess the importance of all release mechanisms active under anticipated and unanticipated conditions. (There will be formal definitions of "anticipated" and "unanticipated" conditions; those definitions may change the scope of the listed activities but will not require any changes in the nature of the activities.) The activities listed will achieve these goals through:

1. Identification of important factors than can affect leaching under anticipated and unanticipated conditions at Yucca Mountain. Items may be derived from any of the activities, but activities D-20-29, D-20-30, D-20-31, D-20-32, and D-20-33 are specifically designed to address this area.

2. Determination of relevant data quantifying release rates of radionuclides from glass. Activities D-20-25 through D-20-36 generate data. The primary data comes from activities D-20-27 and D-20-28, with accessory information coming from the other activities at their conclusions. Additional data (including that determined outside NNWSI) is screened for use in activity D-20-38.

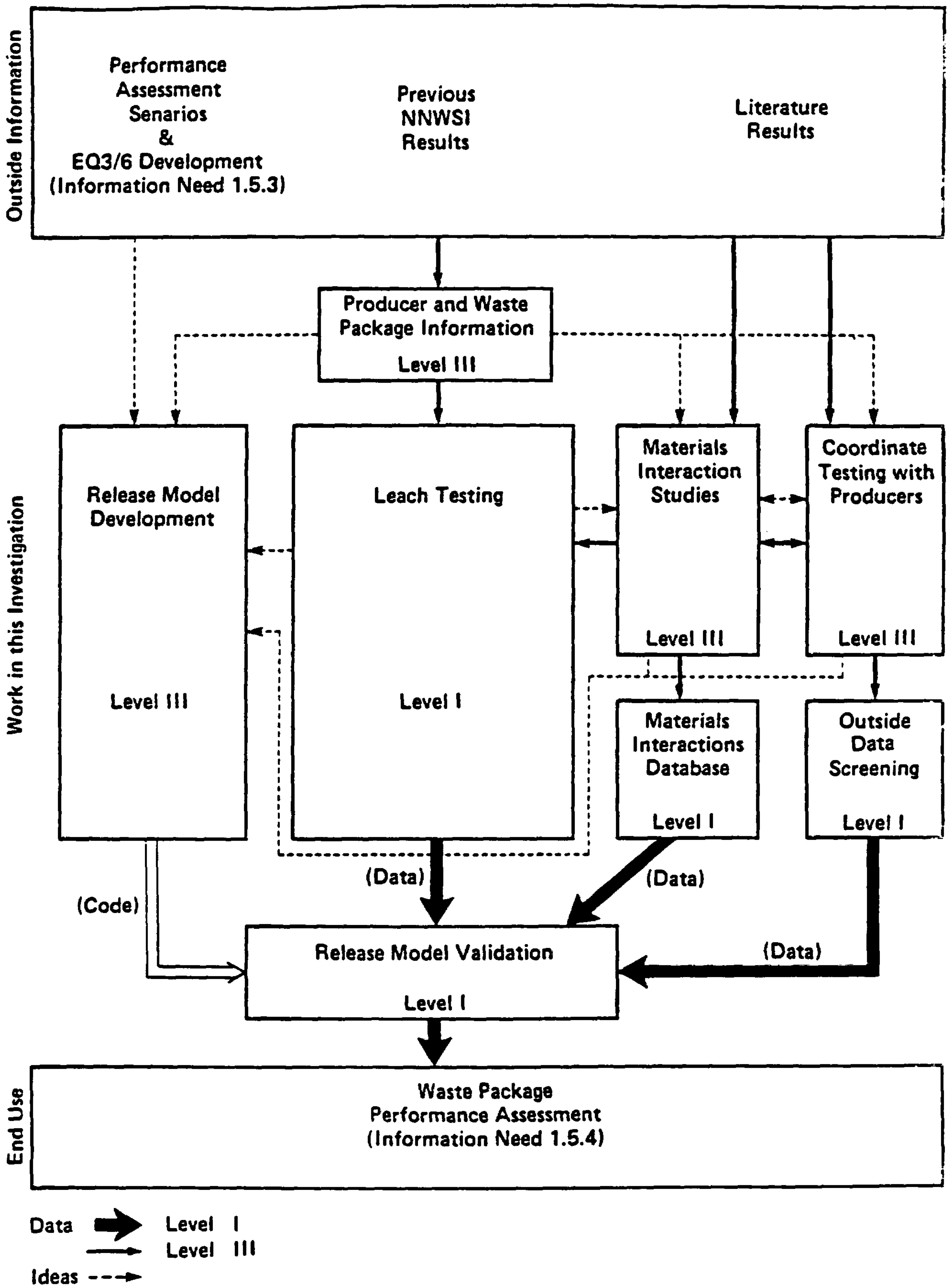
3. Development and testing of models for release under scenarios identified by performance assessment (information need 1.5.3). This work is done in activities D-20-37 and D-20-39.

Because of the large number of activities and the fact that information flows from QA Level III to QA Level I activities, a diagram of that information flow is included (Figure 1).

This investigation plan is not intended as a review of all previous NNWSI glass testing work. That review may be found in the NNWSI Site Characterization Plan, Section 7.4.3.1. Currently, only two glass waste forms have been designated for consideration by NNWSI. Those will be produced by the Defense Waste Processing Facility (DWPF) at the Savannah River Plant and Laboratory (referred to here as SRL) and by the West Valley Demonstration Project (WVDP). The DWPF product is described by Baxter (1983), and the WVDP product is described by Eisenstatt (1986). Should waste forms from the other two defense processing facilities (Hanford and Idaho) be designated for consideration, this plan will be amended to include them.

Figure 1

Glass Waste Form Testing
Information Flow



2.0 Rationale for Selected Studies and Quality Assurance Level Assignments

2.1 Introduction

The technical rationale for the listed activities will be given by type, corresponding to the three areas of study listed in Section 1.2. A rationale for the area of study, as well as for each activity, is given. Quality assurance level assignment sheets for each activity are included in Section 8.0.

The overall rationale for the work in this investigation is as follows. The extension to long times of the semi-empirical relationships discovered in laboratory testing cannot be made without understanding the mechanisms involved and assessing the effects of such factors as the slow build-up of crystalline layers on glass surfaces. Therefore, the overall goal of deriving a usable model for glass release rates can only be achieved through a coupled effort in which laboratory leaching experiments are combined with experiments designed to understand mechanisms. This experimental work is then continuously used to design geochemical models of individual interactions. At the conclusion of the process, a complete model is developed which incorporates the laboratory data and which accurately predicts the results of laboratory and natural analogue experiments. Confidence that the model is applicable to long times is achieved by basing the model on sound geochemical principles, and only using laboratory work to provide values required by the model.

2.2 Integrate Glass Waste Form Information

These activities accumulate information required by the experimental and modeling activities. The waste producer information activity entails participation in the Waste Acceptance Committee and liaison activities with WVDP and DWPF/SRL. The purpose of the activity is to ascertain that the Waste Compliance Plan and Waste Qualification Report contain the information necessary to determine the performance of the waste in a repository at Yucca Mountain. The waste package and repository information activity acquires information from other NNWSI studies. No tests or analyses are performed in either activity.

Activity No.	Name	QA Level
D-20-25	Integrate Glass Waste Form Information Supplied by Waste Producers	III
D-20-26	Integrate Waste Package and Repository Design Information	III

2.3 Characterization of the Glass Waste Form.

2.3.1 Leach Testing of Glass

These two activities are the most important data-collection activities in glass waste form testing. All work in these activities is done at QA Level I. In these two activities, leach testing is conducted under conditions identified from information need 1.5.3 as most important in calculating release rates. Any scenarios to be used in long-term modeling will be directly tested, to the extent possible on a laboratory scale, in these activities. Glasses identified in the producer's Waste Compliance Plans and the Waste Qualification Reports will be tested. Although simulated (nonradioactive) glasses representing important compositional variations will be tested, the emphasis will be on glasses containing the radionuclides expected to remain at 300 to 1000 years after emplacement. The activities have been separated based on test type because of the differing technical requirements of static and Unsaturated testing.

The key outputs from these activities are overall glass degradation rates, radionuclide release rates, and solution compositions in contact with glass.

Activity No.	Name	QA Level
D-20-27	Conduct Unsaturated Testing of WVDP and DWPF Glass	I
D-20-28	Conduct Static Leach Testing of WVDP and DWPF Glass	I

2.3.2 Materials Interactions Affecting Glass Leaching

The purpose of the activities in this area is to determine the mechanisms and nature of glass leaching in the repository environment and to ascertain that no important release mechanism has been overlooked. Extrapolation of laboratory data to the time scales required (10,000 and 100,000 years for anticipated events and processes) is not possible without a fundamental understanding of the mechanisms of glass leaching and of the nature of factors that could perturb leach rates. The data on mechanisms will drive the development of the glass leaching model in activity D-20-37. Data from these activities will be included in the glass release model, either directly or after screening for validation in activity D-20-38.

Activities D-20-29 and D-20-30 (Parametric Studies) provide a means to evaluate the many possible effects on leaching. Activities D-20-31 and D-20-32 are studies of the geochemistry of the glass system and of the layers and solid precipitates that form after extended interaction with water. These studies will provide mechanistic information and will examine

the long-term effects of these processes on glass leaching rates. Activity 0-20-33 investigates factors such as roughness and flow through cracks that may cause laboratory results to differ from those in actual canisters. These activities are done at QA Level III because of their experimental nature. They will determine geochemical and mechanistic data on glass behavior. Actual testing of glass waste forms, based on results of these experiments, is done in the Leach Testing activities (0-20-27 and 0-20-28) at QA Level I. Data generated in these activities will be used in model development and application (0-20-37) after screening (in activity 0-20-38). Data consistency will be confirmed through the use of the leaching model.

Activity 0-20-34 is a QA Level I activity in which data is collected on materials interactions for the cases where experimental work has adequately defined the problem such that QA Level I tests may be conducted or data may be obtained. An example is the development of a library of infrared spectra to use in identifying surface phases. Interactions data that will be important for licensing, but which do not involve actual leach testing of glass (which would be done in activities 0-20-27 and 0-20-28), will be developed in this activity. In the case of interactions studied in activities 0-20-29 through 33, this will involve duplicating an experimental result by using a written procedure derived from the experiment. This activity will carry through to the final input to performance assessment, though the other materials interactions activities will be phased out as the problems are experimentally defined and QA Level III work is no longer needed.

The key outputs of activities 0-20-29 through 0-20-33 are mechanisms and identification of important parameters affecting glass leaching. The key outputs of activity 0-20-34 are values for parameters quantifying the nature of interactions affecting leaching.

Activity No.	Name	QA Level
0-20-29	Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test	III
0-20-30	Parametric Studies of WVDP and DWPF Glass Using Static Leaching Methods	III
0-20-31	Studies of Glass Surface Layers and Precipitates	III
0-20-32	Studies of Geochemical Interactions	III
0-20-33	Studies of Scale Factor in Glass Leaching	III
0-20-34	Development of Licensing Database for Glass Waste Form Materials Interactions	I

2.3.3 Coordinate Testing With Waste Producers

Both the Savannah River Laboratory (working with the DWPF) and the West Valley Demonstration Project are conducting extensive tests of their waste glasses. The purpose of these activities is to coordinate our work with theirs and to assure that data generated by the producers would be usable to NNWSI in licensing. Actual testing will be conducted by the producers, but NNWSI will provide help with experimental design and analysis and will conduct some analyses. Work by NNWSI would be QA Level III, but much of the work by the producers is expected to be QA Level I. (NNWSI work at QA Level I in such matters would be handled under existing QA Level I activities in the appropriate area. The purpose of these activities is not to conduct a testing program but rather to cooperate with activities at DWPF/SRL.)

The key outputs of these activities are the relationships between laboratory and full-scale leaching experiments.

Activity No.	Activity	QA Level
D-20-35	Coordinate Testing with the West Valley Demonstration Project (WVDP)	III
D-20-36	Coordinate Testing with the Savannah River Laboratory and the Defense Waste Processing Facility	III

2.4 Glass Release Modeling

As input to the waste package performance assessment submodel (information need 1.5.3), the glass waste form testing investigation will generate a model for the release of radionuclides from glass under repository conditions. This model will be based upon sound geochemical principles, will use input from the activities listed above as well as from the glass testing literature, and will be validated using both laboratory experiments and natural analogue studies. The model development work is done at QA Level III, and the data and model are validated in QA Level I activities.

The key outputs for these activities are (1) models of glass leaching, (2) a database to use in those models to calculate release, and (3) the validation that the models will accurately predict glass behavior up to 10,000 years (10 CFR 60.113 and 40 CFR 191.13) and 100,000 years (10 CFR 960 3-1-5).

Activity No.	Name	QA Level
D-20-37	Generate Models for Release from Glass	III
D-20-38	Screen Data for Incorporation in Release Model	I
D-20-39	Validate Glass Release Model	I

3.0 Description of Tests and Analyses, and Previous Work

3.1 Introduction

Detailed plans for the 15 activities in Sections 2.2, 2.3, and 2.4 are given in Sections 3.2-3.4. These activities combine experimental work with analyses. Where appropriate, the relative timings of the activities are given. For activities where previous work has been done by NNWSI, a brief description of that work is given. A series of test plans (Section 6.0) will be prepared to provide further details of these activities. All expected use of computer codes is described in section 3.4.

3.2 Integrate Glass Waste Form Information

3.2.1 Integrate Glass Waste Form Information Provided by Waste Producers. D-20-25.

This activity involves participation in the Waste Acceptance Committee and liaison activities with WVDP and DWPF. Participation in the Waste Acceptance Committee assures that the information that NNWSI will need from the producers to qualify glass waste forms is in fact provided in the Waste Qualification Report. This entails review of the producer documents that describe the waste and the Waste Acceptance Plan that describes how the producer will provide the required information.

The liaison activities are to ensure that information on the glass waste forms is provided in a timely fashion, to facilitate review of formal documents and to provide sufficient time for contingency planning. An example of this type of interaction is the ongoing discussion with the waste producers concerning the expected compositions of the glasses as they evolve during the testing programs. This enables NNWSI to keep the glass testing experiments relevant to the expected actual products.

Schedule for the Waste Acceptance Process

The schedule for this activity is tied to that of the Waste Acceptance Committee, and the activity continues to licensing. The schedule for the Waste Acceptance Committee (as presented at the Waste Acceptance Preliminary Specifications NRC briefing, July 31, 1986) is:

Waste Acceptance Preliminary Specifications completed	1/87
Waste Compliance Plans completed	3/87
Waste Qualification Reports completed	6/89
West Valley start-up	9/89
Defense Waste Processing Facility start-up	3/90

3.2.2 Integrate Waste Package and Repository Design Information. D-20-26.

This activity formally accumulates the information required to undertake the experimental and modeling activities requiring design and testing input from other NNWSI activities. No tests or analyses are performed.

3.2.3 Schedule	Start	Complete
Integrate Information Provided by Waste Producers	In Progress	6/89
Integrate Waste Package and Repository Design Information	In Progress	6/89

3.3 Characterization of the Waste Form

3.3.1 Leach Testing of Glass

This is the central area of activity in the glass testing investigation. Its objective is to generate QA Level I data on release from glass for use in performance assessment modeling and for direct use in licensing. Two activities have been defined because of the differing technical requirements of the static and Unsaturated testing. Both activities will use the same glasses and will be conducted at 90°C (principally) as well as at lower temperatures. Water representative of that expected to be found in the repository (J-13 water equilibrated with tuff rock at the test temperature) is used as well as deionized water, which is used in a small proportion of tests to provide a link to the broad body of work conducted outside NNWSI.

3.3.1.1 Conduct Unsaturated Testing of WVDP and DWPF Glass. D-20-27.

Background and Previous Work

The Unsaturated Test measures the interactions between waste glass, canister metal, and repository water that drips onto the glass/metal assembly and then runs off. This simulates the possible release scenario in which a container is perforated at more than one level, allowing water to enter the container, react with glass, and exit the container without standing for an extended length of time. In the test, a cylinder of waste glass is sandwiched between perforated pieces of canister metal, and water is dripped onto the assembly at very low rates. The Unsaturated Test and data obtained using it have been described by Bates and Gerding (1985 and 1986) and Bates et al. (1986a). The test method, along with a representative data package, is currently being prepared for submission to the Materials Review Board (Bates and Gerding, 1987).

The Unsaturated Testing conducted previously has demonstrated several interesting interactions. Because of reactions in which silica and carbonate are precipitated on the glass, it is not uncommon for the glass-metal package to gain weight during testing, which is the result of an interaction between glass and water, precipitating solid phases. Because of this type of interaction, the extent of glass reaction is best measured from the loss of highly soluble elements such as boron. Extensive interaction between the glass and canister metal is occasionally observed in the form of iron and nickel silicates precipitating on the metal and extensive discoloration of the glass where it contacts metal. This enhanced reaction may be due to chemical changes in the 304L stainless steel caused by heat treatments; the test currently uses deliberately sensitized stainless steel to examine this. This interaction will also be extensively examined in parametric studies. Even with these interactions, release rates from the short-term Unsaturated Testing conducted to date are small and are similar to those seen in saturated testing. A QA Level I Unsaturated Test of DWPF glass is currently in progress.

Planned Work

Unsaturated Testing will be conducted on both simulated and radioactive samples of waste glass from both producers. (Unsaturated Testing has already been conducted on simulated DWPF glass; WVDP glass is not yet available for testing). Testing will be done in one-year matrices until the producers publish the Waste Acceptance Plans and the samples of the projected final composition glasses (representing the range expected to be produced) are available. At this point, long-term confirmation testing may begin with open-ended matrices that will extend to licensing. These tests will use glass that is representative of that expected to be present 300 to 1000 years from closure. Unsaturated Testing will be conducted at a minimum of three sites to assure reproducibility. (Testing will be done at LLNL, ANL, and DWPF/SRL; DWPF/SRL is expected to participate in this testing under the Coordinate Testing activity, D-20-36). The details of the test matrices will follow those in the previously published reports, with possible changes derived from the results of parametric studies based on the Unsaturated Test (D-20-29).

3.3.1.2 Conduct Static Leach Testing of WVDP and DWPF Glass. D-20-28.

Background and Previous Work

Static leach testing of glass is conducted with two objectives. First, it tests the release scenario in which water accumulates inside a container and reacts continuously with the glass while overflow and refilling occur. Second, static leach testing provides the simplest and most easily interpreted method of reacting glass with water. The mechanisms and rates derived from this testing may be applied to other scenarios, and the tests are conducted by investigators from all three repository projects and by the two waste producers. This provides a large body of data for use in developing models and calculating releases.

Current static leaching is related to the MCC-1 static leach test (MCC, 1985). As written, this test is too limited to provide information on most conditions of interest to NNWSI, so separate experimental protocols have been developed. These include experiments using different ratios of glass to water and tests including repository material. In all tests, however, the test vessel is unagitated and is sampled terminally. Future static testing will also include the pulsed flow test developed at Catholic University, in which a small proportion of the test fluid is replaced at intervals, simulating an overflow/refill scenario.

NNWSI has conducted a number of static leaching experiments on DWPF glasses and PNL 76-68 glasses, which were proposed as commercial waste glasses. Work on PNL 76-68 glasses is concluded; major reports on PNL 76-68 testing are Bazan and Rego (1986a and 1986b), McVay and Robinson (1984), and Bates and Oversby (1984). Despite the fact that this glass will not be used for disposal, considerable information on mechanisms and the behavior of radionuclides in tuff-dominated systems has been obtained from this work. NNWSI testing of DWPF glasses has been reported in Bates et al. (1986b), Bates and Gerding (1985, 1986), and Bazan and Rego (1985). Collaborative work with SRL has been ongoing in this area, providing a considerable amount of mechanistic and parametric data under NNWSI conditions. No QA Level I static leach testing has been conducted to date.

Planned Work

Static leach testing will be conducted on both simulated and radioactive samples of waste glass from both producers. (Static leach testing has already been conducted on simulated DWPF glass; WVDP glass is not yet available for testing.) Testing will be done in one and two-year matrices until the producers publish their Waste Qualification Reports and the samples of the projected final composition glasses (representing the range expected to be produced) are available. At this point, long-term confirmation testing may begin. These tests will use glass with a radionuclide content that is representative of that expected to be present 300 to 1000 years from closure.

Testing will be conducted principally at 90°C, with some testing at 60°C to determine the effect of temperature on leach rate. Equilibrated J-13 water (equilibrated with tuff rock at the test temperature) will be used. Some tests will use deionized water for comparison to work done elsewhere. As identified by materials interactions testing, repository materials will be included in the testing. It is currently anticipated that tests will be done with glass alone, glass plus 304L stainless steel, and glass plus 304L plus tuff rock.

Long-term confirmation testing will begin as soon as final glass compositions are available from the producers (activity D-20-25). These tests will be conducted as described above, with matrices designed to provide the longest possible test times consistent with input to the licensing process.

3.3.1.3 Schedule

The schedule for these activities is tied to that of the Waste Acceptance Process by the availability of the final waste glass compositions for testing in the long-term confirmation phase. Long-term confirmation testing will continue to licensing to provide as long a time-span as possible of continuous testing of the final waste glasses.

	Begin	End
Unsaturated Testing of Projected WVDP and DWPF Glasses	In Progress	6/89
Static Leach Testing of Projected WVDP and DWPF Glasses	12/86	6/89
Long-Term Confirmation Testing of WVDP and DWPF Glasses Using Unsaturated Testing	6/89	1/91
Long-Term Confirmation Testing of WVDP and DWPF Glasses Using Static Leach Testing	6/89	1/91

3.3.2 Materials Interactions Affecting Glass Leaching

3.3.2.1 Introduction

These activities are intended to determine mechanisms of glass degradation and leaching and to identify important parameters controlling those mechanisms. These studies drive the creation of the glass release model (D-20-37), provide input to the design of Leach Testing (D-20-27 and D-20-28), and provide input to coordinate testing (D-20-35 and D-20-36). In the case of important parameters that are not suitable for determination by Leach Testing (D-20-27 and D-20-28) at QA Level I, this study contains a QA Level I activity for determining those parameters after they have been identified by QA Level III experimentation.

3.3.2.2 Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test. D-20-29.

Background and Previous Work

Background and previous work for the Unsaturated Test Method are described in Section 3.3.1.1. Parametric studies based on the unsaturated test method use similar test configurations, but allow variations in test parameters to determine their relative importance. For instance, the drip rate, waste package size, or temperature of the test may be varied. These experiments examine the different scenarios under which water that is not standing may interact with glass in the repository. An important parameter identified by parametric studies, which is now being examined in QA Level I Unsaturated Testing, is the effect of heat-treated 304L stainless steel on glass degradation rates under these circumstances.

Planned Work

Experiments will be conducted to examine the effects of drip rate, sample size, glass-metal contact, metal heat treatment, glass composition, and oxidation state. Other experiments may be identified from coordinate testing (D-20-35 and D-20-36), producer information (D-20-25), or literature results.

3.3.2.3 Parametric Studies of WVDP and DWPF Glass Using Static Leaching Studies. D-20-30.

Background and Previous Work

Background and previous work in static glass testing are described in Section 3.3.1.2.

Planned Work

Because of the large amount of previous work done in this area, the majority of static leach testing will immediately be conducted in the QA Level I Leach Testing activity (D-20-28). Parametric studies will be used to develop new test methods, in particular the CUA Pulsed Flow Test, into test methods that may be used by NNWSI at QA Level I. In addition, parametric studies of glass composition will be conducted. In general, a short parametric study will be conducted prior to each QA Level I test to identify test parameters. Parametric studies for the first set of QA Level I tests in activity D-20-28 have already been completed (see Section 3.3.1.2).

3.3.2.4 Studies of Glass Surface Layers and Precipitates. D-20-31.

Background and Previous Work

Numerous investigations have shown that, under the conditions anticipated a Yucca Mt., when water contacts glass the glass will react to form surface layers composed of amorphous and crystalline precipitates. These studies have been summarized by Bates et al. (1982); the Defense Leaching Mechanisms Program (Mendel, compiler, 1984); and Aines (1986) among others. Aines (1986) discusses the reasons why these layers are expected to control glass leaching. In short, as thick layers form, leaching fluids will no longer have direct access to fresh waste glass.

These layers are critical to glass modeling for two reasons. First, the phases present in them will control the chemistry of leaching fluids. Second, elements precipitated in these phases may be permanently sequestered. For example, the cesium-rich analcime crystals reported by Bates et al. (1982) may permanently reduce the release of cesium from the waste glass; the identity, formation, and possible destruction mechanisms of these precipitates must be studied to determine this.

The principal applications of this study will be design of the glass leaching model (D-20-37) and geochemical interactions studies (D-20-32). The results will also aid in the design and interpretation of QA Level I leach testing (D-20-27 and D-20-28).

Planned Work

Surfaces of glass reacted with water in other leach testing and parametric study activities will be examined to identify the structure, nature, and composition of surface layers formed on them. Techniques used will include scanning electron microscopy, infrared and raman spectroscopy, electron microprobe analysis, X-ray diffraction analysis, ion microprobe analysis, and other techniques as required. These results will be combined with analyses done in the geochemical interactions study (D-20-32) to interpret the results of leaching tests and studies. In addition, glass surfaces will be reacted as part of this activity to generate specific surface conditions. Included in this work is the hydration of glass in a humid atmosphere to study the effect of glass hydration in the repository in the scenario in which the container is perforated but water does not immediately enter the container.

The principal outputs of this activity will be the identity of phases precipitated on nuclear waste glass, their apparent rates of formation, and their composition including sequestered radionuclides. These will be important aspects of the glass leaching model.

3.3.2.5 Studies of Geochemical Interactions. D-20-32.

Background and Previous Work

This activity examines the geochemical interactions that occur between glass, pour canister and container materials, repository materials, and surface precipitates on glass surfaces. The purpose of this activity is to perform experiments that are optimized to isolate specific interactions, and to model those interactions using EQ3/6. In many cases, previous work has been unsatisfactory in determining the nature of interactions such as that between the silica content of leaching fluids and the rate of leaching. In this study, that interaction would be isolated experimentally by altering the silica content of a leaching fluid, and the results would be modeled using EQ3/6. These experiments will drive the glass release model development.

Planned Work

This activity will provide a highly interactive environment incorporating experimental studies and glass leaching model development. If a specific interaction is identified experimentally in other activities, it will be examined in this activity to determine whether existing geochemical modeling codes are adequate to model the interaction. If more data are required about the interaction, it is obtained through experiments or from the literature if available. Conversely, this activity will also involve the experimental evaluation of interactions that are predicted to occur by the geochemical modeling codes.

Two interactions are currently planned for study. The first is the interaction between silica-containing phases, silica in solution, and the glass dissolution rate. These will be studied by adding silica in solution to leaching fluids and by adding solid phases predicted to control silica solubility. The silica content of the leaching fluids is currently thought to be the principal control on leach rates; hence, this is a critical parameter to examine fully. The second interaction that will be examined is that between heat-treated stainless steel (sensitized or pre-sensitized) and silica-rich solutions. Results from parametric unsaturated studies indicate that the formation of iron and chrome silicates may deplete the leaching fluid in silica and enhance leach rates. Since the pour canister is expected to have undergone a history resulting in heat-induced changes in the metal, this is also an important interaction.

3.3.2.6 Studies of Scale Factor in Glass Leaching. D-20-33.

Background and Previous Studies

Almost all studies of glass leaching are conducted on a laboratory scale because of the tremendous cost of full-scale testing. The one exception in work in the United States is the work of Bickford and Pellarin (1986). Full-scale testing will be conducted in cooperation with the waste producers (D-20-35 and D-20-36). To complement those studies it may also be necessary to do one or more of the following: study the same samples in the laboratory, to study the flow of water through a glass canister, or to study the disaggregation of the glass waste in the canister. The modeling of flow of water through cracks in glass in the pour canister may be critical in the determination of the relative importance of static vs. unsaturated leach testing and, accordingly the weighting of results from those types of testing, in their ultimate use in waste package performance assessment.

Planned Work

Plans will be made for this activity after the results of full-scale testing (D-20-35 and D-20-36) are known. It is anticipated that an assessment of the potential water flow paths in a glass canister will have to be made.

3.3.2.7 Development of Licensing Database for Glass Waste Form Materials Interactions. D-20-34.

Background

Activities D-20-31, D-20-32, and D-20-33 are QA Level III experimental activities designed to understand mechanisms and drive model development (D-20-37). However, it is anticipated that application of the glass release model will require that the values of the important parameters be derived from a QA Level I activity. In addition, there are aspects of materials interactions for which no QA Level III experimental work is necessary, and work can proceed directly at QA Level I. In this activity, experimental work will be used to generate test protocols such that QA Level I data may be derived for important materials interactions parameters that will be used in the glass release model. QA Level III parametric studies of leaching

move to the QA Level I leach testing activities; this activity only concerns data on mechanisms and reaction rates of individual interactions that will be required by the computer model (D-20-37).

Planned Work

Most of the work in this activity will be derived from other activities as the important parameters are identified. The derivation of a library of infrared spectra of phases important to waste glass alteration will be undertaken. The samples used in this library will also be available for other characterization (such as thermodynamic constants or exchange capacity) or for QA Level I testing derived from activities D-20-31 and D-20-32.

3.3.2.8 Schedule

Each of the QA Level III activities in this study feed into a QA Level I activity, either in this activity, in leach testing (D-20-27 and D-20-28), or in model development. Each of the QA Level III activities accordingly decreases in scope as the work is fed into a QA Level I activity.

	Begin	End
Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test	In Progress	6/88
Parametric Studies of WVDP and DWPF Glass Using Static Leaching Methods	In Progress	6/88
Studies of Glass Surface Layers and Precipitate	In Progress	8/89
Studies of Geochemical Interactions	In Progress	8/89
Studies of Scale Factor in Glass Leaching	8/88	8/89
Development of Licensing Database for Glass Waste Form Materials Interactions	6/87	8/89

3.3.3 Coordinate Testing with Waste Producers

3.3.3.1 Introduction

No testing will be conducted by NNWSI as part of this activity. NNWSI will cooperate with the waste producer's testing programs in areas of experimental and test design, in supply of repository materials such as tuff rock and J-13 water, and in post test analysis (in particular in the areas of activities D-20-31,D-20-32, and D-20-33). Both producers will be performing laboratory scale tests similar to those done by NNWSI; this activity will monitor the concurrence between those results. Both producers will also conduct full-scale tests, which NNWSI will use to validate laboratory-scale results and model calculations.

3.3.3.2 Coordinate Testing with WVDP. D-20-35.

WVDP will conduct pulsed-flow and static testing (at CUA) using J-13 water supplied by NNWSI. NNWSI will use the results of this work in designing static leach tests for WVDP glass. It is anticipated that WVDP will conduct leach tests of full-scale canisters, using J-13 water, in which the head-space in the pour canister is filled with water and maintained at 90°C. The experiment will be sampled periodically and will continue for at least two years.

3.3.3.3 Coordinate Testing with DWPF/SRL. D-20-36.

An extensive coordinate testing program with DWPF/SRL is currently underway, resulting in several publications (Bibler, 1986; Bibler et al., 1984). It is anticipated that SRL will conduct a leach test of canister sections (in 55-gallon polyethylene drums, after Bickford and Pellarin, 1986) using J-13 water and a headspace-leaching experiment as described for WVDP. In addition, SRL has conducted, and will continue to conduct, laboratory scale leach testing of fresh, fully radioactive waste glass. This testing requires remote handling for both the production and leaching phases and would be prohibitively expensive for NNWSI to undertake. The results of leaching this fully-radioactive glass will be applied to assessment of the unanticipated condition of container failure prior to the end of the 300 to 1000 year containment period. It is anticipated that SRL will conduct Unsaturated Testing according to the NNWSI Test Procedure. Finally, it is anticipated that SRL will conduct tests of water flow inside glass canisters, in conjunction with modeling and laboratory work in activity D-20-33 (studies of scale factor in glass leaching).

3.3.3.4 Schedule

The detailed schedule for these activities will be set by the producers.

	Begin	End
Coordinate Testing with WVDP	6/87	6/89
Coordinate Testing with SRL/DWPF	In Progress	6/89

3.4 Glass Release Modeling

3.4.1 Introduction

The release of radionuclides from glass waste forms may occur if water contacts a container that has breached. As input to the waste package performance assessment submodel, the glass waste form testing investigation will generate, validate, and apply a model for the release of radionuclides from waste glass under repository conditions. The output from this model will be fed in either tabular or simple functional form to the performance assessment submodel. The model will be based upon sound geochemical principles and will not be a simple fit to laboratory data; on the contrary,

the laboratory data will provide the values of important parameters in the model, and laboratory and natural analogue studies will be used as part of the validation of the model.

3.4.2 Generate Models for Release from Glass. D-20-37.

Background and Previous Work

The objective of this activity is to design models for glass release based on the scenarios identified in information need 1.5.3. The geochemical modeling code package EQ3/6 will be an important part of these models. The extension to long times of the semi-empirical relationships discovered by laboratory testing cannot be made without understanding the mechanisms involved and assessing the effects of factors such as the slow build-up of crystalline layers. The model to be developed will account for glass degradation and radionuclide release using EQ3/6 in a combination of equilibrium and kinetic calculations. The EQ3/6 codes have been described by Wolery (1979, 1983, and 1986) and their proposed application to glass modeling was described by Aines (1986).

Description

Glass performance modeling will depend upon two basic concepts. First, the rate of release from the thermodynamically unstable waste glass is a kinetically controlled process. No formal equilibrium can exist. Second, once components are released from glass, the formation of solids and composition of fluids may be modeled by equilibrium processes. The final outcome of these equilibrium processes will be modeled, providing important limits on the behavior of radionuclides. In addition, the kinetics of these processes may be modeled to provide more accurate estimates of radionuclide concentrations in waste package fluids as a function of time throughout the life of the repository.

The model for glass degradation will incorporate the following items, presented here in the order in which they will be developed:

1. Calculation of the composition of the solutions that are in true equilibrium with the solid phases that precipitate on the surface of nuclear waste glasses.

2. Calculation of the rate of degradation of glass using kinetic rate laws based on transition state theory, deriving rate constants from experimental and natural-analogue studies.

3. Calculation of the rate of formation of solid precipitates, and the concomitant rate at which radionuclides are permanently sequestered in those stable phases.

4. Calculation of the effects of repository materials on the above items, including heat-affected stainless steel from the pour canister.

5. Calculation of the composition of fluids leaving a glass waste package by combining the above items.

In each case the appropriate analytical expressions will be identified from experimental work, from review of the glass degradation literature, and from geochemical modeling concepts incorporated in EQ3/6. Calculations will be performed using EQ3/6 and, if necessary, additional codes serving as pre- and post processors to EQ3/6; the extent to which these are necessary will be determined by future EQ3/6 development and the nature of the performance assessment scenarios identified for the glass release model. Current plans for EQ3/6 code development (EQ3/6, 1986) include one major item required for glass modeling, that being development of a flow-through model where a stationary reacting assemblage (the waste package) reacts with successive packets of water.

3.4.3 Screen Data for Use in Release Model. D-20-38.

Background and Previous Work

An extensive literature on the mechanisms and rates of glass dissolution may be addressed in designing and executing the glass release model. All data generated outside NNWSI will be screened in this activity, including that generated by waste producers. The objectives will be to establish the accuracy and precision of individual parameters and to ascertain that the glass release model uses only accurate and verifiable data. It is anticipated that the principal values and equations in the model will be derived by NNWSI under QA Level I conditions. This activity allows the large body of outside data to be used to corroborate and support the NNWSI data, and it allows important data and ideas generated outside NNWSI to be used in the model.

Description of Planned Work

Data generated outside NNWSI will be collected and examined to determine whether it is consistent with NNWSI data. If it is not, an examination of both data sets will be made to determine the origin of the discrepancy. When outside data is determined to be critical to the operation of the glass model (for example, data from full-scale testing by the producers), the NNWSI SOP-03-03 for using non-NNWSI data will be implemented. It is anticipated that critical producer data will be obtained under QA Level I.

An important aspect of this activity is the comparison of NNWSI data to that collected outside the project. This comparison will ensure that NNWSI is able to confirm that the glass release model is consistent with applicable data that may arise in licensing. When the data are inconsistent, an assessment of the cause of the discrepancy will be prepared. In the instance of the NNWSI data being incorrectly collected or applied, this activity allows the problems to be resolved and new data obtained under one of the data collection activities (D-20-27 through D-20-36). A formal mechanism for this screening process will be established.

3.4.4 Validate Glass Release Model. 0-20-39.

Description of Planned Work

Validation of the glass model will be done in two stages. First, the model will be developed in concert with experimental work and will be tested for its ability to describe accurately the experimental work. An important aspect of this is the use of modeling to aid in understanding the physical processes that are important in glass degradation in activity 0-20-32 (studies of geochemical interactions). Second, the results of long-term modeling will be compared with extrapolations of laboratory data and with natural analogues. This second effort will both test the validity of the model and, more importantly, determine whether the experimental work has examined all the important geochemical interactions that are predicted to occur over long periods of time.

Because EQ3/6 will be a fundamental part of the glass release model, validation activities for that family of codes will be established in conjunction with the other users of the code. The validation areas are:

1. Database. Critical database items will be reviewed under the data screening activity.
2. Code Operation. A series of benchmark validation code runs will be established for EQ3/6 to test major operations common to all applications.
3. Laboratory Experiment Matching. The glass release model must accurately predict the result of laboratory and full-scale leach testing.
4. Natural Analogues. To determine whether the glass release model accurately predicts solution compositions after long-term contact with glass, it will be used to model natural groundwaters in contact with glass.

All four of these validation areas are required to confirm that the model accurately predicts the behavior of glass/water systems for thousands of years.

3.4.5 Schedule

The schedule for model development is tied to the schedules of performance assessment and EQ3/6 code development.

	Begin	End
Generate Models for Release from Glass	In Progress	3/89
Screen Data for Incorporation in Release Model	6/87	6/89
Validate Glass Release Model	10/87	8/89

4.0 Application of Results

The information provided by this investigation will provide the source term for radionuclide release from waste packages. The information directly addresses the following information needs.

Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release as required by 10 CFR 60.113?

1.5.1 Waste package design features that affect the rate of radionuclide release.

1.5.2 Material properties of the waste forms.

1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.

Through input to the above information needs, this investigation will also provide data used to resolve information needs 1.5.4 and 1.5.5, and issues 1.1, 1.9, 1.10, and 1.11.

This information will also serve as part of the source term in the calculation of cumulative releases after 100,000 years in the site evaluation process required by 10 CFR 960.3-1-5. It will also serve as part of the source term input for calculation of cumulative releases to the accessible environment for 10,000 years after disposal, to determine compliance with the EPA regulation (40 CFR 191.13).

The interrelationships among the activities in this investigation have been discussed in each section. In general, the goal of the investigation is to provide input to the waste package performance assessment submodel in the form of output from the glass release model. Important parameters in this model are quantified in the Leach Testing activities (D-20-27 and D-20-28), the materials database activity (D-20-34), and the data screening and validation activities (D-20-38 and D-20-39). The principles, mechanisms, and ideas for the release model are developed in experimental activities and data collection activities (D-20-25, D-20-26, D-20-29 through D-20-33, D-20-35, and D-20-36). In each case, ideas are developed in QA Level III activities, and data for use in the model is derived in QA Level I activities arising from the QA Level III activities.

5.0 Schedule and Milestones

5.1 Discussion and Assumptions

The schedule for individual activities has been discussed in Section 3.0. The overall schedule for the waste package performance assessment investigation is tied to two other schedules: (1) the information required to construct and use the waste package performance assessment code, currently planned for 8/89; and (2) the schedule for the Waste Acceptance Process controls when the final qualification reports are available, currently planned for 6/89. Long-term confirmation testing, using the final waste glass compositions, will continue beyond that date to verify the shorter-term results that will have been input earlier into the performance assessment models. Because of the late date for the final qualification reports, the long-term confirmation testing must be conducted after the initial input to the performance assessment model is made.

This schedule was prepared according to the funding levels in the FY 1988 WPAS. Reductions in funding levels would result in concomitant slippage of the schedule and milestones. Several activities outside this investigation can possibly affect this schedule. (1) The waste producers must meet the June 1989 deadline for production of the WQR. The waste described in the WQR must be reasonably similar to that currently planned; if it is not, new parametric and experimental studies would have to be undertaken in addition to QA Level I testing. Schedule slippage would depend on the degree to which the actual waste glass differs from that described by the current producer documents (Baxter, 1983 and Eisenstatt, 1986). (2) The container material must be selected according to the current scheduled milestone in September 1987. If a container material other than austenitic stainless steel is chosen, some slippage could occur while preliminary tests of that material are conducted in D-20-30 and D-20-32. (3) If the results of exploratory shaft testing, other materials testing, and waste package environment testing do not confirm the current estimates of the package environment, as described in the SCP, schedule slippage concomitant with the degree of discrepancy will occur.

5.2 Schedule

	Start	Complete
<u>Integrate Glass Waste Form Information</u>	In Progress	6/89
Integrate Glass Waste Form Information Provided by Waste Producers. D-20-25.	In Progress	6/89
Integrate Waste Package and Repository Design Information. D-20-26.	In Progress	6/89
<u>Leach Testing of Glass</u>	In Progress	6/89
Conduct Unsaturated Testing of Projected WVDP and DWPF Glasses. D-20-27.	In Progress	6/89

Conduct Static Leach Testing of Projected WVDP and DWPF Glasses. D-20-28.	12/86	6/89
(Long-term confirmation testing will be conducted as a continuation of activities D-20-27 and D-20-28)		
Long-Term Confirmation Testing of WVDP and DWPF Glasses Using Unsaturated Testing. D-20-27.	6/89	1/91
Long-Term Confirmation Testing of WVDP and DWPF Glasses Using Static Leach Testing. D-20-28.	6/89	1/91
Materials Interactions Affecting Glass Leaching	In Progress	1/89
Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test. D-20-29.	In Progress	6/88
Parametric Studies of WVDP and DWPF Glass Using Static Leaching Methods. D-20-30.	In Progress	6/88
Studies of Glass Surface Layers and Precipitates. D-20-31.	In Progress	8/89
Studies of Geochemical Interactions. D-20-32.	In Progress	8/89
Studies of Scale Factor in Glass Leaching. D-20-33.	8/88	8/89
Development of Licensing Database for Glass Waste Form Materials Interactions. D-20-34.	6/87	8/89
Coordinate Testing with Waste Producers	In Progress	6/89
Coordinate Testing with WVDP. D-20-35.	6/87	6/89
Coordinate Testing with SRL/DWPF. D-20-36.	In Progress	6/89
Glass Release Modeling	10/86	8/89
Generate Models for Release from Glass. D-20-37.	In Progress	3/89

Screen Data for Incorporation in Release Model. D-20-38.	6/87	6/89
Validate Glass Release Model. D-20-39.	10/87	8/89

5.3 Milestones

Number	Title	Date
	Report on Unsaturated Testing of DWPF glass.	9/87
C397	Report on Glass Release Model	9/87
M009	Initiate long-term testing of WVDP and DWPF HLW.	10/87
	Determine release from DWPF glass at 60°C relative to that at 90°C.	11/87
	Report on alteration of glass surfaces and geochemical interactions.	11/87
W208	Complete parametric testing of glass.	6/88
M269 & P112	Complete testing for design purposes.	9/88
	Report on database for glass modeling and required model validation exercises.	3/89
	Initiate long-term confirmation testing of WVDP and DWPF glass.	6/89
	Complete study of alteration of glass surfaces.	8/89
M012	Model long-term expected performance of waste forms under repository conditions.	8/89
	Report on leaching of waste glass for license application.	10/89
	Complete long-term confirmatory testing of waste glass.	6/91

6.0 List of Test Plans to Support this Plan

The following test plans will describe in detail the activities described in this investigation plan.

Test Plan	Scheduled Completion Date
NNWSI Plan for Leach Testing of Glass Waste Forms	11/86
Plan for NNWSI Testing of Materials Interactions Affecting Leaching of Glass Waste Forms	3/87
Plan for Coordinate Testing Between NNWSI and Glass Waste Form Producers (DWPF/SRL and WVDP)	5/87
NNWSI Plan for Generation, Testing, and Validation of a Model of Release of Radionuclides from Glass Waste Forms	1/87

7.0 References

Aines, R. D. (1986). Application of EQ3/6 to Modeling of Nuclear Waste Glass Leaching, Lawrence Livermore National Laboratory, in press.

Bates, J. K., D. F. Fischer, and T. J. Gerding (1986b). The Reaction of Glass During Gamma Irradiation in a Saturated Tuff Environment: Part 1, SRL 165 Glass, ANL 85-62, Argonne National Laboratory, Argonne, IL.

Bates, J. K., and T. J. Gerding (1985). NNWSI Phase II Interaction Test Procedure and Preliminary Results, ANL-84-81, Argonne National Laboratory, Argonne, IL.

Bates, J. K., and T. Gerding (1986). One-Year Results of the NNWSI Unsaturated Test Procedure: SRL-165 Glass Application, ANL 85-41, Argonne National Laboratory, Argonne, IL.

Bates, J. K., T. J. Gerding, T. A. Abrajano, and W. Ebert (1986a). NNWSI Waste Form Testing at Argonne National Laboratory: Semi Annual Report, July-December, 1985, UCRL-15801, Lawrence Livermore National Laboratory, Livermore, CA.

Bates, J. K., L. J. Jardine, and M. J. Steindler (1982). "Hydration Aging of Nuclear Waste Glass," Science, Vol. 218, pp. 51-53.

Bates, J. K., and V. M. Oversby (1984). The Behavior of Actinide Containing Glasses During Gamma-Irradiation in a Saturated Tuff Environment, UCRL-90818, Lawrence Livermore National Laboratory, Livermore, CA.

Bates, J. K., and T. J. Gerding (1987). The NNWSI Unsaturated Test Method, Lawrence Livermore National Laboratory, contractor report, in preparation.

Baxter, R. G. (1983). Description of Defense Waste Processing Facility Reference Waste Form and Canister, DP1606, Rev. 1, E. I. DuPont de Nemours and Co., Savannah River Plant, Aiken, SC.

Bazan, F., and J. Rego (1986). The Tuff Reaction Vessel Experiment, UCRL-53735, Lawrence Livermore National Laboratory, Livermore, CA

Bazan F., and J. Rego (1986b). Parametric Testing of Actinide-Doped 76-68 Based Waste Glass, Lawrence Livermore National Laboratory, Livermore, CA (in press).

Bibler, N. E. (1986) Leaching Fully Radioactive SRP Nuclear Waste Glass in Tuff Groundwater in Stainless Steel Vessels. Savannah River Plant and Laboratory, DuPont de Nemours and Co., report DP-MS-85-141. Also, American Ceramic Society, Annual Meeting Proceedings 1986, in press.

Bibler, N. E., Wicks, G. G., Oversby, V. M. (1985) Leaching Savannah River Plant nuclear waste glass in a saturated tuff environment. Materials Research Society Symposium Proceedings, 44, (Scientific Basis for Nuclear Waste Management VIII) C. M. Jantzen, et al., eds., pp. 247-256.

Bickford, D. F., and D. J. Pellarin (1986). "Large-Scale Leach Testing of DWPF Canister Sections," Materials Research Society Symposium Proceedings, (Scientific Basis for Nuclear Waste Management X), J. K. Bates and W. B. Seefeldt (eds.), in press.

DOE, U. S. Department of Energy (1986). Acceptance of Data or Data Interpretation Not Developed Under the NNWSI QA Plan, NNWSI-SOP-03-03, Rev. 0.

EQ3/6 (1986). Geochemical Modeling Plan, Office of Civilian Radioactive Waste Management Program, Scientific Investigation Plan for NNWSI, UCID-20864, Lawrence Livermore National Laboratory, Livermore, CA.

Eisenstatt, L. R. (1986). Description of the West Valley Project Reference High-Level Waste Form and Canister, WVDP-056 Rev. 0, West Valley Demonstration Project, West Valley, NY.

Materials Characterization Center (1985). Static Leach Test Method, MCC-1P.

McVay, G. L., and G. R. Robinson (1984). Effects of Tuff Waste Package Components on Release from 76-68 Simulated Waste Glass, PNL-4897, Pacific Northwest Laboratories, Richland, WA.

Mendel, J. E. (compiler) (1984). Final Report of the Defense High-Level Leaching Mechanisms Program, PNL-5157, Pacific Northwest Laboratories, Richland, WA.

Wolery, T. J. (1979). Calculation of Chemical Equilibrium Between Aqueous Solution and Minerals: The EQ3/6 Software Package, UCRL-52658, Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T. J. (1983). EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: User's Guide and Documentation, UCRL-53414, Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T. J. (1986b). EQ6, A Computer Program for Reaction-Path Modeling of Aqueous Geochemical Systems: User's Guide and Documentation, Lawrence Livermore National Laboratory, Livermore, CA, in preparation.

8.0 Activity QA Level Assignment Sheets

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Integrate Waste Package and Repository Design Information.
0-20-26

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1,
Glass Waste Form Testing Para 2.2

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

11/18/86		11/18/86	
Task Leader	Date	Deputy Leader for QA	Date
		11-18-86	
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

1/23/87			
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Integrate Waste Package and Repository Design Information

ACTIVITY NO.: D-20-26
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM None

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Conduct Unsaturated Testing of WVDP and DWPF Glass.
D-20-27

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing *Para 2.3.1*

Additional Comments:

Activity determined to be of Quality Assurance Level I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Task Leader	Date 11/18/86	Deputy Leader for QA	Date 11-18-86
NNWSI Deputy Leader	Date	NWMP Leader	Date 11-18-86

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Project Sponsor	Date 1/23/87	Project Sponsor Quality Manager	Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Conduct Unsaturated Testing of WVDP and DWPF Glass

ACTIVITY NO.: D-20-27
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	Yes	Procedures under TAB 033-NWMP-P-3.0 apply
4.0 PROC. DOC. CONTROL	Yes	Procedures under TAB 033-NWMP-P-4.0 apply
5.0 INSTR., PROCS, DWGS	Yes	Procedures under TAB 033-NWMP-P-5.0 apply
7.0 CTL OF PUR MATERIALS	Yes	Procedures under TAB 033-NWMP-P-7.0 apply
8.0 I.D. & CTL OF MATERIALS	Yes	See appended list
9.0 CONTROL OF PROCESSES	No	None of the activities require processes with special training
10.0 INSPECTION	Yes	Procedure ANL-NNWSI-05-005. Acceptance Specifications for Glass Forms to be used in the Unsaturated Test Method
11.0 TEST CONTROL	Yes	See appended list
12.0 CTL OF M & T EQUIP	Yes	See appended list
13.0 HANDLING, STOR. & SHIP.	Yes	Procedures under TAB 033-NWMP-13.0 apply
14.0 INSP. TEST & OPER. STAT.	Yes	Procedures pertaining to this element are subsumed in 11.0 Test Control
19.0 SOFTWARE QA	No	No software is used in this activity

NWMP Quality Assurance Element Assignment
Supplemental Procedures List

Title	Number
Rock Crushing Procedure	033-NNWSI-P8.1
Sample Catalog Procedure	033-NNWSI-P8.2
Determination of Anions in Water by Ion Chromatography	1.2.2A-P4 Rev 0
ICP-AES Analysis for Trace Elements in Solutions	1.2.2A-P3 Rev 0
Procedure for Collection and Storage of J-13 Water	033-NNWSI-P13.1
Balance Calibration	033-NNWSI-P12.2
Pu-Np Separation, Pu Repurification, and Plating Preparation.	
Data Log System, Temperature Controllers, and Digital Displays.	
Thermocouples.	
pH Meters	
Sample Labeling and Tracking	

Title	Number
Current Standard Operating Procedures for the Determination of Total Metals in Water by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)	ANL/NNWSI-05-003
Procedure for Uranium in Leachate Solutions	ANL/NNWSI-05-004
Acceptance Specifications and Production Method for NNWSI Glass Forms to be Used in the Unsaturated Test Method	ANL/NNWSI-05-005
Modification and Setup of Blue-M Oven Model OV490A-2 for NNWSI Tests	ANL/NNWSI-05-007
Procedure for Making Actinide-Doped Glass for NNWSI Unsaturated Testing	ANL/NNWSI-05-008
Equilibration of J-13 Water	ANL/NNWSI-05-009
Cleaning Procedures for Test Vessels, Waste Form Holders, O-Rings and Polyethylene Containers Used in the NNWSI Unsaturated Test Method	ANL/NNWSI-05-010
NNWSI Unsaturated Test Procedure	ANL/NNWSI-05-011
Acceptance Specifications and Production Method for Test Vessels, Waste Form Holders, and O-Rings Used in the NNWSI Unsaturated Test Method.	ANL/NNWSI-05-012
Sensitization of Waste Form Holders	ANL/NNWSI-05-013

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Conduct Static Leach Testing of WVDP and DWPF Glass.
D-20-28

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.3.1

Additional Comments:

Activity determined to be of Quality Assurance Level I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86 — Task Leader, Date
John F. Dronkers 11-18-86 — Deputy Leader for QA, Date

Jesse L. Yow Jr. [illegible] — NNWSI Deputy Leader, Date
L. Ramspott 11-18-86 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

[signature] 1/23/87 — Project Sponsor, Date
James Blaylock [illegible] — Project Sponsor Quality Manager, Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Conduct Static Leach Testing of WVDP and DWPF Glass

ACTIVITY NO.: D-20-28
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	Yes	Procedures under TAB 033-NWMP-P-3.0 apply
4.0 PROC. DOC. CONTROL	Yes	Procedures under TAB 033-NWMP-P-4.0 apply
5.0 INSTR., PROCS, DWGS	Yes	Procedures under TAB 033-NWMP-P-5.0 apply
7.0 CTL OF PUR MATERIALS	Yes	Procedures under TAB 033-NWMP-P-7.0 apply
8.0 I.D. & CTL OF MATERIALS	Yes	See appended list
9.0 CONTROL OF PROCESSES	No	None of the activities require processes with special training
10.0 INSPECTION	Yes	Procedure ANL-NNWSI-05-005. Acceptance Specifications for Glass Forms to be used in the Unsaturated Test Method
11.0 TEST CONTROL	Yes	See appended list
12.0 CTL OF M & T EQUIP	Yes	See appended list
13.0 HANDLING, STOR. & SHIP.	Yes	Procedures under TAB 033-NWMP-13.0 apply
14.0 INSP. TEST & OPER. STAT.	Yes	Procedures pertaining to this element are subsumed in 11.0 Test Control
19.0 SOFTWARE QA	No	No software is used in this activity

D-20-28
NWMP Quality Assurance Element Assignment
Supplemental Procedures List

Title	Number
Rock Crushing Procedure	033-NNWSI-P8.1
Determination of Anions in Water by Ion Chromatography	1.2.2A-P4 Rev 0
ICP-AES Analysis for Trace Elements in Solutions	1.2.2A-P3 Rev 0
Procedure for Collection and Storage of J-13 Water	033-NNWSI-P13.1
Preparation of Sawn Glass Monoliths	
Balance Calibration	033-NNWSI-P12.2
Static Leach Test	MCC-1
Pu-Np Separation, Pu Repurification, and Plating Preparation.	
Length Measuring Instruments	
Data Log System, Temperature Controllers, and Digital Displays.	
Pressure Transducers	
Thermocouples.	
pH Meters	
Sample Labeling and Tracking	
Current Standard Operating Procedures for the Determination of Total Metals in Water by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)	ANL/NNWSI-05-003
Procedure for Uranium in Leachate Solutions	ANL/NNWSI-05-004
Procedure for Making Actinide-Doped Glass for NNWSI Unsaturated Testing	ANL/NNWSI-05-008
Equilibration of J-13 Water	ANL/NNWSI-05-009
Sensitization of Waste Form Holders	ANL/NNWSI-05-013

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18,1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test. D-20-29

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.3.2 p.7.

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86 — Task Leader, Date

John H. Dronkers 11-18-86 — Deputy Leader for QA, Date

11-18-86 — NNWSI Deputy Leader, Date

L. Ramspott 11-18-86 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

1/23/87 — Project Sponsor, Date

James Blaylock — Project Sponsor Quality Manager, Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Parametric Studies of WVDP and DWPF Glass Based on the Unsaturated Test
ACTIVITY NO.: 0-20-29
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Parametric Studies of WVDP and DWPF Glass Using Static Leaching Methods. D-20-30

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing *Para 2.3.2., p.7.*

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86 — Task Leader, Date

John F. Dronkers 11/18/86 — Deputy Leader for QA, Date

Jesse L. Yow Jr. — NNWSI Deputy Leader, Date

L. D. Ramspott 11-18-86 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Lester [illegible] 1/23/87 — Project Sponsor, Date

[illegible] — Project Sponsor Quality Manager, Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Parametric Studies of WVDP and DWPF Glass Using Static Leaching Methods

ACTIVITY NO.: D-20-30

DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA ___III___

CITE "YES" ITEM ON LOGIC DIAGRAM ___none___

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Studies of Glass Surface Layers and Precipitates.
D-20-31

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing *Para 2.3.2, p.7.*

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86 — Task Leader, Date
John F. Dronkers 11/18/86 — Deputy Leader for QA, Date

Jesse L. Yow Jr. — NNWSI Deputy Leader, Date
J. Ramspott 11-18-86 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

1/23/87 — Project Sponsor, Date
Project Sponsor Quality Manager, Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Studies of Glass Surface Layers and Precipitates

ACTIVITY NO.: D-20-31
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Studies of Geochemical Interactions.
D-20-32

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1,
Glass Waste Form Testing Para 2.3.2, p.7

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86 John J. Dronkers 11/18/86
Task Leader Date Deputy Leader for QA Date

Jesse L. Yow Jr. 11-18-86 L. Ramspott 11-18-86
NNWSI Deputy Leader Date NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

1/23/87
Project Sponsor Date Project Sponsor Quality Manager Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Studies of Geochemical Interactions

ACTIVITY NO.: D-20-32
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Studies of Scale Factor in Glass Leaching
D-20-33

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.3.2, p.7.

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines	11/18/86	John F. Dronkers	11-18-86
Task Leader	Date	Deputy Leader for QA	Date
Jesse L. Yow, Jr.		J. Ramspott	11-18-86
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

	1/23/87		
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Studies of Scale Factor in Glass Leaching

ACTIVITY NO.: D-20-33
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Development of Licensing Database for Glass Waste Form Materials Interactions. D-20-34

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing *Para 2.3.2, p. 7*

Additional Comments:

Activity determined to be of Quality Assurance Level I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines *11/18/86* *John F. Dronkers* *11/18/86*
Task Leader Date Deputy Leader for QA Date

Jesse L. Yow Jr. *11-18-86* *L. Ramspott* *11-18-86*
NNWSI Deputy Leader Date NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

[signature] *1/23/87* *[signature]*
Project Sponsor Date Project Sponsor Quality Manager Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Licensing Database for Glass Waste Form Materials Interactions
ACTIVITY NO.: D-20-34
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	Yes	Procedures under TAB 033-NWMP-P-3.0 apply
4.0 PROC. DOC. CONTROL	Yes	Procedures under TAB 033-NWMP-P-4.0 apply
5.0 INSTR., PROCS, DWGS	Yes	Procedures under TAB 033-NWMP-P-5.0 apply
7.0 CTL OF PUR MATERIALS	Yes	Procedures under TAB 033-NWMP-P-7.0 apply
8.0 I.D. & CTL OF MATERIALS	Yes	Procedures under TAB 033-NWMP-P-8.0 apply See appended list
9.0 CONTROL OF PROCESSES	No	None of the activities require processes with special training
10.0 INSPECTION	Yes	Procedure ANL-NNWSI-05-005. Acceptance Specifications for Glass Forms to be used in the Unsaturated Test Method
11.0 TEST CONTROL	Yes	See appended list. Other procedures will be developed as required
12.0 CTL OF M & T EQUIP	Yes	See appended list
13.0 HANDLING, STOR. & SHIP.	Yes	Procedures under TAB 033-NWMP-13.0 apply
14.0 INSP. TEST & OPER. STAT.	Yes	Procedures pertaining to this element are subsumed in 11.0 Test Control
19.0 SOFTWARE QA	No	No software is used in this activity

D-20-34
NWMP Quality Assurance Element Assignment
Supplemental Procedures List

Title	Number
X-ray Diffraction Characterization	1.2.2C-P5 Rev 0
Determination of Anions in Water by Ion Chromatography	1.2.2A-P4 Rev 0
ICP-AES Analysis for Trace Elements in Solutions	1.2.2A-P3 Rev 0
Procedure for Preparation of Solid Powder Samples Suspended in Pressed KBr Disks	
Preparation of Sawn Glass Monoliths	
Balance Calibration	033-NNWSI-P12.2
Pu-Np Separation, Pu Repurification, and Plating Preparation.	
Length Measuring Instruments	
Data Log System, Temperature Controllers, and Digital Displays.	
Thermocouples.	
pH Meters	
Sample Labeling and Tracking	
Current Standard Operating Procedures for the Determination of Total Metals in Water by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES)	ANL/NNWSI-05-003
Procedure for Uranium in Leachate Solutions	ANL/NNWSI-05-004
Procedure for Making Actinide-Doped Glass for NNWSI Unsaturated Testing	ANL/NNWSI-05-008
Equilibration of J-13 Water	ANL/NNWSI-05-009
Sensitization of Waste Form Holders	ANL/NNWSI-05-013

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Coordinate Testing with WVDP.
D-20-35

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1,
Glass Waste Form Testing Para 2.3.3

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines	11/19/86	John F. Dronkers	11/19/86
Task Leader	Date	Deputy Leader for QA	Date
Jesse L. Yow Jr.	11-23-86	J. Ramspott	11-19-86
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

[signature]	1/23/87	[signature]	[illegible]
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Cooperative Testing with WVDP

ACTIVITY NO.: D-20-35
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Coordinate Testing with DWPF/SRL
D-20-36

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.3.3

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/19/86
Task Leader Date

John F. Dronkers 11-19-86
Deputy Leader for QA Date

Jesse L. Yow Jr. 11-23-86
NNWSI Deputy Leader Date

J. Ramspott 11-19-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Lester L. [illegible] 1/28/87
Project Sponsor Date

[illegible]
Project Sponsor Quality Manager Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Cooperative Testing with DWPF/SRL

ACTIVITY NO.: D-20-36
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES	IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Generate Models for Release from Glass.
D-20-37

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.4

Additional Comments:

Activity determined to be of Quality Assurance Level ~~IV~~ III

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86
Task Leader Date

John F. Dronkers 11-18-86
Deputy Leader for QA Date

NNWSI Deputy Leader Date

J. Ramospatt 11-18-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

1/23/87
Project Sponsor Date

Project Sponsor Quality Manager Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Integrate Glass Waste Form Information Provided by Waste Producers

ACTIVITY NO.: D-20-25
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM None

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Integrate Glass Waste Form Information Provided by Waste Producers.
D-20-25

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing. Para 2.2

Additional Comments:

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86 — John F. Dronkers 11-18/86

Task Leader Date Deputy Leader for QA Date

Jesse L. Yow Jr. 11-18-86 — [illegible] 11-18-86

NNWSI Deputy Leader Date NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Lester [illegible] 1/23/87 — James [illegible]

Project Sponsor Date Project Sponsor Quality Manager Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Generate Models for Release from Glass

ACTIVITY NO.: 0-20-37
DATE: November 18, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM none

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Screen Data for Incorporation in Release Model.
D-20-38

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.4

Additional Comments:

Activity determined to be of Quality Assurance Level I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines	11/18/86	John H. Dronkers	11-18-86
Task Leader	Date	Deputy Leader for QA	Date
[illegible]	11-18-86	L. Ramspott	11-18-86
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

[illegible]	1/20/87	[illegible]	[illegible]
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Screen Data for Incorporation in Release Model

ACTIVITY NO.: 0-20-38
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	Yes	Procedures under TAB-033-NWMP-3.0 apply
4.0 PROC. DOC. CONTROL	Yes	Procedures under TAB 033-NWMP-4.0 apply
5.0 INSTR., PROCS, DWGS	Yes	Procedures under TAB-033-NWMP-5.0 apply
7.0 CTL OF PUR MATERIALS	Yes	Procedures under TAB-033-NWMP-7.0 apply
8.0 I.D. & CTL OF MATERIALS	No	This is a paperwork exercise only
9.0 CONTROL OF PROCESSES	No	This is a paperwork exercise only
10.0 INSPECTION	No	This is a paperwork exercise only
11.0 TEST CONTROL	No	This is a paperwork exercise only
12.0 CTL OF M & T EQUIP	No	This is a paperwork exercise only
13.0 HANDLING, STOR. & SHIP.	No	This is a paperwork exercise only
14.0 INSP. TEST & OPER. STAT.	No	This is a paperwork exercise only
19.0 SOFTWARE QA	Yes	Procedures under TAB-033-NWMP-19.0 apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: November 18, 1986

Meeting Attendees: Roger Aines
John Dronkers
Jesse Yow
Sandy Wander

Name(s) and Number(s) of Activity:
Validate Glass Release Model.
0-20-39

S.I.P. Identification:
Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1, Glass Waste Form Testing Para 2.4

Additional Comments:

Activity determined to be of Quality Assurance Level I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Roger D. Aines 11/18/86
Task Leader Date

John L. Dronkers 11-18-86
Deputy Leader for QA Date

[illegible]
NNWSI Deputy Leader Date

J. Cammarota 11-19-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

[illegible] 1/23/87
Project Sponsor Date

[illegible]
Project Sponsor Quality Manager Date

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Validate Glass Release Model

ACTIVITY NO.: D-20-39
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	Yes	Procedures under Tab-033-NWMP-3.0 apply
4.0 PROC. DOC. CONTROL	Yes	Procedures under TAB 033-NWMP-4.0 apply
5.0 INSTR., PROCS, DWGS	Yes	Procedures under TAB-033-NWMP-5.0 apply
7.0 CTL OF PUR MATERIALS	Yes	Procedures under TAB-033-NWMP-7.0 apply
8.0 I.D. & CTL OF MATERIALS	Yes	Procedures under TAB-033-NWMP-8.0 apply Additional procedures will be developed as required
9.0 CONTROL OF PROCESSES	No	No special processes are anticipated
10.0 INSPECTION	Yes	Inspection procedures will be developed
11.0 TEST CONTROL	Yes	Test procedures will be developed
12.0 CTL OF M & T EQUIP	Yes	Procedures under TAB-033-NWMP-12.0 apply. Additional procedures will be developed as required
13.0 HANDLING, STOR. & SHIP.	Yes	Procedures under Tab-033-NNWSI-13.0 apply
14.0 INSP. TEST & OPER. STAT.	Yes	Procedures under this element are subsumed in 11.0, Test Control
19.0 SOFTWARE QA	Yes	Procedures under Tab-033-NNWSI-19.0 apply

NNA.871113.0028

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.2.3.1.1

NNWSI Spent Fuel Waste Form Testing

Lawrence Livermore National Laboratory

Revision 0
Manuscript date October 16, 1987

10-19-87
L. D. Ramspott, Technical Project Officer Date

10-16-87
J. J. Dronkers, Deputy for Quality Assurance Date

10/16/87
H. F. Shaw, Technical Area Leader Date

10/16/87
H. F. Shaw, Task Leader Date

10/16/87
C. Bruton, Technical Reviewer Date

11/5/87
Project Sponsor Quality Manager Date

11/6/87
Project Sponsor Date

SAIC/T&MSS

NOV 13 1987

CCF RECEIVED

Table of Contents

1.0 Purposes and Objectives

1.1 Regulatory Requirements

The purpose of spent fuel waste form testing is to determine the rate of release of radionuclides from failed disposal containers holding spent fuel, under conditions appropriate to the Nevada Nuclear Waste Storage Investigations (NNWSI) Project tuff repository. The information gathered in the activities discussed in this document will be used in the following ways:

1) to assess the performance of the waste package and engineered barrier system (EBS) with respect to the containment and release rate requirements of the Nuclear Regulatory Commission (NRC) rule 10-CFR-60.113;

2) as the basis for the spent fuel waste form source term in repository-scale performance assessment modeling to calculate the cumulative releases to the accessible environment over 10,000 years to determine compliance with the Environmental Protection Agency (EPA) rule 40-CFR-191.13;

3) as the basis for the spent fuel waste form source term in repository-scale performance assessment modeling to calculate cumulative releases over 100,000 years as required by the site evaluation process specified in the DOE siting guidelines, 10-CFR-960.3-1-5.

The scientific investigations discussed herein are intended to address directly the following information needs taken from the NNWSI Project Issues Hierarchy (version dated 8/07/86):

"Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release as required by 10-CFR-60.113?

1.5.1 Waste package design features that affect the rate of radionuclide release.

1.5.2 Material properties of the waste forms.

1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system."

Through input to the above information needs, the results of the spent fuel activities will provide data to help resolve information needs 1.4.4, 1.5.4, and 1.5.5, and issues 1.1, 1.4, 1.9, 1.10, and 1.11.

The structure of this spent fuel waste form Scientific Investigation Plan (SIP) closely parallels the information needs listed above and the discussion in Chapter 8 of the NNWSI Project Site Characterization Plan (SCP) of the studies to be undertaken to resolve the information needs. In summary, information about the waste form which can be gathered from vendors, the utilities and other outside sources is accumulated and evaluated (1.5.1); the waste form is subjected to various tests to determine its properties and mechanisms of degradation and radionuclide release (1.5.2); and models to predict the long-term performance of the waste form are developed and tested (1.5.3). Chapter 8 of the SCP defines three studies that are within the domain of this SIP, one study for each of the three information needs listed above. The study for information need 1.5.2 is further subdivided into six areas of study, known as activities. The titles and SCP designations of each study and activities that compose each study are shown in section 1.2.

1.2 Spent Fuel Activities Grouped by SCP Study

Integrate Spent Fuel Information - (SCP Information need 1.5. activities 1.5.1.1.1 and 1.5.1.1.3)

D-20-40 Integrate spent fuel waste form information provided by vendors, utilities, and other sources

D-20-41 Integrate NNWSI Project waste package and repository design information

Characterization of the Spent Fuel Waste Form - (SCP Information need 1.5.2, activities 1.5.2.1.1 through 1.5.2.1.6)

Dissolution/leach tests of spent fuel and UO_2

D-20-42 Saturated, semi-static dissolution tests of spent fuel and UO_2

D-20-43 Unsaturated dissolution tests of spent fuel and UO_2

Oxidation tests on spent fuel and UO_2

D-20-44 Oxidation tests of spent fuel and UO_2 using a thermo-gravimetric apparatus

D-20-45 Oven-oxidation tests of spent fuel and UO_2

Corrosion and release tests from cladding and assembly materials

D-20-46 Corrosion/degradation/release tests on Zircaloy and stainless steel cladding

D-20-47 Corrosion/release tests on assembly hardware

D-20-48 Carbon-14 inventory and release tests

Planning and experimental design

D-20-49 Technique development for test planning and design

Generate Models for Release from Spent Fuel - (SCP Information Need 1.5.3, activity 1.5.3.3.1)

D-20-50 Generate models for release of radionuclides from the spent fuel waste form

D-20-51 Screen data for incorporation into release model

D-20-52 Finalize and validate spent fuel release model

1.3 Information Flow

The goals of the spent fuel waste form testing technical area are: to provide accurate data and models concerning the release of radionuclides from the waste form under tuff repository conditions, and to insure that there is sufficient information to assess the importance of all sources and release mechanisms active under both anticipated and unanticipated conditions. Although at this time, the formal definitions of "anticipated" and "unanticipated" conditions have not been set, any changes from the present, working definitions of these terms may change the scope of the listed activities but will not require any changes in the nature of the activities. The activities will achieve the stated goals through:

1) Identification of the range in properties and types of spent fuel currently in storage and a projection of the same for spent fuel that is yet to be generated, but which is destined for disposal in the first repository. Activity D-20-40 is designed to fulfill this goal.

2) Identification of important factors that can affect radionuclide release. These factors may be identified under any of the listed activities, but numbers D-20-42, D-20-43, D-20-44, D-20-45, D-20-46, D-20-47, and D-20-48 are specifically designed to address this area. Additional data, typically those which are generated by projects other than NNWSI, are screened for use in activity D-20-51.

3) Development and testing of models for release under the scenarios identified by performance assessment. These scenarios are gathered and integrated under activity D-20-41 and the modeling done under activities D-20-50 and D-20-52.

This Scientific Investigation Plan is not intended as a review of all previous NNWSI Project work on the spent fuel waste form. Such a review may be found in section 7.4.3.1 of the NNWSI Project SCP.

2.0 Rationale for Selected Studies and Quality Assurance Level Assignments

2.1 Introduction

In this section, the technical rationale for the listed activities are given by type, corresponding to the three areas of study listed in section 1.2. A rationale for the area of study, as well as for each activity, is given. Quality Assurance level assignment sheets for each activity are included in Section 8 of this document.

The overall justification for the work in this investigation is as follows. The extension to long times of the empirical relationships determined by laboratory testing cannot be made without an understanding of the physical and chemical mechanisms involved in a given process. Therefore, the overall goal of producing a usable model for the release of radionuclides from the spent fuel waste form can only be achieved by coupling the laboratory experiments to an effort to identify and model the process at some more fundamental level. This effort is by its nature, interactive: results of the experimental work drive model development which in turn, suggests new experiments aimed at corroborating and refining the model. At the conclusion of this process, one hopes that a model will result that incorporates the laboratory data and which accurately predicts the results of experiments that were not used in constraining the model. Confidence that the model is applicable to long times will be achieved by basing the model on sound physio-chemical principles and laws.

2.2 Integrate Spent Fuel Information

These activities accumulate information required by the experimental and modeling activities.

Activity D-20-40 entails participation in the Spent Fuel Working Group and liaison activities with the Office of Storage and Transportation Safety (OSTS), the Materials Characterization Center (MCC), and any other groups that may provide data on spent fuel. The purposes of the activity are to accumulate data on the population statistics of spent fuel, insure that representative samples of spent fuel are available for testing, and identify the as-fabricated and as-irradiated characteristics of spent fuel that could affect the inventory and release of radionuclides.

Under activity D-20-41, waste package and repository information that is generated from other NNWSI studies is accumulated. This information is required so that the experimental work can be done under conditions relevant to the repository.

Both of these activities are conducted at QA Level III. Data accumulated under activity D-20-40 that will be used in the release model presented for licensing will be screened before inclusion under the QA Level I activity D-20-51. It is anticipated that all data accumulated under activity D-20-41 that will be used in the spent fuel release model for license application will already be at QA Level I. One function of D-20-41 will be to separate NNWSI Project-generated information that was acquired under QA Level I conditions from that acquired under QA Level III conditions so that only Level I data are used in the model.

Other technical areas within the NNWSI Project Waste Package Task or the Project in general may have need for some of the information assembled by these activities. The validation of data pertaining the spent fuel waste form that is not used in the spent fuel release model, but is used by other areas is the responsibility of the user.

No tests or analyses are performed in either activity.

Activity No.	Name	QA Level
D-20-40	Integrate spent fuel waste form information provided by vendors, utilities, and other sources	III
D-20-41	Integrate NNWSI Project waste package and design information	III

2.3 Characterization of the Spent Fuel Waste Form

2.3.1 Dissolution/leach tests of spent fuel and UO_2

These two activities are the most important data-collection activities in spent fuel waste form testing. All work in these activities is done at QA Level I. The testing is done under conditions identified by activity D-20-41 and D-20-50 (Information Need 1.5.3) as most important in calculating release rates. Any scenarios to be used as the basis for long-term modeling will be tested to the extent possible on a laboratory scale. Spent fuel with characteristics spanning the range identified in activity D-20-40 will be tested. In addition, oxidized fuel produced under activity D-20-45 will be tested. The two dissolution activities have been separated based on the different technical requirements of the semi-static and unsaturated tests.

The key outputs from these activities are the dissolution rate of irradiated fuel, the release rates of radionuclides from

spent fuel, and the solution chemistry of water in contact with spent fuel.

Activity No.	Name	QA Level
D-20-42	Saturated, semi-static dissolution tests of spent fuel and UO_2	I
D-20-43	Unsaturated dissolution tests of spent fuel and UO_2	I

2.3.2 Oxidation tests of spent fuel and UO_2

The purposes of the activities in this area are to determine the rates and mechanisms of oxidation of irradiated UO_2 fuel and to assess the possibility of oxidation of the fuel in the repository. The oxidation of UO_2 to higher O/U ratios may affect the rate of release of radionuclides from the fuel and, due to the volume changes associated with oxidation, may cause enlargement of pre-existing cladding failures. All work in this area is to be done at QA Level I. Some of the oxidized fuel specimens produced under activity D-20-45 will be used in activity D-20-42 and/or D-20-43. The two oxidation activities have been separated based on the different techniques involved in conducting the tests.

The key outputs of activities D-20-44 and D-20-45 are experimental data on the rate of oxidation of irradiated UO_2 as determined from weight-gain curves. These data will be used to drive the generation of a mechanistic model for the oxidation of UO_2 in activity D-20-50.

Activity No.	Name	QA Level
D-20-44	Oxidation tests of spent fuel and UO_2 using a thermogravimetric apparatus	I
D-20-45	Oven-oxidation tests of spent fuel and UO_2	I

2.3.3 Corrosion and release tests of cladding and assembly materials

The testing done in this area is designed to:

1) evaluate the corrosion and failure rate of cladding;

2) determine the rate of release of radionuclides from cladding;

3) determine the rate of release of radionuclides from assembly hardware parts.

The rate at which cladding fails in the repository will, in part, determine the release rate of radionuclides from the enclosed fuel. In addition, both the cladding and other assembly parts contain radionuclides and thus must be characterized with respect to their corrosion and release characteristics. All of the tests conducted in these activities will be done at QA Level I. Because of the different materials involved, work on cladding and hardware have been separated into two different activities. Work on the release of carbon-14 has been put into a third, separate activity because, unlike other radionuclides of concern, it can be released in gaseous form as CO_2. Because of this, the types of tests required to characterize the inventory and release of carbon-14 are quite different than those used for the other radionuclides.

The key outputs of activity D-20-46 are the rates of various failure modes of cladding, and the rate of release of radionuclides from cladding. Activity D-20-47 will provide data on the inventory and release of radionuclides from assembly components. Activity D-20-48 will determine the inventory, distribution, and release characteristics of carbon-14 as gaseous $^{14}CO_2$ from the waste form. The data generated by activities D-20-46 through D-20-48 will be used in the radionuclide release model developed under activity D-20-50.

Activity No.	Name	QA Level
D-20-46	Corrosion/degradation/release tests on Zircaloy and stainless steel cladding	I
D-20-47	Corrosion/release tests on assembly hardware	I
D-20-48	Carbon-14 inventory and release tests	I

2.3.4 Planning and Experimental Design

Many of the tests performed under activities D-20-42 through D-20-48 require a certain amount of initial experimentation to determine the best way to conduct the test. In addition, there are many experimental protocols and examination techniques that, though potentially applicable to the problems being investigated, have never been tried under the conditions relevant to the NNWSI Project spent fuel testing program. This activity is intended to provide a mechanism whereby new experimental techniques can be evaluated with respect to their applicability to a particular test and their ability to provide useful information. This activity is to be conducted at QA Level III in order to allow the maximum flexibility in adapting procedures to the NNWSI testing program while maintaining the cost-effectiveness of the program. If a technique examined under this activity is judged useful or valuable for the spent fuel testing program, then procedures will be written to allow its use in QA Level I activities. It is likely that some of the techniques tried will not work and will never be used in other activities.

The key outputs of this activity are experimental techniques and testing or examination methods that can be used in testing activities conducted at QA Level I.

Activity No.	Name	QA Level
D-20-49	Technique development for advanced test planning and design	III

2.4 Generate Models for Release from Spent Fuel

As input to the waste package performance assessment model (Information Need 1.5.3), the spent fuel waste form testing program will produce a model for the release of radionuclides from the spent fuel waste form under tuff repository conditions. This model will be based on sound physio-chemical principles and will use data from the above experimental activities, as well as the literature as input data. The model will be validated using laboratory experiments, and, if suitable examples can be identified, studies of natural analogues. The model will consist of several sub-models: a sub-model for the release of radionuclides from spent fuel, cladding, and assembly hardware; a sub-model for the failure rate of cladding; and a sub-model for the oxidation of UO_2. The chemical and kinetic aspects of the models will make extensive use of the geochemical modeling code EQ3/6 (Wolery, 1979; 1983; 1987). Initial model development work will be done at QA Level III; however, the model is finalized and the data and

model are validated under QA Level I activities (Activities D-20-51 and D-20-52).

The key outputs for these activities are:

1) a model or models for the release of radionuclides from the spent fuel waste form, consisting of several sub-models;

2) a database to use in these models and sub-models;

3) the validation that the model(s) and sub-models can realistically predict the behavior of the waste form for 10,000 years (10-CFR-60.113 and 40-CFR-191.13) and 100,000 years (10-CFR-960.3-1-5) to the degree necessary to supply source term information to the Performance Assessment areas.

Activity No.	Name	QA Level
D-20-50	Generate models for the release of radionuclides from the spent fuel waste form	III
D-20-51	Screen data for incorporation into the release model	I
D-20-52	Finalize and validate the spent fuel release model	I

3.0 Description of Tests and Analyses, and Previous Work

3.1 Introduction

Detailed plans for the 13 activities covered by this Scientific Investigation Plan are given in Sections 3.2 through 3.4. Where appropriate, the relative timings of the activities are given. When previous work has been done by the NNWSI Project in an activity, a summary of that work is given. For each activity, a series of test plans (Section 6.0) will be prepared to provide further details of the tests in an activity. For many of the activities, several test plans have already been issued. All expected use of computer codes is described in Section 3.4.

The current schedule calls for the start of long-term confirmation tests in mid-1990 to mid-1991. At the present time, it is impossible to predict what these will involve; their content will depend upon the results of the tests conducted over the next four years. If the current schedule holds, an addendum to this Scientific Investigation Plan will be issued that will cover the activities involved in long-term confirmation testing.

3.2 Integrate Spent Fuel Information

3.2.1 Integrate spent fuel waste form information provided by vendors, utilities, and other sources. D-20-40

This activity involves participation in the Spent Fuel Working Group (SFWG) and liaison activities with OSTS, the MCC, and other groups that may provide information on the characteristics of spent fuel. Participation in the SFWG and interaction with the MCC insures that samples of fuel are available for testing that are representative of the population of fuel in storage. This participation consists of attendance at SFWG meetings, and timely review of documents that are generated as a result of SFWG undertakings.

Several efforts are underway by DOE projects to assemble information on both the as-fabricated and the as-irradiated characteristics of fuel. The sources of this information are largely fuel vendors and the utilities. The liaison activities provide a means of providing input to these efforts so that the information required by the spent fuel activities of the NNWSI Project is included in the list of information to be gathered.

No tests or analyses are performed in this activity.

3.2.2 Integrate NNWSI Project waste package and repository design information. D-20-41

This activity provides a mechanism to formally accumulate the information required for the experimental and modeling activities requiring design or testing input from other NNWSI Project activities. No tests or analyses are performed.

3.2.3 Schedule

Schedule	Start	Complete
Integrate spent fuel waste form information provided by vendors, utilities, and other sources	In progress	6/92
Integrate waste package and repository design information	In progress	6/92

3.3 Characterization of the Spent Fuel Waste Form

3.3.1 Dissolution/leach tests of spent fuel and UO_2

This is the primary area of activity in the spent fuel testing program. Its objective is to generate QA Level I data on the release of radionuclides from spent fuel for use in performance assessment modeling and for direct use in licensing. Two activities have been defined because of the differing technical requirements of the saturated and unsaturated tests. Both types of test will use a variety of irradiated fuels that are representative of the population of fuel expected to be emplaced into the first repository. Testing will be done at temperatures below 90°C. Water representative of that expected to be found in the repository (J-13 well water) will be used in most of the tests (Oversby, 1984; Glassley, 1986). A small amount of testing has been done using deionized water to provide a link with similar tests done by others and to assess the effect of water chemistry on release rates. Additional parametric tests of the effect of water chemistry on dissolution rates and equilibrium elemental concentrations are planned.

3.3.1.1 Saturated, semi-static dissolution tests of spent fuel and UO_2. D-20-42

Background and previous work

Saturated dissolution testing of spent fuel is done for two reasons. First, it simulates the scenario in which water accumulates within a failed container and continuously reacts with fuel in rods with failed cladding. Second, it is the simplest and most easily interpreted method of reacting water and fuel. The release mechanisms and rates derived from these tests

can be compared with similar tests done by others, and can be modeled relatively simply.

At the present time, two series of saturated dissolution tests have been completed and a third is in progress. Descriptions of the three tests are given in test plans (Wilson 1983, 1984, 1986) and final reports are available for the first and second test series. (Wilson, 1985, 1987). Work thus far has focused on using Zircaloy clad, pressurized water reactor (PWR) fuel of average burnup and fission gas release (Turkey Point fuel and H. B. Robinson fuel - ATM-101 (Barner, 1985)). Series 1 tests used deionized water while Series 2 used water from well J-13. Both Series were conducted at ambient hot-cell temperature in silica reaction vessels with loose-fitting lids. Series 3 tests are being conducted in sealed, 304L stainless steel vessels (the NNWSI Project reference container material) at ~85°C with J-13 well water as the leachant. One specimen is being run at ~25°C in the same vessel type for comparison with the Series 2 results. An interim report describing the early results of this test has been published (Wilson and Shaw, 1986). All the test Series thus far have included specimens of bare fuel, clad segments of fuel with induced cladding defects, and undefected rod segments.

Each Series produces extensive data on the chemistry of the solution in contact with the fuel sample as a function of time. Both the concentration of radioactive species and non-radioactive species are monitored. In addition, the fuel specimens are examined before and after the test by a variety of methods to determine if any physical changes in the fuel have occurred.

The Series 1 tests were conducted prior to the institution of QA Levels, however testing was done in such a way as to be compatible with the current QA requirements for a Level I activity. If data from this test are needed to support the license application, it will be qualified as Level I using NNWSI SOP-03-03 or NNWSI SOP-15-01. Both Series 2 and Series 3 tests have been conducted under QA Level I. All work to date has been performed by the Westinghouse Hanford Co. at the laboratories of the Hanford Engineering Development Lab., (HEDL-WHC).

Planned work

Saturated dissolution testing will continue using a wider variety of fuel types, including, but not limited to: high-burnup fuel, high-gas-release fuel, boiling water reactor (BWR) fuel, oxidized fuel of known O/U ratio produced under activity D-20-45, and stainless-steel-clad fuel. It is anticipated that fuels that will be used in future tests will be ATM materials provided by the MCC. Tests will also be conducted in an effort to separate the effects of the experimental variables from other, more significant causes. Tests that fall into this category

include, but are not limited to, varying the fuel-to-water ratio used in the tests, conducting tests in stainless steel vessels, but with loose-fitting lids to allow free access of oxygen to the tests, and examining the effect of the presence of Zircaloy cladding in the test vessel. Parametric tests will be conducted on both unirradiated UO_2 and spent fuel to determine the effect of other parameters, such as water chemistry and temperature. At least one duplicate test Series will be conducted by a second investigator at an independent laboratory facility in order to check the reproducibility of the results obtained from the primary investigator and laboratory.

3.3.1.2 Unsaturated dissolution tests of spent fuel and UO_2. D-20-43

Background and planned work

The unsaturated test is designed to measure the interactions between the spent fuel waste form, the canister material and the repository water that drips onto a failed fuel assembly and then runs off. This simulates the scenario in which a container has multiple perforations which allow water to enter the container, contact the fuel, and exit the container without maintaining contact for an extended period of time. The unsaturated test for spent fuel will be adapted from the procedure used for unsaturated testing of the glass waste form (Bates and Gerding, 1985, 1987; Bates et al., 1986). No QA Level I unsaturated dissolution tests on spent fuel have yet been performed. These tests are currently in the planning stages.

Unsaturated testing will be conducted on a variety of fuel types; however, it is unlikely that unsaturated testing will include as many different fuels as is planned for the saturated dissolution tests. Two test series are currently planned, with each Series involving many different fuel specimens. Due to the nature of these tests, each Series will run for at least one year and probably more. As in the saturated tests, it is expected that the data obtained from these tests will include detailed information on the chemistry of the solutions contacting the fuel as a function of time. Pre- and post-test characterization of the solids will be conducted to determine if any physical changes in the fuel or other components of the test have occurred.

3.3.1.3 Schedule

	Begin	End
Saturated, semi-static dissolution tests of spent fuel	In progress	5/92
Unsaturated dissolution tests of spent fuel	12/89	12/91

3.3.2 Oxidation tests on spent fuel and UO_2

These activities are intended to determine the oxidation rate and mechanism of spent UO_2 fuel as a function of time and various environmental parameters. The data from the tests conducted in these activities will be used in activity D-20-50 to construct a model to predict the oxidation state of the uranium in the oxide fuel matrix as a function of time in the repository. A discussion of the potential for spent fuel oxidation in a tuff repository can be found in the report by Einziger and Woodley (1985). Oxidation of the fuel may affect the dissolution rate of the fuel and thus the rate of release of radionuclides from the fuel. In addition,there is a large positive volume change associated with the production of U_3O_8; the oxidation of fuel to this phase would put a large strain on the cladding leading to the possibility of enlargement of pre-existing cladding failures.

There are two oxidation activities, corresponding to the two different techniques used in testing: a thermogravimetric apparatus (TGA), and an oven-oxidation apparatus. Both tests use the weight gain of the sample to monitor the progress of the oxidation, but the two methods provide complimentary information. A TGA test yields a continuous record of the weight gain of a relatively small sample. The oven-oxidation tests do not provide a continuous record of the weight, but can be run for longer periods of time at lower temperatures and can utilize larger samples. This latter point is important because it will be necessary to produce well-characterized samples of oxidized fuel for dissolution tests conducted under activity D-20-42. A discussion of the experimental approach and justification for the chosen test parameters is given by Einziger (1985).

Both techniques maintain the spent fuel specimen in a constant-temperature, constant-humidity environment. The effect of humidity on oxidation rate is being investigated as is the effect of different fuel types. Testing to date has used moderate-burnup, low gas release PWR fuel (Turkey Point fuel). Future work will involve a wider variety of fuel types using ATMs provided by the MCC. The oven-oxidation tests are more suited to testing a wider variety of fuel types than is the TGA because of the capability to run many specimens simultaneously.

3.3.2.1 Oxidation tests of spent fuel and UO_2 using a thermogravimetric apparatus. D-20-44.

Background and previous work

The TGA provides detailed information on the rate of weight gain of a fuel sample. This information will be very important in the effort to document the mechanism of oxidation of spent fuel. In these tests, a fuel sample weighing approximately 200mg is suspended from a balance into a constant temperature oven. The weight is continuously monitored on a recorder. At intervals, samples of the cover gas are taken and analyzed for released fission gasses. The lowest temperature at which it is practical to obtain data using this technique is ~140 - 150°C. At lower temperatures, the rate of weight gain is too slow for a measurable gain to occur within a reasonable time.

A series of TGA tests have been already been conducted for the NNWSI Project and the tests are continuing. The test matrix and experimental procedures are documented in the test plan by Einziger (1986a). The interim results of these tests have been documented in unpublished letter reports. A final report on the current TGA test series is due in the summer of 1987. In general, the oxidation rate obtained from these tests has been in good agreement with rates determined by extrapolating the results of oxidation experiments conducted at higher temperatures.

At the conclusion of a TGA run, the fuel sample is examined using a variety of techniques (X-ray diffraction, ceramography, etc.) to document the types of phases present and to look for physical changes in the fuel. Pre-test characterization of the samples is done to establish a baseline for comparison. There are two QA Level III experiments being conducted under activity D-20-49 that involve the development of new techniques for examining fuel using the ion-microprobe and transmission electron microscope (TEM). When appropriate techniques have been established, this work will be upgraded to QA Level I and become a part of this activity and activity D-20-45.

All TGA tests have been conducted at QA Level I or its equivalent. Results of tests conducted before the institution of the current QA plan will be upgraded to QA Level I through the use of NNWSI SOP-03-03 or NNWSI SOP-15-01.

Planned work

Additional TGA tests are planned using BWR fuel and fuel with higher burnup and gas release. The effect of grain size will also be investigated. The effect of humidity on oxidation rate will continue to be evaluated.

3.3.2.2 Oven-oxidation tests of spent fuel and UO_2. D-20-45.

Background and previous work

The oven oxidation tests are intended to extend the results of the TGA tests to lower temperatures and longer times. In addition, by the nature of the experimental apparatus, many samples of fuel can be oxidized at one time with little additional cost, thus greatly increasing the amount of data that can be acquired for use in licensing. A test was begun in December of 1986 and is scheduled to run for at least 2 years. As additional fuel samples become available, they will be added to the test.

The tests are actually conducted in dry baths rather than conventional ovens. A description of the apparatus is given in the test plan for these tests (Einziger, 1986b). The baths are being run at three different temperatures: 110°C, 130°C, and 175°C. The last temperature overlaps the range of temperatures at which TGA testing has been done and provides a means of checking on the reproducibility of oxidation rates obtained using the two techniques. As in the TGA tests, runs are being conducted at the same temperature but different dew points to assess the effect of humidity on oxidation rate.

All oven-oxidation work to date has been conducted at QA Level I. Testing has been conducted at HEDL-WHC.

Planned work

As noted above, it is planned to add samples of different fuel types to the apparatus as the fuel becomes available. At the least, fuel from BWR reactors, higher burnup and gas release fuels, fuels with different grain size, and Gd-doped BWR fuels will be tested.

At intervals, specimens of the oxidized fuel will be removed and examined by appropriate techniques (X-ray diffraction, ceramography, etc.). The results of these examinations will be compared to pre-test characterization results. It is also planned to examine the oxidized fuel using ion-probe and TEM techniques currently being developed at QA Level III under activity D-20-49. When appropriate techniques are established for these methods, they will be upgraded to QA Level I and performed as a part of this activity.

3.3.2.3 Schedule

	Begin	End
Oxidation tests of spent fuel and UO_2 using a thermogravimetric apparatus	In progress	11/90
Oven-oxidation tests of spent fuel and UO_2	In progress	3/90

3.3.3 Corrosion and release tests on cladding and assembly materials

The testing done in this area has several purposes:

1) evaluate the corrosion and failure rate of cladding;

2) determine the rate of release of radionuclides from cladding;

3) determine the rate of release of radionuclides from assembly hardware parts.

The rate at which cladding fails in the repository will, in part, determine the release rate of radionuclides from the enclosed fuel. In addition, both the cladding and other assembly parts contain radionuclides and thus must be characterized with respect to their corrosion and release characteristics. Because of the different materials involved, work on cladding and hardware have been separated into two different activities. Work on the release of carbon-14 has been put into a third, separate activity because, unlike other radionuclides of concern, it can be released in gaseous form as CO_2. Because of this, the types of tests required to characterize the inventory and release of carbon-14 are quite different than those used for the other radionuclides.

3.3.3.1 Corrosion/degradation/release tests on Zircaloy and stainless steel cladding. D-20-46.

Background and previous work

Work in this activity has two related purposes: to determine the rate at which cladding failure can be expected under repository conditions; and to measure the groundwater-mediated release of radionuclides from cladding. The work to date in this area has been limited to scoping experiments conducted at QA Level III (activity D-20-49) that were designed to develop test methods and test parameters that will be used in QA Level I

tests. This was done to maximize the amount of useful data for licensing that could be obtained for a given funding level.

An overview of the matrix of experiments to determine Zircaloy cladding degradation rate is given in Smith (1985). The choice of specimen types to be evaluated is discussed in Smith (1984a). Several failure modes are being considered: stress corrosion cracking (SCC); generalized corrosion; hydride embrittlement; and hydride reorientation. The rationale for the selection of these mechanisms for study is given in the report on potential cladding failure mechanisms by Rothman (1984). No work on cladding materials other than Zircaloy has been performed at the time of this writing. Neither have detailed studies been performed on the release of radionuclides from various cladding materials.

Planned work

Beginning in FY 1987, work on the failure of Zircaloy cladding by generalized corrosion, SCC, and stress rupture will be upgraded to QA Level I. The results of these tests will be used to model the failure rate of cladding in the repository. The generalized corrosion test will also provide information of the release of radionuclides from cladding. Work on the effect of hydrides on cladding strength is in the planning stages.

3.3.3.2 Corrosion/release tests on assembly hardware. D-20-47.

Background and planned work

As noted above, the non-fuel assembly hardware such as springs, spacers, etc. are a significant reservoir of certain radionuclides, especially nickel isotopes and carbon-14. Since these radionuclides have the potential for release by means of dissolution and/or corrosion of the hardware, it will be necessary to conduct tests to determine the release rate of radionuclides from this portion of the waste form. At the time of this writing, work in this area has not yet begun.

As a part of this Investigation, a series of tests to determine the release rate of radionuclides from assembly hardware will be conducted. The test procedures and environmental conditions have not been established yet; however, the tests will likely resemble the saturated and unsaturated test methods used in the dissolution/leach tests of spent fuel (activities D-20-42 and D-20-43). Corrosion work carried out as part of the container material selection process may be applicable to some of the materials used as assembly hardware. This may aid in reducing the amount of new experimental work necessary to characterize the release from this source. Initial experiments to optimize procedures will be carried out at QA Level III

under activity D-20-49. That activity will feed into this one according to the schedule in section 3.3.3.4.

3.3.3.3 Carbon-14 inventory and release tests. D-20-48.

Background and planned work

Unlike other radionuclides present in the spent fuel waste form during the controlled release period, which require the presence of liquid water for transport, carbon-14 can be released as gaseous CO_2. It appears that approximately half of the carbon-14 inventory of the waste form is associated with the cladding and of that, some fraction is available for relatively rapid release as CO_2 by oxidation in air (Van Koynenburg et al., 1984; 1986). The only available data on the release of $^{14}CO_2$ in air is from a single cask test conducted for the Dry Storage Program. More data are clearly needed to define the inventory, distribution, and release characteristics of carbon-14 in the spent fuel waste form.

No work has been conducted in this activity to date. Development of an experimental setup to etch sequential layers from the outer surface of cladding segments and measure the carbon-14 released is currently underway as part of activity D-20-49. As shown in section 3.3.3.4, this work is scheduled to be transferred to this activity later this year. Testing at QA Level I under this activity will then begin.

The test mentioned above, using an etchant to remove sequential layers of cladding material, will provide information on the radial distribution of carbon-14 in the cladding. A second test, also scheduled to start this year, will involve the exposure of cladding segments to air at elevated temperature. The quantity of carbon-14 that is evolved as CO_2 will be measured. By conducting tests at different temperatures, the temperature coefficient of release can be determined.

Both tests will utilize cladding material that spans the range of known variability in reactor type, burnup, amount of crud deposits, and other variables that may influence the inventory or release of carbon-14.

3.3.3.4 Schedule

Schedule	Begin	End
Conduct corrosion/degradation/ release tests on Zircaloy and stainless steel cladding	In progress	9/89
Conduct corrosion/release tests on assembly hardware	12/88	12/90
Conduct carbon-14 release tests	8/87	12/89

3.3.4 Planning and experimental design

Many of the tests performed under activities D-20-42 through D-20-48 require a certain amount of initial experimentation to determine the best way to conduct the test. In addition, there are many experimental protocols and examination techniques that, though potentially applicable to the problems being investigated, have never been tried under the conditions relevant to the NNWSI Project spent fuel testing program. This activity is intended to provide a mechanism whereby new experimental techniques can be evaluated with respect to their applicability to a particular test and their ability to provide useful information. This activity provides a mechanism for maintaining maximum flexibility in adapting procedures to the NNWSI testing program while maintaining the cost-effectiveness of the program. Those techniques that are examined under this activity and are judged useful or valuable will then be upgraded to QA Level I and used in the other experimental activities. It is likely that some of the techniques tried will not work and will never be used in other activities.

3.3.4.1 Technique development for advanced test planning and design. D-20-49.

Background and previous work

Several activities include tests and/or techniques that have already been "cycled through" this activity. These include the several tests in Zircaloy corrosion activity (D-20-46). Each of the Zircaloy experiments is documented in a test plan (Smith, 1984b; 1986a,b) and each will be or has been documented in a final report (e.g. Smith, 1987). Current experiments being conducted under this activity are:

Evaluation of ion probe techniques for determining the location and amount of oxygen uptake during spent fuel oxidation experiments (for activities D-20-44 and D-20-45).

Development of TEM and STEM techniques for examining fuel structure and phase relations on very fine scale (for activities D-20-42, D-20-43, D-20-44, and D-20-45).

Development of techniques to determine the spatial distribution of carbon-14 in the spent fuel waste form (especially the cladding), and its release characteristics (for activity D-20-48).

Development of an unsaturated test method for dissolution testing of spent fuel (for activity D-20-43).

Development of techniques for saturated dissolution testing of oxidized spent fuel (for activity D-20-42).

All of these experiments are likely to be yield test methods that will be incorporated into the appropriate QA Level I activities given in parentheses above. At that time, the QA Level III experiments will be documented in written reports and the work conducted under this activity will cease.

Planned work

New experiments will be initiated under this activity as potentially useful techniques are discovered. It is anticipated that this activity will continue throughout the life of the entire spent fuel testing program; however, as the program matures, the number of experiments that will be performed under this activity will decline greatly. All work in this activity will be conducted at QA Level III.

3.3.4.2 Schedule	Begin	End
Technique development for advanced test planning and design	In progress	4/91

3.4 Generate Models for Release from Spent Fuel

3.4.1 Introduction

The primary means of release of radionuclides from the spent fuel waste form is by means of liquid water contacting the fuel in a breached container. There is the possibility of the release of some fraction of the carbon-14 in the waste form as gaseous CO_2, a process that does not require the mediation of liquid water. As input to the waste package performance assessment model, the spent fuel waste form testing Investigation will, in collaboration with the performance assessment task, generate and validate a model for the release of radionuclides from the spent fuel waste form under repository conditions. The output of the modeling activities is expected to be a combination of functional relationships and look-up tables that can be incorporated into the performance assessment model.

3.4.2 Generate models for release of radionuclides from the spent fuel waste form. D-20-50.

Background and planned work

The purpose of this activity is to design and use models for the release of radionuclides from the spent fuel waste form based on the scenarios identified in Information Need 1.5.3. The model will consist of several sub-models: a sub-model for the release of radionuclides from spent fuel, cladding, and assembly hardware; a sub-model for cladding performance; and a sub-model for the oxidation of UO_2.

In order to extrapolate the results of laboratory time scale tests to times relevant to the repository, it will be necessary to develop an understanding of the physical and chemical mechanisms involved in all significant processes affecting the waste form. It is recognized that it may not be possible to identify unique mechanisms for all the operant processes. In these cases, an analysis will be performed to determine the sensitivity of the model to the assumption of the different mechanisms. For licensing, the most pessimistic, and hence most conservative, relevant assumptions will be used.

By far the most important sub-model that will be developed is the one that predicts the rate of radionuclide release from the spent fuel, cladding, and assembly hardware. This model will include at least six components:

1. Elements whose release is controlled by the matrix dissolution rate.

2. Elements present in part in the pellet-cladding gap and which are available for rapid release.

3. Elements present in part on grain boundaries and which may show an enhanced release rate.

4. Elements contained in the fuel cladding.

5. Elements contained in stainless steel or other materials used in assembly components.

6. Elements present in any part of the waste form that can be released in a gaseous form (such as carbon-14) and which do not require the mediation of liquid water for their release.

Items 1 through 3 above may be a function of the fuel oxidation state; hence, the necessity for the development of a sub-model for predicting how the fuel will oxidize as a function of time. Since the presence of intact cladding will prevent the release of

radionuclides from items 1 through 3 above, a sub-model for the failure rate of the cladding as a function of time will also be necessary for the proper description of the performance of the waste form.

The output of this activity will be the composition of fluids (including gasses) that issue from a failed waste package as a function of time. The geochemical modeling code EQ3/6 (Wolery, 1979; 1983; 1987) will be used extensively as the basis for calculating the composition of the radionuclide-bearing liquid water that exits a failed container. These analyses will involve a combination of equilibrium and kinetic calculations. It is likely that additional computer codes will need to be developed to serve as pre- and post- processors to EQ3/6; the extent to which these are necessary will be determined by future EQ3/6 development and the nature of the performance assessment scenarios identified in the resolution of Information Need 1.5.3. Current plans for EQ3/6 code development (EQ3/6, 1986). include a major item that is required for the realistic modeling of spent fuel in a failed container: the development of a flow-through model in which a stationary reacting assemblage (the waste form and container) reacts with successive packets of water.

3.4.3 Screen data for incorporation into release model. D-20-51.

Background and planned work

There is extensive literature on the mechanisms of the dissolution and oxidation of UO_2, both irradiated and unirradiated. These data may be of use in the development of the release model for the spent fuel waste form. All data generated outside of the NNWSI Project will be screened in this activity, as well as the data that are gathered under the QA Level III activities, D-20-40 and D-20-41. The objective will be to establish the accuracy and precision of this data and to insure that the spent fuel release model uses only accurate and verifiable data. It is anticipated that the release model will be based predominantly on data generated within the NNWSI Project under QA Level I activities. This activity allows the large body of outside data to be used to corroborate and support the NNWSI Project data. In addition, this activity allows important data and idea generated outside of the NNWSI Project to be used in the model.

Data generated outside of the NNWSI Project will be collected and analyzed to determine if it is consistent with comparable NNWSI Project data. If it is not, an examination of all applicable data sets will be made to determine the origin of the discrepancy. Though it is not currently anticipated that outside data will be a critical part of the spent fuel waste form release model, if such data are found to be critical to the

model, the NNWSI SOP-03-03 (DOE, 1986) for using non-NNWSI Project data will be implemented.

It is likely that some of the data used in the release model will require a peer review to establish their validity. Similarly, peer review is likely to be the only way to validate some of the concepts and interpretations made use of in the model. The procedures for conducting such a review are given in 033-NMWP-P-2.2 of the Quality Assurance Program Plan for the NNWSI Project (Lawrence Livermore National Lab., 1987).

The most important aspect of this activity is the comparison of NNWSI Project data to that collected outside of the Project. This comparison is designed to ensure that the Project will be able to affirm during the licensing process that the spent fuel release model is consistent with all applicable data. When there are inconsistencies in the data, as is probably inevitable, an assessment of the possible causes of the discrepancy will be prepared. In the case of the NNWSI Project data being improperly collected, interpreted, or applied, this activity allows the problems to be resolved and new data obtained under one of the data collection activities. A formal mechanism for this screening process will be established in conjunction with the Glass Waste Form Task.

3.4.4 Finalize and validate spent fuel release model. D-20-52.

Background and planned work

Validation of the spent fuel waste form model will be done in two stages. First, the model will be developed in parallel with the experimental work and will be tested for its ability to describe accurately the experimental results. Some additional tests on simpler systems than that represented by the waste form itself may be necessary to validate the model properly. Second, the results of long-term modeling will be compared with extrapolations and with natural analogues if appropriate analogues can be identified. Even if exact analogues cannot be found in nature, it is likely that even dissimilar natural systems will provide a means of at least testing the validity of the principles used in the fuel model. The second part of the validation effort will test both the validity of the model and determine whether the experimental work has examined all the important chemical processes and interactions that may occur over long periods of time. Thus, the final model development will actually be conducted under this activity. This will most likely involve simply a "fine tuning" of the model developed under Activity D-20-50.

Because the geochemical modeling code EQ3/6 will be a fundamental part of the spent fuel release model, validation

activities for that family of codes will be established in conjunction with other users of the codes. The validation areas are:

1. **Database.** Critical database items will be reviewed under the data screening activity (D-20-51).

2. **Code Operation.** A series of benchmark code runs will be established for EQ3/6 to test major operations common to all applications.

3. **Experiment Matching.** The spent fuel model must accurately predict the results of laboratory testing.

4. **Natural Analogues.** To determine if the EQ3/6 code accurately predicts the behavior of actinide-bearing systems, it will be used to model natural uranium-rich deposits in contact with groundwater.

3.4.5 Schedule

Schedule	Begin	End
Generate models for the release of radionuclides from the spent fuel waste form	In progress	10/92
Screen data for incorporation into release model	6/87	10/92
Finalize and validate spent fuel release model	10/87	10/93

4.0 Application of Results

The information provided by this Investigation will provide the source term for radionuclide release from waste packages containing the spent fuel waste form. This information will be used by the waste package performance assessment task to model the performance of the waste packages under repository conditions. The information obtained by this Investigation directly addresses the following Information Needs:

Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release as required by 10-CFR-60.113?

1.5.1 Waste package design features that affect the rate of radionuclide release.

1.5.2 Material properties of the waste forms.

1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.

Through input to the above Information Needs, this Investigation will also provide data that is required to resolve Information Needs 1.4.4, 1.5.4, and 1.5.5, and Issues 1.1, 1.4, 1.9, 1.10, and 1.11.

The spent fuel information will also be used to develop the source term in the calculation of cumulative releases of radionuclides to the accessible environment for 10,000 years as required in order to comply with EPA regulation 40-CFR-191.13. It will also be used as part of the source term for cumulative release calculations for 100,000 years after disposal in the site evaluation process required by 10-CFR-960.3-1-5.

5.0 Schedules and Milestones

5.1 Discussion and Assumptions

The schedule for individual activities has been identified in Section 3.0. The overall schedule for this Investigation is tied to two other schedules: the information required for the construction and use of the waste package performance assessment code (currently scheduled completion date: 6/92, with interim, partial code packages due on 9/87 and 7/89); and the need to complete the documentation required for the Draft Environmental Impact Statement (EIS), which is currently scheduled for publication in 10/93.

As noted in section 3.0, the current schedule calls for the start of long-term confirmation tests in mid-1990 to mid-1991. At the present time, it is impossible to predict what these tests will involve; their content will depend upon the results of the tests conducted over the next four years and the results of Exploratory Shaft testing. If the current schedule holds, an addendum to this Scientific Investigation Plan will be issued that will cover the activities involved in the long-term confirmation tests.

This schedule was prepared according to the reference case funding levels in the FY1989 WPAS. Reductions in the funding levels would result in slippage in the milestones and schedules. The timely completion of milestones in other areas can also affect the schedule of this Investigation. (1) The container material must be selected according to the scheduled milestone of 9/88. If a container material other than austenitic stainless steel is chosen, then some slippage could occur while testing of waste form behavior in association with the container material is conducted under activities D-20-42, D-20-43, D-20-46, D-20-47, and D-20-49. (2) If the results of exploratory shaft testing, other materials testing, and waste package environment testing do not support the current estimates of the package environment, as described in the SCP, schedule slippage concomitant with the degree of discrepancy will occur.

5.2 Schedule

	Start	End
Integrate spent fuel waste form information provided by vendors, utilities, and other sources. D-20-40.	In Progress	6/92
Integrate NNWSI Project waste package and repository design information. D-20-41.	In Progress	6/92
Saturated, semi-static dissolution tests of spent fuel and UO_2. D-20-42.	In Progress	5/92
Unsaturated dissolution tests of spent fuel and UO_2. D-20-43.	12/89	12/91
Oxidation tests of spent fuel and UO_2 using a thermogravimetric apparatus. D-20-44.	In Progress	11/90
Oven-oxidation tests of spent fuel and UO_2. D-20-45.	In Progress	3/90
Corrosion/degradation/release tests on Zircaloy and stainless steel cladding. D-20-46.	In Progress	9/89
Corrosion/release tests on assembly hardware. D-20-47.	12/88	12/90
Carbon-14 inventory and release tests. D-20-48.	8/87	12/89
Technique development for test planning and design. D-20-49.	In Progress	4/91
Generate models for release of radionuclides from the spent fuel waste form. D-20-50	In Progress	10/92
Screen data for incorporation into release model. D-20-51.	6/87	10/92
Finalize and validate spent fuel release model. D-20-52.	10/87	10/93

5.3 Milestones

Number	Title	Date
P001	Report on release rate testing of Spent Fuel in J-13 water at 85°C. (D-20-42)	12/86
R205	Final report on release rate testing of spent fuel in J-13 water at 85°C. (D-20-42)	9/87
P111	Initiate dissolution testing of partially oxidized spent fuel. (D-20-42 and D-20-45)	12/87
P250	Start parametric dissolution tests of spent fuel. (D-20-42)	11/87
M269	Complete fuel testing for advanced conceptual design. (D-20-42 through D-20-46, D-20-48)	9/88
M006	Report on results of spent fuel dissolution tests using partially oxidized fuel. (D-20-42)	7/89
P257	Model long-term expected performance of waste form under repository conditions. (D-20-50)	8/89
P251	Start long-term fuel oxidation confirmation tests. (D-20-44 and D-20-45)	4/90
M011	Final report on Zircaloy corrosion. (D-20-46)	5/90
P252	Start long-term Zircaloy corrosion confirmation tests. (D-20-46 and D-20-48)	6/90
P253	Hardware release testing complete. (D-20-47)	1/91
P254	Fuel oxidation tests using TGA complete. (D-20-44)	5/91
P255	Start long-term fuel dissolution confirmation tests. (D-20-42 and D-20-43)	5/91
P201	Final report on the oxidation rate and mechanism of spent fuel oxidation. (D-20-44, D-20-45, D-20-50)	9/91
P256	Spent fuel testing for draft EIS complete. (D-20-42 through D-20-49)	6/92

M012	Model long-term expected performance of spent fuel waste form under repository conditions to support draft EIS (D-20-50 through D-20-52)	10/92
P258	Documentation for draft EIS complete. (all activities)	10/93

6.0 List of Test Plans to Support this Study Plan

6.1 Previously Issued Test Plans	Issue date
Test plan for spent fuel cladding containment credit tests., C. N. Wilson (HEDL TC-2353-2).	11/83
Test plan for Series 2 spent fuel cladding containment credit tests., C. N. Wilson (HEDL TC-2353-3).	10/84
Zircaloy spent fuel cladding electrochemical scoping experiment., H. D. Smith (HEDL TC-2562).	12/84
Technical test description of activities to determine the potential for spent fuel oxidation in a tuff repository., R. E. Einziger (HEDL-7540).	6/85
Zircaloy cladding corrosion degradation in a tuff repository: initial experimental plan., H. D. Smith (HEDL-7455, Rev. 1).	7/85
Test plan for Series 2 thermogravimetric analyses of spent fuel oxidation., R. E. Einziger and R. E. Woodley (HEDL-7556).	2/86
"C-ring" stress corrosion cracking scoping experiment for Zircaloy spent fuel cladding., H. D. Smith (HEDL-7546).	3/86
Zircaloy spent fuel cladding electrochemical corrosion experiment at 170°C and 120PSIA H_2O., H. D. Smith (HEDL-7545).	4/86
Test plan for Series 3 NNWSI spent fuel leaching/dissolution tests., C. N. Wilson (HEDL-7577).	4/86
Test plan for long-term, low-temperature oxidation of spent fuel, Series 1., R. E. Einziger (HEDL-7560).	6/86

6.2 Additional Test Plans

	Scheduled completion da
Test plan for parametric dissolution tests of spent fuel.	10/87
Addendum and amendments to TGA oxidation test plan.	10/87
Test plan for NNWSI Zircaloy corrosion tests.	11/87
Test plan for dissolution tests of partially oxidized fuel (NNWSI Series 4).	12/87
Test plan for carbon-14 inventory and release tests.	1/88
Test plan for release tests on assembly hardware.	2/88
Plan for data screening, and model generation, testing and validation for spent fuel release.	2/88

Additional test plans or addenda and amendments to the above test plans will be issued should the need arise.

7.0 References

Barner, J. O. (1985) Characterization of LWR Spent Fuel MCC-Approved Testing Material -- ATM-101. PNL-5109 Rev. 1, Pacific Northwest Lab., Richland, WA.

Bates, J. K. and Gerding, T. J. (1985) NNWSI Phase II Interaction Test and Preliminary Results. ANL-84-81, Argonne National Lab., Argonne, IL.

Bates, J. K. and Gerding, T. J. (1987) The NNWSI Unsaturated Test Method. Lawrence Livermore National Lab. Contractor Report, (in prep.).

Bates, J. K., Gerding, T. J., Abrajano, T. A., and Ebert, W. (1986) NNWSI Waste Form Testing at Argonne National Laboratory: Semi Annual Report. July-December, 1985. UCRL-15801, Lawrence Livermore National Lab., Livermore, CA.

DOE, U. S. Department of Energy (1986) Acceptance of Data or Data Interpretation Not Developed Under the NNWSI QA Plan. NNWSI-SOP-03-03, Rev. 0.

Einziger, R. E. (1985) Technical Test Description of Activities to Determine the Potential for Spent Fuel Oxidation in a Tuff Repository. HEDL-7540, Westinghouse Hanford Co., Richland, WA.

Einziger, R. E. (1986a) Test Plan for Series 2 Thermogravimetric Analyses of Spent Fuel Oxidation. HEDL-7556, Westinghouse Hanford Co., Richland WA.

Einziger, R. E. (1986b) Test Plan for Long-Term, Low-Temperature Oxidation of Spent Fuel, Series 1. HEDL-7560, Westinghouse Hanford Co., Richland, WA.

Einziger, R. E. and Woodley, R. E. (1985) Evaluation for the Potential for Spent Fuel Oxidation Under Tuff Repository Conditions. HEDL-7452, Westinghouse Hanford Co., Richland, WA.

EQ3/6 (1986) Geochemical Modeling Plan. Office of Civilian Radioactive Waste Management Program, Scientific Investigation Plan for NNWSI, UCID-20864, Lawrence Livermore National Lab., Livermore, CA.

Glassley, W. E. (1986) Reference Waste Package Environment Report. UCRL-53726, Lawrence Livermore National Lab., Livermore, CA.

Lawrence Livermore National Laboratory (1987) Quality Assurance Program Plan. Nevada Nuclear Waste Storage Investigations. Lawrence Livermore National Lab., Livermore, CA.

Oversby V. M. (1984) Reaction of the Topopah Spring Tuff with J-13 Well Water at 90ºC and 150ºC. UCRL-53552, Lawrence Livermore National Lab., Livermore, CA,

Rothman, A. J. (1984) Potential Corrosion and Degradation Mechanisms of Zircaloy Cladding on Spent Nuclear Fuel in a Tuff Repository. UCID-20172, Lawrence Livermore National Lab., Livermore, CA.

Smith, H. D. (1984a) Spent Fuel Cladding Characteristics and Choice of Experimental Specimens for Cladding-Corrosion Evaluation Under Tuff Repository Conditions. HEDL-TC-2530, Westinghouse Hanford Co., Richland, WA.

Smith, H. D. (1984b) Zircaloy Spent Fuel Cladding Electrochemical Corrosion-Scoping Experiment. HEDL-TC-2562, Westinghouse Hanford Co., Richland, WA.

Smith, H. D. (1985) Zircaloy Cladding Corrosion Degradation in a Tuff Repository. HEDL-7455, Rev. 1, Westinghouse Hanford Co., Richland, WA.

Smith, H. D. (1986a) "C-Ring" Stress Corrosion Cracking Scoping Experiment for Zircaloy Spent Fuel Cladding. HEDL-7546, Westinghouse Hanford Co., Richland, WA.

Smith, H. D. (1986b) Zircaloy Spent Fuel Cladding Electrochemical Corrosion Experiment at 170ºC and 120 PSIA H_2O. HEDL-7545, Westinghouse Hanford Co., Richland, WA.

Smith, H. D. (1987) Electrochemical Corrosion Scoping Experiments - An Evaluation of the Results. HEDL-7637, Westinghouse Hanford Co., Richland, WA.

Van Konynenburg, R. A., Smith, C. F., Culham, H. W., and Smith, H. D. (1984) Behavior of Carbon-14 in Waste Packages for Spent Fuel in a Repository in Tuff. UCRL-90855 Rev. 1, Lawrence Livermore National Lab., Livermore, CA.

Van Konynenburg, R. A., Smith, C. F., Culham, H. W., and Smith, H. D. (1986) Carbon-14 in Waste Packages for Spent Fuel in a Tuff Repository. UCRL-94708, Lawrence Livermore National Lab., Livermore, CA.

Wilson, C. N. (1983) Test Plan for Cladding Containment Credit Tests. HEDL-TC-2352-2, Westinghouse Hanford Co., Richland, WA.

Wilson, C. N. (1983) Test Plan for Cladding Containment Credit Tests. HEDL-TC-2352-2, Westinghouse Hanford Co., Richland, WA.

Wilson, C. N. (1984) Test Plan for Series 2 Spent Fuel Cladding Containment Credit Tests. HEDL-TC-2353-3, Westinghouse Hanford Co., Richland, WA.

Wilson, C. N. (1985) Results from NNWSI Series 1 Spent Fuel Leach Tests. HEDL-TME 84-30, Westinghouse Hanford Co., Richland, WA.

Wilson, C. N. (1986) Test Plan for Series 3 NNWSI Spent Fuel Leaching/Dissolution Tests. HEDL-7577, Westinghouse Hanford Co., Richland, WA.

Wilson, C. N. (1987) Results from Cycles 1 and 2 of NNWSI Series 2 Spent Fuel Dissolution Tests. HEDL-TME 85-22, Westinghouse Hanford Co., Richland, WA.

Wilson, C. N. and Shaw, H. F. (1986) Experimental Study of the Dissolution of Spent Fuel at 85ºC in Natural Groundwater. UCRL-94633, Lawrence Livermore National Lab., Livermore, CA.

Wolery, T. J. (1979) Calculation of the Chemical Equilibrium Between Aqueous Solutions and Minerals: The EQ3/6 Software Package. UCRL-52628, Lawrence Livermore National Lab., Livermore, CA.

Wolery, T. J. (1983) EQ3NR, A computer Program for Geochemical Aqueous Speciation-Solubility Calculations: User's Guide and Documentation. UCRL-53414, Lawrence Livermore National Lab., Livermore, CA.

Wolery, T. J. (1987) EQ6, A Computer Program for Reaction-Path Modeling of Aqueous Geochemical Systems: User's Guide and Documentation. (in prep) Lawrence Livermore National Lab., Livermore, CA.

8.0 Quality Level Assignment Sheets

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NNWSI QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Integrate Spent Fuel Waste Form Information provided by Vendors, Utilities, and other sources

ACTIVITY NO.: D-20-40
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM None

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-R 3A.0 Good professional practices apply
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply & no tests performed
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Integrate Spent Fuel Waste Form Information provided by Vendors, Utilities, and other sources
D-20-40

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87
Task Leader — Date

W. J. Dankers 6/11/87
NWMP Deputy Program Leader for QA — Date

6/3/87
NNWSI Project Leader — Date

6/3/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87
Project Sponsor — Date

11/5/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Integrate NNWSI Project Waste Package and Design Information

ACTIVITY NO.: D-20-41
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____III____

CITE "YES" ITEM ON LOGIC DIAGRAM ____None____

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-R 3A.0 Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply & no tests performed
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Integrate NNWSI Project Waste Package and Design Information
D-20-41

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L
Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____III____________.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87
Task Leader Date

R E [signature] for J. Dorkins 6/1/87
NWMP Deputy Program Leader for QA Date

6/3/87
NNWSI Project Leader Date

[signature] Ramspott 6/3/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87
Project Sponsor Date

James Blaylock 11/5/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and saf y? Yes → / (No)	I
2.	Does the item or activity involve waste isolation? Yes → / (No)	I
3.	Does the item or activity involve or affect retrievability? Yes → / (No)	I
4.	Is the intended purpose of this activity to provide data for a license application? (Yes) → / No	(I)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes → / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes → / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes → / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes → / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes → / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes → / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes → / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Saturated, Semi-Static Dissolution Tests of Spent Fuel and UO_2

ACTIVITY NO.: D-20-42
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES	
	LLNL	HEDL/PNL/ANL	LLNL	HEDL/PNL/ANL
3.0 DESIGN CONTROL 3A 3B	Yes No	Yes	033-NWMP-R 3A.0 Not a design activity.	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL	Yes	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	No	Yes		As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS	Yes	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	No	Yes		033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	No	No	No special processes involved	
10.0 INSPECTION	No	Yes		033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	No	Yes		033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Yes		033-NWMP-R 12.0 Rev. 0
13.0 HANDLING, STOR. & SHIP.	No	Yes		033-NWMP-R 13.0 Rev. 0
14.0 INSP. TEST & OPER. STAT.	No	Yes		033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Saturated, Semi-Static Dissolution Tests of Spent Fuel and UO_2
D-20-42

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

[signature] 6/1/87	[signature] for J. Dukers 6/1/87
Task Leader — Date	NWMP Deputy Program Leader for QA — Date
[signature] 6/3/87	[signature] 6/3/87
NNWSI Project Leader — Date	NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/6/87	[signature] 11/5/87
Project Sponsor — Date	Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	(Yes) →	(I)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Unsaturated Dissolution Tests of Spent Fuel and UO_2

ACTIVITY NO.: D-20-43
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES	
		LLNL	PNL/HEDL	LLNL	PNL/HEDL
3.0 DESIGN CONTROL	3A 3B	Yes No	Yes	033-NWMP-R 3A.0 Not a design activity.	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL		Yes	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS		No	Yes		As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS		Yes	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS		No	Yes		033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES		No	No	No special processes involved	
10.0 INSPECTION		No	Yes		033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL		No	Yes		033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP		No	Yes		033-NWMP-R 12.0 Rev. 0
13.0 HANDLING, STOR. & SHIP.		No	Yes		033-NWMP-R 13.0 Rev. 0
14.0 INSP. TEST & OPER. STAT.		No	Yes		033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA		No	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Unsaturated Dissolution Tests of Spent Fuel and UO_2
D-20-43

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Task Leader	Date 6/1/87	NWMP Deputy Program Leader for QA	Date 6/1/87
NNWSI Project Leader	Date 6/3/87	NWMP Leader	Date 6/3/87

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Project Sponsor	Date 11/6/87	Project Sponsor Quality Manager	Date 11/5/87

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes → / No	I
2.	Does the item or activity involve waste isolation? Yes → / No	I
3.	Does the item or activity involve or affect retrievability? Yes → / No	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes → / No	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes → / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes → / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes → / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes → / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes → / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes → / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes → / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Oxidation Tests of Spent Fuel and UO_2 using a TGA

ACTIVITY NO.: D-20-44
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA: I

CITE "YES" ITEM ON LOGIC DIAGRAM: 4

QA ELEMENT	APPLIES: LLNL	APPLIES: PNL/HEDL	IF NO - JUSTIFICATION / IF YES - LIST NEEDED PROCEDURES: LLNL	IF NO - JUSTIFICATION / IF YES - LIST NEEDED PROCEDURES: PNL/HEDL
3.0 DESIGN CONTROL 3A	Yes	Yes	033-NWMP-R 3A.0	As implemented in the contractors QAPP.
3B	No		Not a design activity.	
4.0 PROC. DOC. CONTROL	Yes	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	No	Yes		As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS	Yes	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	No	Yes		033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	No	No	No special processes involved	
10.0 INSPECTION	No	Yes		033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	No	Yes		033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Yes		033-NWMP-R 12.0 Rev. 0
13.0 HANDLING, STOR. & SHIP.	No	Yes		033-NWMP-R 13.0 Rev. 0
14.0 INSP. TEST & OPER. STAT.	No	Yes		033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Oxidation Tests of Spent Fuel and UO_2 using a TGA
D-20-44

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L
Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____I____________.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Task Leader — Date 6/1/87 | NWMP Deputy Program Leader for QA — Date 6/1/87

NNWSI Project Leader — Date 6/3/87 | NWMP Leader — Date 6/3/87

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Project Sponsor — Date 11/4/87 | Project Sponsor Quality Manager — Date 11/5/87

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	(Yes) →	(I)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Oven Oxidation Tests of Spent Fuel and UO_2

ACTIVITY NO.: D-20-45
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES	
	LLNL	PNL/HEDL	LLNL	PNL/HEDL
3.0 DESIGN CONTROL	3A Yes 3B No	Yes	033-NWMP-R 3A.0 Not a design activity.	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL	Yes	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	No	Yes		As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS	Yes	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	No	Yes		033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	No	No	No special processes involved	
10.0 INSPECTION	No	Yes		033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	No	Yes		033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Yes		033-NWMP-R 12.0 Rev. 0
13.0 HANDLING, STOR. & SHIP.	No	Yes		033-NWMP-R 13.0 Rev. 0
14.0 INSP. TEST & OPER. STAT.	No	Yes		033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Oven Oxidation Tests of Spent Fuel and UO_2
D-20-45

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87
Task Leader Date

6/1/87
NWMP Deputy Program Leader for QA Date

6/3/87
NNWSI Project Leader Date

6/3/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87
Project Sponsor Date

11/5/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	(Yes) →	(I)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Corrosion/Degradation/Release Tests on Zircaloy and Stainless Steel Cladding

ACTIVITY NO.: D-20-46
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ______ I ______

CITE "YES" ITEM ON LOGIC DIAGRAM ______ 4 ______

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES	
	LLNL	PNL/HEDL	LLNL	PNL/HEDL
3.0 DESIGN CONTROL	3A Yes 3B No	Yes	033-NWMP-R 3A.0 Not a design activity.	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL	Yes	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	No	Yes		As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS	Yes	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	No	Yes		033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	No	No	No special processes involved	
10.0 INSPECTION	No	Yes		033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	No	Yes		033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Yes		033-NWMP-R 12.0 Rev. 0
13.0 HANDLING, STOR. & SHIP.	No	Yes		033-NWMP-R 13.0 Rev. 0
14.0 INSP. TEST & OPER. STAT.	No	Yes		033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Corrosion/Degradation/Release Tests on Zircaloy and Stainless Steel Cladding D-20-46

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ______I______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87
Task Leader Date

6/1/87
NWMP Deputy Program Leader for QA Date

6/3/87
NNWSI Project Leader Date

6/3/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87
Project Sponsor Date

11/5/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	(Yes) →	(I)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Corrosion/Release Tests on Assembly Hardware

ACTIVITY NO.: D-20-47
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES	
	LLNL	PNL/HEDL	LLNL	PNL/HEDL
3.0 DESIGN CONTROL	3A Yes 3B No	Yes	033-NWMP-R 3A.0 Not a design activity.	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL	Yes	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	No	Yes		As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS	Yes	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	No	Yes		033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	No	No	No special processes involved	
10.0 INSPECTION	No	Yes		033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	No	Yes		033-NWMP-R 11.0 Rev. 1
12.0 CTL OF M & T EQUIP	No	Yes		033-NWMP-R 12.0 Rev. 0
13.0 HANDLING, STOR. & SHIP.	No	Yes		033-NWMP-R 13.0 Rev. 0
14.0 INSP. TEST & OPER. STAT.	No	Yes		033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	No	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Corrosion/Release Tests on Assembly Hardware
D-20-47

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ______I______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87
Task Leader Date

6/1/87
NWMP Deputy Program Leader for QA Date

6/3/87
NNWSI Project Leader Date

6/3/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87
Project Sponsor Date

11/5/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes → / No	I
2.	Does the item or activity involve waste isolation? Yes → / No	I
3.	Does the item or activity involve or affect retrievability? Yes → / No	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes → / No	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes → / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes → / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes → / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes → / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes → / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes → / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes → / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Carbon 14 Inventory and Release Tests

ACTIVITY NO.: D-20-48
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES	
		LLNL	CONTRACTOR
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-R 3A.0 Not a design activity.	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev.1 033-NWMP-P 5.1 Rev.0 033-NWMP-P 5.2 Rev.0	As implemented in the contractors QAPP
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	Yes	033-NWMP-R 8.0 Rev. 0	
9.0 CONTROL OF PROCESSES	No	No special processes	
10.0 INSPECTION	Yes	033-NWMP-R 10.0 Rev. 0	
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 0	
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R 12.0 Rev. 0 033-NWMP-P 12.2 Rev. 0 (LLNL only)	
13.0 HANDLING, STOR. & SHIP.	Yes	033-NWMP-R 13.0 Rev. 0 033-NWMP-P 13.1 Rev. 0 (LLNL only)	
14.0 INSP. TEST & OPER. STAT.	Yes	033-NWMP-R 14.0 Rev. 0	
19.0 SOFTWARE QA	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Carbon 14 Inventory and Release Tests D-20-48

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87 — Task Leader, Date	6/1/8 — NWMP Deputy Program Leader for QA, Date
6/3/87 — NNWSI Project Leader, Date	6/3/87 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87 — Project Sponsor, Date	11/5/87 — Project Sponsor Quality Manager, Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No ↓)	Yes →	I
2.	Does the item or activity involve waste isolation? (No ↓)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No ↓)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? (No ↓)	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No ↓)	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No ↓)	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No ↓)	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No ↓)	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No ↓)	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No ↓)	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No ↓)	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Technique Development for Test Planning and Design

ACTIVITY NO.: D-20-49
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM None

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES LLNL	CONTRACTOR
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-P 3A.0	As implemented in the contractors QAPP.
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev.0	As implemented in the contractors QAPP.
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply	
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0	As implemented in the contractors QAPP
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply	
9.0 CONTROL OF PROCESSES	No	No special processes involved	
10.0INSPECTION	No	Good professional practices apply	
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 0	
12.0 CTL OF M & T EQUIP	No	Good professional practices apply	
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply	
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply	
19.0 SOFTWARE QA	No	No software development	

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Technique Development for Test Planning and Design
D-20-49

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____III____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87		6/1/87	
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
6/3/87		6/3/87	
NNWSI Project Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87		11/5/87	
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes → (No ↓)	I
2.	Does the item or activity involve waste isolation? Yes → (No ↓)	I
3.	Does the item or activity involve or affect retrievability? Yes → (No ↓)	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes → (No ↓)	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes → (No ↓)	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes → (No ↓)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes → (No ↓)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes → (No ↓)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes → (No ↓)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes → (No ↓)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes → (No ↓)	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Generate Models for Release of Radionuclides from the Spent Fuel Waste Form

ACTIVITY NO.: D-20-50
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM None

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-P 3A.0 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	No special processes
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Generate Models for Release of Radionuclides form the Spent Fuel Waste Form
D-20-50

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____III____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87	6/1/87
Task Leader — Date	NWMP Deputy Program Leader for QA — Date
6/3/87	6/3/87
NNWSI Project Leader — Date	NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87	11/5/87
Project Sponsor — Date	Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes → / No ↓	I
2.	Does the item or activity involve waste isolation? Yes → / No ↓	I
3.	Does the item or activity involve or affect retrievability? Yes → / No ↓	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes → / No ↓	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes → / No ↓	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes → / No ↓	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes → / No ↓	II
8.	If the item or activity were to fail or is performed inadequataly could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes → / No ↓	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes → / No ↓	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes → / No ↓	II
11.	Can the item or activity cause major cost overrun or schedula slippage? Yes → / No ↓	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? No (circled)	Yes →	I
2.	Does the item or activity involve waste isolation? No (circled)	Yes →	I
3.	Does the item or activity involve or affect retrievability? No (circled)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	Yes (circled) →	I (circled)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Screen Data for Incorporation into Release Model
D-20-51

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____I____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87	6/1/87
Task Leader — Date	NWMP Deputy Program Leader for QA — Date
6/3/87	6/3/87
NNWSI Project Leader — Date	NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/4/87	11/5/87
Project Sponsor — Date	Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Screen Data for Incorporation into Release Model

ACTIVITY NO.: D-20-51
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____I____

CITE "YES" ITEM ON LOGIC DIAGRAM ____4____

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-P 3A.0 Not a design activity
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev. 0
5.0 INSTR., PROCS, DWGS	No	No drawings or procedures
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	No	No materials used
9.0 CONTROL OF PROCESSES	No	No special processes
10.0 INSPECTION	No	No objects produced
11.0 TEST CONTROL	No	No tests conducted
12.0 CTL OF M & T EQUIP	No	No tests conducted
13.0 HANDLING, STOR. & SHIP.	No	No materials used or produced
14.0 INSP. TEST & OPER. STAT.	No	No tests conducted
19.0 SOFTWARE QA	No	No software development

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Validate the Spent Fuel Release Model

ACTIVITY NO.: 0-20-52
DATE: May 8, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____________________

CITE "YES" ITEM ON LOGIC DIAGRAM ____________________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A Yes 3B No	033-NWMP-R 3A.0 Not a design activity.
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Rev.0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-P 5.0 Rev.1 033-NWMP-P 5.1 Rev.0 033-NWMP-P 5.2 Rev.0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P 7.0 Rev. 0
8.0 I.D. & CTL OF MATERIALS	Yes	033-NWMP-R 8.0 Rev. 0
9.0 CONTROL OF PROCESSES	No	No processes apply
10.0 INSPECTION	Yes	033-NWMP-R 10.0 Rev. 0
11.0 TEST CONTROL	Yes	033-NWMP-R 11.0 Rev. 0
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R 12.0 Rev. 0 033-NWMP-P 12.2 Rev. 0
13.0 HANDLING, STOR. & SHIP.	Yes	033-NWMP-R 13.0 Rev. 0 033-NWMP-P 13.1 Rev. 0
14.0 INSP. TEST & OPER. STAT.	Yes	033-NWMP-R 14.0 Rev. 0
19.0 SOFTWARE QA	Yes	033-NWMP-R 19.0 Rev. 0

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 8, 1987

Meeting Attendees: Henry Shaw
Virginia Oversby
Larry Ramspott
Ron Schwartz

Name(s) and Number(s) of Activity: Validate the Spent Fuel Release Model D-20-52

S.I.P. Identification: Scientific Investigation Plan for NNWSI WBS Element 1.2.2.3.1.L Spent Fuel Waste Form Testing

Additional Comments:

Level of Quality Assurance ____________________.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

6/1/87
Task Leader — Date

6/1
NWMP Deputy Program Leader for QA — Date

6/3/87
NNWSI Project Leader — Date

6/3/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/6/87
Project Sponsor — Date

11/5/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

NNA.871113.0027

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.2.3.2

Metal Barrier Selection and Testing

Lawrence Livermore National Laboratory

Revision 0
Manuscript Date October 20, 1987

10-22-87

L. D. Ramspott, Technical Project Officer — Date

10/20/87

J. J. Dronkers, Deputy for Quality Assurance — Date

Oct. 20, 1987

R. D. McCright, Task Leader (acting) — Date

Oct. 20, 1987

R. A. Van Konynenburg, Technical Reviewer — Date

10/30/87

Project Sponsor Quality Manager — Date

11/3/87

Project Sponsor — Date

Scientific Investigation Plan
Metal Barrier Selection and Testing Task - WBS 1.2.2.3.2
Revision 0
October 1987

Table of Contents

List of Acronyms

AISI - American Iron and Steel Institute

ASTM - American Society for Testing and Materials

CDA - Copper Development Association

CFR - Code of Federal Regulations

DOE - Department of Energy

ESCA - Electron scattering for chemical analysis

EIS - Environmental Impact Statement

FY - Fiscal Year

IN - Information Need

LLNL - Lawrence Livermore National Laboratory

NACE - National Association of Corrosion Engineers

NNWSI - Nevada Nuclear Waste Storage Investigations

NRC - Nuclear Regulatory Commission

NWMP - Nuclear Waste Management Program

QA - Quality assurance

QAPP - Quality Assurance Program Plan

SCC - Stress corrosion cracking

SCP - Site Characterization Plan

SIP - Scientific Investigation Plan

WBS - Work breakdown structure

1.0 Purpose and Objectives

1.1 Regulatory Requirements

The purpose of the work outlined in this plan is to determine the rate at which the metal barrier will be degraded by its interaction with the repository environment and to project these determinations over the time scale of interest in demonstrating first, the containment of the waste, and second, the controlled release of radioisotopes. Several degradation mechanisms of the metal barrier are possible, and a significant effort in this plan is directed toward providing information which will be used in determining which of the several degradation mechanisms will operate in the repository environment. In addition, several candidate metal barrier materials are presently under consideration, and a large effort in this plan is directed toward providing information that will be used as the basis in selecting the material for the license application waste package design. A brief discussion of how the current list of candidate materials developed can be found in Section 7.0.

The information generated in this plan will be used to show that the waste package meets the containment requirements of 10 CFR 60.113. In addition, the information is used, in part, to demonstrate the waste package retrievability requirements in 10 CFR 60.111 (b). Along with information generated in the plans for waste form testing (both spent fuel and glass waste forms), the information from this plan will serve as a component in determining the source term for repository performance assessment modeling. Results from this work will provide the waste package environment task with information describing critical environmental parameters and how they affect the container material performance, thus indicating areas to be examined during the exploratory shaft investigations. Furthermore, the information will contribute, in part, toward estimating the source term in the calculation of long term cumulative releases. These calculations form part of the estimates of releases to the accessible environment required for 40 CFR 191.13 (cumulative releases after 10,000 years) and for completion of the site evaluation process required for 10 CFR 960.3-1-5 (cumulative releases after 100,000 years).

The Metal Barrier Selection and Testing Scientific Investigation Plan addresses the following information needs:

Issue 1.4: Will the waste package meet the performance objective for containment as required by 10 CFR 60.113?

- IN 1.4.1 Waste package design features that affect the performance of the container.
- IN 1.4.2 Material properties of the container.
- IN 1.4.3 Scenarios and models needed to predict the rate of degradation of the container material

Through input to the above information needs, the work covered by this plan will also provide data used to address information needs 1.4.4 and 1.4.5 (Performance assessment for containment objectives); 1.5.4 and 1.5.5 (Performance assessment for controlled release objectives); 1.10.1 and 1.10.2

(Waste package desig 2.6.1 (Preclosure design crit. .a concerned with materials, handling, and identification), 4.3.1 (Waste package production technology), and 4.5.1 (Waste package costs).

1.2 Metal Barrier Selection and Testing Activities Grouped by SCP Investigations

The investigations and activities of the three 1.4 Information Needs (IN) from the Site Characterization Plan (SCP) are grouped as follows: (1) IN 1.4.1 is concerned with characterization of the as-fabricated and as-emplaced waste package container; (2) IN 1.4.2 is concerned with characterization of the waste package container after emplacement (hence the emphasis on different degradation modes); and (3) IN 1.4.3 is concerned with modeling to predict the rates of these different degradation modes.

There is not a one-to-one correspondence between the full set of investigations and activities listed under the above INs and the activities described in this Scientific Investigation Plan (SIP) for the Metal Barrier Selection and Testing Task (WBS 1.2.2.3.2). This situation occurs because the 1.4 Issue and subsumed Information Needs exist to resolve containment issues, while the content of this SIP is addressed specifically to the metal barrier, which is not the only engineered containment barrier. Thus, the investigations and activities associated with the properties of a ceramic liner in IN 1.4.1, 1.4.2 and 1.4.3 as an alternative waste package design are discussed in the SIP for "other materials" (WBS 1.2.2.3.3). The Metal Barrier SIP is centered around laboratory testing, development of models to predict resistance to various degradation modes, and characterizing the properties of the candidate metals and alloys as materials of construction. The characteristics of the processes for actually fabricating the container and constructing the waste package are, therefore, discussed in the SIP for "Design, Fabrication, and Prototype Testing" (WBS 1.2.2.4). Thus, some of the activities discussed in IN 1.4.1 more logically fall into that SIP. There is the obvious need for close co-operation between the activities for these different WBS element SIPs, hence the identification of integration activities between the appropriate plans.

Although the Metal Barrier SIP has several features analogous to those found in the SIPs for characterizing the spent fuel and the borosilicate glass waste forms (WBS 1.2.2.3.1), there are two unique features of the Metal Barrier SIP that distinguish it and influence the course of the planned activities. These features are:

(1) the process for specifying which of the several candidate materials will be selected for the license application design. In order to arrive at a defensible selection process, many of the activities must be conducted in parallel for the different candidate materials. This means that a number of activities will be carried out to a level to provide needed information for the selection process, but that the full suite of activities will be completed only for the candidate material that is selected for the license application design.

(2) much information on characterizing the candidate metals comes from the open literature and from various commercial sources, including potential vendors for the container material. The information often derives from non-nuclear applications. Unlike information on other materials that are part of the waste package (e.g. borosilicate glass or uranium dioxide fuel elements), these sources of information are largely outside the control of the DOE, NRC, or other governmental agencies.

This has important q ity assurance implications wit egard to the number of possible sources of information and the completeness of the documentation. Because a strong argument for the selected container material will be built on previous and successful uses of the material in other engineering applications, it is vital to use available information on performance of the candidate materials. Therefore, a considerable effort is involved in determining what previously published information in the technical literature is relevant and applicable to the present work.

METAL BARRIER WORK OUTLINE FROM SCP

Note: The asterisked (*, **) investigations and activities from the SCP (as listed below) are not discussed in the Metal Barrier Selection and Testing SIP. Discussions of these will be found in the SIP for Design, Fabrication and Prototype Testing (items marked *), and in the SIP for Other Materials (items marked **).

Info Need	Investigation	Activity

1.4.1 Waste package design features that affect the performance of the container

1.4.1.1 Integrate design and materials information (metal container)

1.4.1.1.1 Mechanical properties

1.4.1.1.2 Microstructural properties

*1.4.1.1.3 Physical properties

*1.4.1.1.4 State of stress in the container

*1.4.1.1.5 Characterization and inspection of weld integrity

*1.4.1.1.6 Characterization of the container surface

**1.4.1.2 Integrate design and materials information (metal container with a ceramic liner)

**1.4.1.2.1 Feasibility evaluation of fabricating a ceramic-lined waste package

1.4.2 Material properties of the container

1.4.2.1 Selection of the container material for the license application design

1.4.2.1.1 Establishment of selection criteria and their weighting factors

1.4.2.1.2 Material selection

Info Need	Investigation	Activity
	1.4.2.2	Degradation modes affecting candidate copper-base container materials
		1.4.2.2.1 Assessment of degradation modes in copper-base materials
		1.4.2.2.2 Metallurgical aging and phase stability
		1.4.2.2.3 Low temperature oxidation
		1.4.2.2.4 General aqueous corrosion
		1.4.2.2.5 Hydrogen entry and embrittlement
		1.4.2.2.6 Pitting, crevice, and other localized attack
		1.4.2.2.7 Stress corrosion cracking
		1.4.2.2.8 Other potential degradation modes
	1.4.2.3	Degradation modes affecting candidate austenitic container materials
		1.4.2.3.1 Assessment of degradation modes in austenitic materials
		1.4.2.3.2 Metallurgical aging and phase transformations
		1.4.2.3.3 Low temperature oxidation
		1.4.2.3.4 General aqueous corrosion
		1.4.2.3.5 Intergranular attack and intergranular stress corrosion cracking
		1.4.2.3.6 Hydrogen entry and embrittlement
		1.4.2.3.7 Pitting, crevice, and other localized attack
		1.4.2.3.8 Transgranular stress corrosion cracking
		1.4.2.3.9 Other potential degradation modes
	**1.4.2.4	Degradation modes affecting the ceramic liner
		**1.4.2.4.1 Assessment of the degradation modes affecting the ceramic liner
		**1.4.2.4.2 Laboratory test plan for ceramic liner materials

Info Need	Investigation	Activity
1.4.3 Scenarios and models needed to predict the rate of degradation of the container material		
	1.4.3.1 Models for copper and copper alloy degradation	
		1.4.3.1.1 Metallurgical aging and phase stability
		1.4.3.1.2 Low temperature oxidation
		1.4.3.1.3 General aqueous corrosion
		1.4.3.1.4 Hydrogen entry and embrittlement
		1.4.3.1.5 Pitting, crevice and other localized attack
		1.4.3.1.6 Stress corrosion cracking
		1.4.3.1.7 Other potential degradation modes
	1.4.3.2 Models for austenitic material degradation	
		1.4.3.2.1 Metallurgical aging and phase transformations
		1.4.3.2.2 Low temperature oxidation
		1.4.3.2.3 General aqueous corrosion
		1.4.3.2.4 Intergranular attack and intergranular stress corrosion cracking
		1.4.3.2.5 Hydrogen entry and embrittlement
		1.4.3.2.6 Pitting, crevice, and other localized attack
		1.4.3.2.7 Transgranular stress corrosion cracking
		1.4.3.2.8 Other potential degradation modes
	**1.4.3.3 Models for ceramic material degradation	
		**1.4.3.3.1 Dissolution of alumina
		**1.4.3.3.2 Loss of fracture toughness

At the present time, the NNWSI Project is considering the technological feasibility of producing a ceramic-lined metal container as a waste package design option. In such a case, the long-term container performance function would largely be taken by the ceramic material with the function of the metal to be largely limited to the handling and emplacement operations. If the Project were to choose this option, then much of the work discussed in this SIP would be truncated.

1.3 Activity Groupi[ng] for the Metal Barrier Selecti[on] and Testing SIP

For this plan, certain of the above activities group together naturally because of parallel efforts (e.g. model development for the various degradation modes in each alloy system; laboratory test plans corresponding to each degradation mode) and because these grouped activities have the same determined quality assurance levels. These groupings define the activities of the Metal Barrier Selection and Testing task as described in this SIP.

Metal Barrier Selection Process (see sections 2.2 and 3.2)

- E-20-13 Degradation mode surveys
- E-20-15 Establishment of criteria for metal barrier selection
- E-20-19 Metal barrier selection

Metal Barrier Performance Modeling (see sections 2.3 and 3.3)

- E-20-16 Development of models for degradation modes, mechanical properties, and microstructure
- E-20-20 Integration of models for selected material
- E-20-21 Performance parameter studies
- E-20-25 Validation of model

Metal Barrier Performance Testing (see sections 2.4 and 3.4)

- E-20-17 Experimental technique development
- E-20-18 Parametric studies of metal degradation and microstructure
- E-20-22 Development of plans for license application support tests
- E-20-23 License application support tests

Design Properties of the Metal Barrier (see sections 2.5 and 3.5)

- E-20-14 Coordination with package design
- E-20-24 Determination of mechanical and microstructural properties of metal

The numbers assigned to these thirteen activities are in approximate chronological sequence as can be seen in Figure 2 in Section 5.0 'Schedule and Milestones'.

The following list is a cross reference between activities from the SCP Information Needs of Issue 1.4 and the activities described in this plan. The titles of the activities are given in the preceding lists. There is not a one-to-one correspondence, and not all of the activities from this plan are included, because E-20-13 is a precurssor to other work in this plan and does not directly correspond to activities in the Information Needs.

SIP Sections	SIP Activity Number	SCP Activity Number
2.5 and 3.5	E-20-24	1.4.1.1.1 1.4.1.1.2
	E-20-14	1.4.1.1.3 1.4.1.1.4 1.4.1.1.5 1.4.1.1.6
2.2 and 3.2	E-20-15	1.4.2.1.1
	E-20-19	1.4.2.1.2
2.4 and 3.4	E-20-17 E-20-18 E-20-22 E-20-23	1.4.2.2.1 1.4.2.2.2 1.4.2.2.3 1.4.2.2.4 1.4.2.2.5 1.4.2.2.6 1.4.2.2.7 1.4.2.2.8 1.4.2.3.1 1.4.2.3.2 1.4.2.3.3 1.4.2.3.4 1.4.2.3.5 1.4.2.3.6 1.4.2.3.7 1.4.2.3.8 1.4.2.3.9
2.3 and 3.3	E-20-16 E-20-20 E-20-21 E-20-25	1.4.3.1.1 1.4.3.1.2 1.4.3.1.3 1.4.3.1.4 1.4.3.1.5 1.4.3.1.6 1.4.3.1.7 1.4.3.2.1 1.4.3.2.2 1.4.3.2.3 1.4.3.2.4 1.4.3.2.5 1.4.3.2.6 1.4.3.2.7 1.4.3.2.8

1.4 Information Flow

The goals of metal barrier selection and testing are to select one (or (two) material(s) from the present list of six candidates that will be used for advanced waste package design work and to test the selected material(s) to provide adequate data for models concerning the long-term chemical and metallurgical stability of the material(s) under anticipated conditions and a reasonable number of credible but unanticipated conditions. The present list of candidates are AISI 304L, AISI 316L, and Alloy 825 in the "austenitic" family and CDA 102, CDA 613, and CDA 715 as copper-base materials.

As illustrated in Figure 1, information from sources outside this plan is required for several of the activities of this plan. These outside sources, labeled as 'Information Input', include previously published information in the technical literature on the degradation modes of the candidate materials, previous results from NNWSI-sponsored work on metal barrier investigations, NNWSI-sponsored work on the near-package environment, work on other material components of the waste package and engineered barriers (including borehole liners, cements, and grouts), performance assessment scenarios, and geochemical modeling (to derive the physical and chemical environment surrounding the waste package container). Another input will be the use of the EQ3/6 code in the selection process.

Another source of "information" from outside the Metal Barrier Selection and Testing task is in the box labeled 'Working Constraints' in Figure 1. These include the performance requirements established by the various Federal regulations, the assessment of the repository environment before and after emplacement of the waste packages (including the DOE-NRC approved definitions of anticipated and unanticipated processes and events), and the preliminary design requirements (Conceptual Design Level). A unique feature of the Yucca Mountain site is that the repository will be located in the unsaturated zone, above the permanent water table. An important advantage of this location is that some of the environmental features can be "engineered" to create more favorable conditions to prolong the container lifetime. A good example of engineering the environment is to maintain the temperature at the container surface above the unrestrained boiling point of water for as long as possible on a large majority of the waste packages. This is done by considering the heat load per package and configuring the repository with a suitable heat load per unit area. As part of the NNWSI strategy to demonstrate the containment objectives, the waste package container (metal barrier), the waste form, and the engineered environment are jointly considered as the "containment barrier". This strategy is more fully explained in the discussion of the resolution of Issue 1.4 in Chapter 8 of the SCP. The regulatory requirements, the waste package design requirements and the repository environment assessment (including ways to engineer the environment to enhance the waste package performance) are viewed as constraints, because they establish some limits on what must be accomplished in the activities in this plan.

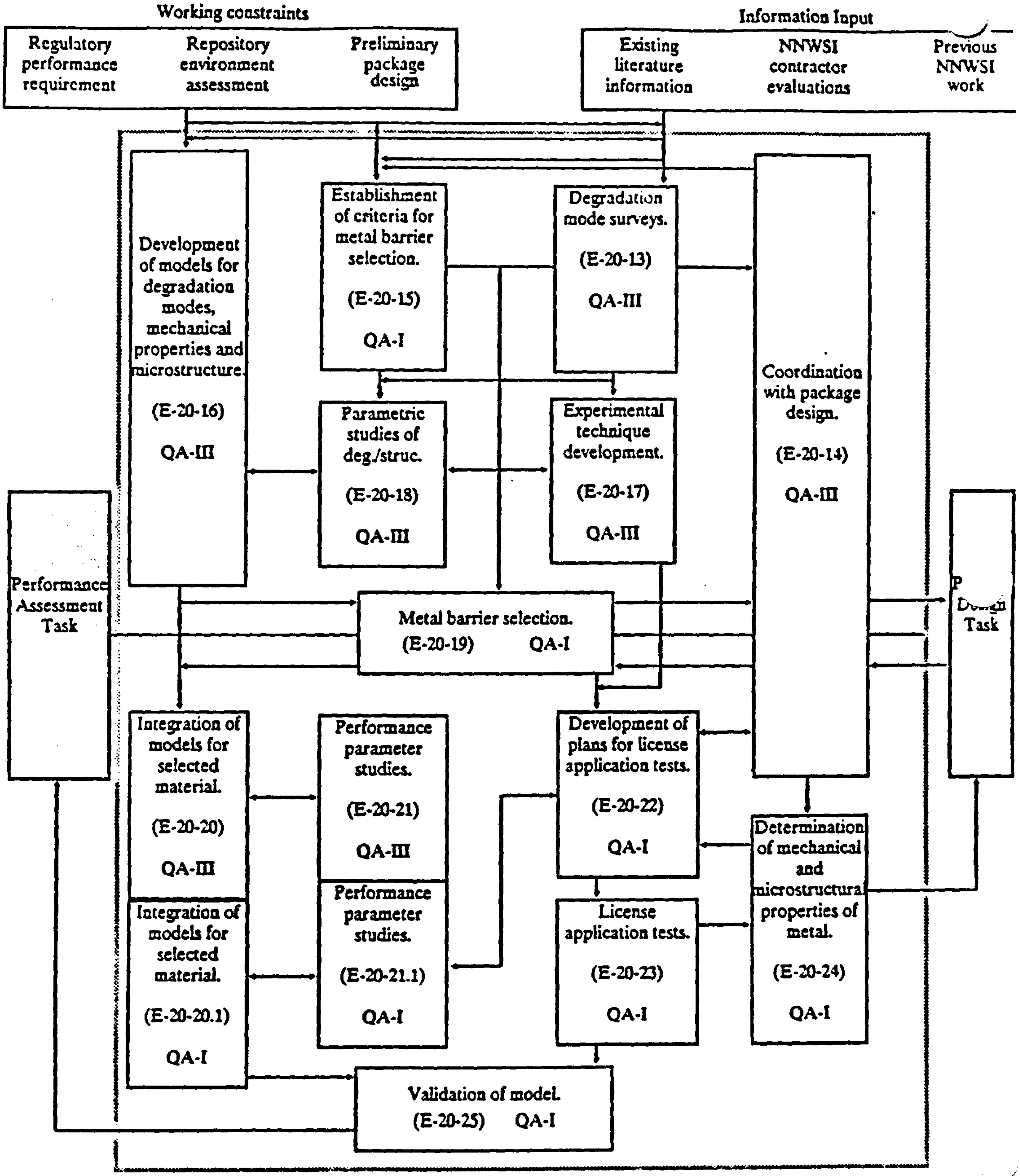
As seen in Figur , the activities in this plan . . naturally divided into two parts, separated by the selection step. Up until this selection the work covers all six initial candidate metals, including three austenitic alloys and three copper-base alloys. The three austenitic alloys are iron-base (stainless steels) and nickel-base (alloy 825) with the primary phase (austenite) being a face-centered cubic structure in all alloys. The copper-base alloys are also face-centered cubic in structure. All of these materials are hardened by solute additions or by cold work; all of the materials possess considerable ductility over a wide range of temperatures. These materials are widely used in industrial and structural applications; a major reason for their use is good corrosion resistance in many different kinds of environments, although the candidate materials differ on the limits of environmental conditions in which they can be successfully used. In the most general considerations of materials, all of the candidate materials are reasonably simple in microstructure (no intentional secondary phases for hardening), although there are important differences among the candidates on this point. While a high-purity copper is one of the candidate materials, this material, too, can be regarded as a dilute alloy. In fact, it may be desirable to add or retain some deoxidizing elements (in the 100's to 1000's ppm range) to make the material more readily weldable and to prevent formation of internal copper oxides. Thus the words "alloy" and "material" are used interchangeably and synonymously in this SIP.

Criteria for selecting the material(s) or alloy(s) for use in the final design must be decided upon, and an information base prepared to support these criteria. This information base includes corrosion models, corrosion data, existing literature, and evaluations from authoritative sources in the metals industry. After the selection of the alloy(s), the activities concentrate on generating a validated model for the material(s) performance in the repository environment. This model will be confirmed by laboratory tests. In effect, those elements of the plan above the "selection" activity in Figure 1 are directed toward making that selection. Those activities below the "selection" are directed toward validation of the long term performance model of the metal selected. When this task is completed, the validated model will become a portion of the overall repository performance assessment model used to support advanced designs and the license application.

Two other waste package tasks that have substantial interaction with the Metal Barrier Selection and Testing Task are shown in Figure 1: the Waste Package Design, Fabrication and Prototype Testing Task and the Waste Package Performance Assessment Task. There must be interaction between the Metal Barrier Selection and Testing work and the work in these two tasks to provide coordination as the work evolves. This is to insure that the metal barrier selected will be compatible with the design and fabrication features being researched (and vice versa), and that the degradation models developed in this task will mesh when needed with the overall performance model. The output from this task will be: 1) the selection of one (or two) alloys, a description of mechanical and microstructural properties, and performance confirming tests, provided to the Design Task; 2) validated models to describe the behavior of the material under repository conditions provided to the Performance Assessment Task.

Information from some additional waste package tasks (not shown explicity in Figure 1) influences the course of activities in the Metal Barrier Selection and Testing Task. To a lesser extent, information from the Metal Barrier Selection and Testing Task is used in these tasks but does not have a primary influence on the course of work planned in them. Information about the environment near the container surface comes from the Environment Task and is shown in Figure 1 as one of the "Information Inputs" and one of the "Working Constraints". The primary concern is the environment outside the container, but in a few instances there is concern about the environment inside the container. This information is important in analyzing the degradation modes for the candidate materials.
Information derived in the Metal Barrier Task on corrosion of candidate materials influences the Environment Task and also the Waste Form Testing Task. Corrosion products formed during the long-term degradation of the container will influence the waste package environment (particularly if the products are somewhat soluble and can be transported) and may degrade the performance of the waste form. The "compatibility" of the package container and the waste form is proposed as one of the factors in selecting the container material. Output from the Metal Barrier Selection and Testing Task on corrosion product formation is one of many factors that goes into the EQ3/6 geochemical code, shown in Figure 1 as the Performance Assessment Task.

Figure 1
Metal Barrier Selection and Testing Information Flow



2.0 Rationale for S... cted Activities and Quality As... ance Level Assignments

The rationale for the four work areas and thirteen activities listed in Section 1.2, and their QA level assignments are discussed in this section.

2.1 Introduction

The work in this plan is the content of WBS element 1.2.2.3.2 (Metal Barrier Selection and Testing) and is concerned with the long-term models to predict the mechanical and microstructural properties of the container material, and the rates of occurrence and rates of propagation for the different possible degradation modes. In most cases, the environmental, mechanical, and metallurgical factors that cause the different degradation modes are known from previous experience with the candidate materials, so that the starting point for model development comes from observation, measurement and understanding of those environmental, mechanical, and metallurgical factors that influence these degradation modes in the context of the repository setting. Laboratory work is centered around quantifying these degradation modes in the time periods generally available for laboratory testing (periods ranging from several hours to a few years). The general purpose of this laboratory work is to determine the rates of the different degradation modes as they relate to the physical, chemical, and mechanical properties of the container material and its surroundings. Confidence is gained in the model development by predicting to progressively longer time periods what is expected to occur and then actually conducting experiments or tests over those time periods to confirm the prediction. The rationale of this approach is to begin the laboratory activities in more highly aggressive conditions than expected (where the phenomenon under investigation is accelerated to occur in a short period of time) and then to reduce the aggressiveness of the conditions in order to approach the anticipated environmental conditions as a limit (where the same phenomenon occurs in progressively longer time periods). As needed, the models are modified in accordance with the results from the laboratory work.

In parallel with modeling and laboratory activities, this task will also select one (or two) materials for advanced study from the preliminary list of candidates. This selection process provides a dividing line between broad-based preliminary screening activities and the detailed final activities producing documentation for a license application design metal barrier. As noted above, this task will also interface with two others: waste package design and performance assessment. The intent of these interface activities is to insure that the results of this task are compatible with the results and requirements of these other efforts, and to keep the effort of this Scientific Investigation Plan directed toward the same goals as the other program elements.

2.2 Metal Barrier S... ction Process

These activities describe the process for selecting one or two materials for advanced design and performance testing. A set of criteria for material or alloy selection is needed to compare candidate materials with one another. An initial set of 'survey papers', each of which assesses the importance of particular degradation modes to a family of alloys, will provide a framework for evaluating the performance of candidates in the selection process. The selection process includes the documentation and review requirements for metal barrier selection.

Activity E-20-13 Degradation mode surveys

The 'Degradation mode surveys' (E-20-13) are a consolidation of available information related to the expected performance of the two families (copper-base and austenitic) of candidate alloys with respect to each particular mode of degradation (e.g. localized corrosion). The surveys will specifically concentrate on documentation of data needed to compare degradation rates of the container material over long time periods. The degradation modes are defined as chemical or mechanical processes (and sometimes combinations of these) that penetrate the metal structure and ultimately perforate it. The reason for separating the processes into the different modes is that the penetration follows different propagation patterns. These modes are explained more fully in the parts of Chapter 7 and 8 of the SCP dealing with metal barriers and in several texts on corrosion of metals - see Section 7.0 of this SIP.

The rate of perforation of the metal container and the number of containers perforated are important factors in demonstrating the performance of the waste package for containment and of the engineered barrier system for controlled release. The goal is to determine for each candidate alloy which degradation modes are insignificant, which are potentially significant, and which appear to limit an alloy in meeting the performance objectives. The rationale for this activity is that a great deal of information is available on metal performance, but it must be evaluated and applied to the specific case of a metal barrier in a Yucca Mountain waste container to assess the prospects for repository performance. Thirteen combinations of alloy family and degradation modes have been identified for assessment. Completion of these surveys will provide documented statements of potential alloy performance, which will serve as the input to the selection process. The data assessed will also provide input to model development.

This activity (E-20-13) will be conducted at QA Level III. The container material selection criteria (E-20-15) and the selection process itself (E-20-19) will be conducted at Level I. However, the survey information that is used in the selection is not directly tied to the license application data, which will be generated after the container material selection. The purpose of the survey information is to guide the work that will be followed once the selection is made. Much of the basic information to be used in the survey of degradation modes comes from the open technical literature, which does not have a QA level associated with it.

Activity E-20-1. Establishment of Criteria for Metal Barrier Selection

The criteria for selection of a metal barrier alloy(s) for advanced work must be developed, reviewed, and approved. Activity E-20-15 'Establishment of criteria for metal barrier selection' is the process of defining those criteria. The rationale for this work is that a metal barrier material cannot properly be chosen until the criteria for selection are established and accepted by a process of peer review and comment as provided for in the Quality Assurance Program Plan (QAPP) of the Nuclear Waste Management Program (NWMP).

This activity will be conducted at QA Level I. The reason for this level assignment is that the selected material and the defense of its selection are fundamental bases of the license application data base. The container material selection is also an important project milestone, and its delay would cause considerable slip in the project schedule. This fact alone would make the material selection and selection criteria Level II, but the fact that the primary intention of the activity is to provide the reasons for selecting the material for the license application design makes the activity Level I.

Activity E-20-19 Metal barrier selection

'Metal barrier selection' will be performed in activity E-20-19. Input for the selection will come from the performance models developed in this task and described in section 2.3, from the degradation surveys described above, and from the parametric studies described in section 2.4. The selection will be based on the criteria described in activity E-20-15, and will also be subject to peer review and comment. The rationale for selecting the barrier material(s) before the completion of model development and validation testing is that much more time and effort are required for validation of the performance model than for an informed and defensible selection. That is, a variety of candidates can be examined to a level that determines which ones are conservatively sufficient to meet the performance requirements, and to rank them in terms of performance. That is all that is required at this level to narrow the candidate list to one (or two). Much more work is then required to complete the long term performance model and validate it with testing. This larger effort, which is required for repository performance assessment but not for material selection, can then be focused on the selected alloy(s).

This activity is assigned QA Level I. The rationale for this assignment is the same as that given for the previous activity on the selection criteria, because the material selected and the defense of the selection are a fundamental part of the data that will be generated to support the license application. The reasons that the criteria for selection and the selection process itself are split into two activities are (A) to allow the timing sequence of the two activities, (B) to allow a possible change in the composition of the peer review panel for the two activities, and (C) to document the selection criteria and the selection process as separate activities.

In summary, the ee activities for the Metal Ba er Selection Process Area are:

Activity No.	Name	QA Level
E-20-13	Degradation mode surveys	III
E-20-15	Establishment of criteria for metal barrier selection	I
E-20-19	Metal barrier selection	I

2.3 <u>Metal Barrier Performance Modeling</u>

These activities are directed toward producing models of material degradation for use in the selection process, and then integrating these degradation models into a metal barrier performance model of the alloy(s) selected, to be validated by laboratory tests and utilized by the repository performance assessment task. Model development work will be conducted at QA Level III. The models will be validated at Level I and data for parameters central to the model will be collected at Level I.

<u>Activity E-20-16 Development of models for degradation modes, mechanical properties and microstructures</u>

Activity E-20-16 'Development of models for degradation modes, mechanical properties and microstructures' will serve two primary purposes. One purpose of this activity is to provide support for the selection process. Degradation models, primarily related to the corrosion resistance of the materials but occasionally concerned with retention of fracture toughness, are based on established electrochemical and metallurgical principles. These models address those modes deemed important to long term performance as guided by the degradation modes surveys, described in Section 2.2. Data input will include the metallurgical literature (especially that which is related to corrosion), and previous NNWSI experimental work. Closely related to modeling the degradation modes are modeling activities for characterizing the mechanical and microstructural properties of the as-fabricated container and the changes that will occur ('aging phenomena') as a function of time in the repository.

For the second p ose of this activity, those mo .s applicable to the selected alloy will be further developed and integrated into a long-term metal barrier performance assessment model to be validated and used by the repository performance assessment task in the advanced design and licensing phases. The rationale is to develop individual degradation mode models for all of the processess which must be considered in the selection activity, then combine those models which are relevant to produce a unified performance assessment model for the container. Thus, the model development activity begins before container material selection and continues for some time after the selection process (see Figure 2).

The models for degradation modes can be broken into 'sub-models'; in some cases this is an advantage because some aspects of the degradation process will be more amenable to modeling than other aspects. One example is that the detection of a sensitized microstructure in austentic stainless steels and nickel-base materials is more readily modeled than the environmental aspects of intergranular attack and intergranular stress corrosion cracking. Another example is that ammonia formation (such as by radiolysis of atmospheric gases) is more readily modeled than the metallurgical or mechanical aspects of stress corrosion cracking in copper and copper-base alloys. In both cases (sensitization or ammonia formation), the process being modeled is the critical step in the degradation mode and can be modeled with greater confidence because the model is confined to either the container material (sensitization) or to the environment (ammonia formation). This point is discussed further in Section 3.3.1.

This activity on model development is assigned QA Level III. The reason for this level assignment is that the individual models themselves are not directly part of the license data base (Level I), nor is the general 'integration' of the models into a single performance model. QA Level III parametric studies (E-20-18) support development of these models (discussed in Section 2.4). The activity on model development (and model integration) does not have a major impact on project schedules or on design phases to conduct comparisons of alternatives (criteria for Level II assignment). However, preparation of the integrated performance model for use in support of the license application (E-20-20.1), the data to support it (E-20-21.1), and validation of the model (E-20-25) are Level I activities. The validation will be made according to results of key performance parameter studies (E-20-21.1) and with data generated under license application support tests (E-20-23). Both E-20-21.1 and E-20-23 are QA Level I activities.

<u>Activity E-20-20 and E-20-20.1 Integration of models for selected material</u>

The 'Integration of models for selected material' activity (E-20-20 and E-20-20.1) follows the previous development phase and the alloy selection. Those degradation models which apply to the alloy(s) selected must be integrated with the design features and repository environment information to produce a long term performance model of the waste package. The reason for this 'integration' activity is that more than one degradation model can occur at a time. The model associated with aging effects in the container, including the mechanical and microstructural property changes associated with these, and the model associated with low temperature oxidation of the container are applicable from the time the container is emplaced in the repository, while many of the other models (especially those associated with aqueous corrosion phenomena) are applicable to certain time periods or when certain conditions occur in the repository.

The environment and the container will change with time, and waste packages at different locations in the repository will experience different environmental conditions. The containers themselves will be produced over a 25-30 year period of time, and will conceivably have some variation in composition and microstructure. All of these factors will determine when a given model is 'in effect' and when it is not.

This activity is split into two parts with different QA levels because much of the work to integrate the models does not support license application directly but is the process of getting the performance model working correctly. Thus activity (E-20-20) is assigned QA Level III for the same reasons given for assigning the model development activity (E-20-16) Level III. The primary purpose of the integration is to 'allocate' among the several models over what portion of time and over what portion of container population the individual models are applicable. The portion of this activity which is assigned QA level I (E-20-20.1) involves preparation of the parametric data from E-20-21.1 and predictions of container performance. This will be used to support the license application and other critical programmatic decisions in other tasks such as container design and fabrication where the metal barrier performance is important. The parametric data for this activity comes from E-20-21.1 which is also QA level I.

Activity E-20-21 and E-20-21.1 Performance parameter studies

'Performance parameter studies' (E-20-21 and E-20-21.1) is an activity to interface with the integration of the individual models (E-20-20 and E-20-20.1), described above. This activity involves gathering key parametric input for the integrated metal barrier model, and guaranteeing that the metal barrier model is consistent with the requirements of the repository performance model. It will also provide any additional parametric data needed to complete the individual degradation models. The word 'key' is used here because the parameters that will be studied are those that are identified as being important because of their strong influence on those degradation modes that are determined to be central in predicting container lifetimes in the time periods of concern. Identification of these key parameters comes after container material selection and after the model development work has indicated which parameters have the greatest sensitivity toward the process being modeled (activities E-20-18 and E-20-16). This 'Performance parameter studies' activity may include data collection from outside the project and certification of this data according to the appropriate quality assurance provisions to allow its use to directly support Level I work; this activity may also include laboratory tests. Tests would be performed under this activity if they were not direct performance tests, such as those in activity E-20-23.

This activity is split into two parts with different QA levels because some of the information required for model integration (E-20-20) is of a general nature and does not directly support either the model validation or the license application design, and some of the information does support these Level I activities. The first portion of the activity, E-20-21, which is assigned QA Level III, supplies information on all of the physical, chemical, metallurgical, and mechanical parameters that have some influence on metal performance. It is similar in nature to activity E-20-18 but is focused on the selected material and supports model integration rather than general development. The second portion of this activity is E-20-21.1 and is assigned QA Level I. The rationale for this assignment is that this activity directly supplies input required for completion of the performance model (E-20-20.1 and E-20-25), QA Level I activities that will be used in the license application

data base. Activity 20-21.1 classifies information .th regard to its importance and reviews and certifies information needed for QA Level I activities. Documentation of these decisions becomes a central factor in completing the modeling work in the Metal Barrier Selection and Testing Task.

Activity E-20-25 Validation of model

'Validation of model' (E-20-25) will validate the integrated metal barrier degradation model by comparison to QA Level I test data. As described earlier, the model will be based on accepted electrochemical and metallurgical principles. The rationale is to verify that the model is phenomenologically correct by comparison to laboratory tests which map a parameter space in corrosion environment and time. Demonstration that the model accurately predicts the results of these tests will be used to validate the model for use in the Repository Performance Assessment. If suitable natural analogs can be found, they will be used to enhance the validation of the time parameterization. The peer review process may also be used to support model validation.

This activity is assigned QA Level I, because the results of the validation will be a critical part of the data submitted in support of the license application.

In summary, the activities under the Metal Barrier Performance Modeling area are:

Activity No.	Name	QA Level
E-20-16	Development of models for degradation modes, mechanical properties, and microstructure	III
E-20-20 E-20-20.1	Integration of models for selected material	III I
E-20-21	Performance parameter studies	III
E-20-21.1	Performance parameter studies	I
E-20-25	Validation of model	I

It should be noted here that detailed model development and validation plans cannot be provided until after the material selection process is completed.

2.4 Metal Barrier Pe rmance Testing

Laboratory testing of metal barrier performance is required for three reasons. First, in the time leading up to selection of one (or two) alloys, experiments will provide data to the degradation modeling effort and will help guide the selection process. After selection, there will be a need for QA level I input into the degradation models as they are consolidated into a container performance model. Finally, tests will be needed to provide support for validation of the metal barrier model over a range of repository-relevant parameters.

Activity E-20-17 Experimental technique development

Activity E-20-17 is 'Experimental technique development'. Custom laboratory tests are likely to be needed. Standard corrosion test procedures should be adequate for most general material surveys and some of the model development support. However, to precisely conform to the modes of degradation experienced in a repository environment, and to vary the parameters of tests in the same way that the models vary parameters, custom techniques, using recent advances in electrochemical and surface sciences, may be required. To measure the slight degradations experienced in the relatively benign environments expected in experiments and tests performed within reasonable time scale, enhanced sensitivity is required in some experimental techniques. Examples of some techniques that may be employed are discussed in Section 3.4.1.

The work in this activity will be conducted at QA Level III. This is truly experimental work. There is some technological risk involved in undertaking this kind of work in that not all of the promised advances in techniques will necessarily give useful results. On the other hand, there are considerable benefits to be gained if mechanistic arguments can be successfully made about how fundamental electrochemical and metallurgical processes operate, in order to make the unique long-range characterization and performance predictions required for nuclear waste disposal. The bulk of the work undertaken in activity E-20-23 (License application support tests) will likely use standard test procedures and recommended practices developed by professional organizations such as ASTM, NACE and others. These tests have widespread use and acceptance; however, acceptance of new kinds of tests by professional organizations is a slow process. A good part of the effort in activities E-20-22 and E-20-23 (both QA Level I activities) will be concerned with selection of test methods to use in generating the license application data. The result of work performed in activity E-20-17 is to determine whether some of these advanced techniques should be included in those Level I activities.

Activity E-20-18 Parametric studies of metal degradation and microstructure

During the development of degradation mode models described in Section 2.3 corrosion data will be required that are not available from other sources or are unique to Yucca Mountain repository conditions. These will fall under activity E-20-18 'Parametric degradation studies'. The rationale is to provide the container material selection and model development activities in a timely manner.

]he behavior of the c tainer material depends on sev 1 physical, chemical, metallurgical, and me anical parameters; identification of which of these parameters are the central or key ones to predicting the performance under repository conditions is needed to proceed toward generating meaningful data for the license application. This activity begins before selection of container materials for advanced design work and continues until the selection process is completed. After selection of a container material, information gathering and key parameter identification is continued under activity E-20-21.

This activity will be conducted at QA Level III. The information that comes out of this activity will not be used directly in the license application, but it will identify those parameters that will be used in generating the QA Level I work in activities E-20-21.1, E-20-22, and E-20-23.

Activity E-20-22 Development of plans for license application support tests

After selection of an alloy(s) for advanced design work, a set of QA Level I tests must be planned in conjunction with the model integration work of Section 2.3 to allow eventual validation of the metal barrier performance model. Such tests cannot be conducted until a comprehensive set of test plans has been prepared, reviewed, and accepted. Preparation of these plans in activity E-20-22 'Development of plans for license application support tests' includes a review and comment process to ensure that the scope, accuracy and precision of the tests will be adequate for performance confirmation.

This planning activity will be developed at QA Level I. Documentation of how decisions were reached with regard to selection of test methods and selection of key parameters is needed to directly support the license application data (criterion for Level I). As indicated in the information flow diagram (Figure 1) and in discussions in the text on related activities, the plans will be periodically revised as important new information becomes available, for example, from activity E-20-17 on technique development or from activities E-20-21 and E-20-21.1 on parametric investigations.

Activity E-20-23 License application support tests

The most intensive laboratory work in this task is in activity (E-20-23) 'License application support tests'. These tests, as planned in the activity described above, will be used to validate the metal barrier performance model, and will provide data to predict the expected long term metal barrier performance. The rationale behind these tests will be to test the alloy(s) chosen over a range of environment and time combinations to provide data for use in specially designed tests for validating the integrated performance model of the metal barrier, as described in activity E-20-25. Severe environments will produce measurable degradation in accessible times to validate models of the degradation process. Monitoring the decrease in the degradation kinetics as the environment tends toward that in the repository will provide validation of the time parameterization in the models. Long time natural analogs, if available, will allow further validation in the time parameter. This activity will be conducted at QA Level I. The reason for this assignment is that this activity will generate license application design data.

In summary, the activities in the Metal Performance Testing area are:

Activity No.	Name	QA Level
E-20-17	Experimental technique development	III
E-20-18	Parametric degradation studies	III
E-20-22	Development of plans for license application support tests	I
E-20-23	License application support tests	I

It should be noted here that detailed plans for activities E-20-22 and E-20-23 cannot be developed until after the material selection process is completed.

2.5 Design Properties of Metal Barrier

This area comprises those properties of the metal barrier (as it is designed to be used in a waste package) that affect material selection and performance. These include the temperature and radiation field due to the radioactive decay, physical and mechanical properties of the metal, design details such as thickness of the container and the loads that it will experience, and microstructural characteristics such as grain size and internal precipitates both in the weld metal and the base metal. There are two activities in this area.

Activity E-20-14 Coordination with package design

The first activity in this area is 'Coordination with package design' (E-20-14). The rationale behind this activity is to ensure continued information exchange with the package design task. Examples of the kinds of information exchange are given in Section 3.5.1. This co-ordination is required to assure that the metal barrier selection and package design do not progress independently and end up with incompatible requirements.

This activity will be conducted at QA Level III as there is no license application design data being generated in the activity. This activity will continue throughout the active period of this SIP; the activity is not directly linked to any particular important scheduled milestone. However, this activity does serve to transmit information between the two tasks. Information from analyses being performed in other activities (e.g. E-20-18, E-20-21, and E-20-21.1) is used to determine 'key' parameters (especially metallurgical parameters). Information flows back from this activity to identify which of the mechanical and microstructural properties are central to making performance predictions (activity E-20-24).

Activity E-20-24 Determination of mechanical and microstructural properties of the selected metal barrier material

This activity is concerned with characterization and documentation of the important mechanical and microstructural properties of the selected container material in the as-fabricated and as-emplaced condition. Many of the activities concerned with survey of degradation modes, identification of key performance-related parameters, model development and integration, and testing to produce license application data and validation of the performance model depend on an accurate characterization of these key properties. This activity is closely linked with the Design, Fabrication, and Prototype Testing Task because the container fabrication process and the welding or other closure process have a significant influence on the mechanical and micro-structural properties. Examples of mechanical and microstructural properties are given in Section 3.5.2. The particular properties that will be documented in this activity are those that are deemed important from the model development and integration activities (E-20-16 and E-20-20) and the parametric studies (E-20-18, E-20-21 and E-20-21.1). Additionally, from the point of view of fabricating, closing, and inspecting the container, there are certain desirable mechanical and microstructural properties, and these considerations must also weigh in the final material specifications.

Information from this activity will ultimately be used, in part, for establishing acceptance criteria for the waste package container. This information is provided to the Design Task and ultimately to those areas of the NNWSI Project responsible for the waste package manufacturing and handling facilities. Nearly all testing techniques for mechanical or microstructural properties are destructive. Therefore, a major contribution from this activity will be a technical basis for establishing a sampling program to assure that the finished container meets the specifications. Possible approaches to achieve this end are more fully explained in IN 1.4.1 of the SCP.

This activity will be conducted at QA Level I. The characterization and documentation of these properties serve as a basis for much of the modeling and testing work from which long-term performance behavior predictions are derived. Characterization of the starting conditions is a crucial point in establishing the validity of the predictions, and this meets the criterion for Level I (data for license application).

In summary, the activities under the grouping of Design Properties of the Metal Barrier are:

Activity No.	Name	QA Level
E-20-14	Coordination with package design	III
E-20-24	Determination of mechanical and microstructural properties of selected metal barrier material	I

3.0 Description of ' ts, Models, and Analyses

3.1 Introduction

The thirteen activities defined in Sections 2.1 - 2.4 are described in the following sections. For those activities in which previous NNWSI work has been performed, that work is described. An outline of the work planned under this Investigations Plan is included, as is the expected schedule. Detailed test, model, and analysis plans which will ultimately be required by this Investigation are listed in Section 6.0.

3.2 Metal Barrier Selection Process

3.2.1 Degradation mode surveys (E-20-13)

This activity is an analysis of all the degradation modes that are believed to pose a potential performance threat to one or more of the candidate metals for the container. These surveys will be a set of papers summarizing available information addressing whether any particular mode of degradation can be active under Yucca Mountain conditions, under what conditions it would be active, and what measures could be taken to avoid degradation. The surveys will become a baseline of information used to evaluate which degradation modes must be pursued in advanced tests and which can be eliminated from further consideration because they will not be active under postulated repository conditions. The surveys will also support the selection process, where they will provide input into a QA level I assessment of the degradation modes. That assessment will then be used to narrow the field of candidate metals to one or two. It is expected that some candidates will have more potential degradation threats than others. Selection criteria may favor those candidates that have few or no active degradation modes. A final application of the surveys will be as input to the Package Design Task to assist in evaluating design issues which could reduce or enhance the activity of degradation modes.

The candidate metals can be divided into two distinct alloy families, austenitic (iron-base and nickel-base) and copper-base. These families respond quite differently to the same environment. Because of this natural grouping, the assessments will be combinations of degradation mode and alloy family. While the fundamental mechanisms for corrosion resistance are similar within a family of alloys, individual members can exhibit substantial differences in behavior in certain environments. The common modes of environmental degradation can also be grouped into similar categories. Not all degradation categories apply to both alloy families, because some types of corrosion are not active with one of the families. Thirteen combinations of degradation mode and metal family have been identified that are at least conceivable under repository conditions. There is also a category of 'other' to allow continued survey of possible modes that appear remote now but that future investigations in this and other project tasks may reveal to be more important. Identified in this 'other' category are (1) additional mechanical degradation modes (e.g. low temperature creep) occurring at slow rates over long periods of time at the modestly elevated temperature in the repository and (2) the possibility of greatly enhanced corrosion degradation modes occurring because of substantial modification of the chemical environment by micro-organisms either native to the repository site or introduced during the construction and operational periods.

vey papers to be prepared FY87 FY88.

General Corrosion and Oxidation - Copper-base alloys. (FY87)
Localized Corrosion - Copper-base alloys. (FY88)
Stress Corrosion Cracking - Copper-base alloys. (FY-88)
Hydrogen Effects - Copper-base alloys. (FY87)
Phase Stability and Ageing - Copper-base alloys. (FY87)
Other Degradation (Creep) - Copper-base alloys. (FY87)
- - - - -
General Corrosion and Oxidation - Austenitic alloys. (FY87)
Localized Corrosion - Austenitic alloys. (FY88)
Transgranular Stress Corrosion Cracking - Austenitic alloys. (FY88)
Intergranular Stress Corrosion Cracking - Austenitic alloys. (FY88)
Hydrogen Effects - Austenitic alloys. (FY87)
Phase Transformation and Ageing - Austenitic alloys. (FY87)
Other Degradation -Austenitic alloys. (FY88)

3.2.2 Establishment of criteria for metal barrier selection (E-20-15)

The objective of this activity is the development of a methodology to select the container material from the list of candidate materials. A peer review group will be formed as provided for under the NWMP - QAPP (033-NWMP-P 2.2) to review this methodology and its use in arriving at the final material choice.

The following list is a preliminary list of the criteria for selecting a container material for the license application design and will serve as input to this activity:

1. Will the material meet the performance allocated to the container in achieving the containment objectives (substantially complete containment under anticipated processes and events occurring in the repository)?

    a. Resistance to oxidation.
    b. Resistance to general aqueous corrosion.
    c. Resistance to environmentally accelerated cracking (stress corrosion cracking and hydrogen embrittlement).
    d. Resistance to pitting, crevice, or other localized attack.
    e. Demonstration of adequate mechanical properties.
    f. Resistance to mechanical embrittlement.

2. Can the performance of the material under repository conditions be adequately predicted?

    a. Predictability of physical and chemical properties of as-emplaced container.
    b. Existence of models to explain and predict degradation phenomena, or ability to develop such models.
    c. Existence of models to extrapolate laboratory data relating to degradation phenomena to repository time scales and conditions, or ability to develop such models.

3. Will the co iner material interact favorab. with other components?

   a. Interactions with waste form.
   b. Interactions with borehole liner.
   c. Interactions with the package environment.

4. Can a container be made of this material?

   a. Fabricability of container body.
   b. Weldability of container ("closeability" if a nonwelded closure).
   c. "Inspectability" of closure.

5. Are the container material and process for fabricating it practicable?

   a. Availability of container material.
   b. As-fabricated container costs.
   c. Quality control requirements (and costs).
   d. Repository handling costs.

6. How can confidence in the selection be gained?

   a. Previous engineering applications of the material.
   b. Available data base on the material.
   c. Favorable (or unfavorable) experiences with the material.

Weighting factors for each of the preceding criteria (and any others chosen) will need to be established. It is expected that the previously listed criteria in 1, 2 and 4 will have the heaviest weighting, but all of the criteria have some importance. One approach is to assign a maximum number of points to each item in the criteria list and a minimum number for each item that the material must pass. As a rather extreme example, it does no good to have a highly corrosion resistant material that cannot be fabricated and closed.

Where appropriate and available, examples of methods that have successfully been used to predict longer term behavior of materials from short-time laboratory or field tests will be used. Examples may derive from atmospheric corrosion testing, marine corrosion testing, underground testing, chemical process industry testing, or nuclear and fossil fuel power plant testing. These examples will provide information for some of the items listed in 1, 2 and 6.

Development of tl selection criteria, weightings, nd organization of the peer review group are the items to be completed in this activity. The Nevada Nuclear Waste Storage Investigations (NNWSI) Project will use its own staff and consultants to develop the selection criteria and weighting factors. The selection criteria and weightings will then be reviewed by the peer review panel as per the Quality Assurance Program Plan. Following revision, if necessary, the criteria will be used to assess the candidate materials and select a material or materials in activity E-20-19. The peer review panel will consist of approximately seven individuals with backgrounds in different areas of metallurgy and materials science and with different work experiences to achieve a balance of viewpoints and perceptions.

3.2.3 Metal barrier selection (E-20-19)

This activity is the actual metal barrier selection step. The selection process will consist of applying the selection criteria to the list of candidate materials. As part of the process an assessment of degradation modes will be made for each material based on the survey papers from activity E-20-13. NNWSI Project personnel and consultants will perform the selection. Input will be the selection criteria and weighting factors from the previous activity, the degradation mode surveys from the first activity, consultant reports, NNWSI parameter studies, and existing literature information. There will be two components to the decision. First, each candidate will be examined to assure that its performance meets the minimum requirements, allowing a conservative margin for uncertainties. Second, it is proposed that a 'quantitative figure of merit' technique be used, in which each candidate alloy is judged on the established criteria. The quantitative scores, multiplied by the established weighting factors, are summed to provide the ranking total for the alloy. The selection process will be documented in a report on alloy selection. A peer review panel will be convened to review the report. It is expected that the same panel used for activity E-20-15 will be used for this review, but some additions might be made to address critical decision points. The selection, after review, revision if needed, and approval by the review group, shall be used to guide subsequent performance confirmation tests and degradation model development. The selected metal barrier material(s) and its physical, mechanical, and microstructural properties will also be used by the waste package design task as input into the advanced design work.

3.3 Metal Barrier P...ormance Modeling

3.3.1 Development of models for degradation modes, mechanical properties, and microstructure (E-20-16)

The analyses performed under this activity are directed toward producing a set of models for any degradation modes to which the container may be susceptible. The set of models will cover all degradation modes considered to be important for each candidate material in the repository environmental and thermal setting. The models will be preliminary in nature because of the large effort required to make them exhaustive, and because of the limited application required of these models before the selection step. Those models relevant to the selected alloy(s) will be further developed after selection, as described in activity E-20-20. This activity will also develop models to predict the mechanical properties and microstructure of the container material in the repository environment.

Prediction of the long-term performance of the metal barrier under repository conditions requires that all significant degradation mechanisms be identified and the probability of their occurrence be quantified. For all degradation modes that might be significant, a physical-chemical model must be developed that will allow extrapolation of data gathered in the laboratory to the times and conditions relevant to the repository. In many cases, the analysis to determine whether the degradation mode might occur requires the same model that will allow prediction of long-term behavior. Thus, in this activity analyses are included that both assess the relevance of particular degradation processes and develop models to describe their action under repository conditions. The tools that are developed under this activity will be used in the Performance Assessment Task to predict the condition of the containers as a function of time for both anticipated processes and events and for other, low probability cases for which source term data are requested by that Task.

The modeling activities discussed in this activity and the laboratory experiments discussed in E-20-18 are closely related. They are both described in fairly basic terms in Chapter 8 of the SCP (Information Need 1.4.3) with much greater detail to be provided in the laboratory test plan to be written for the activities. The results of this activity will be used in the selection of the alloy(s) for advanced work (activity E-20-19), and those portions of these models that apply to the alloy(s) selected will be used in activity E-20-20.

A fundamental element that transcends all the modeling of degradation modes that have some chemical features is a model for the corrosion potential. Various environmental parameters in the aqueous phase (e.g. pH, dissolved oxygen and other gasses, cation speciation, anion speciation, radiolytically produced species as well as temperature) influence the corrosion potential. Metallurgical parameters (e.g. alloy composition and phases — including the effects of strain and prior fabrication history on these) also influence the corrosion potential. While more difficult to measure experimentally, the concept of corrosion potential also exists under "dry" oxidation conditions. The potential under dry conditions might be approximated by modeling the potential under conditions of a thin electrolyte layer as a function of thickness, and then letting the thickness approach zero. Initiation and propagation of non-uniform corrosion modes are governed by "critical potentials", so that models for these modes are based on the values of the

critical potentials : ative to the corrosion potenti . The values of the critical and corrosion potentials will change with time as environmental and metallurgical conditions in the repository and in the container material change. Many of the details depend on the material that is selected for the advanced designs.

Models for predicting critically susceptible microstructures for the onset of non-uniform corrosion modes (e.g. sensitization in stainless steels and nickel-base materials) are derived from considerations of the metallurgical reaction kinetics. These follow from nucleation-and-growth models based on diffusion of the critical component (diffusion of chromium to react with carbon). Particularly at the relatively low temperatures of interest in the repository, models must consider both high-diffusivity paths (grain boundaries, dislocations) and low-diffusivity paths (atom movements in the crystal matrix). Also, the reaction kinetics to form the carbide can become rate controlling at low temperatures. Models for sigma phase formation (a brittle phase) are based on nucleation and growth kinetics and will be developed by a similar approach. Some metallurgical reactions that are of interest (because the transformation products are brittle and are usually more prone to stress corrosion and/or hydrogen embrittlement) are diffusionless (e.g., martensitic reactions in stainless steels and possibly in aluminum bronze), and the modeling approach is therefore different. Martensitic reactions are usually considered in the context of critical temperatures to begin the transformation and to complete the transformation. High strains greatly increase the critical temperatures, so that they can coincide with the repository temperatures for the more susceptible materials (304L). Models for these are built upon the effect of temperature, strain, and alloy composition with evidence for the formation being resolution by optical microscopy.

The extent to which the modeling activities will be carried out depends on the material selected for advanced designs and the results of degradation mode assessments for the materials and different degradation modes being considered.

3.3.2 <u>Integration of models for selected material (E-20-20 and E-20-20.1)</u>

The analyses of this activity follow those of the preceding one (E-20-16) and the metal barrier selection step (E-20-19). This activity involves taking those degradation mode models that are relevant to the selected alloy, completing them, and integrating them with required input from activity E-20-21 and E-20-21.1 concerning the material and repository conditions to provide performance predictions for the metal barrier. This activity will interface with the Performance Assessment Task to produce container performance models consistent with the needs of that Task.

The work of this activity is closely related to the information gathering and laboratory testing activities of E-20-21, E-20-21.1 and E-20-23. They are described in general terms in Chapter 8 of the SCP (Information Need 1.4.2) and will be detailed in the individual test and analysis plans to be written for the material(s) selected for the advanced designs. Particularly in the case of localized corrosion and stress corrosion cracking, there is a considerable need to select detailed test methods as well as materials, and this selection is best left until after the final material is selected.

3.3.3 Performance rameter studies (E-20-21 and E -21.1)

The QA Level III portion of this activity (E-20-21) consists of information collection and tests to support the development of degradation models but which do not support the validation and license application. This activity serves a role after the selection step similar in nature to the role of activity E-20-18 before selection. This activity continues those experiments from E-20-18 which apply to the selected alloy to assist model development. The experiments can be divided into eight categories of degradation, and can be further divided naturally into the two families of candidate alloys (austenitic and copper-base). The eight categories are:

1. Metallurgical aging and phase transformations.
2. Low temperature oxidation
3. General aqueous corrosion.
4. Intergranular attack and intergranular stress corrosion cracking.
5. Hydrogen entry and embrittlement.
6. Pitting, crevice, and other localized attack.
7. Transgranular stress corrosion cracking.
8. Other potential degradation modes

The QA Level I portion of this activity (E-20-21.1) consists of information collection and tests to support the completion and integration of degradation models including any data which supports the validation (E-20-25) or the license application design. Details of this activity will not be available until the preliminary models are complete (E-20-16), the alloy(s) for advanced design work is chosen (E-20-19), and model integration (E-20-20) is ready to commence. Until that time, the parametric information needs for this task will not be known. When appropriate, analysis and or test plans will be prepared and reviewed to assure that the parametric input into the metal barrier performance model is adequate and accurate. This activity is a QA Level I analog of activity E-20-18 and will gather or generate data on critical issues such as chromium diffusion, phase stability, and chloride ion effects (austenitic materials) and such as rates and concentrations of nitric acid or ammonia formation (copper-base materials). The data will be used in the development and integration of the performance model (E-20-20.1) but are not distinct validation tests (E-20-25).

3.3.4 Validation of model (E-20-25)

This activity will conduct QA Level I metal barrier material tests and compare the results with the predictions of the degradation model. The purpose is validation of the model for long term waste package performance predictions. Substantial variance of the model from the test results must be investigated, and explained. A peer review process will monitor the results and review the validation. Input into this activity will be the long term material performance model from E-20-20.1 and the test results from E-20-23.

3.4 Metal Barrier Pe rmance Testing

3.4.1 Experimental technique development (E-20-17)

This activity involves the development of custom laboratory techniques for degradation testing and examination of metal barrier candidates. It involves both analyses of requirements and existing techniques and laboratory testing to develop techniques. One portion of this activity will be an ongoing review of the experimental requirements for metal barrier testing. As the investigation progresses, there may be an evolution of test requirements, since they are dependent upon the results of activities E-20-13, E-20-19, and E-20-16. As these experimental requirements are identified, an assessment of existing techniques will be made to determine whether the need is already filled. Established techniques that are required but not already available to the NNWSI program will be obtained, either by installing and developing expertise at LLNL or by contract to other laboratories with established capabilities. It is possible that needs will be identified that are not met by established techniques. In this case, an effort will be made to develop the required capability either at LLNL or at a contractor facility. The work under this activity will be done at QA level III. However, any techniques developed here that will be used for activities E-20-21.1 or E-20-23 will have QA Level I procedures written for them.

Examples of experimental requirements that may lead to developmental work include:

1) use of microelectrodes to measure and monitor electrochemical potentials in small areas. A great deal of technical literature is concerned with measurement of electrode kinetics as a function of statically or dynamically applied electrochemical potentials. On this basis, potential regions are established. These regions are bounded by so-called 'critical potentials' that govern where particular kinds of corrosion can occur. In conventional electrochemical techniques, potentials are measured on areas with a linear dimension of approximately 1 mm, while advanced techniques allow potential measurements on area with linear dimensions of 10 micro-meters, and considerably less in the most advanced techniques (about 30 nano-meters). This advancement permits an experimenter to monitor the potential distribution that would occur around a freshly initiated crack, crevice, pit, or other surface feature on a corroding metal surface. Conventional electochemical techniques will complement the microelectrode work.

2) use of advanced microanalytical techniques to measure and monitor the concomitant environmental chemical concentration gradients along with the electrochemical potential gradients existing in a crack, crevice, pit or other surface feature on a corroding metal surface. Such techniques involve selective ion probes or intense light sources.

3) use of advanc. microscopic techniques to inves..igate changes occurring in the metal or alloy. These techniques include advancements in scanning and transmission electron microscopy to examine and analyze very small precipitates, transformation products, or other microstructural features of interest. With the latest "state of the art" microscopes, resolution to 10 Angstroms (and lower) is possible. Resolution of these small particles is important in establishing credibility of metallurgical models (e.g. sensitization in stainless steels; martensitic transformations in stainless steel and possibly aluminum bronze) proposed for predicting changes in the container material with time.

4) use of advanced surface and analytical techniques to investigate the chemical and structural composition of protective films and layers on corroding metal surfaces. From this information, the kinetics of film formation and re-formation when broken can be determined. Of possible interest are advancements in scanning tunneling electron microscopy to examine in situ surfaces exposed to aqueous environments, and spectroscopic ellipsometric techniques to investigate in situ the structure and growth kinetics of passive films. More conventional in vacuo techniques, e.g. Auger electron spectroscopy and ESCA techniques, will be used to supplement the in situ techniques, as needed.

The intent in developing the above techniques is to allow examination of grain boundaries, arrays of dislocations, sub-critical size precipitates, local anodes and cathodes, and other fundamental factors in elucidating the mechanisms for corrosion and other degradation modes. These advanced techniques are to be used in conjunction with more established and conventional corrosion test methods (as discussed in the next section)

3.4.2 Parametric studies of metal degradation and microstructure (E-20-18)

The work in this activity will be QA level III experiments to provide specific corrosion data needed throughout the model development phase, and to act as input to the selection process. Those studies to be used in the selection process are needed in the near term (FY 87-88). Some of these are currently planned and should begin soon. Examples of these near term studies include:

Identification of the sensitization rate-determining step in austenitic stainless steel at low temperatures (Cr diffusion within grains, Cr diffusion along dislocations, rate of carbide formation, etc.) and develop a means to show this microscopically.

Determine the lowest critical chloride ion concentration (lowest critical potential) that will cause 1) pitting, 2) crevice, 3) transgranular SCC in the three austenitic alloys and develop means to demonstrate this.

Verification that a high radiation field will not cause a high oxidation or general corrosion rate, or onset of SCC by ammonia formation, in copper-base materials.

A substantial am t of previous work has been do by the NNWSI Project on experiments to examine these issues in relevant environments. A variety of experiments were conducted at Lawrence Livermore National Laboratory from 1982 to 1986. Additional experimental work was conducted at several contractor sites (Pacific Northwest Laboratory, Westinghouse Hanford Co., Ohio State University, San Diego State University, University of Minnesota, and the University of Florida). These are described in a general way in the Site Characterization Plan (Section 7.4.2) and some of the reports from these experimental activities are cited in Section 7.0 of this SIP. Several additional reports are in preparation. These reports will serve as input to the 'Degradation mode surveys' of activity E-20-13.

The candidate materials in the NNWSI Project are regarded as corrosion resistant materials, as opposed to corrosion allowance materials. This means that the oxidation and general corrosion rates for the candidate materials in all the anticipated environments (and in many of the credible, although unanticipated, environments) during the containment and isolation periods are sufficiently low that perforation of the container wall in the time periods of concern by these mechanisms is very improbable. However, these modes will occur continuously from the time of emplacement, and they are of interest in establishing the background conditions (including the characterization of protective films and their change with time) for the metal surface.

The more serious concerns for container failure during the time periods of interest are the other corrosion modes listed above as well as metallurgical aging and transformation reactions leading to structures that are brittle or more subject to localized corrosion and stress corrosion modes. Many of the advanced techniques listed in the previous section are planned to be used for the purpose of investigating under what conditions these corrosion modes are initiated and propagated. The bulk of this activity is analysis of the rates of initiation and propagation, as they apply to the environmental conditions (including temperature and radiation fields) and the population of containers (including their fabrication history and mechanical stress distribution). These conditions will not be uniformly distributed on the surface of a given container and will vary among the population of emplaced containers in the repository. Localized corrosion, stress corrosion, and hydrogen embrittlement have important statistical components, related to the distribution of environmental, metallurgical, and strain conditions from point to point, and the manifestation of these is a distribution in the rate of attack by these modes.

As discussed und activity E-20-16 'Development c models for degradation modes, mechanical properties, and microstructure', the fundamental "tie line" between the different degradation modes is the relationship between critical potentials for the initiation and propagation steps of the different modes of localized and stress corrosion and the electrochemical corrosion potential. Measurement of the corrosion potential and the various critical potentials is the key link between the modeling and performance activities. This means that, for example, a series of pre-cracked stress corrosion cracking tests will be conducted on a suitable fracture mechanics-type of specimen at different applied potentials in a given set of otherwise constant environment conditions. The crack propagation rate will then be measured as a function of time and applied potential. The critical potential for initiation of measurable crack growth is then determined. Other pieces of information, such as the crack propagation rate, the crystallographic path, continuity or discontinuity of the propagation, and tendency toward crack branching, will be used eventually to estimate the time-to-failure of a container. Several metallurgical parameters can be introduced into the test series to indicate the effects of key microstructural parameters such as degree of sensitization (stainless steels) or aluminum segregation (aluminum bronze) on the crack propagation rate and critical potential. The effect of mechanical factors such as stress intensity and size of the plastic zone on crack propagation and critical potential can also be obtained from the same series of experiments. Thus, a single set of experiments (with parameters well chosen and with a high degree of sensitivity to crack growth measurements) can yield an impressive amount of information that can be used to predict failure rates. Also, all three of the basic factors (susceptible microstructure, aggressive environment, critical stress) needed in determining stress corrosion susceptibility will be present in the test series.

3.4.3 Development of plans for license application support tests (E-20-22)

The purpose of this activity is to produce the test plans for the long term tests of metal barrier performance. After the selection process has chosen one (or two) metal alloys for advanced work, tests will be required to determine the behavior of that metal in a variety of environments. The plans for those tests must be sufficient to provide the data needed to model the performance of the metal barrier. These plans will be developed by NNWSI personnel and contractors as a QA level I task.

Detailed preparation of these plans will not be possible until activities E-20-13 and E-20-19, that serve as input to the plans, are complete, and results are available from the early portions of E-20-17 and E-20-18. Some examples of tests that <u>might</u> follow are sensitive weight loss coupon tests, crevice tests (with controlled crevice gap sizes), and constant load stress corrosion tests (on both smooth and pre-cracked specimens). In several cases, these will be designed as "null tests", where the prediction is that no measurable effect should occur. The credibility of the null tests is established on the sensitivity of the measurement and the time over which the tests are conducted. It is impossible to demonstrate long-term predictions on null tests <u>alone</u>, but null tests conducted in accordance with a credible model that predicts no effect should add substance to the demonstration.

3.4.4 License app' ation support tests (E-20-23)

This activity is the QA level I performance testing of the selected metal barrier. After the candidate alloys have been found to meet minimum performance requirements and have been ranked against one another, one (or two) alloy(s) will become the selected metal barrier material(s) for advanced design work (see activity E-20-19). The job of this investigation beyond that point is to concentrate on this selected alloy to produce a validated model for its long term performance in the Yucca Mountain environment and to produce the data required by the model to predict that performance. Data required for the model to support the license application is the product of this activity. The previous activity (E-20-22) describes the preparation of the plans for these tests. Details of the tests will not be available until completion of the plans. Note that data used specifically for the model validation (activity E-20-25) will be produced in activity E-20-25.

Until completion of the metal barrier selection process, the description and goals of these tests cannot be finalized. It is expected that the tests will include both anticipated repository service environment and material conditions which should yield null results for material degradation, and more aggressive conditions which should yield a result predictable by the performance model. Material conditions include simulated or actual weld microstructures, as well as representative base metal conditions.

Examples of types of tests which <u>might</u> be selected are:

> weight loss coupon tests (general aqueous corrosion and oxidation, also indicates pitting and other localized attack), crevice cell corrosion tests, slow strain rate tests (stress corrosion cracking), constant load stress corrosion tests, constant deformation stress corrosion tests (C-rings, U-bends, bent beam), fracture mechanics tests (stress corrosion and hydrogen embrittlement), electrochemical polarization tests (general and localized corrosion), various stress corrosion tests at constant applied potentials, localized and stress corrosion tests in irradiated environments, "scratch" potential or other tests to indicate the mechanical and electrochemical breakdown of passive films, straining electrode tests (film rupture and repassivation kinetics in analysis of localized and stress corrosion analyses), hydrogen permeation tests, double cantilever beam tests (hydrogen embrittlement and stress corrosion cracking susceptibility), corrosion tests using AC impedance techniques (general corrosion for determining passive film characteristics), multiple sample techniques using stochastic analysis (probability for localized corrosion), scanning electrode imaging (localized pH and other chemical changes in sequestered regions), analysis of electrochemical noise (pitting frequency), in situ Raman spectroscopy (speciation in passive films particularly on copper-base alloys to show selective leaching), low-angle X-ray (oxidation films), stress wave emission (discontinuity of stress corrosion crack propagation), ion chromatography (determination of anions and cations in solution), and band gap measurements (identify film species).

Other possible techniques of an advanced nature are discussed under activity E-20-17.

3.5 Design Properties of Metal Barrier

3.5.1 Coordination with package design (E-20-14)

This activity is the interaction and information interface between the metal barrier task and the package design task. The purpose of this activity is to provide an ongoing analysis of the interaction between the decisions and information gained by the Metal Barrier Selection and Testing task and the Waste Package Design task. There are many potential impacts, both beneficial and adverse, that these two tasks could have on each other. The Metal Barrier Selection and Testing Task interfaces with several other tasks (as indicated in Figure 1); these interfaces are handled by communication between the affected Task Leaders. However, the interface with the Design, Fabrication, and Prototype Testing Task is regarded as the most important one, and therefore warrants a special activity.

Some examples of these Metal Barrier-Design interactions include the criteria of 'fabricability' and 'weldability' for the container material selection. In many cases, small changes in the alloy composition (particularly in micro-constituents) play an important role in determining the weldability of different candidate materials and may influence (and improve) the corrosion performance of the material. The metallurgical and microstructural features of the weld are important parameters in selecting a technique for non-destructive evaluation of the weld. The choice of the methods used for fabricating and for welding the metal container (or other closure method) are important considerations in evaluating the performance of the container material, because of the close relationship between composition (and its variations in the welded region and heat affected zone), microstructure, residual stress, and the susceptibility to the forms of corrosion (localized corrosion, stress corrosion cracking) that are important in limiting the container integrity. Furthermore, the processes for fabricating and closing the container are viewed as having an important influence on metallurgical reactions (such as phase transformations and precipitation of carbides and other phases) in the metallurgically metastable candidate materials. Non-welded closure methods also have important implications in the corrosion performance of the closure region.

Handling and emplacement operations in the repository also need to be considered in establishing the long-term container performance, since these operations may impart some degree of surface defects and contamination on the container. Some aspects of the repository design work (not a responsibility of LLL, but closely monitored by the Waste Package Design Task) also influence the performance of the container. These include the emplacement geometry, areal power loading of containers, and the borehole liner configuration. Also, the choice of cements, grouts, or other materials to support the borehole liner need to be reviewed as to their effect (favorable or unfavorable) on the container material performance.

It is, therefore, the function of this activity to review all of the issues and activities of the two tasks, document their interaction, and insure communication of that interaction. Information will be gathered from the design task under this activity, sorted by QA Level and application, and passed on to other activities of this plan. No specific tests or analyses are planned for this activity.

3.5.2 Determinatic ›f mechanical and microstructur properties of metal (E-20-24)

This activity provides information about the mechanical and microstructural condition of the container material at the time of emplacement. After the container material and the fabrication and closure processes have been selected this activity will determine those material properties that affect the performance of the container, and in many cases set limitations on the acceptable range of those properties. This information will be used as input to the performance model and will also be used by the Package Design Task. The results of this activity may also form a set of specifications and tolerances for material production, fabrication, and closure.

The principal mechanical properties of interest are the following:

1. Yield strength.
2. Ultimate tensile strength.
3. Elongation (or other measure of ductility, such as reduction in area).
4. Modulus of elasticity.
5. Impact strength (or other measure of fracture toughness).

Knowledge of the effect of metal fabrication processing and inter-relationships between mechanical properties and microstructural properties is also required. This includes the effect of such factors as phase distribution, grain size, inclusion content, and previous plastic deformation. The effect of the strain rate on the mechanical properties is also needed. While individual mechanical properties are listed above, the entire stress-strain relationship merits attention in order to enable one to evaluate the toughness of the material when subjected either to low strain rate or to high strain rate processes during handling or that can later develop in the containment period.

Because the microstructure is intimately related to fabrication process variables and, in some cases, to relatively small compositional variations, this dependence will be documented. The microstructures of the fusion zone and heat-affected zones around the weld must also be characterized; characterization of these depends strongly on the welding process variables, and in some welding processes, on the composition of the filler materials. The microstructural features of importance include the following:

1. Primary phases present and their distribution.
2. Secondary phases and evidence of precipitation reactions.
3. Segregation effects.
4. Grain size and distribution of grain size.
5. Evidence of preferred orientation.
6. Identification and distribution of nonmetallic inclusions.

The time at elevated temperature (during the container fabrication and closure process) is influential in determining the above features.

4.0 Application of I ults

The activities of this investigation directly address Issue 1.4 of the Site Characterization Plan. The primary applications of the results will be: 1) to select a material(s) for advanced design work for use by the Waste Package Design Task, and 2) to provide a validated model (and data for use by the model) of that material's long-term behavior in the repository environment to the Performance Assessment Task. The secondary application of the results is to indicate what changes (if any) the presence of the metallic container produces on the package and repository environment. These changes would be incorporated into the EQ3/6 geochemical code and its subsequent use in establishing performance of other waste package components. The information, test results, and models obtained in this investigation will also be applied in several other ways:

1. To provide, along with a considerable amount of information supplied by the Design, Fabrication, and Prototype Testing Task, a description of the "as-emplaced" container for use in predicting repository performance.

2. To establish meaningful laboratory test conditions for activities discussed under the grouping 'Metal Barrier Performance Testing'. Results from these tests input into the models for the different degradation modes. These test conditions specify the environmental, metallurgical and strain conditions that govern the susceptibility to certain forms of localized corrosion, stress corrosion cracking, and hydrogen embrittlement (those forms of corrosion are expected to be most important in limiting the container lifetime in the time periods of concern in demonstrating containment and controlled release). For some of the candidate alloys, projections of microstructures that may develop over the long-term containment period are important because of either potential embrittlement problems or greater susceptibility to different corrosion modes. Analysis of the expected as-fabricated, as-welded (or otherwise assembled), as-emplaced structure serves as the basis for beginning these projections.

3. To form part of the basis for materials selection for final waste package designs, and to complete that selection. The selection process is discussed in activities E-20-15 and E-20-19. As discussed in section 3.2.2, it is anticipated that the performance under expected repository conditions, the predictability of the performance, and the fabricability of the material will be the paramount criteria, but considerations of mechanical and physical properties plus other practical considerations may be expected to play an important role in the selection process. An important part of the fabricability and weldability issues relates to whether or not unfavorable mechanical-microstructural features are produced in an otherwise resistant material.

4. To form a basis for establishing any additional specifications on the composition and mechanical properties of the candidate materials beyond the normal industry specifications.

5. To provide guidance in selecting the industrial processes for forming, joining, and handling the container. These results will further serve as input to information needs under Issues 2.1 (Options for retrievability), 2.6 (Preclosure design criteria) 4.3 (Waste package production technology), and 4.5 (Waste package costs).

7. To complete certain elements of the waste package design which are materials-dependent. Most waste package design features, at the conceptual level, are not sensitive to which material is eventually selected. At the advanced design stage, detail on the selected material and processes for producing and handling the container is needed. These results are input into Information Need 1.10.2.

8. To complete considerations in several repository design-related options. These include a decision on whether the containers are emplaced horizontally or vertically in the boreholes, and the use and configuration of borehole liner materials (currently it is suggested to use comparable materials for the container and borehole liner to eliminate any galvanic corrosion effects). Also, the emplacement and operational activities in the repository may be partly influenced by the container material selected, to insure that projections on its performance are not compromised.

9. To provide to the waste package environment task a description of the corrosion products that are expected to form in the near-package environment. These species may influence the performance of other waste package components and are of interest in assessing the modification to the natural environment caused by degradation of the waste package container.

5.0 Schedule and Mil :ones

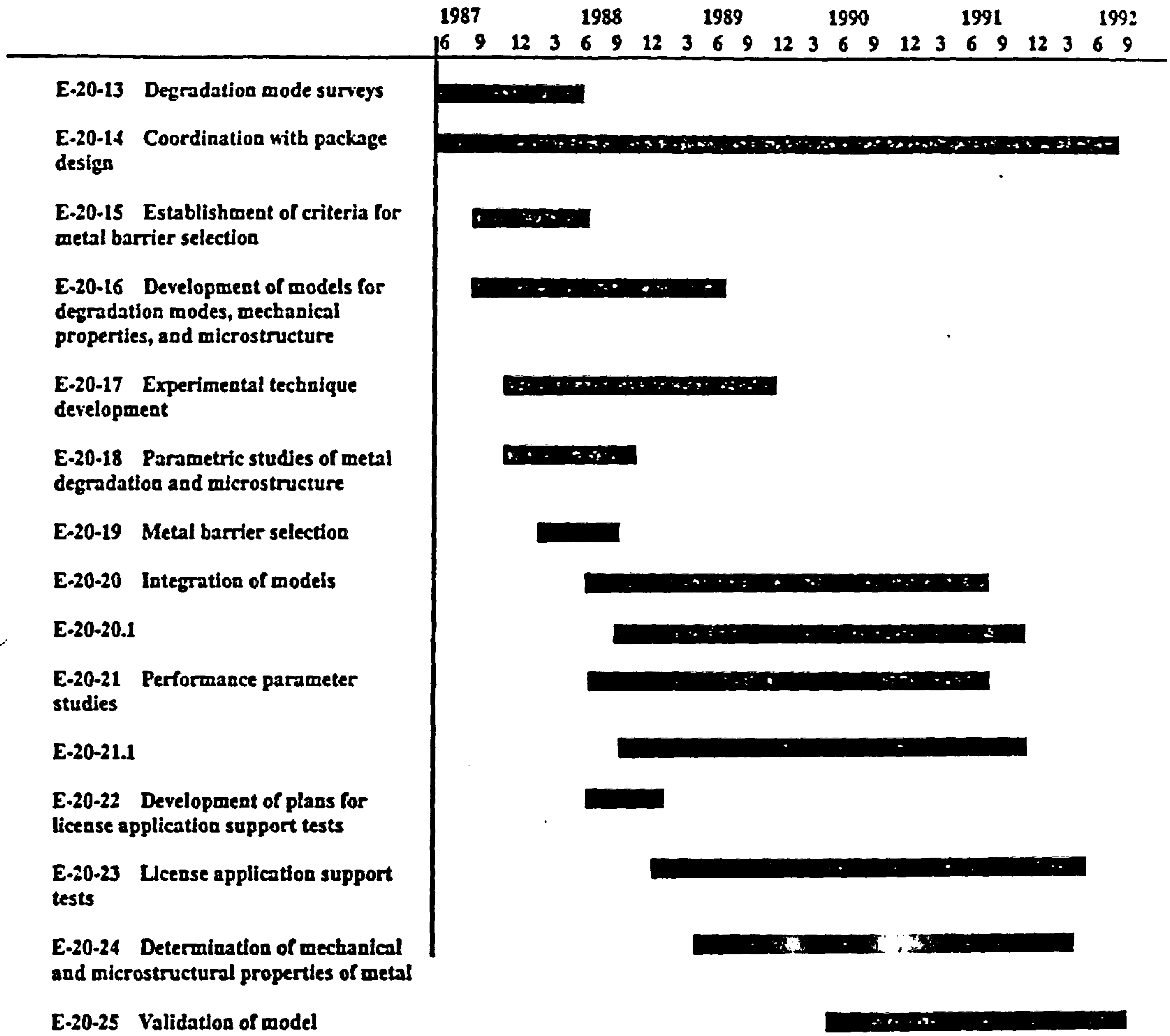
A schedule of the approximate start and completion dates for the thirteen different activities discussed in this SIP is given in Figure 2.

The milestones for the work in the Metal Barrier Selection and Testing WBS Element (1.2.2.3.2) are given in the table below with completion dates indicated.

Milestone number	Milestone level	Deliverable	Date
M265		Metal barrier material selected (E-20-19)	30 Sept 88
P259		Test plan for metal barrier license application data acquisition (E-20-22)	30 Jan 89
P260		Initiate license application testing program (E-20-23)	30 June 89
P261		Complete data acquisition to support draft EIS performance calculations (E-20-23)	30 June 92
P262		Provide input to waste package performance assessment task to support draft EIS (E-20-25)	30 Sept 92
P040		Final report on oxidation/corrosion performance of selected container material to support draft EIS	1 Oct 93
------ Continued work beyond the scope of this investigation plan ------			
P263		Develop test plans for long-term confirmatory testing	30 Mar 93

* Milestone listing and numbering is consistent with the reference case for FY-89 budget requests (March 1987).

Figure 2
Metal Barrier Selection and Testing Activity Time Line



6.0 List of Test Pl to Support this Scientific Inv :igation Plan

The following test and analysis plans will describe in detail the activities forming this investigation:

Metal barrier selection review plan	1/88
Metal barrier test plan (for selected material)	1/89
Metal barrier degradation model development and integration plan (for selected material)	3/89
Metal barrier performance model validation plan	1/90

The test plan and plan for model development and integration depend very much on which material is selected in 1988 for advanced design work. Plans for testing and modeling are centered around the appropriate and applicable degradation modes for the different candidates, so that it is not possible to give many details until the material selection is completed. However, it is envisioned that each of the plans listed above will be completed in stages, the initial stage being an umbrella plan that covers the broad aspects of the planned activities. This will be followed by more detailed plans for testing and modeling that will cover particular aspects, such as pitting corrosion, crevice corrosion, or stress corrosion.

7.0 History of Metal rrier Candidate List

The set of materials selected as candidates for waste package containers in the tuff repository has undergone some evolution over the course of the NNWSI project, and it is helpful to briefly review the history of candidate selection.

In late 1982 the NNWSI Project selected a repository horizon in the Topopah Spring member of the Paintbrush Tuff. This horizon lies in the unsaturated zone, well above the permanent water table. Initially, the NNWSI project selected AISI 304L stainless steel as its reference material and a relatively thin-walled design for its containers. A number of factors contributed to these choices. First of all, it was known that there would be no significant lithostatic or hydrostatic pressure on the containers if emplaced in tuff above the water table. Therefore, thick walls would not be necessary for the prevention of buckling, as is the case for most other proposed deep geologic sites. This situation seemed to lend itself to use of a thin, corrosion resistant material rather than a thicker, corrosion allowance material. Secondly, the Defense Waste Processing Facility at Savannah River had already selected AISI 304L stainless steel as the reference material for borosilicate glass pour canisters for its defense waste. It appeared likely at that time (and has since been established as policy by the federal government) that defense waste and commercial waste would be emplaced in the same repository. NNWSI's initial proposal was thus to use the pour canisters as the metal barriers for defense waste, and to fabricate containers of the same material (AISI 304L stainless steel) for the spent fuel. Past experience with austenitic stainless steels in hot air and dry steam environments had been very satisfactory, and it appeared that this material would serve well in the unsaturated tuff environment at temperatures above the boiling point.

The process by which AISI 304L stainless steel was selected as the reference material also resulted in the selection of three other alternatives: AISI 321, AISI 316L, and Alloy 825. These were chosen for their increased resistance to particular types of corrosion, should this be found necessary after more detailed testing, particularly if extensive contact with an aqueous phase was found to be likely, or if the environment turned out to be more severe than anticipated.

This candidate selection process involved the comparison of 17 commercial alloys according to the criteria of mechanical properties, weldability, corrosion resistance, and cost. In the absence of enough detailed information to establish relative weights for these four criteria, all four were considered to be equally important. Using available corrosion data, which in some cases was rather sparse, the 17 candidates were ranked and resulted in the selection of the four austenitic alloys AISI 304L, 321, 316L, and alloy 825 for further consideration.

As the project proceeded it became clear that the AISI 304L stainless steel of the borosilicate glass pour canisters would have been subjected to a thermal history that might lead to sensitization of the material to intergranular stress corrosion cracking and that differential thermal expansion during cooling of the poured glass and the canister would put the canister walls into hoop tension, aggravating this situation. It was therefore decided to modify the waste package design for the glass waste forms to include an outer container surrounding the pour canister. The thermal history and the stress state in this container could be better controlled, so as to reduce the threat of intergranular stress corrosion cracking.

In 1984 at the request of OCRWM, NNWSI began to investigate the feasibility of using copper-base materials for waste package containers. After consultation with the Copper Development Association, Inc. and the International Copper Research Association, Inc., three copper-base materials were selected for further consideration: CDA 102 (oxygen-free copper), CDA 613 (aluminum bronze), and CDA 715 (70-30 copper-nickel). Copper-base materials appeared to offer several potential advantages. First of all, among the available engineering metals, copper alone is able to co-exist thermodynamically with water (under some conditions). The driving force for corrosion and oxidation is thus smaller for copper than for materials such as Fe-Cr-Ni alloys that depend on passive film formation for their corrosion resistance. Localized and stress-assisted forms of corrosion are thus generally less severe for copper-base materials. Evidence for survivability of copper materials can be seen in the existence of native copper deposits and in copper and bronze artifacts recovered from the ruins of earlier civilizations.

Another potential advantage of the copper-base candidates is the simpler microstructures compared to the austenitic materials. Unlike iron, copper has no phase transformations. Thus the phase stability of copper-base materials appears to be of a lesser concern than it is with the iron-base austenitic materials.

After it was decided to include copper-base materials as candidates for further consideration, it became necessary to reduce the number of the other candidates in order to bring the scope of the testing program within the range of available resources. It was decided to eliminate AISI 321 from further consideration because AISI 316L offers the same benefits as AISI 321, as well as additional ones, so that the range of qualities has been preserved within the austenitic family. This decision leads us to the present six candidates for the metal barrier: AISI 304L and 316L stainless steels, high-nickel austenitic alloy 825, oxygen-free copper CDA 102, 7% aluminum bronze CDA 613, and 70-30 copper-nickel CDA 715. Within this field of candidates we thus have materials based upon three different metals: iron, nickel (essentially), and copper. We have corrosion-resistant materials, and we also have one (CDA 102) that can be viewed in some respects as a corrosion allowance material (CDA 102 would likely be used with a greater wall thickness than the others, anyway, because of its lower strength).

8.0 Annotated Refere List

The content of this SIP complements material prepared for Chapter 7 (Section 7.4.2) and Chapter 8 (Issue 1.4 and Information Needs 1.4.1-1.4.5) of the SCP that are currently undergoing final review by the NNWSI Project Office and the DOE Office of Geological Repositories. The material in Chapter 7 reviewed the choice of candidate materials, preliminary analyses of degradation modes for the materials in the context of the Yucca Mountain repository environment, and the results of experimental activities (mostly corrosion testing activities). The Chapter 8 material covered the information flow to and from other waste package and repository task elements and outlined the work to be done in the next several years. The material in this SIP breaks down this work into discrete activities.

A reference list for some related publications by selected subject areas is given below. This is by no means an exhaustive source on the subject, but is given as a guide for further reading.

1. Materials Selection

The first paper gives the rationale used to select the first candidate materials (austenitic materials) for the NNWSI Project.

E. W. Russell, R. D. McCright and W. C. O'Neal, "Containment Barrier Metals for High-Level Waste Packages in a Tuff Repository", Lawrence-Livermore Laboratory Report UCRL 53449, October, 1983.

This work was followed up with additional explanation on corrosion considerations by:

R. D. McCright, H. Weiss, M. C. Juhas, and R. W. Logan, "Selection of Candidate Canister Materials for High-Level Nuclear Waste Containment in a Tuff Repository", Lawrence-Livermore Laboratory Report UCRL 89988, (November, 1983)

Further reading on principles in selecting stainless steels and nickel-base alloys is found in:

A. J. Sedriks, Corrosion of Stainless Steels, Chapter 2, John Wiley and Sons, New York (1979)

Copper-base materials were added as candidate materials to the NNWSI Project, and the rationale for their addition was discussed in:

R. D. McCright, "FY-85 Status Report on Feasibility Assessment of Copper-Base Waste Package Container Materials in a Tuff Repository", Lawrence-Livermore Laboratory Report UCID 20509, (September, 1985)

A very informative discussion of many engineering materials and their potential application as nuclear waste containers is found in:

K. Nuttall and V. F. Urbanic, "An Assessment of Materials for Nuclear Fuel Immobilization Containers", Atomic Energy of Canada, Ltd., report AECL-6440, (September, 1981)

2. Degradation Modes

Several good texts exist that discuss corrosion modes and causative factors. The ones that we most frequently refer to are:

M. G. Fontana and N. D. Greene, Corrosion Engineering, 2nd edition, McGraw-Hill, New York (1977). A new edition of this is due to be published this year.

L. L. Shreir (editor), Corrosion, Newnes-Buttersworth, London and Boston (1976). This is in many ways, the text on the subject and is very complete in its treatment of the phenomenology and preventive measures. It is a thick two-volume set; volume 1 is on metal/environment reactions and is the one most applicable to the present work.

An older text, but one which is chock full of information and contains lots of engineering data (most newer texts concentrate more on explaining mechanisms), is:

F. L. LaQue and H. R. Copson, Corrosion Resistance of Metals and Alloys, 2nd edition, Reinhold Publishing Co., New York, (1963)

3. Corrosion Test Results

Some reports from NNWSI-sponsored work that have been used in establishing preliminary analyses on important degradation modes are:

M. C. Juhas, R. D. McCright, and R. E. Garrison, "Corrosion Behavior of Stressed and Unstressed 304L Specimens in Tuff Repository Environmental Conditions", Lawrence-Livermore laboratory Report UCRL 91804, (November, 1984)

R. S. Glass, G. E. Overturf, R. A. Van Konynenburg, and R. D. McCright, "Gamma Radiation Effects on Corrosion: Electrochemical Mechanisms for the Aqueous Corrosion Processes of Austenitic Stainless Steels", Corrosion Science, vol. 26, p. 577 (August, 1986)

C. F. Acton and R. D. McCright, "Feasibility Assessment of Copper-Base Waste Package Container Materials in a Tuff Repository", Lawrence-Livermore Laboratory Report UCID 20847 (September, 1986)

R. E. Westerman, S. G. Pitman, and J. H. Haberman, "Corrosion Testing of Type 304L Stainless Steel in Tuff Groundwater Environments", Pacific Northwest Laboratory Report PNL-5829 (March, 1987) (in review)

The authoritative source on corrosion test methods is:

W.H. Ailor, Handbook on Corrosion Testing and Evaluation, John Wiley and Sons, New York, (1971).

4. Modeling Activities

The model of sensitization of stainless steel is discussed in:

T. A. Mozhi, W. A. T. Clark, K. Nishimoto, W. B. Johnson, and D. D. Macdonald, "The Effect of Nitrogen on the Sensitization of AISI 304 Stainless Steel", Corrosion, vol. 41, p.555 (October, 1985)

T. A. Mozhi, H. S. Betrabet, V. Jagannathan, B. E. Wilde, and W. A. T. Clark, "Thermodynamic Modeling of Sensitization of AISI 304 Stainless Steel Containing Nitrogen", Scripta Metallurgical, vol. 20, p. 723, (May 1986)

The model of corrosion potentials is discussed in:

M. Urquidi-Macdonald, D. D. Macdonald, and S. Lenhart, "Mathematical Models for the Redox Potential and Corrosion Potentials for High-Level Nuclear Waste Canisters in Tuff Environments", SRI Report PYD-8292 (February, 1987) (in review)

Appendix A

Quality assurance level assignment sheets.

- Level of quality assurance assignment approval sheets
- Checklists for assigning quality assurance levels
- NWMP Quality assurance element assignments

LEVEL OF QUAL.(Y ASSURANCE LEVEL ASSIGNMENT ~ PROVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Ramspott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Degradation Mode Surveys

S.I.P. Identification:

E-20-13

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87
~~Technical Area Leader~~ Task Leader — Date

R. Schwartz / for J. Dronkers 6/22/87
NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87
NWMP Project Leader — Date

L. Ramspott 6/20/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Spencer 10/3/87
Project Sponsor — Date

James Blaylock 10/30/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIS FOR ASSIGNING QUALITY ASSURANC EVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes	I
2.	Does the item or activity involve waste isolation? (No)	Yes	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Degradation Mode Surveys

ACTIVITY NO.: E-20-13
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____III____

CITE "YES" ITEM ON LOGIC DIAGRAM ________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN 3A CONTROL 3B	yes no	033-NWMP-R 3.0 part A good professional practices apply
4.0 PROC. DOC. CONTROL	yes	033-NWMP-P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS	no	good professional practices apply
7.0 CTL OF PUR MATERIALS	yes	033-NWMP-P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS	no	good professional practices apply
9.0 CONTROL OF PROCESSES	no	good professional practices apply
10.0 INSPECTION	no	" " " "
11.0 TEST CONTROL	no	" " " "
12.0 CTL OF M & T EQUIP	no	" " " "
13.0 HANDLING, STOR. & SHIP.	no	" " " "
14.0 INSP. TEST & OPER. STAT.	no	" " " "
19.0 SOFTWARE QA	no	" " " "

FIGURE 20.0.2

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: June 12, 1987 .

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Co-ordination with Package Design

S.I.P. Identification:

E-20-14

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87 — ~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Dankers 6/22/87 — NWMP Deputy Program Leader for QA — Date

Jesse L. Yow, Jr. 6/19/87 — NWMP Project Leader — Date

L. Rampsott 6/20/87 — NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/3/87 — Project Sponsor — Date

James Blaylock 10/30/87 — Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIS[T F]OR ASSIGNING QUALITY ASSURANC[E L]EVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	No		
2.	Does the item or activity involve waste isolation?	Yes	I
	No		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	No		
4.	Is the intended purpose of this activity to provide data for a license application?	Yes	I
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Co-ordination with Package Design

ACTIVITY NO.: E-20-14
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ___III___

CITE "YES" ITEM ON LOGIC DIAGRAM ______________________

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP-R 3.0 part A
	3B	no	good professional practices apply
4.0 PROC. DOC. CONTROL		yes	033-NWMP-P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		no	good professional practices apply
7.0 CTL OF PUR MATERIALS		yes	033-NWMP-P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	good professional practices apply
9.0 CONTROL OF PROCESSES		no	" " " "
10.0 INSPECTION		no	" " " "
11.0 TEST CONTROL		no	" " " "
12.0 CTL OF M & T EQUIP		no	" " " "
13.0 HANDLING, STOR. & SHIP.		no	" " " "
14.0 INSP. TEST & OPER. STAT.		no	" " " "
19.0 SOFTWARE QA		no	" " " "

FIGURE 20.0.2

LEVEL OF QUAL ASSURANCE LEVEL ASSIGNMENT A OVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity: Establishment of Criteria for Metal Barrier Selection

S.I.P. Identification:

E-20-15

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87
~~Technical Area Leader~~ Date
Task Leader

R. Schwartz for J. Doukas 6/22/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/19/87
NWMP Project Leader Date

L. Ramspott 6/20/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Shaw 10/3/87
Project Sponsor Date

James Blaylock 10/30/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIS" FOR ASSIGNING QUALITY ASSURANC' 'EVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	(No)		
2.	Does the item or activity involve waste isolation?	Yes	I
	(No)		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	(No)		
4.	Is the intended purpose of this activity to provide data for a license application?	(Yes)	(I)
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

ACTIVITY: Establishment of Criteria for Metal Barrier Selection

ACTIVITY NO.: E-20-15
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work involved
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	this is a paper study
9.0 CONTROL OF PROCESSES		no	this is a paper study
10.0 INSPECTION		no	this is a paper study
11.0 TEST CONTROL		no	this is a paper study
12.0 CTL OF M & T EQUIP		no	this is a paper study
13.0 HANDLING, STOR. & SHIP.		no	this is a paper study
14.0 INSP. TEST & OPER. STAT.		no	this is a paper study
19.0 SOFTWARE QA		no	this is a paper study

FIGURE 20.0.2

LEVEL OF QUAL. ASSURANCE LEVEL ASSIGNMENT A OVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCri

Name(s) and Number(s) of Activity: Development of Models for Degradation Modes, Mechanical Properties, and Microstructures

S.I.P. Identification:

E-20-16

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87
~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Dankers 6/22/8
NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87
NWMP Project Leader — Date

L. Ramspott 6/20/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Skous 11/3/87
Project Sponsor — Date

James Blaylock 10/30/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKL' FOR ASSIGNING QUALITY ASSURA' LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes	I
2.	Does the item or activity involve waste isolation? (No)	Yes	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMF JALITY ASSURANCE ELEMENT ASSIG .NT

ACTIVITY: Development of Models for Degradation Modes, Mechanical Properties, and Microstructures
ACTIVITY NO.: E-20-16
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work- good professional practi apply.
4.0 PROC. DOC. CONTROL		yes	033-NWMP P-4.0 Rev 0
5.0 INSTR., PROCS, DWGS		no	good professional practices apply
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P-7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	good professional practices apply
9.0 CONTROL OF PROCESSES		no	" " " "
10.0 INSPECTION		no	" " " "
11.0 TEST CONTROL		no	" " " "
12.0 CTL OF M & T EQUIP		no	" " " "
13.0 HANDLING, STOR. & SHIP.		no	" " " "
14.0 INSP. TEST & OPER. STAT.		no	" " " "
19.0 SOFTWARE QA		no	" " " "

FIGURE 20.0.2

LEVEL OF QUAL' ASSURANCE LEVEL ASSIGNMENT AF JVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Experimental Technique Development

S.I.P. Identification:
E-20-17

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87
~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Drakers 6/22/87
NWMP Deputy Program Leader for QA — Date

Jesse L Yow Jr. 6/19/89
NWMP Project Leader — Date

L. Ramspott 6/20/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester [illegible] 11/3/87
Project Sponsor — Date

James Blaylock 10/30/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIST R ASSIGNING QUALITY ASSURANCE VELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes / No	I
2.	Does the item or activity involve waste isolation? Yes / No	I
3.	Does the item or activity involve or affect retrievability? Yes / No	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes / No	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Experimental Technique Development

ACTIVITY NO.: E-20-17
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____III____

CITE "YES" ITEM ON LOGIC DIAGRAM ________

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work- good professional practi apply
4.0 PROC. DOC. CONTROL		yes	033-NWMP P-4.0 Rev 0
5.0 INSTR., PROCS, DWGS		no	good professional practices apply
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P-7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	good professional practices apply
9.0 CONTROL OF PROCESSES		no	" " " "
10.0 INSPECTION		no	" " " "
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0 "
12.0 CTL OF M & T EQUIP		no	good professional practices apply
13.0 HANDLING, STOR. & SHIP.		no	" " " "
14.0 INSP. TEST & OPER. STAT.		no	" " " "
19.0 SOFTWARE QA		no	" " " "

FIGURE 20.0.2

LEVEL OF QUAL ASSURANCE LEVEL ASSIGNMENT A OVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCri

Name(s) and Number(s) of Activity:

Parametric Studies of Metal Degradation and Microstructure

S.I.P. Identification:

E-20-18

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87 — ~~Technical Area Leader~~ Task Leader — Date

Robert E. Schwartz for J. Dinkes 6/29 — NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87 — NWMP Project Leader — Date

L. Ramspott 6/20/87 — NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester [illegible] 11/3/87 — Project Sponsor — Date

James Blaylock 10/30/87 — Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIS OR ASSIGNING QUALITY ASSURANC EVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes	I
2.	Does the item or activity involve waste isolation? (No)	Yes	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Parametric Studies of Metal Degradation and Microstructure

ACTIVITY NO.: E-20-18
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ____

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work- good professional pract apply
4.0 PROC. DOC. CONTROL		yes	033-NWMP P-4.0 Rev 0
5.0 INSTR., PROCS, DWGS		no	good professional practices apply
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P-7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	good professional practices apply
9.0 CONTROL OF PROCESSES		no	" " " "
10.0 INSPECTION		no	" " " "
11.0 TEST CONTROL		yes	033-NWMP R11.0 Rev 0
12.0 CTL OF M & T EQUIP		no	good professional practices apply
13.0 HANDLING, STOR. & SHIP.		no	" " " "
14.0 INSP. TEST & OPER. STAT.		no	" " " "
19.0 SOFTWARE QA		no	" " " "

FIGURE 20.0.2

LEVEL OF QUAL ASSURANCE LEVEL ASSIGNMENT A OVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:
Metal Barrier Selection

S.I.P. Identification:
E-20-19

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87
~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Donkers 6/22/87
NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87
NWMP Project Leader — Date

L. Ramspott 6/20/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/3/87
Project Sponsor — Date

James B. Laybock 10/30/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLI FOR ASSIGNING QUALITY ASSURA LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes / No (circled)	I
2.	Does the item or activity involve waste isolation? Yes / No (circled)	I
3.	Does the item or activity involve or affect retrievability? Yes / No (circled)	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes (circled) / No	I (circled)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

ACTIVITY: Metal Barrier Selection

ACTIVITY NO.: E-20-19

DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work involved
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	this is a paper study
9.0 CONTROL OF PROCESSES		no	this is a paper study
10.0 INSPECTION		no	this is a paper study
11.0 TEST CONTROL		no	this is a paper study
12.0 CTL OF M & T EQUIP		no	this is a paper study
13.0 HANDLING, STOR. & SHIP.		no	this is a paper study
14.0 INSP. TEST & OPER. STAT.		no	this is a paper study
19.0 SOFTWARE QA		no	this is a paper study

FIGURE 20.0.2

LEVEL OF QUALI.. ASSURANCE LEVEL ASSIGNMENT AP..OVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Integration of Models for Selected Material

S.I.P. Identification:

E-20-20

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87 — ~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Dankes 6/22/87 — NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87 — NWMP Project Leader — Date

L. Ramspott 6/20/87 — NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Luke P. Skinner 11/3/87 — Project Sponsor — Date

James Blaylock 10/30/87 — Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIS' 'OR ASSIGNING QUALITY ASSURANC' EVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes / No	I
2.	Does the item or activity involve waste isolation? Yes / No	I
3.	Does the item or activity involve or affect retrievability? Yes / No	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes / No	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NW. QUALITY ASSURANCE ELEMENT ASSI ENT

ACTIVITY: Integration of Models for Selected Material

ACTIVITY NO.: E-20-20

DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A 3B	yes no	033-NWMP R 3.0 part A no design work- good professional prac apply
4.0 PROC. DOC. CONTROL		yes	033-NWMP P-4.0 Rev 0
5.0 INSTR., PROCS, DWGS		no	good professional practices apply
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P-7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	good professional practices apply
9.0 CONTROL OF PROCESSES		no	" " " "
10.0 INSPECTION		no	" " " "
11.0 TEST CONTROL		no	" " " "
12.0 CTL OF M & T EQUIP		no	" " " "
13.0 HANDLING, STOR. & SHIP.		no	" " " "
14.0 INSP. TEST & OPER. STAT.		no	" " " "
19.0 SOFTWARE QA		no	" " " "

FIGURE 20.0.2

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Integration of Models for Selected Material (Level I)
S.I.P. Identification:

E-20-20.1

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 9/14/87
~~Technical Area Leader~~ Task Leader / Date

R. Schwartz for 10/20/87
NWMP Deputy Program Leader for QA / Date

L. Ramspott 10-22-87
NWMP Project Leader / Date

L. Ramspott 10-22-87
NWMP Leader / Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

[signature] 11/3/87
Project Sponsor / Date

James Blaylock 10/30/87
Project Sponsor Quality Manager / Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3
A-20.1-1

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	No		
2.	Does the item or activity involve waste isolation?	Yes	I
	No		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	No		
4.	Is the intended purpose of this activity to provide data for a license application?	Yes	I
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Integration of Models for Selected Material (Level I)

ACTIVITY NO.: E-20-20.1
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ____I____

CITE "YES" ITEM ON LOGIC DIAGRAM ____4____

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		yes	033-NWMP R 8.0 Rev 0
9.0 CONTROL OF PROCESSES		yes	033-NWMP R 9.0 Rev 0
10.0 INSPECTION		no	no inspections of hardware
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0
12.0 CTL OF M & T EQUIP		yes	033-NWMP R 12.0 Rev 0
13.0 HANDLING, STOR. & SHIP.		yes	033-NWMP R 13.0 Rev 0
14.0 INSP. TEST & OPER. STAT.		yes	033-NWMP R 14.0 Rev 0
19.0 SOFTWARE QA		no	no software development expected

FIGURE 20.0.2

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Performance Parameter Studies (Level III)

S.I.P. Identification:

E-20-21

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87 — ~~Technical Area Leader~~ Task Leader, Date

R. Schwartz for J. Dankers 6/22/87 — NWMP Deputy Program Leader for QA, Date

Jesse L. Yow Jr. 6/19/87 — NWMP Project Leader, Date

L. Rampsott 6/20/87 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Skousen 11/3/87 — Project Sponsor, Date

James Blaylock 10/30/87 — Project Sponsor Quality Manager, Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIS˙ OR ASSIGNING QUALITY ASSURANC EVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? No	Yes	I
2.	Does the item or activity involve waste isolation? No	Yes	I
3.	Does the item or activity involve or affect retrievability? No	Yes	I
4.	Is the intended purpose of this activity to provide data for a license application? No	Yes	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Performance Parameter Studies (Level III)

ACTIVITY NO.: E-20-21
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA ___III___

CITE "YES" ITEM ON LOGIC DIAGRAM ____________

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work- good professional pra apply
4.0 PROC. DOC. CONTROL		yes	033-NWMP P-4.0 Rev 0
5.0 INSTR., PROCS, DWGS		no	good professional practices apply
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P-7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	good professional practices apply
9.0 CONTROL OF PROCESSES		no	" " " "
10.0 INSPECTION		no	" " " "
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0 "
12.0 CTL OF M & T EQUIP		no	good professional practices apply " " " "
13.0 HANDLING, STOR. & SHIP.		no	" " " "
14.0 INSP. TEST & OPER. STAT.		no	" " " "
19.0 SOFTWARE QA		no	" " " "

FIGURE 20.0.2

LEVEL OF QUAL ASSURANCE LEVEL ASSIGNMENT A JVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Performance Parameter Studies (Level I)

S.I.P. Identification:

E-20-21.1

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87 ~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Dankers 6/22/87 NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87 NWMP Project Leader — Date

L. Rampsott 6/20/87 NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/3/87 Project Sponsor — Date

James Blaylock 10/30/87 Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	No (circled)		
2.	Does the item or activity involve waste isolation?	Yes	I
	No (circled)		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	No (circled)		
4.	Is the intended purpose of this activity to provide data for a license application?	Yes (circled)	I (circled)
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Performance Parameter Studies (Level I)

ACTIVITY NO.: E-20-21.1
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		yes	033-NWMP R 8.0 Rev 0
9.0 CONTROL OF PROCESSES		yes	033-NWMP R 9.0 Rev 0
10.0 INSPECTION		no	no inspections of hardware
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0
12.0 CTL OF M & T EQUIP		yes	033-NWMP R 12.0 Rev 0
13.0 HANDLING, STOR. & SHIP.		yes	033-NWMP R 13.0 Rev 0
14.0 INSP. TEST & OPER. STAT.		yes	033-NWMP R 14.0 Rev 0
19.0 SOFTWARE QA		no	no software development expected

FIGURE 20.0.2

LEVEL OF QUAL ASSURANCE LEVEL ASSIGNMENT A OVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Development of Plans for License Application Support Tests

S.I.P. Identification:

E-20-22

Additional Comments:

Level of Quality Assurance ______I______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87 — ~~Technical Area Leader~~ Task Leader, Date

R. Schwartz for J. Drakes 6/22/87 — NWMP Deputy Program Leader for QA, Date

Jesse L. Yow Jr. 6/19/87 — NWMP Project Leader, Date

L. Ramspott 6/20/87 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P Skinner 11/3/87 — Project Sponsor, Date

James Blaylock 10/30/87 — Project Sponsor Quality Manager, Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLI FOR ASSIGNING QUALITY ASSURAN LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	No (circled)		
2.	Does the item or activity involve waste isolation?	Yes	I
	No (circled)		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	No (circled)		
4.	Is the intended purpose of this activity to provide data for a license application?	Yes (circled)	I (circled)
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWM QUALITY ASSURANCE ELEMENT ASSI .ENT

ACTIVITY: Development of Plans for License Application Support Tests

ACTIVITY NO.: E-20-22
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work involved
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		no	this is a paper study
9.0 CONTROL OF PROCESSES		no	this is a paper study
10.0 INSPECTION		no	this is a paper study
11.0 TEST CONTROL		no	this is a paper study
12.0 CTL OF M & T EQUIP		no	this is a paper study
13.0 HANDLING, STOR. & SHIP.		no	this is a paper study
14.0 INSP. TEST & OPER. STAT.		no	this is a paper study
19.0 SOFTWARE QA		no	this is a paper study

FIGURE 20.0.2

LEVEL OF QUAL..Y ASSURANCE LEVEL ASSIGNMENT A. ROVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

License Application Support Tests

S.I.P. Identification:

E-20-23

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87
~~Technical Area Leader~~ Task leader — Date

R. Schwartz for J. Drakers 6/22/
NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87
NWMP Project Leader — Date

L. Rampsott 6/20/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Skinner 11/3/87
Project Sponsor — Date

James Blaylock 10/30/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLI FOR ASSIGNING QUALITY ASSURANC LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	No		
2.	Does the item or activity involve waste isolation?	Yes	I
	No		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	No		
4.	Is the intended purpose of this activity to provide data for a license application?	Yes	I
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NW QUALITY ASSURANCE ELEMENT ASS MENT

ACTIVITY: License Application Support Tests

ACTIVITY NO.: E-20-23
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		yes	033-NWMP R 8.0 Rev 0
9.0 CONTROL OF PROCESSES		yes	033-NWMP R 9.0 Rev 0
10.0 INSPECTION		no	no inspections of hardware
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0
12.0 CTL OF M & T EQUIP		yes	033-NWMP R 12.0 Rev 0
13.0 HANDLING, STOR. & SHIP.		yes	033-NWMP R 13.0 Rev 0
14.0 INSP. TEST & OPER. STAT.		yes	033-NWMP R 14.0 Rev 0
19.0 SOFTWARE QA		no	no software development expected

FIGURE 20.0.2

LEVEL OF QUAL? ASSURANCE LEVEL ASSIGNMENT AF)VAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Determination of Mechanical and Microstructural Properties of Metals
S.I.P. Identification:
E-20-24

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R Daniel McCright 6/19/87 — ~~Technical Area Leader~~ Task Leader — Date

R. Schwartz for J. Dankers 6/22/87 — NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87 — NWMP Project Leader — Date

L. Ramspott 6/20/87 — NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Ahlmer 11/3/87 — Project Sponsor — Date

James Blaylock 10/30/87 — Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes No	I
2.	Does the item or activity involve waste isolation? Yes No	I
3.	Does the item or activity involve or affect retrievability? Yes No	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes No	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes No	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

P ? QUALITY ASSURANCE ELEMENT AS SNMENT

ACTIVITY: Determination of Mechanical and Microstructural Properties of Metals

ACTIVITY NO.: E-20-24
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		yes	033-NWMP R 8.0 Rev 0
9.0 CONTROL OF PROCESSES		yes	033-NWMP R 9.0 Rev 0
10.0 INSPECTION		no	no inspections of hardware
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0
12.0 CTL OF M & T EQUIP		yes	033-NWMP R 12.0 Rev 0
13.0 HANDLING, STOR. & SHIP.		yes	033-NWMP R 13.0 Rev 0
14.0 INSP. TEST & OPER. STAT.		yes	033-NWMP R 14.0 Rev 0
19.0 SOFTWARE QA		no	no software development expected

FIGURE 20.0.2

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: June 12, 1987

Meeting Attendees: L. Rampsott, R. Schwartz, V. Oversby, W. Halsey, D. McCright

Name(s) and Number(s) of Activity:

Validation of Model

S.I.P. Identification:

E-20-25

Additional Comments:

Level of Quality Assurance I

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

R. Daniel McCright 6/19/87
~~Technical Area Leader~~ Task Leader — Date

R. Schwartz / for J. Dankers 6/22/8
NWMP Deputy Program Leader for QA — Date

Jesse L. Yow Jr. 6/19/87
NWMP Project Leader — Date

L. Rampsott 6/20/87
NWMP Leader — Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Spence 11/3/87
Project Sponsor — Date

James Blaylock 10/30/87
Project Sponsor Quality Manager — Date

RETURN TO LLNL NWMP QA FILE

FIGURE 20.0.3

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes	I
	(No)		
2.	Does the item or activity involve waste isolation?	Yes	I
	(No)		
3.	Does the item or activity involve or affect retrievability?	Yes	I
	(No)		
4.	Is the intended purpose of this activity to provide data for a license application?	(Yes)	(I)
	No		
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes	I
	No		
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes	I
	No		
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes	II
	No		
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes	II
	No		
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes	II
	No		
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes	II
	No		
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes	II
	No		

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

FIGURE 20.0.1

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Validation of Model

ACTIVITY NO.: E-20-25
DATE: June 12, 1987

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A	yes	033-NWMP R 3.0 part A
	3B	no	no design work
4.0 PROC. DOC. CONTROL		yes	033-NWMP P 4.0 Rev 0
5.0 INSTR., PROCS, DWGS		yes	033-NWMP P 5.0 Rev 0
7.0 CTL OF PUR MATERIALS		yes	033-NWMP P 7.0 Rev 0
8.0 I.D. & CTL OF MATERIALS		yes	033-NWMP R 8.0 Rev 0
9.0 CONTROL OF PROCESSES		yes	033-NWMP R 9.0 Rev 0
10.0 INSPECTION		no	no inspections of hardware
11.0 TEST CONTROL		yes	033-NWMP R 11.0 Rev 0
12.0 CTL OF M & T EQUIP		yes	033-NWMP R 12.0 Rev 0
13.0 HANDLING, STOR. & SHIP.		yes	033-NWMP R 13.0 Rev 0
14.0 INSP. TEST & OPER. STAT.		yes	033-NWMP R 14.0 Rev 0
19.0 SOFTWARE QA		no	no software development expected

FIGURE 23.0.2

NNA.871113.0029

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.2.3.4
(non EQ3/6 Data Base Portion)

Integrated Testing

Lawrence Livermore National Laboratory

Revision 0
Manuscript Date May 29, 1987

L. D. Ramspott, Technical Project Officer — Date 6/8/87

J. J. Dronkers, Deputy for Quality Assurance — Date 6-9-87

V. M. Oversby, Task Leader and Technical Area Leader — Date 6/4/87

R. Silva, Technical Reviewer — Date 6/4/87

Project Sponsor Quality Manager — Date 11/6/87

Project Sponsor — Date 11/6/87

SAIC/T&MSS

NOV 13 1987

CCF RECEIVED

Table of Contents

1.0 Purpose and Objectives

1.1 Regulatory Requirements

The purposes of the Integrated Testing Task (NNWSI WBS 1.2.2.3.4) are

(1) Develop laboratory data on thermodynamic properties for actinide and fission product elements for use in the EQ3/6 geochemical modelling code;

(2) Determine the transport properties of radionuclides in the near-field environment;

(3) Develop and validate a model to describe the rate of release of radionuclides from the near-field environment.

Activities to achieve item (1) have been described in the Scientific Investigation Plan for EQ3/6, where quality assurance levels were assigned to the activities. This Scientific Investigation Plan describes activities to achieve the second and third purposes. The information gathered in these activities will be used in the following ways:

(1) to assess compliance with the performance objective for the Engineered Barrier System (EBS) to control the rate of release of radionuclides if the repository license application includes part of the host rock in the EBS (10 CFR 60.113);

(2) to provide a source term for release of radionuclides from the waste package near-field environment to the system performance assessment task for use in showing compliance with the Environmental Protection Agency requirements contained in 40 CFR 191.13;

(3) to provide a source term for release of radionuclides from the waste package near-field environment to the system performance assessment task for use in doing calculations of cumulative releases of radionuclides from the repository over 100,000 years as required by the site evaluation process specified in 10 CFR 960.3-1-5.

The scientific investigations discussed herein are intended to address directly the following information needs taken from the Nevada Nuclear Waste Storage Investigation (NNWSI) Project Issues Hierarchy (version dated 8/07/86):

Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release as required by 10 CFR 60.113?

1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.

1.5.5 Determination of the amount of the (sic) radionucl s leaving the near-field environment of the waste package.

Through input to the above information needs, the results of the integrated testing activities will provide data to help resolve Issues 1.1, 1.5, and 1.9.

The structure of this integrated testing plan parallels the information needs listed above and the discussions in Chapter 8 of the NNWSI Project Site Characterization Plan (SCP) of the studies to be undertaken to provide information to resolve Issue 1.5. In summary, interactions between waste package components or between components and the environment will be evaluated (where the work is not already covered in another WBS element) and interactions between radionuclide-bearing solutions and the welded, devitrified Topopah Spring tuff (Tpt) will be studied. The results of these activities will be used to develop a source term model for radionuclide transport in the near-field environment. This model, when combined with the results of geochemical and fluid transport modelling, will provide a description of the release of radionculides from the near field environment. The model for radionuclide transport and the results of the geochemical modelling calculations will be validated under an activity described in this SIP; the fluid transport model will be validated under an activity described in the Performance Assessment SIP.

1.2 Integrated Testing Activities Grouped by SCP Study

Waste Package performance assessment model development (SCP Information Need 1.5.3, Investigation 1.5.3.5, Activity 1.5.3.5.3)

G-20-5 Interaction of materials under repository conditions

Determine Radionuclide Transport Parameters (SCP Information Need 1.5.5, Investigation 1.5.5.1, Activities 1.5.5.1.1 and 1.5.5.1.2)

G-20-2 Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope

G-20-3 Interaction of actinide bearing solutions with rock core samples

G-20-8 Planning and experimental design

Radionuclide Transport Modeling in the near-field waste package environment (SCP Information Need 1.5.5, Investigation 1.5.5.2, Activities 1.5.5.2.1 and 1.5.5.2.2)

G-20-6 Source term model development

G-20-7 Source term model validation

1.3 Information Flow

The goal of the integrated testing activities is to determine how the radionuclides that escape from breached waste packages interact with the repository rock and fluid system. Activity G-20-5 investigates interactions of materials with each other or with the environment if those interactions are not included in other waste package activities. New analytical methods and experimental designs are developed and evaluated under activity G-20-8. Information developed under Waste Package Environment, Container Material Testing, and Waste Form Testing will be combined in the source term model development activity (G-20-6) to provide the boundary conditions for source term calculations. This combination will give estimates of the volumes of fluids that might escape from breached waste packages and the concentrations of radionuclides in those fluids. Information gathered under activities G-20-2 and G-20-3 will provide parameters needed to describe the interaction of the radionuclide-bearing fluids with the repository rock and fluid system. The source term model developed under activity G-20-6 and validated under G-20-7 will be used in conjuction with fluid flow and transport models developed under the Performance Assessment task to provide estimates of the quantity of radionuclides that travel through the near field rock. A boundary will be selected within the near-field environment to serve as the transfer point for source term estimates from the waste package performance assessment models to the system performance assessment models.

2.0 Rationale for Selected Studies and Quality Assurance Level Assignments

2.1 Introduction

In this section, the technical rationale for the listed activities are given by type, corresponding to the three areas of study listed in section 1.2. A rationale for each activity is given. Quality assurance level assignment sheets for each activity are included in Section 8 of this document.

2.2 Waste Package Performance Assessment Model Development

The development of performance models for the waste forms, the container, and for the waste package environment are handled under the WBS elements for these entities. In some cases there is an interaction between two or more of these entities that does not logically fit into the work plan for a single area. These items are handled as part of integrated testing under activity G-20-5. This activity investigates the interactions among waste package, engineered barrier system, and waste package environment components. Interactions are investigated at QA level III; if the interactions are found to be significant in terms of waste package or engineered barrier system performance, QA level I activities will be planned. At present, the only interaction that has been identified for study under this activity is characterization of water flow through breaches in metals. The objective of the study will be to determine what fraction of water that drips onto a container und repository conditions, such as dripping from a fracture, would enter t container through a breach in the container.

Activity No.	Name	QA Level
G-20-5	Interaction of materials under repository conditions	III

2.3 Determine Radionuclide Transport Parameters

This study area consists of three activities. The first involves the investigation of diffusion of radionuclides into rock under static, water-saturated conditions. The second activity investigates the interaction of radionuclide-bearing solutions with core samples of rock under flowing conditions. The third activity covers the development and assessment of new analytical methods and the design of new experiments to investigate materials interactions. The last activity includes the assessment of natural analog systems.

The experiments that are done under glass waste form testing to investigate geochemical interactions and radiation effects sometimes contain wafers of Topopah Spring tuff rock. As the glass waste form dissolves, radionuclides are released into the solution. These dissolved, or possibly colloidal, radionuclides can then diffuse into

the rock and migrate through the rock. Activity G-20-2 uses the CAMECA ion microscope to determine the distribution of radionuclides in the rock at the end of the waste form tests. All of the waste form tests that form the basis for G-20-2 studies have been conducted at QA level III; therefore, G-20-2 has been assigned QA level III. Should any waste form tests conducted at QA level I contain rock or mineral samples that require analysis, a new activity would be undertaken at QA level I.

In the repository setting, the interaction of radionuclides with the host rock will generally occur under conditions of fluid flow. The distribution of radionuclides between fluid and solid phases might be affected by the fluid flow process and by whether the flow occurs under saturated or unsaturated conditions. Activity G-20-3 will develop methods to conduct experiments and tests of radionuclide transport using core samples of Topopah Spring tuff. Method development and initial applications will be done at QA level III. Once the methods are adequately developed, they will be applied to experiments and tests done under the laboratory hydrology study area (activities B-20-1 and B-20-2). The QA level assignment for work conducted under activity G-20-3 will then be the same as that for the hydrology study. It is probable that activities B-20-1 and B-20-2 will be at different levels for some time; thus, two level assignments are needed for this work. If the hydrology study is at QA level I, the radionuclide transport activity will be designated G-20-3.1

Advances in analytical methods in recent years have opened the way for studies that could not have been contemplated 5 to 10 years ago. The development of a two dimensional ion counting detector for the CAMECA ion microscope is an example of such a development. This detector, which is based on a resistive anode encoder, will allow us to map in three dimensions the distribution of actinides in samples of tuff. The resolution achievable is approximately 1 micrometer in each of two dimensions (the horizontal analytical plane) and less than 0.05 micrometers in the third dimension. To allow the NNWSI Project to benefit from this and future analytical developments, activity G-20-8 is included in the integrated testing task to evaluate analytical methods and experimental design.

Activity No.	Name	QA Level
G-20-2	Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope	III
G-20-3	Interactions of actinide-bearing solutions with rock core samples	III
G-20-3.1	QA Level I applications of activity G-20-3	I
G-20-8	Planning and experimental design	III

2.4 Radionuclide Transport Modeling in the near-field waste package environment

The information developed under the activities described above must be combined with data obtained as the results of studies conducted under the Waste Package Environment, Waste Form Testing, and Container Materials Testing tasks so that a model can be developed for the source term for radionuclide release from the repository near-field environment. This is the model that will be used to provide input to the repository system modeling task. Activity G-20-6 covers the accumulation of data from other tasks, integration of the data for input to the source term model, and development of the source term model. Model development will be done at QA level III. The model will then be validated for the range of conditions required by NNWSI performance assessment tasks by conducting tests at QA level I. Final model validation may be accomplished through a peer review process.

Activity No.	Name	QA Level
G-20-6	Source term model development	III
G-20-7	Source term model validation	I

3.0 Description of Tests and Analyses, and Previous Work

3.1 Introduction

Detailed plans for the activities covered by this Scientific Investigation Plan are given in sections 3.2 through 3.4. The relative timing for activities is given where it is relevant to the planning and the QA level assignments. Each section contains a summary of any work previously conducted as part of the NNWSI Integrated Testing WBS element related to the activities covered by the section. The discussion of previous work is not intended to cover work conducted under WBS elements other than Integrated Testing or work conducted outside the NNWSI Project. Such work will be cited only where it helps to identify issues to be addressed in the planned work for Integrated Testing activities. Test plans will be developed for the QA level I activities described in sections 3.3 and 3.4. If the preliminary investigations of fluid flow into breached containers provide results that indicate further study is warranted, a test plan will be developed for that activity. All expected use of computer codes is discussed in section 3.4.

A separate WBS element titled Integrated Testing was introduced into the WBS Dictionary for the NNWSI Project in FY 1985. Because of the timing of the introduction, no funding was provided to the new WBS element until FY 1986. Thus, the amount of previous work conducted under the Integrated Testing task has been rather limited.

The current schedule calls for the start of Exploratory Shaft construction in July, 1988. If the shaft construction is delayed, activities described in sections 3.3 and 3.4 that depend on the use of rock recovered during shaft construction or on interaction with activities conducted in the Exploratory Shaft test facility will be delayed.

3.2 Waste Package Performance Assessment Model Development

3.2.1 Interaction of materials under repository conditions (G-20-5)

The purpose of this activity is to investigate interactions between two or more engineered barrier system components that might have significant effects on the performance of the engineered barrier system. In some cases, interactions of this type were already included in the plans for other WBS elements at the time the Integrated Testing element was created. These interactions are frequently central to the performance of a system element, such as the effects of container materials on waste form performance. For this reason, it was considered more appropriate to leave the work on those interactions in the WBS element where the work was originally identified as needed. The Integrated Testing task, then, was reserved for the investigation of materials interactions that had not yet been identified as significant to performance by other WBS elements, but that might have a significant effect on the performance of the total engineered barrier system.

To date, only one interaction has been identified that might effect the performance of the engineered barrier system, but was not incluc in the work plans for a waste package WBS element. That interaction is the characterization of water flow through breaches in the metal container. The capillary barrier of the unsaturated zone will normally prevent liquid water from contacting the waste container; however, under some conditions water flow in the unsaturated zone can result in mechanisms for water contact with the waste container. The most likely mechanism for water contact is probably by wicking from the partially saturated rock where the container is in direct contact with the rock. A second possible contact mechanism is by water dripping from a fracture onto the container. This mechanism would operate under conditions of higher flux than the first mechanism.

Where water drips onto the container, it is possible that the dripping would occur onto a region that contained a breach. Experiments will be conducted under this activity to determine the effect of water drip rate, water temperature, breach location, and breach geometry on the fraction of water that contacts a breach, but does not flow through the breach. The experiments will use small metal cylinders that contain a well-characterized defect, which has been intentionally induced into the cylinder. The fraction of water that enters through the breach will be determined as a function of breach size, breach shape, drip rate, and orientation of the breach relative to the water source. The effect of water temperature will be studied in a separate series of experiments using one or two breach configurations. Results of the experiments will be modelled to give an estimate of the significance of the water flow effects on the ability of water to enter breached containers. If the results indicate that the effects provide a significant reduction in water flow into the container, the study will be expanded to investigate the effects of corrosion products at the breach location on fluid flow.

Based on the results of these experiments and model calculations, some larger scale tests may be designed and executed. These tests would be done at QA level I.

Schedule

	Start	Complete
Interaction of materials under repository conditions	4/88	3/91

3.3 Determine Radionuclide Transport Parameters

3.3.1 Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope (G-20-2)

Diffusion of radionuclides into the rock matrix and sorption reactions with the rock surfaces are two mechanisms that can retard the transport of radionuclides with respect to the flow rate of water through the rock. Conventional measurements of these parameters rely on the use of changes in the concentration of dissolved species in solutions before and after contact with rock materials. For diffusion experiments, the rock itself is either not examined to determine radionuclide content, or surface techniques such as radiography are used. The surface techniques give a measure of the quantity of material adhering to or contained in the rock samples and, in some cases, its distribution in the plane of the sample surface. All material present in the rock within a distance equal to the penetration depth of the measurement technique is included in the surface value determined.

Phinney et al. (1987) used the CAMECA Ion Microscope to examine Topopah Spring tuff rock wafers that had been part of glass waste form dissolution tests. The waste form tests were conducted with the glass samples submerged in J-13 well water at 90°C in a gamma radiation field. Dissolution of the glass waste form introduced elements such as plutonium and uranium into the water. These elements were then able to diffuse into the rock under essentially static conditions, and to interact with the rock surface. Because flow of fluid was not forced through the rock, these measurements will give data that is not affected by advective flow effects.

The results obtained by Phinney et al. (1987) showed that a very slow diffusion process occurred in the rock. The diffusion profiles obtained for lithium, uranium, and plutonium gave very similar diffusion coefficients with an average value of approximately 10^{-16} cm^2/sec. This value is about 11 orders of magnitude smaller than that calculated by Travis (1984) using data obtained from a two day experiment in which an aqueous solution containing stronium-90 was equilibrated with a wafer of tuff. Travis (1984) modelled the changes in concentration of the solution in contact with the tuff to deduce values for the sorption coeffiecient and the diffusion coefficient. He did not report results of any examination of the tuff wafer itself. It is possible that the slow diffusion pathway existed in his experiments, too, but was not detected because of the dominance of the rapid diffusion pathway during the short time period of the experiment.

In the repository setting, where long times and distances are involved, a slow diffusion pathway could act as an important sink for radionuclides. This would occur because radionuclides, once they became entrained in the slow diffusion process, would take a long time to reach a crack or other microstructural feature that would allow more rapid diffusion to occur. Recent, unpublished work, using the detector system discussed in section 3.3.3, suggests that the tuff wafers examined by Phinney et al. (1987) may contain evidence for a more rapid transport

pathway as well as the slow diffusion pathway. Thus, modelling of the transport of ions in the near-field environment of the waste package may require the use of two or more scale factors for the transport processes.

Examination of tuff rock wafers that have been part of waste form dissolution tests will be continued to further investigate the slow diffusion transport path. In addition, some controlled laboratory experiments using solutions doped with a single radionuclide or a simple mixture of radionuclides will be conducted to attempt to pick up evidence for the more rapid diffusion pathway. These experiments will also investigate the effects of sample surface preparation and other experimental parameters that might cause bias in the results. The methods of examination will be similar to those described in Phinney et al. (1987), but may include the use of the resistive anode encoder detector discussed in section 3.3.3. It may also be useful to examine diffusion profiles in single mineral specimens or glass samples to determine the effects of grain boundaries and cracks on the transport process. For this reason, the activity title includes minerals and glasses, as well as rock samples.

Saturated conditions, where the rock is submerged in water, are not expected for the repository horizon under anticipated processes and events. Thus, it is unlikely that tests done at QA level I under submerged conditions will need to be investigated under activity G-20-2. If a need is later identified for QA level I data from this type of test, a test plan and procedures will be developed for the work. The main purpose of activity G-20-2 as presently constituted is to provide information on the types of flow mechanisms that are relevant to the near-field environment of the waste package and to aid in the design of tests to be conducted under activity G-20-3.

Schedule	Start	Complete
Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope	in progress	9/89

3.3.2 Interactions of actinide-bearing solutions with rock core samples (G-20-3)

Radionuclide transport in the repository setting will occur by means of fluid flow through massive rock. The flow paths may be along grain boundaries, through interconnected pores, or along fractures. Transport parameters, such as diffusion coefficients and distribution coefficients, may be different for static and flowing systems. This activity will develop techniques for measuring the transport of radionuclides in rock core samples. The initial meaurements will be based on the system developed by Failor et al. (1982). The system for fluid injection will be modified to allow for slower injection rates and low flow rates. Depending on the results obtained using the modified system, some experiments will be conducted under conditions of two phase flow.

The goal of this activity is to develop procedures that can be used in conjuction with activities B-20-1 and B-20-2 of the Waste Package Environment task. Those activities cover laboratory measurement of the transport of fluid phases in samples of the Topopah Spring tuff. Tracer levels of selected radionuclides or stable isotope tracers will be added to the fluids used in the hydrologic tests and experiments. Concentrations of the tracers in fluids that exit from the core samples will be monitored. At the conclusion of the experiments, the rock samples will be sectioned and the distribution of radionuclides and other tracers will be determined using the ion microscope and other methods developed as part of activity G-20-8. The QA level for this work will be level III during the technique development stage. When the work is linked to activities B-20-1 and B-20-2, the work will assume the same QA level as those activities. For work done at QA level I, the activity number for radionuclide and tracer distribution work will be G-20-3.1. Prior to the initiation of work at QA level I, a test plan and procedures will be written to cover the planned work.

The purpose of this work is to determine the nature of the transport mechanisms for radionuclides in the near-field environment of the waste packages. The existence of more than one transport mechanism for fluid and ionic transport through the rock is suspected, based on the results discussed in section 3.3.1. If more than one scale of diffusive transport exists, provision for two or more transport parameters for diffusion must be included in the flow and transport model for the near-field environment (G-20-6 and Performance Assessment Scientific Investigation Plan Activity I-20-1). The existence of more than one transport mechanism could also affect the interpretation of test results in the waste package environment test planned for the exploratory shaft.

Schedule	Start	Complete
Interactions of actinide-bearing solutions with rock core samples	in progress	9/91

3.3.3 Planning and Experimental Design (G-20-8)

Development of new analytical methods and the application of existing methods to new situations are frequently beset by "teething problems". For this reason, an activity set at QA level III is included to allow for the development of techniques that can later be applied to QA level I activities if warranted. One of the areas where this activity may prove to be particularly useful is the investigation of possible natural analog systems. Such systems might be suitable for use in the model validation activity (G-20-7); however, before QA level I work is initiated, it is more cost and time effective to explore the potential for use at QA level III.

There are presently two techniques that will be evaluated under this activity. Others may be added as they become available. The first technique is the use of a special ion-counting detector for the CAMECA Ion Microscope. This detector is based on a resistive anode encoder (RAE) and will allow the full imaging capabilities of the microscope to be exploited. Samples studied under activity G-20-2 will be examined using the RAE detector and the integrated RAE response will be compared with the data obtained using the conventional detector system. The purpose of this comparison is to determine whether any analytical bias that might compromise the quality of the quantitative results obtained occurs when the RAE is used.

The second technique that will be examined is the field measurement of sorption and desorption rate constants using the short half-life members of the uranium and thorium decay series. Krishnaswami et al. (1982) developed a method to estimate these rate constants and applied the method to the study of several groundwaters. Their method holds promise as a possible validation technique for laboratory-based models of sorption processes. Two developments are needed before the method could be used as a validation tool. First, extension to shorter-lived members of the decay chains is needed to allow data to be gathered for more elements. Second, a modification of the technique for use under unsaturated flow conditions is needed. Extension to shorter half-lived species will be tested by conducting an experiment using J-13 well water. Following these experiments, adaptation of the method for use in the unsaturated zone will be begun. If adaptation for unsaturated flow conditions is successful, a validation test will be planned and included under activity G-20-7.

Schedule	Start	Complete
Planning and experimental design	in progress	10/91

3.4 Radionuclide Transport Modeling in the near-field waste package environment

3.4.1 Source term model development (G-20-6)

Calculation of the performance of the respository system will use a source term for radionuclide release from the near-field environment of the waste packages. The integrated computer model for the source term is developed under the Waste Package Performance Assessment task. Input of data to the model is done through the development of modules for the individual components of the waste package system. The source term model development to be conducted under this activity is the work related to developing a physical-chemical model for radionuclide interactions with the near-field environment rock and fluid systems.

The main features of the model to be developed will be a description of the interaction of radionuclide-bearing solutions with the porous, fractured Topopah Spring tuff in the vicinity of the waste package. The model will describe the effects of the thermal and radiation field on the interaction processes as well as the effects of variation in the chemical composition of the fluid phase. It is expected that the final form of the model will be a series of analytical expressions that would form the basis for a module to be added to the waste package performance assessment system code.

The model will be based on the results of experiments and tests conducted under activities G-20-2 and G-20-3, as well as any applicable results obtained under the studies of the geochemistry of the Yucca Mountain site during Site Characterization and Exploratory Shaft testing. Model development is done at QA level III. Prior to use in a repository license application, the model will be validated over the range of intended use under activity G-20-7.

Schedule	Start	Complete
Source term model development	10/87	3/91

3.4.2 Source term model validation (G-20-7)

Data that will be used to support a repository license application must be acquired at QA level I or be upgraded to level I through one or more of the processes described in NNWSI SOP-03-03 (DOE, 1986). The first portion of the model validation activity will be to screen the data to be used in the model to ensure that it meets QA level I requirements. Should any non-level I data be needed, the provisions of NNWSI SOP-03-03 will be implemented.

Validation of the source term model will be accomplished through a combination of laboratory testing, natural analog studies, and peer review. The source term model, combined with the flow and transport computer model developed under the performance assessment task, will be

used to predict the results of a laboratory scale test prior to execution of the test. The test will then be performed under QA lev I control and the results compared to the model predictions. The quality of the match achieved between predicted and achieved results will determine the degree of validation provided by this means.

Laboratory testing cannot be done on a scale large enough in dimensions or long enough in time to validate the source term model for the full range of near-field conditions. Validation for long time periods may be achieved through the study of suitable natural analog systems. The main difficulty in the use of natural analogs for validation is the selection and matching of the analog system to the repository case. Natural analog systems will be investigated first under activity G-20-8 to assess their suitability for use in model validation. Those systems that appear to be suitable will be studied under QA level I control in this activity to provide partial validation for the source term model. The term "partial validation" is used because it is considered to be very unlikely that a perfect match for the respository situation will be found.

Peer review is considered to be an essential part of the validation activity for the source term model. There are several reasons for this. First, the use of natural analogs in the validation process will need peer review of the suitability of the analog system for validation purposes. Second, it is unlikely that any single analog system or even a combination of systems will cover the full range of conditions required for analysis of repository near-field performance. Thus, pee review of the source term model is needed to provide confidence that th model will be accepted as adequate during the licensing process.

Schedule	Start	Complete
Source term model validation	7/88	1/93

4.0 Application of Results

The information provided by this investigation will provide the source term for radionuclide release from the near-field environment of the waste packages. This information will be used by the waste package performance assessment task to model the behavior of the ensemble of waste packages under repository conditions. The information gathered under activity G-20-5 will provide an evaluation of materials interactions that might prove significant to the performance of the repository. Where significant effects are found, they will be incorporated into the waste package performance assessment model. The information obtained in this investigation directly addresses the following information needs taken from the Nevada Nuclear Waste Storage Investigation (NNWSI) Project Issues Hierarchy (version dated 8/07/86):

Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release as required by 10-CFR-60.113?

- 1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.
- 1.5.5 Determination of the amount of the (sic) radionuclides leaving the near-field environment of the waste package.

Through input to the above information needs, the results of the integrated testing activities will provide data to help resolve Issues 1.1, 1.5, and 1.9.

5.0 Schedule and Milestones

5.1 Discussion and Assumptions

The schedule for individual activites has been given in Section 3.0. The overall schedule for this investigation is tied to three other schedules. The first is the construction schedule for the Exploratory Shaft, because some of the activities will need input of materials or results from the shaft activities. Shaft construction is currently scheduled to start in July, 1988. The second is the development of the waste package performance assessment code, currently scheduled for completion in 6/92 with interim releases in 9/87 and 7/89. Both of these schedules must be met to allow the schedule for this investigation to be met. The final schedule tie is an output requirement that sets the termination date for this investigation. Material developed as a result of this investigation must be supplied to the waste package and system performance assessment task in time to complete the Draft Environmental Impact Statement (EIS), which is currently scheduled to be published in 10/93.

The schedule and milestones were prepared according to the reference case in the FY 1989 WPAS. Reductions in funding levels would result in slippage of both the schedule and milestones. Severe reductions would require that some of the work not be done.

5.2 Schedule

Activity		Start	Complete
G-20-5	Interaction of materials under repository conditions	4/88	3/91
G-20-2	Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope	in progress	9/89
G-20-3	Interactions of actinide-bearing solutions with rock core samples	in progress	9/91
G-20-8	Planning and experimental design	in progress	10/91
G-20-6	Source term model development	10/87	3/91
G-20-7	Source term model validation	7/88	1/93

5.3 Milestones

Number	Title	Date
T041	Initiate validation of geochemical calculations (G-20-7)	7/88
M264	Models for integrated testing of waste forms and container materials developed (all activities)	3/91
P270	Conduct Integrated Tests of waste package components to validate modeling calculations (G-20-3 and G-20-7)	1/93
M014	Issue final integrated data base to Waste Package Performance Assessment to support draft EIS (all activities)	10/92
P273	Complete documentation to support draft EIS (all activites)	10/93

6.0 List of test plans to support this Scientific Investigation Plan

Test Plan	Scheduled Completion Date
Source term validation plan	1/89
Test plan for radionuclide transport in rock core samples	4/88

Additional test plans or addenda and amendments to the above test plans will be issued should the need arise.

7.0 References

DOE, U. S. Department of Energy (1986). Acceptance of Data or Data Interpretation Not Developed Under the NNWSI QA Plan. NNWSI-SOP-03-03.

Failor, R., D. Isherwood, E. Raber, and T. Vandergraaf (1982). Laboratory studies of radionuclide transport in fractured Climax granite. UCRL-53308, Lawrence Livermore National Laboratory, Livermore, CA 94550.

Krishnaswami, S., W. G. Graustein, and K. K. Turekian (1982). Radium, thorium and radioactive lead isotopes in groundwaters: Application to the in situ determination of adsorption-desorption rate constants and retardation factors, Water Resources Research 18, 1663-1675.

Phinney, D.L., F. J. Ryerson, V. M. Oversby, W. A. Lanford, R. D. Aines, and J. K. Bates (1987). Integrated Testing of the SRL-165 Glass Waste Form, Materials Research Society Symposia Proceedings vol. 84, 433-446.

Travis, B. J. (1984) TRACR3D: A model of flow and transport in porous/fractured media. LA-9667-MS, Los Alamos National Laboratory, Los Alamos, NM 87545.

8.0 Quality Level Assignment Sheets

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-2 Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope.

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V.H. Oversby 6/6/87 Task Leader Date	NWMP Deputy Program Leader for QA Date
6/8/87 NNWSI Deputy Leader Date	6/8/87 NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/2/87 Project Sponsor Date	James Blaylock 11/6/87 Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Determination of elemental profiles in rocks, minerals, and glasses using the Ion Microscope

ACTIVITY NO.: G-20-2
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ____

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	 Not a design activity
4.0 PROC. DOC. CONTROL		No; Level III	Good professional practices apply
5.0 INSTR., PROCS, DWGS		No; Level III	Good professional practices apply
7.0 CTL OF PUR MATERIALS		No; Level III	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS		No; Level III	Good professional practices apply
9.0 CONTROL OF PROCESSES		No; Level III	Good professional practices apply
10.0 INSPECTION		No; Level III	Good professional practices apply
11.0 TEST CONTROL		No; Level III	Good professional practices apply
12.0 CTL OF M & T EQUIP		No; Level III	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.		No; Level III	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.		No; Level III	Good professional practices apply
19.0 SOFTWARE QA		No; Level III	Good professional practices apply

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety?	Yes → / No	I
2.	Does the item or activity involve waste isolation?	Yes → / No	I
3.	Does the item or activity involve or affect retrievability?	Yes → / No	I
4.	Is the intended purpose of this activity to provide data for a license application?	Yes → / No	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?	Yes → / No	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction?	Yes → / No	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?	Yes → / No	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?	Yes → / No	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components?	Yes → / No	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?	Yes → / No	II
11.	Can the item or activity cause major cost overrun or schedule slippage?	Yes → / No	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-3 Interactions of actinide-bearing solutions with rock core samples.

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance ________III________.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V.M. Oversby 6/6/87
Task Leader Date

John S. Dronkers 6/9/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/8/87
NNWSI Deputy Leader Date

L. Ramspott 6/8/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Okum 11/2/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Interactions of actinide-bearing solutions with rock core samples

ACTIVITY NO.: G-20-3
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	 Not a design activity
4.0 PROC. DOC. CONTROL		No; Level III	Good professional practices apply
5.0 INSTR., PROCS, DWGS		No; Level III	Good professional practices apply
7.0 CTL OF PUR MATERIALS		No; Level III	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS		No; Level III	Good professional practices apply
9.0 CONTROL OF PROCESSES		No; Level III	Good professional practices apply
10.0 INSPECTION		No; Level III	Good professional practices apply
11.0 TEST CONTROL		No; Level III	Good professional practices apply
12.0 CTL OF M & T EQUIP		No; Level III	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.		No; Level III	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.		No; Level III	Good professional practices apply
19.0 SOFTWARE QA		No; Level III	Good professional practices apply

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-3.1 QA Level I applications of activity G-20-3.

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance ______I______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V.M. Oversby 6/6/87
Task Leader Date

John A. Brockard 6/9/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/8/87
NNWSI Deputy Leader Date

J. Ramspott 6/8/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P Skinner 11/7/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: QA Level I applications of activity G-20-3

ACTIVITY NO.: G-20-3.1
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	033-NWMP-R 3A.0 No design
4.0 PROC. DOC. CONTROL		Yes	033-NWMP-P 4.0
5.0 INSTR., PROCS, DWGS		Yes	033-NWMP-P 5.0, 5.1, 5.2
7.0 CTL OF PUR MATERIALS		Yes	033-NWMP-P 7.0
8.0 I.D. & CTL OF MATERIALS		Yes	033-NWMP-R 8.0
9.0 CONTROL OF PROCESSES		No	No special processes
10.0 INSPECTION		Yes	033-NWMP-R 10.0
11.0 TEST CONTROL		Yes	033-NWMP-R 11.0
12.0 CTL OF M & T EQUIP		Yes	033-NWMP-R 12.0
13.0 HANDLING, STOR. & SHIP.		Yes	033-NWMP-R 13.0 and P 13.1
14.0 INSP. TEST & OPER. STAT.		Yes	033-NWMP-R 14.0
19.0 SOFTWARE QA		Yes	033-NWMP-R 19.0

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	(Yes) →	(I)
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-5 Interaction of materials under repository conditions

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance ______III______.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V.M. Oversby 6/6/87
Task Leader Date

John F. Dronkers 6/9/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/8/87
NNWSI Deputy Leader Date

J. Ramspott 6/8/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Skinner 11/7/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Interaction of materials under repository conditions

ACTIVITY NO.: G-20-5
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ____________

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0	Yes	
	3B.0	No	Not a design activity
4.0 PROC. DOC. CONTROL		No; Level III	Good professional practices apply
5.0 INSTR., PROCS, DWGS		No; Level III	Good professional practices apply
7.0 CTL OF PUR MATERIALS		No; Level III	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS		No; Level III	Good professional practices apply
9.0 CONTROL OF PROCESSES		No; Level III	Good professional practices apply
10.0 INSPECTION		No; Level III	Good professional practices apply
11.0 TEST CONTROL		No; Level III	Good professional practices apply
12.0 CTL OF M & T EQUIP		No; Level III	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.		No; Level III	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.		No; Level III	Good professional practices apply
19.0 SOFTWARE QA		No; Level III	Good professional practices apply

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC	LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? Yes → (No)	I
2.	Does the item or activity involve waste isolation? Yes → (No)	I
3.	Does the item or activity involve or affect retrievability? Yes → (No)	I
4.	Is the intended purpose of this activity to provide data for a license application? Yes → (No)	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? Yes → (No)	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? Yes → (No)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? Yes → (No)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? Yes → (No)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? Yes → (No)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? Yes → (No)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? Yes → (No)	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-6 Source term model development

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance ________III__________.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V. M. Oversby 6/6/87
Task Leader Date

John F. Dronkert 6/9/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/8/87
NNWSI Deputy Leader Date

L. Ramspott 6/8/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester L. Skousen 11/7/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Source term model development

ACTIVITY NO.: G-20-6
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	 Not a design activity
4.0 PROC. DOC. CONTROL		No; Level III	Good professional practices apply
5.0 INSTR., PROCS, DWGS		No; Level III	Good professional practices apply
7.0 CTL OF PUR MATERIALS		No; Level III	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS		No; Level III	Good professional practices apply
9.0 CONTROL OF PROCESSES		No; Level III	Good professional practices apply
10.0 INSPECTION		No; Level III	Good professional practices apply
11.0 TEST CONTROL		No; Level III	Good professional practices apply
12.0 CTL OF M & T EQUIP		No; Level III	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.		No; Level III	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.		No; Level III	Good professional practices apply
19.0 SOFTWARE QA		No; Level III	Good professional practices apply

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? No	Yes →	I
2.	Does the item or activity involve waste isolation? No	Yes →	I
3.	Does the item or activity involve or affect retrievability? No	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-7 Source term model validation

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V. M. Oversby 6/6/87
Task Leader Date

John F. Doonkeal 6/9/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/8/87
NNWSI Deputy Leader Date

J. Ramspott 6/8/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Lester P. Skinner 11/5/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NNWSI QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Source term model validation

ACTIVITY NO.: G-20-7
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT		APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0	Yes	033-NNWSI-R 3A.0
	3B.0	No	No design
4.0 PROC. DOC. CONTROL		Yes	033-NNWSI-P 4.0
5.0 INSTR., PROCS, DWGS		Yes	033-NNWSI-P 5.0, 5.1, 5.2
7.0 CTL OF PUR MATERIALS		Yes	033-NNWSI-R 7.0
8.0 I.D. & CTL OF MATERIALS		Yes	033-NNWSI-R 8.0
9.0 CONTROL OF PROCESSES		No	No special processes
10.0 INSPECTION		Yes	033-NNWSI-R 10.0
11.0 TEST CONTROL		Yes	033-NNWSI-R 11.0
12.0 CTL OF M & T EQUIP		Yes	033-NNWSI-R 12.0
13.0 HANDLING, STOR. & SHIP.		Yes	033-NNWSI-R 13.0
14.0 INSP. TEST & OPER. STAT.		Yes	033-NNWSI-R 14.0
19.0 SOFTWARE QA		Yes	033-NNWSI-R 19.0

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

CHARACTERISTIC		LEVEL
Does the item or activity involve or affect public radiologic health and safety? No	Yes →	I
Does the item or activity involve waste isolation? No	Yes →	I
Does the item or activity involve or affect retrievability? No	Yes →	I
Is the intended purpose of this activity to provide data for a license application? No	Yes →	I
Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

CHARACTERISTIC		LEVEL
Does the item or activity involve or affect public radiologic health and safety? No	Yes →	I
Does the item or activity involve waste isolation? No	Yes →	I
Does the item or activity involve or affect retrievability? No	Yes →	I
Is the intended purpose of this activity to provide data for a license application? No	Yes →	I
Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-8 Planning and experimental design

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V. M. Oversby 6/6/87
Task Leader Date

6/9/87
NWMP Deputy Program Leader for QA Date

Jesse L. Yow Jr. 6/8/87
NNWSI Deputy Leader Date

L. Ramspott 6/8/87
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

11/2/87
Project Sponsor Date

James Blaylock 11/6/87
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NNWP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Planning and experimental design

ACTIVITY NO.: G-20-8
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	 Not a design activity
4.0 PROC. DOC. CONTROL		No; Level III	Good professional practices apply
5.0 INSTR., PROCS, DWGS		No; Level III	Good professional practices apply
7.0 CTL OF PUR MATERIALS		No; Level III	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS		No; Level III	Good professional practices apply
9.0 CONTROL OF PROCESSES		No; Level III	Good professional practices apply
10.0 INSPECTION		No; Level III	Good professional practices apply
11.0 TEST CONTROL		No; Level III	Good professional practices apply
12.0 CTL OF M & T EQUIP		No; Level III	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.		No; Level III	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.		No; Level III	Good professional practices apply
19.0 SOFTWARE QA		No; Level III	Good professional practices apply

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? (No)	Yes →	I
2.	Does the item or activity involve waste isolation? (No)	Yes →	I
3.	Does the item or activity involve or affect retrievability? (No)	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? (No)	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? (No)	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? (No)	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? (No)	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? (No)	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? (No)	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? (No)	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? (No)	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-7 Source term model validation

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V. M. Oversby	6/6/87	John J. [signature]	6/9/87
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
Jesse L. Yow Jr.	6/8/87	J. Ramspott	6/8/87
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Source term model validation

ACTIVITY NO.: G-20-7
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA I

CITE "YES" ITEM ON LOGIC DIAGRAM 4

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	033-NWMP-R 3A.0 No design
4.0 PROC. DOC. CONTROL		Yes	033-NWMP-P 4.0
5.0 INSTR., PROCS, DWGS		Yes	033-NWMP-P 5.0, 5.1, 5.2
7.0 CTL OF PUR MATERIALS		Yes	033-NWMP-R 7.0
8.0 I.D. & CTL OF MATERIALS		Yes	033-NWMP-R 8.0
9.0 CONTROL OF PROCESSES		No	No special processes
10.0 INSPECTION		Yes	033-NWMP-R 10.0
11.0 TEST CONTROL		Yes	033-NWMP-R 11.0
12.0 CTL OF M & T EQUIP		Yes	033-NWMP-R 12.0
13.0 HANDLING, STOR. & SHIP.		Yes	033-NWMP-R 13.0
14.0 INSP. TEST & OPER. STAT.		Yes	033-NWMP-R 14.0
19.0 SOFTWARE QA		Yes	033-NWMP-R 19.0

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

CHARACTERISTIC		LEVEL
Does the item or activity involve or affect public radiologic health and safety? No (circled)	Yes →	I
Does the item or activity involve waste isolation? No (circled)	Yes →	I
Does the item or activity involve or affect retrievability? No (circled)	Yes →	I
Is the intended purpose of this activity to provide data for a license application? No	Yes (circled) →	I
Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
..es the activity involve a decision phase which is to be ..nducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
..n the item or activity cause major cost overrun or schedule ..ippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: May 29, 1987

Meeting Attendees: Ron Schwartz
Jesse Yow
Virginia Oversby

Name(s) and Number(s) of Activity: G-20-8 Planning and experimental design

S.I.P. Identification: NNWSI WBS Element 1.2.2.3.4 (non EQ 3/6 Data Base Portion) Integrated Testing

Additional Comments:

Level of Quality Assurance _____III_____.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

V.M. Oversby	6/6/87		6/9/87
Task Leader	Date	NWMP Deputy Program Leader for QA	Date
Jesse L. Yow Jr.	6/8/87		6/8/87
NNWSI Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO NWMP DEPUTY PROGRAM LEADER FOR QA WITH COPY TO TASK LEADER

Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Planning and experimental design

ACTIVITY NO.: G-20-8
DATE:

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II. Elements 1, 2, 11, 15, 16, 17, 18, 21, and 22 apply to work done at Quality Assurance Level III.

LEVEL OF QA III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES		IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN CONTROL	3A.0 3B.0	Yes No	Not a design activity
4.0 PROC. DOC. CONTROL		No; Level III	Good professional practices apply
5.0 INSTR., PROCS, DWGS		No; Level III	Good professional practices apply
7.0 CTL OF PUR MATERIALS		No; Level III	Good professional practices apply
8.0 I.D. & CTL OF MATERIALS		No; Level III	Good professional practices apply
9.0 CONTROL OF PROCESSES		No; Level III	Good professional practices apply
10.0 INSPECTION		No; Level III	Good professional practices apply
11.0 TEST CONTROL		No; Level III	Good professional practices apply
12.0 CTL OF M & T EQUIP		No; Level III	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.		No; Level III	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.		No; Level III	Good professional practices apply
19.0 SOFTWARE QA		No; Level III	Good professional practices apply

CHECKLIST FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	CHARACTERISTIC		LEVEL
1.	Does the item or activity involve or affect public radiologic health and safety? No	Yes →	I
2.	Does the item or activity involve waste isolation? No	Yes →	I
3.	Does the item or activity involve or affect retrievability? No	Yes →	I
4.	Is the intended purpose of this activity to provide data for a license application? No	Yes →	I
5.	Can a failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? No	Yes →	I
6.	Does the activity involve a decision phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? No	Yes →	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? No	Yes →	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? No	Yes →	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability, or maintainability of engineered systems, structures, or components? No	Yes →	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? No	Yes →	II
11.	Can the item or activity cause major cost overrun or schedule slippage? No	Yes →	II

LEVEL III WHEN ALL THE ANSWER TO ALL QUESTIONS ABOVE IS "NO".

NNA.870522.0038

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.2.4.L

NNWSI WASTE PACKAGE DESIGN, FABRICATION, AND PROTOTYPE TESTING TASK

LAWRENCE LIVERMORE NATIONAL LABORATORY

November, 1986

Lawrence D. Ramspott, LLNL-TPO	12-9-86 Date
John J. Dronkers, Deputy for QA	12-16-86 Date
Lynden B. Ballou, Design and Field Testing Technical Area Leader	12-9-86 Date
Thomas A. Nelson, P.I.	12-9-86 Date
Edward W. Russell, Originator	12-9-86 Date
Ting-Yu Lo, Technical Reviewer	12-10-86 Date
James Blaylock, Project Sponsor Quality Manager	12/16/86 Date
Lester P. Skousen, Project Sponsor, Chief Technical Development and Engineering	12/16/86 Date

Table of Contents

List of Acronyms

ACD..................................Advanced Conceptual Design

LAD..................................License Application Design

LLNL.................................Lawrence Livermore National Laboratory

MGDS.................................Mined Geologic Disposal System

NDE..................................Nondestructive Evaluation

NNWSI................................Nevada Nuclear Waste Storage Investigations

NWMP.................................Nuclear Waste Management Program

OGR..................................Office of Geologic Repositories

QA...................................Quality Assurance

SIP..................................Scientific Investigation Plan

SNL..................................Sandia National Laboratories

SSR..................................Site Specific Requirements

WBS..................................Work Breakdown Structure

WMPO.................................Waste Management Project Office

WPDR.................................Waste Package Design Requirements

1.0 OBJECTIVES AND ISSUES ADDRESSED

The activities addressed in this Scientific Investigation Plan are directed toward planning and developing the design inputs that are necessary to design the NNWSI waste package. Scientific Investigations are configured to provide specific data for design inputs in the areas of parametric studies; requirements for the Advanced Conceptual Design phase; process development for disposal container fabrication, final closure, and nondestructive evaluation; and design validation through prototype testing. Studies that were undertaken prior to initiation of the work described herein have aided in scoping the current design task but are not discussed here. They are discussed in O'Neal, et al*. This work will provide information needed to address the following issues (NNWSI Issues Hierarchy revision 8/07/86):

Issue 1.10: "Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.135 and (b) provide information to support resolution of the performance issues?"

Issue 2.6: "Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.135 and (b) provide information to support resolution of the performance issues?"

*O'Neal, W.C., Gregg, D.W., Hockman, J.N., Russell, E.W., and Stein, W., 1984 "Preclosure Analysis of Conceptual Waste Package Designs for a Nuclear Waste Repository in Tuff," Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53595.

Issue 4.3: "Are the waste package production technologies adequately established to support resolution of the performance issue?"

Issue 4.5: "Are the waste package and repository costs adequately established to support resolution of the performance issues?"

Issues indirectly affected by this work are the following:

Issue 1.4: "Will the waste package meet the performance objective for containment as required by 10 CFR 60.113?"

Issue 1.5: "Will the waste package and repository engineered barriers meet the performance objective for radionuclide release rates as required by 10 CFR 60.113?"

Issue 2.1: "Will the repository preserve the option of waste retrieval as required by 10 CFR 60.111 using reasonably available technology?"

2.0 RATIONALE FOR SELECTED STUDIES

This section primarily describes work to be done up to the culmination of the Advanced Conceptual Design (ACD) phase. There will be a subsequent License Application Design phase (LAD) of the waste package, and the studies described herein may be continued or revised during the LAD phase. The following describes the rationale for the major activities that will yield design input for the ACD.

2.1 Parametric Studies

This activity will involve parametric studies that will be conducted as necessary in the areas of structural and thermal analysis, and in other areas that will be identified when the waste package designs evolve, such as criticality assessment and container material assessment.

Structural parametric studies will be conducted to establish criteria for container preclosure and postclosure performance objectives. The waste emplacement package must be capable of sustaining (1) normal handling and packaging operational loads without loss of containment and (2) accidents either without loss of containment or with a limited release of radionuclides as required in 10 CFR 20 when applicable. A container accept/reject loading envelope will be developed for loading conditions anticipated during normal handling, emplacement, and retrieval operations and for postulated off-normal conditions at the repository. The effects of plastic flow on a microstructural level will be assessed for the container material.

Thermal parametric studies will be conducted to evaluate the effects of variations in thermal properties, emplacement configurations and heat transfer characteristics on waste form, container, and near-field rock temperatures. These studies will provide a basis for designs that are consistent with the postclosure containment strategy. Other parametric studies will be conducted as needed to support development of design inputs.

2.2 Development of Waste Package Design Requirements (WPDR)

The purpose of the WPDR document is to define what functions of the MGDS are allocated to the waste package subsystems (functional requirements), how or how well those functions are to be performed (performance criteria), what environment the waste package must function in (site interfaces), what waste the package is to contain (waste interfaces), how the waste package will be handled (repository interfaces), and under what conditions the waste package must function (constraints). The WPDR shall specify these requirements to a level of detail adequate to direct ACD of the waste package.

The WPDR document will be prepared as a prerequisite to the initiation of the ACD. The document will define the requirements, performance measures, constraints and interfaces to be incorporated in the waste package designs.

2.3 Preliminary Ultrasonic Technique Evaluation

This activity, a prerequisite to the "Container Closure Nondestructive Evaluation (NDE) Process Development" activity, will involve the assessment of ultrasonic techniques and review of the literature to identify and evaluate

feasible techniques that are consistent with container material and with the certification of the final container closure.

2.4 Container Fabrication Process Development

Container fabrication development will be pursued to assess process alternatives and to recommend and demonstrate a method for fabrication of disposal containers through production of full-scale prototypes. This activity will be done concurrently with others that address final closure, nondestructive evaluation, and material acquisition.

2.5 Container Closure Process Development

The purpose of the container final closure development activity is to assess alternatives, to recommend and demonstrate a joining method, and to design a full-scale functioning system for the final closure of disposal containers. This activity will be done concurrently with others addressing fabrication, nondestructive evaluation, and materials acquisition.

2.6 Container Closure Nondestructive Evaluation (NDE) Process Development

The purpose of the container final closure NDE development is to assess alternatives identified by the prerequisite activity, "Preliminary Ultrasonics Technique Evaluation," and to recommend and demonstrate a NDE process for final certification that the container closure meets the quality control requirements. This activity will be done concurrently with others addressing fabrication, closure, and materials acquisition.

2.7 Materials Acquisition

The materials acquisition activity is necessary to address the procurement and scheduling of materials necessary to support the fabrication, closure, and NDE development activities as well as to assess the long-term production requirements for materials for disposal containers.

2.8 Prototype Testing

Prototypes of the container designs developed will be tested as appropriate to determine that design requirements are met.

3.0 DESCRIPTION OF TESTS AND ANALYSES

Sections 3.1-3.8 describe in detail the activities that are primarily in support of the waste package Advanced Conceptual Design and secondarily in support of the subsequent License Application Design. The activities covered are Scientific Investigations as described in QA Element 3A, not engineering design activities as described in QA Element 3B.

3.1 Parametric Studies

Parametric studies will be undertaken, as required, to investigate specific aspects of the evolving container designs. Structural studies will involve computer modeling, using well-documented, validated computer codes to understand the effects on the container from loading conditions anticipated during normal handling, emplacement, and retrieval operations and from postulated accident conditions at the repository. The effects of resulting plastic deformation on potential long-term, localized-corrosion initiation sites due to the surface defect geometry and the resulting residual stress will be explored. This will involve a literature search and appropriate laboratory testing to establish data for metals designated by the metal barriers task. The main interfaces will be definition of container loads associated with handling scenarios as defined by SNL, definition of loading on the container due to the near-field host rock by the package environment task, description of pertinent preclosure and postclosure performance measures by the performance assessment task, and description of the geometry of potentially damaging defects by the metal barriers task.

Parametric thermal studies will be done to study the effects of variations in thermal loading from the waste forms, emplacement configureations, and heat transfer characteristics on design options as related to temperatures of the waste forms, containers, and near-field rock. Computer modeling will be done, using well-documented, validated computer codes to determine the effects of these variations on the temperature histories of the waste package components and the near-field repository. Important interfaces will be repository designs and operating plans developed by SNL and waste package component properties.

As the waste package designs evolve, other areas will be identified for further study, such as criticality assessment and container material assessment.

3.2 Development of Waste Package Design Requirements

This activity consists of the development, review, and approval of a Waste Package Design Requirements document. This document will be prepared as a prerequisite to the initiation of the ACD. It will be used to communicate the design requirements to OGR, to other organizations within the Project, and to the design contractor. At the end of the ACD phase, the WPDR will be updated, incorporating the knowledge gained during that design phase for use in the license application design (LAD) phase.

It is likely at the initiation of the waste package ACD that not all requirements can be specified. The design requirements will indicate where such uncertainties exist and will provide assumptions to be used during ACD. It is a goal of ACD to resolve all such uncertainties to allow full specification of the design requirements for LAD.

The general approach will be to analyze and translate the Site Specific MGDS Requirements (SSR) document into specific waste package design requirements. All interfaces will be defined with respect to other waste package tasks and repository design.

3.3 Preliminary Ultrasonic Technique Evaluation

This activity will involve an ultrasonic technique assessment/literature search, which will result in a report to identify alternative techniques that will be pursued in the subsequent "Container Closure NDE Process Development" activity.

Ultrasonic techniques have been tentatively selected for investigation for the NDE of the container final closure because the high background radiation levels will exclude the use of conventional radiographic techniques, and other innovative methods (both radiographic and electromagnetic) do not appear to be able to meet the anticipated flaw detection requirements or are relatively high risk development programs.

3.4 Container Fabrication Process Development

The container fabrication process development activity consists of a multi-year, multi-phase subcontract to assess alternatives and to recommend and demonstrate a method for fabrication of disposal containers through production of full-scale prototypes. Emphasis will be placed on minimizing the number of joints and on obtaining a uniform, fine-grained microstructure of the metal container.

This approach will involve the following steps: (1) fabrication process assessment/literature review; (2) small specimen formability testing; (3) sub-scale prototype evaluations; and (4) full-scale prototype fabrication, including development of process specifications. This activity will be pursued concurrently with three related activities described in Sections 3.5, 3.6, and 3.7, and information developed in one activity will be coordinated with the other activities. For example, container material microstructural properties required by the nondestructive evaluation process will constrain the fabrication development activity, and information on formability from this activity will be a criterion in the container metal selection decision. Deliverables from this activity will include: from phase one of the subcontract, a fabrication process assessment report; from phase two, test specimens and sub-scale mockup fabrications with a formal evaluation report and proposed specifications for both a primary and an alternate fabrication process; and from phase three, a final report and final specification package and several sets of full-scale prototype parts.

Interfaces occur with the other three process development activities mentioned above, and with the metal barriers task concerning container metal selection and microstructural defect geometry specification.

3.5 Container Closure Process Development

The container final closure development activity consists of a multi-year, multi-phase subcontract to assess alternatives, to recommend and demonstrate a joining method, and to design a full-scale functioning system for the final closure of disposal containers at the repository. Emphasis will be

placed on a simple, reliable, maintainable system that (1) will provide throughput to support the projected disposal container production schedule; (2) is capable of operation in the repository hot-cell; and (3) will produce a closure that limits defects and has a microstructure suitable for NDE. This approach will involve the following steps: (1) joining process assessment/literature search (yields approximately five candidate processes); (2) specimen/flat plate testing; (3) test rings (less than full-scale), one reference and one alternate process; (4) full scale prototype rings, one reference and one alternate process; and (5) preliminary system design with drawings and specifications. This activity will be pursued concurrently with the related activities discussed in Sections 3.4, 3.6, and 3.7, and information developed in this activity will be coordinated with the others. Deliverables from this activity will include: from phase one of the subcontract, a joining process assessment report; from phase two, sub-scale and full-scale test closure joints with a formal evaluation report and proposed specifications for both primary and alternate joining processes; and from phase three, a final report and final drawings and specifications, and full-scale closure joints.

Interfaces occur with the three process development activities mentioned above, and with the metal barriers task concerning container metal selection and microstructural defect geometry specification.

3.6 Container Closure Nondestructive Evaluation (NDE) Process Development

The container final closure NDE development activity consists of a multi-year, multi-phase effort to assess alternative ultrasonic NDE techniques identified by the prerequisite activity, "Preliminary Ultrasonics Technique

Evaluation;" (Section 3.3) to recommend and demonstrate a reference ultrasonic NDE technique; and to design a full-scale system for the final NDE of disposal container closures at the repository. Ultrasonics has been selected for investigation because the high background radiation levels will exclude the use of conventional radiographic techniques, and other NDE methods do not appear to meet the probable flaw detection requirements. Emphasis will be placed on a reliable, maintainable, state-of-the-art system that (1) will support the projected disposal container production schedule, (2) can be operated in the repository hot-cell, and (3) can certify that the container closure meets the probable defect limitation requirements. This approach will involve the following steps: (1) ultrasonics technique assessment/literature search to be done in the "Preliminary Ultrasonic Technique Evaluation" activity; (2) ultrasonics technique/signal processing development; (3) manufacture and testing of specimens with representative defects; (4) preliminary design and specification of ultrasonic system, compatible with the repository design; (5) examination of prototypical closure rings; and (6) final NDE system specifications and drawings. This activity will be pursued concurrently with the related process development activities discussed in Sections 3.4, 3.5 and 3.7, and information developed in this activity will be corodinated with the others. Deliverables from this activity will include a formal evaluation report covering NDE specimen manufacture and testing as well as the NDE of prototypical closure rings; and a final report and final specifications for the NDE system. Interfaces occur with the preliminary ultrasonic technique evaluation activity, with the three process development activities mentioned above, and with the metal barriers task concerning container metal selection and microstructural defect geometry specification.

3.7 Materials Acquisition

The container materials acquisition activity includes procurement and scheduling of materials necessary to support the container fabrication, closure, and NDE development activities and will also include assessment of the production requirements for disposal container material to support repository operation. Emphasis will be placed first on procurement of small quantities of materials necessary for specimens and prototypes with chemical composition and microstructural characteristics consistent with the specifications from the metal barriers task.

Assessments will be made of mill-run type quantities necessary to support disposal container production requirements. The general approach will be to communicate the material forms and quantities, with specifications, to various American metals production houses, and to identify potential sources and methods. Appropriate analyses will be made using metallurgical and production engineering principles, and resulting information will feed into the container design process. Deliverables from this activity will include materials for specimens and prototypes, and a final report on assessment of production considerations.

Interfaces occur with the three process development activities and with the metal barriers task concerning container metal selection and microstructural requirements.

3.8 Prototype Testing

This activity involves testing of prototypes developed to determine that the design requirements are met and to establish design inputs for the License Application Design (LAD) phase of the waste package. The general approach will involve: (1) developing a prototype testing specification package; (2) developing a prototype testing procurement package; (3) technical direction of the actual testing and test data reduction; and (4) preparing the final report, documenting the test results, and clearly defining design input for LAD. The major interface will be with the SNL repository design effort.

4.0 APPLICATION OF RESULTS

The activities discussed in this SIP will be used as design inputs to the ACD and to the LAD. At the culmination of both the ACD and LAD, formal design phase reports will be written that will be submitted for review and approval by DOE. The results of the scientific investigations will be summarized as an integral part of these reports.

5.0 SCHEDULE AND MILESTONES

Approximate schedules for waste package design, fabrication, and prototype testing activities are given in Section 5.1. An approximate schedule for interface inputs is presented in Section 5.2. Variations in delivery of these inputs will cause significant variations in schedules presented for both activities and milestones.

5.1 Activity Schedule

The durations of the activities given below are based on the assumption that the funding requests are approved. Reduced funding will result in delays in completion of those activities. The dates provided (as determined by LLNL) are designed to mesh with the projected design completion dates listed in the DOE Headquarters (RW-23.1) memo of November 4, 1986.

Activity Milestones	Date
Parametric Studies FY87-FY89	
Ongoing activity - deliverables dependent upon studies conducted	
Evaluation of Waste Package Design Requirements (WPDR)	
Deliverable: Design Requirements Document for ACD Milestone number: P080	8/31/87
Deliverable: Updated Requirements Document for LAD Milestone number: M267	12/31/89

Preliminary Ultrasonic Technique Evaluation

Deliverable: Evaluation report — 4/30/87

Milestone number: TBD

Container Fabrication Process Development

Deliverables:

Phase 1, Fabrication process assessment report	8/31/87
Phase 2, Test specimens, report, and specifications for primary and alternate fabrication process	7/31/88
Phase 3, Final report, specification package, and four sets of prototype parts	8/31/89

Milestone number: TBD

Container Closure Process Development

Deliverables:

Phase 1, Joining process assessment report	1/31/88
Phase 2, Test closure joints, evaluation report, and proposed specification for primary and alternate joining processes	11/30/88
Phase 3, Final report, drawings, specifications, and full-scale closure joints	8/31/89

Milestone number: TBD

Container Closure Nondestructive Evaluation (NDE) Process Development

Deliverables:

Evaluation report covering NDE specimen manufacture and testing	2/28/89

Final report and specifications for the NDE system 2/28/90

Milestone number: TBD

Materials Acquisition

Deliverables:

Materials for process evaluation	8/31/87
Materials for prototypes	5/31/88
Final report on assessment of production	8/31/89

Prototype Testing

Deliverable: Test completion	12/31/89
Milestone number: M262	
Deliverable: Final report	6/30/90
Milestone number: P203	

5.2 Interface Schedule

The interface schedule will also be subject to slippage if the budget submitted in FY87 is reduced.

5.2.1 Inputs

- o Metal Barriers Task
  1. Container metal selection: FY87
  2. Objectionable defect size from a post-closure containment perspective: FY87
- o Performance Assessment Task
  1. Performance measures for waste package design: preliminary in FY87 and final in FY89

- Package Environment Task
  1. Preliminary characterization of the near-field waste package environment: FY87
- Sandia National Laboratories (SNL)
  1. Container loading conditions due to repository operations: early FY87
  2. Loading on waste package due to host rock: FY87-FY88
  3. Near-field rock properties permissable host rock thermal loading: FY87-FY88
  4. Repository design information relating to development of prototype testing specifications: FY88

5.2.2 Outputs

All outputs from the scientific investigations described herein will provide specific data for inputs to the waste package design.

External interfaces with the repository design will be handled through the actual waste package design activity as described in QA element 033-NWMP-R38.0 (under review by WMPO).

6.0 QUALITY ASSURANCE

6.1 QA Level Assignments

QA level assignments for all activities listed in this SIP have been internally approved and documented by LLNL. Quality Assurance Level Assignment Sheets for these activities are attached.

The following is a list of the activities discussed in this SIP with associated QA levels. Engineering design activities are not considered to be Scientific Investigations and therefore are not included in this SIP.

Activity Designator	Title	QA Level
H-20-1	Parametric Studies	III
H-20-2	Development of Waste Package Design Requirements (WPDR)	II
H-20-3	Preliminary Ultrasonics Technique Evaluation	III
H-20-4	Container Fabrication Process Development	I
H-20-5	Container Closure Process Development	I
H-20-6	Container Closure Nondestructive Evaluation (NDE) Process Development	I

Activity Designator	Title	QA Level
H-20-7	Materials Acquisition	I
H-20-9	Prototype Testing	I

6.2 Computer Code Documentation

A partial listing of the documentation for the computer programs that may be used in activities described in this SIP includes:

Burns, Patrick J. (1982), TACO2D, A Finite Element Heat Transfer Code, Lawrence Livermore National Laboratory, Livermore, CA, UCID-17980, Rev. 2.

Hallquist, J. O. (1982), DYNA3D Users Manual (Nonlinear Dynamic Analysis of Solids in Three Dimensions), Lawrence Livermore National Laboratory, Livermore, CA, UCID-19592.

Hallquist, J. O. (1984), NIKE3D: An Implicit, Finite-Deformation, Finite Element Code for Analyzing the Static and Dynamic Response of 3-Dimensional Solids, Lawrence Livermore National Laboratory, Livermore, CA, UCID-18822, Rev. 1.

Mason, W. E. (1983), TACO3D, A 3-Dimensional, Finite Element, Heat Transfer Code, Sandia National Laboratories, Livermore, CA, SAND 8308212.

Montan, D. N. (1986), The Plus Family, A Set of Computer Programs to Evaluate Analytic Solutions of the Diffusion Equation, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20680.

Shapiro, Arthur B. (1986), <u>TOPAZ2D - A Two-Dimensional Finite-Element Code for Heat Transfer Analysis, Electrostatic, and Magnetostatic Problems</u>, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20824.

Shapiro, Arthur B. (1985), <u>TOPAZ3D - A Three-Dimensional Finite Element Heat Transfer Code</u>, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20484.

6.3 Required QA Procedures and Requirements

The following QA topics (relevant to this SIP), are addressed in the required procedure or requirement of the NWMP Quality Assurance Program Plan as is indicated.

QA Topic	Procedure/Requirement
Change Control	033-NWMP-P. 2.0, 3.0, 5.0, 6.0
Interface Control	033-NWMP-P. 1.0, 6.0, 033-NWMP-R. 7.0
Control Item Interfaces	033-NWMP-P. 3.0, 4.0, 6.0, 15.0, 17.0, 20.0, 033-NWMP-R. 8.0, 11.0
Technical Review of Publications	033-NWMP-P, 22.0

7658N

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Parametric Studies
H-20-1

Additional Comments: For description, see SIP Para. 3.1.

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86 — Task Leader, Date
John L. Dronkers 12-10-86 — Deputy Leader for QA, Date

12-9-86 — Waste Package Design Technical Area Leader, Date
12-9-86 — NWMP Leader, Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

12/17/86 — Project Sponsor, Date
James Blaylock 12/16/86 — Project Sponsor Quality Manager, Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Parametric Studies

ACTIVITY NO.: H-20-1
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON QALA CHECK SHEET None

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES	IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CT OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Development of Waste Package Requirements
H-20-2

Additional Comments: For description, see SIP Para. 3.2.

Activity determined to be of Quality Assurance Level II.
This activity will result in a document that communicates design requirements to OGR, to other organizations within the Project and the design contractor.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86 John H. Dronkers 12/10/86
Task Leader Date Deputy Leader for QA Date

L. Ballou 12-9-86 L. Ramspott 12-9-86
Waste Package Design Date NWMP Leader Date
Technical Area Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

Lester 12/17/86 James Blaylock 12/16/86
Project Sponsor Date Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Waste Package Requirements

ACTIVITY NO.: H-20-2
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA II

CITE "YES" ITEM ON QALA CHECK SHEET Step 10

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES		IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	Yes	(3A only)	Peer Review procedure will be used to review this document. Procedure is under development.
4.0 PROC. DOC. CONTROL	No		This a paper study
5.0 INSTR., PROCS, DWGS	No		"
7.0 CTL OF PUR MATERIALS	No		"
8.0 I.D. & CT OF MATERIALS	No		"
9.0 CONTROL OF PROCESSES	No		"
10.0 INSPECTION	No		"
11.0 TEST CONTROL	No		"
12.0 CTL OF M & T EQUIP	No		"
13.0 HANDLING, STOR. & SHIP.	No		"
14.0 INSP. TEST & OPER. STAT.	No		"
19.0 SOFTWARE QA	No		"

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Preliminary Ultrasonics Technique Evaluation
H-20-3

Additional Comments: For description, see SIP Para. 3.3.

Activity determined to be of Quality Assurance Level III.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86
Task Leader Date

John H. Dronkers 12-10-86
Deputy Leader for QA Date

L. Ballou 12-9-86
Waste Package Design Technical Area Leader Date

L. Ramspott 12-9-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

Lester [illegible] 12/17/86
Project Sponsor Date

James Blaylock 12/16/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Preliminary Ultrasonics Technique Evaluation

ACTIVITY NO.: H-20-3
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA III

CITE "YES" ITEM ON QALA CHECK SHEET None

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES	IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	No	Good professional practices apply
4.0 PROC. DOC. CONTROL	No	Good professional practices apply
5.0 INSTR., PROCS, DWGS	No	Good professional practices apply
7.0 CTL OF PUR MATERIALS	No	Good professional practices apply
8.0 I.D. & CT OF MATERIALS	No	Good professional practices apply
9.0 CONTROL OF PROCESSES	No	Good professional practices apply
10.0 INSPECTION	No	Good professional practices apply
11.0 TEST CONTROL	No	Good professional practices apply
12.0 CTL OF M & T EQUIP	No	Good professional practices apply
13.0 HANDLING, STOR. & SHIP.	No	Good professional practices apply
14.0 INSP. TEST & OPER. STAT.	No	Good professional practices apply
19.0 SOFTWARE QA	No	Good professional practices apply

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Container Fabrication Process Development
H-20-4

Additional Comments:

Activity determined to be of Quality Assurance Level I.
For description please see para. 3.4 of SIP.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86
Task Leader Date

John L Dronkers 12-10-86
Deputy Leader for QA Date

L Ballou 12-9-86
Waste Package Design Technical Area Leader Date

L Ramspott 12-9-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

12/17/86
Project Sponsor Date

12/16/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Container Fabrication Process Development

ACTIVITY NO.: H-20-4
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON QALA CHECK SHEET Step #6

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3.0 DESIGN 033-NWMP-P3A CONTROL	Yes (only 3A)	
4.0 PROC. DOC. CONTROL	Yes	Proc. 033-NWMP-P4.0 033-NWMP-P7.0
5.0 INSTR., PROCS, DWGS	Yes	Proc. 033-NWMP-R5.0
7.0 CTL OF PUR MATERIALS	No	This will be done by subcontractor
8.0 I.D. & CT OF MATERIALS	No	Will be responsibility of subcontractor
9.0 CONTROL OF PROCESSES	No	Contract is to provide for a process
10.0 INSPECTION	No	Will be responsibility of subcontractor
11.0 TEST CONTROL	No	Will be responsibility of subcontractor
12.0 CTL OF M & T EQUIP	No	Will be responsibility of subcontractor
13.0 HANDLING, STOR. & SHIP.	No	Will be responsibility of subcontractor
14.0 INSP. TEST & OPER. STAT.	No	Will be responsibility of subcontractor
19.0 SOFTWARE QA	No	No software development or use is envisioned

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Container Closure Process Development
H-20-5

Additional Comments: For description, see SIP Para. 3.5.

Activity determined to be of Quality Assurance Level I.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86
Task Leader Date

John J. Dronkers 12-10-86
Deputy Leader for QA Date

12-9-86
Waste Package Design Technical Area Leader Date

J. Ramospott 12-9-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

12/17/86
Project Sponsor Date

Jane Blaylock 12/16/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Container Closure Process Development

ACTIVITY NO.: H-20-5
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON QALA CHECK SHEET Step #6

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES	IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	Yes (only 3A)	Proc. 033-NWMP-P3A
4.0 PROC. DOC. CONTROL	Yes	Proc. 033-NWMP-P4.0 033-NWMP-P7.0
5.0 INSTR., PROCS, DWGS	Yes	Proc. 033-NWMP-R5.0
7.0 CTL OF PUR MATERIALS	No	This will be done by subcontractor
8.0 I.D. & CT OF MATERIALS	No	Will be responsibility of subcontractor
9.0 CONTROL OF PROCESSES	No	Contract is to provide for a process
10.0 INSPECTION	No	Will be responsibility of subcontractor
11.0 TEST CONTROL	No	Will be responsibility of subcontractor
12.0 CTL OF M & T EQUIP	No	Will be responsibility of subcontractor
13.0 HANDLING, STOR. & SHIP.	No	Will be responsibility of subcontractor
14.0 INSP. TEST & OPER. STAT.	No	Will be responsibility of subcontractor
19.0 SOFTWARE QA	No	No software development or use is envisioned.

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Container Closure Nondestructive Evaluation (NDE) Process Development
H-20-6

Additional Comments:

Activity determined to be of Quality Assurance Level I.
For reference see para. 3.6 of SIP.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86
Task Leader Date

John F. Dronkers 12-10-86
Deputy Leader for QA Date

L. Ballou 12-9-86
Waste Package Design Technical Area Leader Date

L. Ramspott 12-9-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

12/17/86
Project Sponsor Date

James Blaylock 12/16/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Container Closure Nondestructive Evaluation (NDE) Process Development

ACTIVITY NO.: H-20-6
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON QALA CHECK SHEET Step #6

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES	IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	Yes (3A only)	Proc. 033-NWMP-P3A
4.0 PROC. DOC. CONTROL	Yes	Proc. 033-NWMP-P4.0
5.0 INSTR., PROCS, DWGS	Yes	Proc. 033-NWMP-R5.0
7.0 CTL OF PUR MATERIALS	Yes	Proc. 033-NWMP-P7.0
8.0 I.D. & CT OF MATERIALS	Yes	Proc. 033-NWMP-R8.0
9.0 CONTROL OF PROCESSES	No	This activity is a process development activity.
10.0 INSPECTION	Yes	Proc. 033-NWMP-R10.0
11.0 TEST CONTROL	No	This activity is a process development activity.
12.0 CTL OF M & T EQUIP	Yes	Proc. 033-NWMP-R12.0
13.0 HANDLING, STOR. & SHIP.	Yes	Proc. 033-NWMP-R13.0
14.0 INSP. TEST & OPER. STAT.	No	This is a process development activity
19.0 SOFTWARE QA	Yes	Proc. 033-NWMP-R14.0

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Materials Acquisition
H-20-7

Additional Comments:

Activity determined to be of Quality Assurance Level I.
For reference see para. 3.7 of the SIP.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Nelson 12-9-86
Task Leader Date

John J. Dronkers 12-10-86
Deputy Leader for QA Date

12-9-86
Waste Package Design Technical Area Leader Date

Ramspott 12-9-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

12/12/86
Project Sponsor Date

James Blaylock 12/16/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Materials Acquisition

ACTIVITY NO.: H-20-7
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON QALA CHECK SHEET Step #6

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES	IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	Yes	3A only
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P4.0
5.0 INSTR., PROCS, DWGS	No	This is an activity that purchases bulk material
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P7.0
8.0 I.D. & CT OF MATERIALS	Yes	033-NWMP-R8.0
9.0 CONTROL OF PROCESSES	No	This is an activity that purchases bulk material
10.0 INSPECTION	Yes	033-NWMP-R10.0
11.0 TEST CONTROL	No	This is an activity that purchases bulk material
12.0 CTL OF M & T EQUIP	No	This is an activity that purchases bulk material
13.0 HANDLING, STOR. & SHIP.	Yes	033-NWMP-R13.0
14.0 INSP. TEST & OPER. STAT.	No	This is an activity that purchases bulk material
19.0 SOFTWARE QA	No	This is an activity that purchases bulk material

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Advanced Conceptual Design
H-20-8

Additional Comments:

Activity determined to be of Quality Assurance Level II.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Wilson 12-9-86
Task Leader Date

John H. Dronkers 12-10-86
Deputy Leader for QA Date

L. Ballou 12-9-86
Waste Package Design Technical Area Leader Date

L. Ramspott 12-9-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK LEADER

Project Sponsor Date

James Blaylock 12/16/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Advanced Conceptual Design

ACTIVITY NO.: H-20-8
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA II

CITE "YES" ITEM ON QALA CHECK SHEET Step #10

QA ELEMENT	APPLIES IF YES - LIST NEEDED PROCEDURES		IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	Yes	(38)	033-NWMP - R38
4.0 PROC. DOC. CONTROL	Yes		033-NWMP-P4.0
5.0 INSTR., PROCS, DWGS	Yes		033-NWMP-R5.0
7.0 CTL OF PUR MATERIALS	Yes		033-NWMP-P7.0
8.0 I.D. & CT OF MATERIALS	No		No hardware is involved
9.0 CONTROL OF PROCESSES	No		No hardware is involved
10.0 INSPECTION	No		No hardware is involved
11.0 TEST CONTROL	No		No hardware is involved
12.0 CTL OF M & T EQUIP	No		No hardware is involved
13.0 HANDLING, STOR. & SHIP.	No		No hardware is involved
14.0 INSP. TEST & OPER. STAT.	No		No hardware is involved
19.0 SOFTWARE QA	Yes		033-NWMP-R19.0

LEVEL OF QUALITY ASSURANCE LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Meeting: December 2, 1986

Meeting Attendees: Lyn Ballou
John Dronkers
Ed Russell

Name(s) and Number(s) of Activity:
Prototype Testing
H-20-9

Additional Comments:

Activity determined to be of Quality Assurance Level I.
For reference see para. 3.8 of SIP.

APPROVE LEVEL OF QUALITY ASSURANCE DETERMINATION

Thomas A. Wilson 12-9-86
Task Leader Date

John F. Dronkers 12-10-86
Deputy Leader for QA Date

L. B. Ballou 12-9-86
Waste Package Design Technical Area Leader Date

J. Ramospatt 12-9-86
NWMP Leader Date

TER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK ADER

Lester P. Skousen 12/17/86
Project Sponsor Date

James Blaylock 12/16/86
Project Sponsor Quality Manager Date

TURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Prototype Testing

ACTIVITY NO.: H-20-9
DATE: December 2, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

LEVEL OF QA I

CITE "YES" ITEM ON QALA CHECK SHEET Step #6

QA ELEMENT	APPLIES	IF YES - LIST NEEDED PROCEDURES / IF NO - JUSTIFICATION
3.0 DESIGN CONTROL	Yes	3A only
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P4.0
5.0 INSTR., PROCS, DWGS	Yes	033-NWMP-R5.0
7.0 CTL OF PUR MATERIALS	Yes	033-NWMP-P7.0
8.0 I.D. & CT OF MATERIALS	Yes	033-NWMP-R8.0
9.0 CONTROL OF PROCESSES	No	There are no special process involved
10.0 INSPECTION	No	There are no inspections of hardware required
11.0 TEST CONTROL	Yes	033-NWMP-R11.0
12.0 CTL OF M & T EQUIP	Yes	033-NWMP-R17.0
13.0 HANDLING, STOR. & SHIP.	Yes	033-NWMP-R13.0
14.0 INSP. TEST & OPER. STAT.	No	No status indications are required
19.0 SOFTWARE QA	No	No software to be developed or contemplated

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.2.5.L

NNWSI WASTE PACKAGE PERFORMANCE ASSESSMENT

LAWRENCE LIVERMORE NATIONAL LABORATORY

Revision 1

October 14, 1986

[signature] for L.D. Ramspott — 10-28-86

L. D. Ramspott, Technical Project Officer — Date

[signature] — 10-22-86

J. J. Dronkers, Deputy for Quality Assurance — Date

[signature] — 10/17/86

Kenneth G. Eggert, Principal Investigator — Date

[signature] — 11/3/86

Project Sponsor Quality Manager — Date

[signature] — 11-3-86

Project Sponsor — Date

Table of Contents

1.0 Purpose and Objective of Studies

The purpose and objectives of performance assessment are to conduct integrated assessments of waste package designs in order to qualify those designs with respect to the containment and release requirements of 10 CFR 60. In addition, a source term of releases from the waste package as a function of time must be provided to total repository performance assessment for calculation of releases to the accessible environment. Therefore, performance assessment directly addresses the following information needs (taken from 8/7/86 version of NNWSI information needs):

Issue 1.4: "Will the waste package meet the performance objective for containment as required by 10 CFR 60.113?"

1.4.3 Scenarios and models needed to predict the time to loss of containment and the ensuing degradation of the containment barrier.

1.4.4 Estimates of the rates and mechanisms of containment barrier degradation in the repository environment for anticipated and unanticipated processes and events.

1.4.5 Determination of the time to loss of substantially complete containment of the waste packages for anticipated processes and events.

Issue 1.5: "Will the waste package and repository engineered barriers meet the performance objective for radionuclide release rates as required by 10 CFR 60.113?"

1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.

1.5.4 Determination of the release rates of radionuclides from the engineered barrier system for anticipated and unanticipated processes and events.

1.5.5 Determination of the amount of the radionuclides leaving the near-field environment of the waste package.

Processes that affect release and containment failure do not occur independently but in an interrelated manner. Therefore, performance assessment calculations require that the effects of these interacting degradation and release mechanisms on waste package performance in an unsaturated tuff environment be calculated in an integrated manner. It is also recognized that waste package performance may not be calculated independently of the surrounding hydrologic environment. Further, differences in scale of interest may require an interfacing calculation between the engineered barrier system (EBS) boundary and the total system performance calculations. Since representation of the waste package environment is a necessary component of performance assessment calculations, it should be noted that changes in EBS definition will not affect the waste package performance

assessment codes nor the strategies needed to produce those codes.

Performance assessment will integrate the processes affecting waste package life and releases into computational models. To address the reasonable assurance standard to be applied by NRC, these models will incorporate a methodology to provide for probabilistic analysis of waste package reliability. Subprocess models will be obtained from investigations performed by the other subtasks of the waste package task. The basic data needs of performance assessment are served by those investigations. Therefore, the activities of performance assessment are those necessary to integrate and process information from the other subtasks with computational models. As will be explained below, quality assurance levels are assigned to be consistent with waste package design phases. Data and submodels supplied by activities outside of performance assessment will be required to have quality assurance levels consistent with the levels assigned the performance assessment activity using the data or models.

Waste package performance assessment contains three broad categories of activities. These activities are as follows:

1. Development of a hydrothermal flow and transport model to test concepts to be used in establishing boundary conditions for performance calculations, and to interface EBS release calculations with total system performance calculations.

2. Development of a waste package systems model to provide integrated deterministic assessments of performance and analyses of waste package designs.

3. Development of an uncertainty methodology for combination with the system model to perform probabilistic reliability and performance analysis waste package designs.

The first category contains activities that aid in determining the scope of a separate, simplified set of hydrologic calculations needed to characterize the waste package environment for performance assessment calculations. These detailed hydrothermal calculations are included in the waste package performance assessment subtask as a matter of project history at LLNL, but do not represent direct performance assessment calculations. The last two activity categories are directly concerned with waste package performance calculations.

Work on performance assessment activities to date has concentrated on evaluation of codes for application to hydrothermal problems and waste package system simulation. In addition, planning of interfaces with other waste package subtasks other interested NNWSI Project parties has been underway.

2.0 Rationale for Selected Studies

2.1 Introduction

The following subsection will discuss the technical rationale for the performance assessment activities. Quality assurance assignment sheets for these activities are attached in the appendix of this document. The Quality Assurance element that applies to all performance assessment activities is Procedure 19.0; Software Quality Assurance. A detailed Software Quality Assurance Plan is currently being developed for Waste Package Performance Assessment. The rationale for level assignments requires some explanation.

Detailed hydrothermal flow and transport calculations will be necessary to determine the scope of hydrologic phenomena affecting waste package performance. Concepts developed during these modeling activities will be used to form a basis for constructing the waste package environment subroutines of the performance assessment system model. This activity will provide conceptual input to more simplified system model development but will not supply code used in performance calculations; therefore, it is assigned QA Level III throughout the Project.

Two groups of waste package performance assessment activities, development and application of the waste package system model (Activities I-20-5 through I-20-13) and development and application of uncertainty methodologies (Activities I-20-14 through I-20-19), show an evolution of quality assurance level beginning at Level III and ending at Level I. Using the development and application of the system model as an example should clarify this process. The rationale for this approach follows the evolution of the waste package designs. The first version of the system model is used to evaluate methods of analysis for use in a system model. Using the flow chart supplied with each level assignment, it can be seen that activities using this version of the systems model (Activities I-20-5 to I-20-7) are assigned a QA Level III. Similarly, uncertainty analysis activities I-20-14 and I-20-15 are QA Level III activities.

The next phase is the development and application of a system model for analysis of the advanced conceptual design (Activities 1-20-8, -9, and -10). These activities will be based on an entirely new computer program using concepts learned in the earlier phase. New information and submodels from the other waste package subtasks will be incorporated into this program. The

program will be used to analyze the advanced conceptual design. In this case, design alternatives will be evaluated. Therefore, these activities are assigned QA Level II. Similarly, uncertainty analysis activities (I-20-16 and I-20-17) based on this performance assessment system model will have QA Level II.

The final phase is the development and application of a system model to the license application design (Activities I-20-11, -12, and -13). Again, these will be based on new code, incorporating aspects of the earlier codes and final information and data from the other subtasks. This program will be used to provide estimates of waste package design performance for direct use in the license application. In addition, the code will also supply a source term for use in total system performance assessment. Therefore, these activities are assigned QA Level I. The uncertainty analysis activities using the final version of the system model will be used to produce the distributions needed to provide reasonable assurance for source term calculations and, therefore, also have QA Level I.

The rationale for the studies will be grouped by type, i.e., hydrothermal flow and transport, system model development and application, and uncertainty analysis. A rationale for each activity under these groups is presented. All of the activities of performance assessment are either code development or analyses of waste package problems. Therefore, the rationale for each activity basically answers the question of why a particular approach was selected.

2.2 Hydrothermal flow and transport

The durations of the hydrothermal flow and transport activities are as follows:

Activity No.	Activity	Duration (months)	Quality Level
I-20-1	Development of detailed near-field flow and transport model	25	III
I-20-2	Verification and validation of detailed flow and transport model	33	III
I-20-3	Sensitivity analysis of near-field flow and transport model	14	III
I-20-4	Analysis of source term attenuation in near-field host rock	22	III

These activities are not strictly in sequence, but overlap to some extent. For example, the development of the near-field model will be more or less continuous over the period discussed in Section 5. It will overlap with part of the verification and validation period, and the sensitivity analysis is likely to indicate areas that may require more work. The analysis of the source term will overlap to a small degree with the end of the sensitivity analysis section; however, this activity will basically require that the other activities are complete. Documentation of the detailed hydrothermal

activities will be in the form of user manuals and application reports published as UCRL technical reports.

2.2.1 Development of near-field flow and transport model (I-20-1)

A near-field flow and transport model is necessary to understand boundary conditions of the waste package performance assessment model that are imposed by the immediate waste package environment. The development of this model may take place by modification of existing or development of new numerical simulations for flow and transport in the fractured host rock surrounding the waste package. The detailed simulation will be used in the development of a simplified flow and transport submodel for direct use in the performance assessment system model.

Numerical simulation of flow and transport in host rock is the only method sufficiently flexible to allow analysis of this aspect of the waste package environment. Other methods such as analytical solutions or even physical analogues are too restrictive to be representative.

Code development will consist of one continuous activity that must precede analyses using the code. As new information is obtained through either laboratory or exploratory shaft waste package environment tests, this information will be incorporated into the model. Therefore, this effort will heavily concentrate initially on development to produce a working code and developmental efforts will continue throughout the Project. Past work has concentrated on evaluating the applicability of available hydrothermal flow and transport codes. Codes considered included WAFE, TOUGH, and PETROS. All of these codes will require considerable modification to be applicable to the near-field environment.

As part of the code development process, a conservative method for analysis of flow and transport within the waste package will be selected. This method will be combined with the near-field host rock model to provide a more realistic source term for detailed transport calculations.

2.2.2 Verification and validation of detailed flow and transport model (I-20-2)

Two basic methods will be used to verify the hydrothermal code. The first method is to verify the code by comparing analytical solutions with related problems. This method provides the best verification of a numerical code; however, it is limited by the existence of analytical solutions only for restrictive boundary conditions, geometries, etc. Therefore, in addition to comparison with analytical solutions, the code will be compared via benchmarking activities with other independently developed numerical codes of similar scope. The verification activity will occur after the development of the first version of the hydrothermal code and after each major revision of the code.

Validation of the detailed model will be accomplished using data from exploratory shaft and laboratory waste package environment tests. These activities will test the code using physical approximations of the actual waste package environment. However, the experiments planned with the exploratory shaft and waste package environment activities will exercise the major components of this model. Model validation will be performed after the code verification is complete and after experimental results are available.

2.2.3 Sensitivity analysis of near-field flow and transport model (I-20-3)

Performance assessment calculations will require simplification of all process models included in the code. Without this simplification, a model that integrates the processes affecting waste package degradation could not be used to conduct the probabilistic reliability analysis required by NRC. To simplify a detailed calculational model, one must identify the most significant parameters affecting performance. The process of identifying these parameters is known as sensitivity analysis. After the model is verified and validated, sensitivity analysis will be performed to define the scope of phenomena needed to develop the simplified model for performance assessment.

2.2.4 Analysis of source term attenuation in near-field host rock (I-20-4)

Initially, release calculations made by the performance assessment models will provide release from the engineered barrier system, now considered to be the edge of the emplacement borehole. There are some indications that the first meter of tuff could provide significant sorption of many radionuclide species released from the waste package. The level of resolution required for analysis of the effect of the host rock immediately surrounding the waste package may require higher resolution than that practical for total system performance assessment.

These transport calculations are based on releases predicted by waste package performance assessment calculations. Therefore, the transport calculations are necessarily dependent on EBS release calculations. They will involve analysis of retardation in the first few meters of host rock, and high

resolution analysis of extreme event scenarios. Uncertainties regarding the number of analyses required are difficult to discuss since they will depend on the outcome of the modeling activity. Again, these concepts will aid in determining the scope required of the system model waste package environment routine. These modeling and analyses activities will provide input to activities to analyze waste package EBS performance performed by SNL under WBS 1.2.1.4. Documentation will include UCRL reports, user manuals, and Milestone P204 (See Section 5.5).

2.3 Development of the systems model and analyses of waste package designs

The durations of the system model development and analysis activities are as follows:

Activity No.	Activity	Duration (months)	QA Level
I-20-5	Development of version I of system model	6	III
I-20-6	Verification and validation of system model version I	6	III
I-20-7	Testing of system model using waste package design concepts	46	III

Activity No.	Activity	Duration (months)	QA Level
I-20-8	Development of system model version II for analysis of anticipated and unanticipated events	4	II
I-20-9	Verification and validation of system model II	4	II
I-20-10	Analysis of advanced conceptual design with system model version II	7	II
I-20-11	Development of version III of system model for analysis of anticipated and unanticipated events	5	I
I-20-12	Verification and validation of system model version III	6	I
I-20-13	Analysis of license application design with system model version III	11	I

2.3.1 Development of version I (I-20-5)

The system model of the waste package is an essential step towards obtaining a license for the NNWSI repository design. To obtain a license, it will be necessary to provide evidence that the waste package design is capable

of performing its function for the required time durations. Clearly, this is not possible through experimentation because it would take hundreds of years to physically test the waste package design. Consequently, the performance of the waste package design must be addressed theoretically, using the best data and predictive models to estimate the actual physical processes that will occur following closure of the repository.

This task involves the theoretical specification as well as the computer implementation of a waste package system model. The system model will deterministically calculate the performance parameters of interest given the specific design characteristics of the waste package. It will couple the various physical and chemical process models derived from the results of the other, more empirical, waste package task study efforts.

A computer implemented, theoretical system model to predict the performance of the waste package was used for many reasons. First, there are a number of synergistic physical and chemical processes, e.g., irradiative damage and heating, thermal expansion and stress, mechanical loading, corrosion, etc., which can lead to premature failure of the waste package. Since these processes are coupled, affecting one another's importance and rate of occurrence, it is not possible to assemble independent assessments of the likely history of particular waste package components or processes into a credible prediction of the total waste package performance. It is essential that a time-dependent, complete, and coupled system model of the waste package be used to coherently assess the behavior of the waste package in the repository environment.

Previous work on this activity has centered on evaluation of the waste package performance assessment code WAPPA for application to the NNWSI waste package. The formulation of this code appears inadequate for this purpose; and therefore, a new formulation is required.

The system model will be developed in parallel with the various physical and chemical process models. This is possible because, to a large degree, the process models within the system model will act more or less as black boxes, accepting certain physical parameters (e.g., time, temperature, water chemistry) as input, and returning one or more physical parameters (e.g., corrosion rate, thermal expansion, water chemistry) as output. The system model will couple these physical process models and determine their time-dependent behavior. Documentation of the development of this model will include UCRL reports, user manuals, and Milestone M276 (see Section 5.5).

2.3.2 Verification and validation of system model version I (I-20-6)

This effort involves the testing of the various physical and chemical process models (submodels) for use in the systems model. The submodels will be the result of extensive interaction with other, experimentally based, investigative efforts. As the submodels for a particular process (e.g., irradiative heating, waste material dissolution, mechanical loading) are developed, verification that the computer implementation of the submodels is in agreement with the theoretical model will be required. The theoretical submodels will be tested by comparison with analytical solutions and laboratory measurements to ensure that they do correctly represent their respective physical processes and that these processes are the correct ones for use in the system model.

This effort will be conducted in parallel with the system model development for reasons explained in Section 2.3.1. Documentation of this activity will be in the form of UCRL reports.

2.3.3 Testing of system model using waste package design concepts (I-20-7)

Once the system model and accompanying submodels have been independently developed, verified, and validated, it will become necessary to test the integrated model. This effort will involve running the system model with configurations formed of waste package design concepts. The results of this test will show logical or conceptual errors in the computer or theoretical model.

Another important aspect of testing the system model will be in the form of the sensitivity analysis. Sensitivity analysis will involve measuring the degree of sensitivity of the waste package performance measures calculated by the system model to the various waste package design input parameters, as well as the various internal data and process submodels of the system model. The results of this analysis will assist in improvement of the system model in succeeding versions, and also will provide useful information to the uncertainty analysis (see Section 2.4); therefore, it will provide conceptual input to activities I-20-8 to I-20-19. Although this activity begins with testing the first version of the system model, it will continue in order to provide a method for testing system model analysis methods throughout the duration of the project. Documentation of this activity will be in the form of UCRL reports.

2.3.4 Development of system model version II for analysis of anticipated and unanticipated events (I-20-8)

This effort is similar in nature to that described in Section 2.3.1. Some exceptions are that this version of the system model will be based upon the advanced conceptual design of the waste package, will be used to evaluate waste package designs, and will also address unanticipated events. Results of this study will be used in Activity I-20-9.

2.3.5 Verification and validation of system model version II (I-20-9)

This subtask is similar to that described in Section 2.3.2. Results of this study will be used in activity I-20-10. Documentation of this activity will appear as UCRL reports.

2.3.6 Analysis of advanced conceptual design with system model version II (I-20-10)

This subtask is similar to that described in Section 2.3.3. At this point the system model will be baselined and documentation will include user manuals developed as UCRL reports and Milestones M260 and M263 (see Section 5.5). This model will serve as a kernel for uncertainty methodology development activities to be used to analyze advanced waste package design performance (Activity I-20-16 and I-20-17). Also output of this activity will be used directly to evaluate waste package design alternatives (Activity I-20-11).

2.3.7 Development of version III of system model for analysis of anticipated and unanticipated events (I-20-11)

This effort is similar to that in Section 2.3.1 with the exception that this model will focus on the license application design of the waste package. The model developed under this activity will be used in Activities I-20-12 and I-20-13.

2.3.8 Verification and validation of system model version III (I-20-12)

This subtask is similar in content to Section 2.3.2. Results of this activity will be used in I-20-13. Documentation of this activity will appear as UCRL reports.

2.3.9 Analysis of license application design with system model version III (I-20-13)

This subtask is similar in nature to that described in Section 2.3.3. This model version will be baselined and applied to the license application waste package design. Results will form a portion of the EBS release and containment performance input to radionuclide source term construction performed under WBS 1.2.1.4 by SNL. Documentation will include UCRL reports and milestones M268 (see Section 5.5).

2.4 Uncertainty analysis

Uncertainty analysis activities are as follows:

Activity No.	Activity	Duration (month)	QA Level
I-20-14	Development of uncertainty analysis methodologies for testing with the system model	48	III
I-20-15	Verification of suitability of uncertainty methods using system model version I	7	III
I-20-16	Development of uncertainty methodology incorporating version II of the system model	20	II
I-20-17	Verification of uncertainty methodology and application to analysis of advanced conceptual design	6	II
I-20-18	Refinement of uncertainty methodology and incorporate final version of system model	7	I
I-20-19	Uncertainty analysis of license application design and derivation of source term for total system performance	15	I

There are two types of work in these activities--developing methodologies and applying the methodologies to waste package designs. There are three stages that correspond to the three design stages of conceptual design, advanced conceptual design, and license application design and to the three stages of system performance model development.

Uncertainty analysis is needed to address such questions as:

- With what reliability will the waste package meet its long-term performance goals?

- What will be the range and distribution of the waste package's performance measures, which are in units of the performance goals?

- What are the values and the intrinsic variability of the source term of radionuclide releases over time from the waste package to the total repository system?

An analysis is needed and an experimental approach alone is unfeasible because:

- The purpose is to look for what is by design a rare event, the failure of the waste package to fulfill its performance goals.

- Many joint occurrences of events and coupled evolution of processes in the characterization of the range of likely or possible outcomes must be considered.

2. The cumulative probability distribution on cumulative release of radionuclides to 10,000 years is information required by NRC regulations.

3. The cumulative probability distribution on other performance measures will increase the confidence in the reliability results.

4. A description of the variability in the waste package source term time history will be provided as an input to total repository system reliability analysis.

This activity begins with examination of methodologies for possible use in the first uncertainty model, but it will continue in a similar function throughout the project. This activity will provide results about analysis feasibility and thus will provide a guide to subsequent development activities. This activity will require outside inputs at certain phases. These inputs consist of waste package design and the conceptual model development in the corresponding system performance model to start the uncertainty method development. Further, a waste package analysis and sensitivity analysis using the system performance model is required before putting the finishing touches on the uncertainty method development and computer code implementation. Results of this activity will be documented in UCRL reports. The results of this activity will be used in Activities I-20-15 to I-20-19.

2.4.2 Verification of suitability of uncertainty methods using system model version I (I-20-15)

There are uncertainties in which methodologies for uncertainty analysis will be selected and used. Provision is made in this activity for evaluating and selecting methodologies. Initial selection will depend on selection criteria such as feasibility and usefulness as a learning tool. An issue that is particularly important is which among models, data, and design features will most limit the accuracy and applicability of the first analysis cycles. Results of this activity will be in the format of UCRL reports and concepts learned in this activity will guide work in Activity I-20-16.

2.4.3 Development of uncertainty methodology incorporating version II of the system model (I-20-16)

This development will be based upon the concepts learned in Activities I-20-14 and I-20-15. It will incorporate the version of the system model to be used to assess performance of the advanced conceptual design. Results will be in the form of UCRL reports and will be used in Activity I-20-17.

2.4.4 Verification of uncertainty methodology and application to analysis of advanced conceptual design (I-20-17)

This activity will verify the methodology developed in Activity I-20-16. Application of the methodology to advanced conceptual design will be reported as a UCRL report. Concepts learned in this activity will guide work in Activity I-20-18.

2.4.5 Refinement of uncertainty methodology and incorporate final version of system model (I-20-18)

This activity will use the results of Activity I-20-17 to refine the uncertainty methodology for application to the license application design. The results of this development will be documented in a UCRL report and as part of milestone M273 (see Section 5.5).

2.4.6 Uncertainty analysis of license application design and derivation of source term for total system performance (I-20-19)

The activity will use the refinements of the uncertainty methodology made in Activity I-20-18 to analyze the license application design. This activity will provide the loss of containment and EBS source term distributions to the total system performance calculations to be performed under WBS 1.2.1.4. The results will be documented in a UCRL report and, along with results of Activity I-20-18, will appear in milestone M273.

3.0 Description of Tests and Analyses

3.1 Introduction

The entire waste package performance assessment subtask consists of program development and analyses. As described in Section 2.0 of this plan, the activities of the subtask are divided into three groups: (1) hydrothermal flow and transport; (2) development and application of system model; and (3) development and application of uncertainty methodology. The plans for these activities will be discussed in detail in the following subsections of Section 3.0.

3.2 Hydrothermal flow and transport

3.2.1 Development of detailed near-field flow and transport model (I-20-1)

Numerical modeling of the coupled multiphase heat, fluid flow, and contaminant transport is necessary to predict the waste package environment and to provide a realistic source term to total system performance assessment. This detailed analysis will not be directly used in performance assessment calculations but will serve as a guide for a simplified model, which will be part of the performance assessment system model. The numerical simulations focus on understanding the fundamental mechanisms governing heat and fluid flow in partially saturated fractured rock. Understanding the roles that fractures and adjoining matrix blocks play as conduits to liquid and vapor phase transport is of particular interest. This interaction will influence the extent of dry out in the surrounding host rock and the rate at which rewetting can occur as the thermal output of the waste decreases. These processes impact assessment of waste package corrosion mechanisms and rates and will influence transport rates near the waste package after containment failure.

The approach to be used will be to construct a three-dimensional fully implicit, finite difference solution to the partial differential equations governing multiphase fluid flow in partially saturated fractured rock. Included in this formulation are equations for the transport of heat, and the phase changes required to simulate steam-water-air systems. The solution of the transport equation for contaminants will not initially be fully coupled with the flow model but will be partially driven by velocities calculated by the flow model.

Particular attention will be given to the role of fractures in characterizing the flow and transport problem. Fracture characterization will be attempted in two ways to obtain the most accurate model for the zone nearest the emplacement borehole. Synthetic characteristic curves that integrate the properties of matrix and fractures into single curves will be tested to examine the applicability of a single porosity model. Some simulations of discrete fracture response will be performed to determine how the response of a discretely modeled fractured media differs from the continuum approach. If significant, those effects will be built into the simulation.

Radionuclide transport modeling will be studied to address two basic questions. First, the effect of the thermal pulse on the concentration of ions adversely affecting performance of the waste package will be examined. Second, the attenuation of radionuclide transport due to retardation in the first few meters of host rock will be studied to understand how the near-field host rock may modify the source term resulting from release.

These issues will be resolved by hydrothermal modeling. The basic approach for model development will be to survey the existing literature and work already in progress on the NNWSI Project to identify applicable work. Based upon that work, a new model will be formulated, either as a new simulation or as a modification of an existing code, that will address the problems discussed above. This development effort will pause for verification and validation as appropriate data becomes available. Development will resume in order to modify the code as new data from site investigations or from retardation studies is obtained. Development will continue until verification and validation exercises indicate that an accurate, representative model has been obtained.

3.2.2 Verification and validation of detailed flow and transport model (I-20-2)

Verification exercises will determine the accuracy with which the numerical simulation solves the partial differential equations of flow and transport for a given geometry and set of boundary conditions. This task will be accomplished in two ways. First, since comparisons of the numerical solution with analytical solutions are only available for certain geometries and boundary conditions, it may be possible to use this method only for isothermal single-phase unsaturated flow or for steady-state solutions of more complex systems.

A second method of verification is to compare results with other independently developed, numerical hydrothermal simulations to test the model on more complex problems. This method will allow solutions to problems containing geometries and boundary conditions that are much nearer to actual waste package environment conditions to be verified. Comparison with other numerical simulations in many cases provides the only means to examine the accuracy of predicted results.

Validation exercises require comparison of results of simulations of field or laboratory experiments with the measurements taken during those experiments. Again two types of studies are planned. First, laboratory experiments will be conducted under controlled and often restrictive conditions that will exercise many of the features of the hydrothermal model. An example is a heat pipe experiment in partially saturated rock. In this case, partial validation is possible since the laboratory experiment is intended to track matrix saturation changes as a function of time and space, and the experiment will be conducted at temperatures that will cause a phase change.

More comprehensive validation experiments are planned for the exploratory shaft tests. In the waste package environment tests, a heater will be placed in host rock, and the changes in the saturation field in a fractured rock mass will be examined. Contaminant transport calculations will require validation using data to be obtained from tracer and sorbing species tests to be conducted as part of the exploratory shaft tracer tests.

3.2.3 Sensitivity analysis of near-field flow and transport model (I-20-3)

To derive simplified waste package environment models for performance assessment calculations, the most sensitive parameters of the hydrothermal flow and transport model must be identified. There are basically two methods under consideration for approaching this problem. The first is to vary individual parameters systematically, holding all others constant, and to record the changes observed in model results. This method is simple, and although not considered rigorous, it often provides the most practical approach. The most rigorous approach would be to develop an adjoint solution for the hydrothermal code. Both methods are currently under consideration. A decision on which method will be used will await the results of early model development. The results of this activity will provide the basis for the system model hydrothermal environment submodel.

3.2.4 Analysis of source term attenuation in near-field host rock (I-20-4)

After all other activities of hydrothermal modeling are completed, the detailed model will be used to analyze the transport of radionuclides in the first few meters of host rock. The selection of radionuclides will depend on the EBS source term calculations with the performance assessment code.

Basically, the study will consist of introducing partition coefficients that allow representation of the retardation mechanisms expected in the waste package environment. The solubilities of radionuclides in the groundwater will be used to limit the concentrations that can be predicted in the liquid phase transport.

3.3 Development of the system model and analysis of waste package designs

3.3.1 Development of version I of system model (I-20-5)

The first version of the system model, which has now been largely specified, is being reviewed. This model includes data flow descriptions that will provide the basis for development of the first version of the deterministic system model, named PANDORA-1 (PANDORA, PERFORMANCE ASSESSMENT MODEL FOR NUCLEAR WASTE PACKAGE DESIGNS OMITTING RELIABILITY APPLICATIONS).

PANDORA-1 will consist of a main routine which presently drives seven physical and chemical process models:

1. radiation
2. thermal
3. mechanical
4. waste package environment
5. corrosion
6. waste form alteration
7. waste transport (within the waste package)

Each of the process models will, in turn, consist of subprocess models which interact among themselves and with subprocess models from other physical processes.

As stated, PANDORA will be a deterministic model; it will use point estimates of input quantities to arrive at point estimates of the performance indicators (i.e., time-to-loss-of-containment and rate of release). It is intended that PANDORA act as the core of another program that will perform the uncertainty analysis. This development will be partially reported in Milestone M276 (see Section 5.5) reported in final form in UCRL reports.

3.3.2 Verification and validation of system model version I (I-20-6)

PANDORA will consist of a driver routine that utilizes seven process models (submodels) to calculate the performance characteristics of the waste package. These submodels will effectively act as black boxes; input parameters, which may be the output parameters of other process models, will be fed into a submodel, and the submodel will return a set of parameters (e.g., radial temperature profile, gamma dose at a location, corrosion rate) related to that particular physical process. The physical process models will be stepped through time, and performance characteristics will be calculated at various time steps. In this way, the time-dependent behavior of the waste package and its radionuclide contents will be calculated deterministically.

PANDORA-1 will involve the use of some submodels that are quite sophisticated, while others may be rather simplistic. It is expected that subsequent versions of PANDORA, which will be developed as the waste package design evolves, will involve increasingly sophisticated physical process

models. This evolution will depend heavily on the work of the other waste package subtasks. As each subtask completes experimental phases, thereby obtaining new empirical data and/or developing better formulations to represent the physical processes, the new data or formulations will be assimilated by the system modeling effort.

As each submodel is developed, there will be a verification and validation phase for that submodel. This testing stage will examine only the independent submodels, possibly examining limited aspects of submodel interactions. Results of this activity will appear in UCRL reports and will be used in Activity I-20-7.

3.3.3 Testing of system model using waste package design concepts (I-20-7)

Once the driver routine for PANDORA and the independent physical process models have been written, verified, and validated, the verification and validation of the performance of the entire system model will be started. This final step in the development of PANDORA will involve testing of the system model using the configuration of the waste package conceptual design.

The initial testing process will involve tests of the performance characteristics of the waste package using the nominal values specified in the conceptual design. However, sensitivity analysis will be used to further indicate the behavior characteristics of PANDORA. The sensitivity analysis program, PROMET, will be developed near the end of the PANDORA development process. PROMET will be a program that is designed to perform sensitivity analysis for PANDORA. It is essentially a shell that exercises PANDORA as a subroutine. The different approaches to performing the sensitivity analysis

will be investigated while PANDORA is being developed. The choice of sensitivity analysis methodology will, to some degree, be dependent on the final design and operating characteristics of PANDORA.

The sensitivity analysis will also serve another purpose in the performance assessment subtask. Uncertainty analysis, which will provide the probabilistic calculation of the waste package performance characteristics, will utilize the results from PROMET to determine which input parameters, submodels, subprocess models, etc. have the greatest influence over the performance characteristics. In this way, the uncertainty analysts will be able to prioritize their examination of the effect of specifying distributions, rather than point estimates, for various inputs and parameters of PANDORA. Results of this study will be reported in UCRL reports and will be used in Activities I-20-8 to I-20-19. Milestone M260 (see Section 5.5) will be among the early reports from this activity.

3.3.4 Development of system model version II for analysis of anticipated and unanticipated events (I-20-8)

This effort will be similar to that of Activity I-20-5 with a few significant changes. First, this version of the system model, PANDORA-2, will be based upon the advanced conceptual design for the NNWSI waste package. Second, unlike PANDORA-1, this version of the system model will be designed to accommodate analyses of unanticipated events as well as anticipated events. Third, in designing this version of PANDORA, the results of the sensitivity analysis of PANDORA-1 will be used as a significant additional set of data to guide the development effort. Last, preliminary results of the uncertainty analysis of PANDORA-1 should be available before the design and development of

PANDORA-2 is complete. The information from the uncertainty analysis could prove to be quite useful in making design modifications to the deterministic model.

Each successive version of the system model, and therefore, PANDORA-2, will be treated as the development of an entirely new model. Each physical process model and subprocess model, as well as all auxiliary routines, will be thoroughly examined for appropriateness in each version. Also, decisions will be made regarding the most appropriate computer system environment, computer language, etc. to be used for each new version of PANDORA.

3.3.5 Verification and validation of system model version II (I-20-9)

This effort should be essentially of the same nature as Activity I-20-6. Results will be documented in UCRL reports and will be used in Activity I-20-10.

3.3.6 Analysis of advanced conceptual design with system model version II (I-20-10)

After the driver and physical process models for PANDORA-2 have been completed, and verification and validation of the integrated system model is complete, analysis using the parameters from the advanced conceptual design (ACD) will be performed. It is expected that the results of the performance assessment of the ACD will be fed back into the design process for the license application version of the NNWSI waste package.

During the analysis of the ACD with PANDORA-2, development and utilization of the second version of the sensitivity analysis program, PROMET-2 will be planned. The results from this sensitivity analysis of version II of the system model will be utilized in Activity I-20-11 and reported in UCRL reports and Milestone M263 (see Section 5.5).

3.3.7 Development of system model version III for analysis of anticipated and unanticipated events (I-20-11)

The effort will be similar to Activities I-20-5 and I-20-8, with the exception that the development process will be based on the license application design of the NNWSI waste package. Results will be reported in UCRL reports and will be used in Activities I-20-12, I-20-13, I-20-18, and I-20-19.

3.3.8 Verification and validation of system model version III (I-20-12)

This effort will be similar to Activities I-20-6 and I-20-9. Results will be reported in UCRL reports and will be used in Activity I-20-13.

3.3.9 Analysis of license application design with system model version III (I-20-13)

This effort will be the final deterministic simulation of the license application design. Source terms and times to containment failure will be calculated in Activity I-20-19 using the results of this activity. Milestone M268 (see Section 5.5) will document this model.

3.4 Uncertainty analysis

There is some inherent variation in fabrication and environmental parameters and, hence, in the performance values of waste packages, even with uniform design and well-controlled fabrication and emplacement conditions. Uncertainty analysis addresses this problem by analyzing the reliability of the waste packages and be developing an explicit description of the inherent variation in waste package performance.

The plan for uncertainty analysis was developed based on the purposes of the analysis and the nature of the subject matter. The purposes of the uncertainty analysis are:

1. Analyze the reliability of the waste package performance with respect to its performance criteria:

    a. Time of essentially complete containment;

    b. Release rates for individual radionuclides for a period of 10,000 years;

    c. Total release as of 10,000 years.

2. Provide a cumulative probability distribution function (CDF) on the total release as of 10,000 years.

3. Provide a source term, including description of variability, to the total repository system performance assessment and reliability assessment.

Possible additional uses of uncertainty analysis are:

4. Provide CDFs of other performance measures.

5. Determine the data elements or modeling areas contributing most to the uncertainty (i.e., assess sensitivity of uncertainty) as a guide to additional tests or model refinement to reduce the uncertainty.

Assessment of reliability with respect to performance criteria means assessing the probability that the performance value is on the acceptable side (high for time of containment, low for releases and release rates) of the performance criteria. This assessment is one point on the CDF. A low probability that the waste package would not meet its performance criteria and a high confidence in this low probability are desirable.

When the assessment of the CDF to performance values is extended well beyond the performance criteria and correspondingly to higher probabilities of occurrence, it must be recognized that confidence in the CDF values becomes progressively less. Paradoxically, the better the waste package design and performance become, the less accurately its actual performance value can be predicted, even though a high confidence on lower bounds of performance may be realized. An example of an assessed CDF and a format for depicting confidence interval on the assessed CDF is shown in Figure 1. There are two types of uncertainty in waste package performance shown separately in Figure 1: the best estimate CDF represents the uncertainty due to inherent variability; and the higher and lower CDFs represent the confidence in the best estimate CDF due to a finite state of knowledge. Although separate, if desired, the CDFs can be merged using the calculational tools of probability theory to get one overall uncertainty.

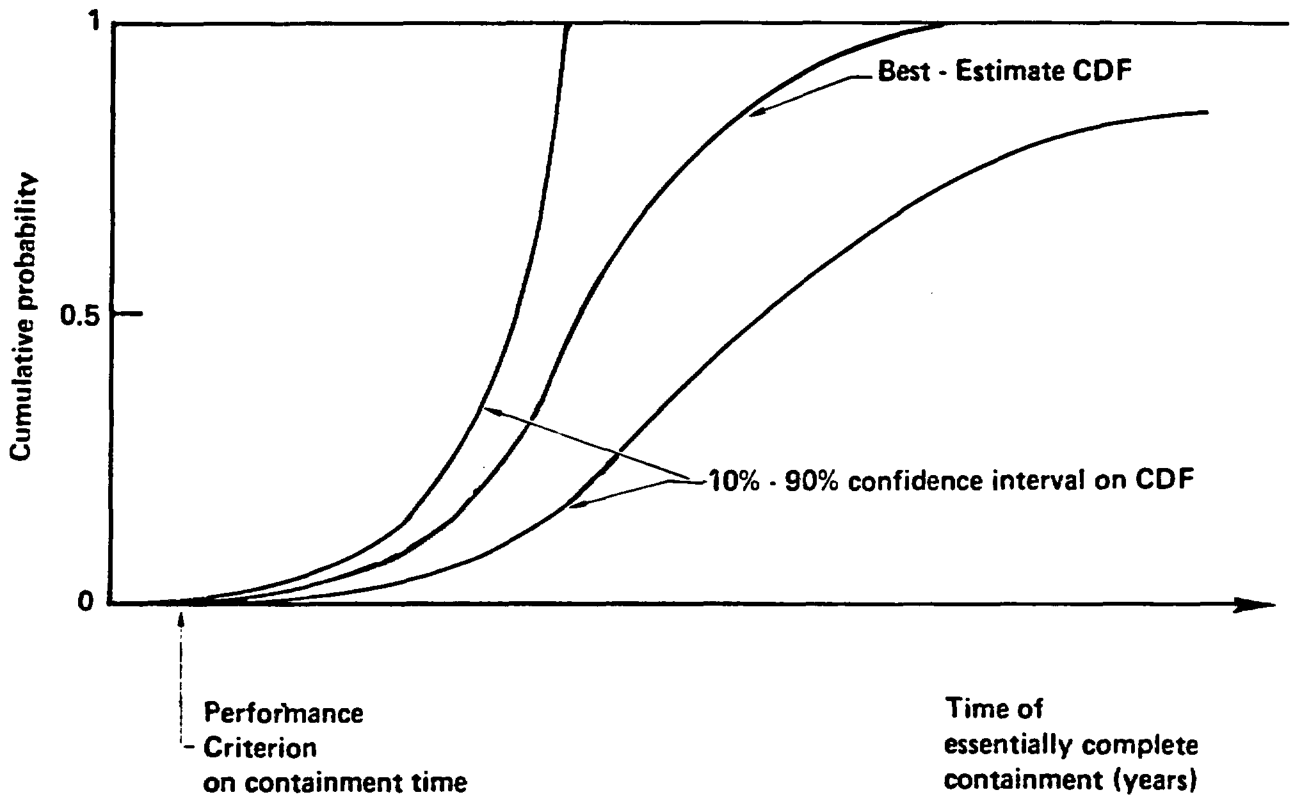


Fig. 1. Example of an assessed CDF depicting confidence intervals on the distribution.

The strategy for uncertainty analysis is to perform the analysis incrementally in three cycles because of the stages of information becoming available from other subtask tests and the stages in waste package design, i.e., conceptual design, advanced conceptual design, and licensing design. There will also be stages in the experience with the applicability of uncertainty analysis methodologies and in sensitivity-of-uncertainty results. This experience will guide further cycles in the methodology development process.

The stages and the step-by-step plan for carrying out the uncertainty analysis are as follows.

3.4.1 Development of uncertainty analysis methodologies for testing with the system model (I-20-14)

3.4.1.1 Examine methodologies

First, various existing methods of reliability analysis will be examined for applicability and feasibility. Methods to improve on computational efficiency or accuracy will be explored or created.

Features of the waste package performance process that must and will be addressed in the selection of a suitable uncertainty analysis method include:

1. The identification and description of failure modes.

2. The continuous and multidimensional range of input parameters affecting package performance.

3. The coupling of parameters in processes.

4. The interactions of processes and the gradually changing conditions of the waste package.

Numerous methodologies exist to date. They will be reviewed and evaluated in order to choose the most promising ones. All of the methodologies require information on the distributions of values of the input parameters. These will be treated as probability distributions of random variables. Not all of the input parameters need to be treated as random variables. The parameters needing such treatment can be determined from results of the sensitivity analysis of the deterministic system model coupled with preliminary estimates of the amount of variability in the parameters.

Several methods are available to evaluate the CDF of a performance measure (such as total EBS release). One group of methods involves sampling from the probability distribution of the input variables and doing repeated deterministic calculations of the performance using these samples of inputs. In this way, a sample of output performance values is accumulated, which approximates the CDF of the output. The input sampling may be by purely random sampling, by stratified sampling such as Latin Hypercube sampling, or by stratified selection.

Other methods of evaluating the CDF include analytic methods of propagating moments of the input probability distributions to moments of the output probability distributions. In addition, some methods involve combined techniques of response surface analysis to get a simplified model of the deterministic process and then sampling inputs and using the simplified model.

To evaluate the reliability of the waste package in meeting its performance criteria, several methods are available. Sampling as in evaluating the CDF is possible but may be inefficient if the unreliability to be determined is very low. Biased sampling may be of some help in this case. Another approach determines the first few central moments of the output distribution from the sample used in evaluating the CDF and then extrapolated this distribution to high or low probabilities using the moments. This approach is easy but has a relatively large uncertainty due to the extrapolation.

Another group of methods for evaluating the reliability involves finding the dividing surface in the multidimensional input space between the "success" space (i.e., those combinations of inputs which give a successful performance outcome) and the "failure" space. One then integrates the joint probability measure of the input variables over the failure space to determine the probability of failure. Usually it is too tedious an exercise to determine the exact dividing surface between success and failure spaces, so one falls back on a simpler dividing surface between a "safe" space and an "unsafe" space. The unsafe space contains some undetermined part of the success space and all of the failure space. The idea is to find some simple method to qualify and delineate a safe space, even at the expense of conceding some possible success regions to the opposite space.

3.4.1.2 Select methodologies

Selection criteria, which may include combinations of feasibility, defensibility, manageable input data needs, usefulness in the analysis, accuracy, and usefulness, will be determined as a learning tool in the phased development process. One or several methodologies from those evaluated in Section 3.4.1.1 will be selected to answer the questions posed for the first version of the system model and the conceptual design.

3.4.1.3 Develop computer program

A computer program to implement the selected uncertainty analysis methodologies will be developed. This is expected to be a substantial project. It will be done in a methodical and documented manner of computer program development.

3.4.2 Verification of suitability of uncertainty methods using system model version I (I-20-15)

3.4.2.1 Develop input data on parameter probability distributions

Data describing the probability distributions of those parameters of the deterministic model that must be treated as random variables will be developed. Parameters that need such treatment can be determined from results of the sensitivity analysis of the deterministic system model coupled with preliminary estimates of the amount of variability in the parameters. The format of the data will depend on the uncertainty methodologies selected, and may include type of distribution, moments, and upper and lower limits on values.

The data on probability distributions will need to be provided by other subtasks in the Waste Package Task, which contain the data, experimental programs, and expertise on the individual processes and their parameters.

3.4.2.2 Estimate secondary uncertainties and gaps in the data in Section 3.4.2.1

Asking for a probability distribution is asking for more information than is contained in just a best-estimate value or a mean value. The basic measurements and analyses on measurements to support distribution information may be available only to a limited extent, thus leaving some uncertainty in the distribution information. This is known as secondary uncertainty to distinguish it from the uncertainty in the value actually obtained when sampling from the distribution.

3.4.2.3 Perform trial computer runs using hypothetical data to demonstrate functioning of program and to identify some major features of program performance, such as effects of probability distribution input values and of submodel performance

This step is exploratory, but important. Often in a large complex system of software or hardware, the implications of the whole are not obvious from knowledge of the parts or of the specification. Effects of the whole model on submodel performance, of submodel interactions, and of input data combinations should be explored. Some trial runs can be guided by knowledge of the internal structure of the model. These runs allow examination of expected major influences on the output from certain submodels or certain input

uncertainty values. Other trial runs should be "black-box" input-output studies. Any unanticipated major influences on output should be studied until they can be understood.

3.4.2.4 Perform uncertainty analysis of conceptual design

This step will take the input data applicable to the conceptual design determined in Section 3.4.2.1 and do an uncertainty analysis of that design. The uncertainty analysis will include reliability analysis of the waste package meeting its performance criteria, CDFs of performance values, and source term over time with some description of its uncertainty.

3.4.2.5 Estimate the secondary uncertainty in the results in Section 3.4.2.4

This step will estimate the uncertainty in the probability distribution values and characterizations done in Section 3.4.2.4. The sources of this uncertainty include uncertainty in inputs, models, and limitations in sample size and algorithm accuracy due to time tradeoffs.

3.4.2.6 Estimate the major sources of this secondary uncertainty in the results in Section 3.4.2.4.

This estimation will provide some guidance to the next cycle of development. The estimation at this stage may be done by a combination of qualitative and subjective judgments and a limited amount of sensitivity-of-uncertainty computerized analysis.

The major purpose of the analyses in Sections 3.4.2.4 and 3.4.2.5 is to check the feasibility of the approach, that is, whether enough data is available to support it, how much manpower and computer time it takes, how large the uncertainties in the results are, and whether the uncertainties in the results can be meaningfully described.

3.4.2.7 Perform uncertainty analysis or sensitivity-of-uncertainty analysis for alternate design features as needed

This step can check out the implications on reliability arising from alternate design features or from design parameters that could be changed. At this cycle in the methodology development, any results and recommendations will need to be checked on a case-by-case basis to make sure they are significant and not the result of oversimplification of the model or input data. Results of this activity will be reported in UCRL reports, and concepts will be incorporated into Activity I-20-16.

3.4.3 Development of uncertainty methodology incorporating version II of the system model (I-20-16)

These activities will parallel those presented in Section 3.4.1 except that it will be necessary to address new questions that will arise with the analysis of the advanced conceptual design. Expected new questions concern the analysis of scenarios based on unanticipated events and combination of the results of analyses of anticipated and unanticipated events into a net reliability and a net CDF for performance values. The source term will remain uncombined; separate source term descriptions conditional on the specified unanticipated events will be developed. Any new features due to the new

advanced conceptual design must also be treated in the analysis. The degree of accuracy and/or the degree of defensibility required of the analyses will be increased at this cycle, consistent with the quality assurance level required for analysis of alternative designs.

Based on requirements and on methodology selection criteria, refinements or additions to the first cycle methodology may be added. If found desirable, an essentially different methodology may be selected. A new computer program for uncertainty analysis will then be developed. This development will be treated as a new computer program even if major parts of methods developed in Section 3.4.1 are adopted for reuse. The program will be developed following a methodical standard procedure of scoping, specification, design, and cooling. Results of this activity will be reported in UCRL reports and will be used in Activity I-20-17.

3.4.4 Verification of uncertainty methodology and application to analysis of advanced conceptual design (I-20-17)

This activity will parallel that described in Section 3.4.2; however, analyses will be made of the advanced conceptual design. Therefore, it will be necessary to develop input data on parameter probability distributions and on scenario probabilities. Secondary uncertainties will then be estimated, and gaps in the input data identified. Trial computer runs will then be performed using hypothetical data to demonstrate the functioning of the program and to identify some major features of program performance, such as effects of input uncertainties and submodel performance.

An uncertainty analysis of advanced conceptual design will follow trial runs. This will include estimation of the secondary uncertainty in the analysis results and the major sources of this secondary uncertainty. After identifying some techniques or representative problems for use in verification of uncertainty methodology, a limited verification of the uncertainty methodology will be conducted. Results of this activity will be reported in UCRL reports, and concepts will guide the work in Activity I-20-18.

3.4.5 Refinement of uncertainty methodology and incorporate final version of system model (I-20-18)

After analysis of the advanced conceptual design, it will be necessary to examine new questions as well as the nature and accuracy required of analyses. This activity will be guided by results of previous cycles of waste package analysis. At this time, it may be necessary to add methodologies or select alternate methodologies. After these questions are addressed, a new computer program for uncertainty analysis will be developed. Results of this activity will be used in Activity I-20-19 and will be documented in UCRL reports.

3.4.6 Uncertainty analysis of license application design and derivation of source term for total system performance (I-20-19)

As before, input data on parameter probability distributions and on scenario probabilities will be developed. Again, this will include estimating remaining secondary uncertainties in the input data. Trial computer runs will be made using hypothetical data to demonstrate the functioning of the program

and to identify some major features of program performance, such as effects of input uncertainties and submodel performance. Some techniques or representative problems for use in verification and validation of uncertainty methodology will be identified, and a verification and validation of the uncertainty methodology will be performed.

Reliability analysis of license application design will then proceed, leading to the required complimentary cumulative distribution functions for performance measures. Further, an analysis will be conducted to derive the source term for total system performance, including description of the variability in the source term. Finally, estimates and descriptions of the secondary uncertainty in these results will be made. This analysis will then serve as input to total system performance assessment performed under WBS 1.2.1.4. Activity results will be reported in Milestone M273 (see Section 5.5).

3.5 Equipment

Performance assessment consists of computational activities; therefore, the equipment used in these activities are computer systems. Presently, performance assessment plans to use two computer systems. The system to be used for program development and testing is a network of Sun workstations and Ridge computers that are located in the Earth Sciences Department at Lawrence Livermore National Laboratory. These systems are UNIX-based computers linked by a Ethernet network. The UNIX operating system provides utilities to facilitate operating system software configuration management as required by software quality assurance requirements.

Application of the hydrothermal system model and uncertainty codes will be utilized in Magnetic Fusion Energy Computing Center (MFECC) computers at Lawrence Livermore National Laboratory. This center currently consists of two CRAY I computers, a CRAY X-MP computer, and a CRAY-2 supercomputer. These computers are being linked to a laboratory-wide Ethernet network which will communicate with the Sun workstation network via a UNIX shell at MFECC. This system will provide for the large number of system model executions (foreseen to be) required for uncertainty analysis. The Ethernet network will also allow the control of applications, as required by quality assurance procedures.

4.0 Application of Results

4.1 Detailed hydrothermal flow and transport

These calculations are necessary to provide an understanding of the hydrologic environment of the waste package. The results will be used as a basis for formulation of the waste package environment submodel of the performance assessment code. Cases simulated by this model will be used to verify that submodel. Further, sensitivity analysis of this model will help to determine the significant variables to be included in performance assessment calculations. The model will also be useful in the design of experiments for the exploratory shaft waste package environment tests.

The releases calculated from the Engineered Barrier System may not be the most appropriate source term for total system performance assessment calculations. Therefore, this model will allow examination of radionuclide transport in the immediate vicinity of emplacement. Through these calculations, the environment submodel of the waste package performance

assessment code can be modified to include the effects of retardation near the package if desired.

4.2 System model development and application

At present, three versions of the system model are planned. The first version is an initial test bed for deterministic waste package performance assessment modeling concepts. The second version will be used to analyze advanced conceptual design alteratives. The final version of the system model will deterministically calculate waste package performance. It will be used to analyze the license application design directly to develop bounding values of performance. In addition, it will be incorporated into the uncertainty methodology to provide a means for determining the complimentary cumulative distribution functions for time to waste package failure and for radionuclide release rates. The system models developed prior to the final version will provide a basis for testing analytical techniques and will be used to screen waste package designs.

4.3 Uncertainty analysis methodologies

The uncertainty methodology will be used to provide the direct input to the total system performance assessment in the form of a probabilistic source term. Further, it will be used to evaluate the reliability of the waste package with respect to the containment and release requirements of 10 CFR 60. This methodology will incorporate the successive versions of the system model to construct the required complimentary cumulative distribution function.

5.0 Schedule and Milestones

5.1 Discussion and assumptions

The subsections that follow present schedules for waste package performance assessment activities. These activities are grouped into three basic efforts: (1) hydrothermal modeling of near field flow and transport; (2) development of the waste package systems model; and (3) uncertainty analysis. The schedules presented are based on assumptions described and on a continued level of effort consistent with the 1988 WPAS submission.

Since performance assessment collects information to perform the required calculations, the schedule for activities presented is based on inputs from other waste package subtasks that are expected on a continuous basis. However, because the performance assessment system modeling effort will produce a series of three codes, deadlines exist for final input of information into the system code. Assumptions are also made regarding the time at which the advanced conceptual and license application waste package designs will be available. Data for validation and refinement of the waste package environment are expected from the exploratory shaft experiments. Finally, input from the total system performance assessment effort is expected to provide scenarios to be included in the waste package performance assessment. Variations in the delivery of these inputs will cause significant variations in the schedules presented for activities and milestones.

The following schedule presents dates by which input from activities other than performance assessment are needed to meet the milestone dates for performance assessment.

1. Waste package subtask inputs

   a. submodels for analysis of conceptual designs — 11/86

   b. submodels for analysis of advanced conceptual designs — 8/87

   c. submodels for analysis of license application design — 8/88

2. Waste package designs

   a. conceptual design — currently available

   b. advanced conceptual design, preliminary input — 11/87

   c. advanced conceptual design, final input — 4/88

   d. license application design — 6/89

3. Exploratory shaft (ES) data

   a. preliminary ES input — 9/88

   b. final ES input — 7/89

4. Scenarios for anticipated and unanticipated events

   a. preliminary input — 11/87

   b. final input — 7/89

5.2 Hydrothermal flow and transport modeling

The purpose of the near-field flow and transport modeling is to provide boundary conditions for performance assessment, a component of the waste package environment submodel, an interface between the waste package environment submodel, and a theoretical interface between the waste package and total system performance assessments. Therefore, the schedule above conforms to the requirements of the performance assessment calculations. The development of the flow and transport submodel is included as part of system

model development activities. Activities I-20-1 and I-20-2, rovide the necessary theoretical basis for the submodel to be included in the system model. Activity I-20-3 occurs concurrently with the system and with uncertainty analysis of the license application design and helps to provide source terms to the total system performance assessment when the waste package performance assessment calculations are complete.

The following table presents the hydrothermal flow and transport activities and their durations:

	Analyses	Duration
I-20-1	Development of detailed near-field flow and transport model	7/86-8/88
I-20-2	Verification and validation of detailed flow and transport model	2/87-11/89
I-20-3	Sensitivity analysis of near-field flow and transport model	7/87-9/88
I-20-4	Analysis of source term attenuation in near-field host rock	1/89-11/90

5.3 Development of the systems model and analyses of waste package designs

The development of the system model parallels the schedule for development of waste package designs. The first version of the system model will utilize waste package design concepts that first appeared in the Site Characterization Plan. The second version will contain revisions reflecting new data from the investigation subtasks (e.g., metal barriers, waste form degradation, waste package environment, etc.) and will be used to analyze the advanced conceptual design. The final version will be used to analyze the license application design. This version will incorporate the conclusions of the investigation subtasks. Though all versions will undergo verification and validation, the final version will require the most effort in this area since it will be the most complex and will be used to produce input to total system performance assessment.

The schedule for system model activities is as follows:

	Analyses	Duration
I-20-5	Development of version I of system model	7/86-1/87
I-20-6	Verification and validation of system model version I	7/86-1/87
I-20-7	Testing of system model using waste package design concepts	1/87-11/90

I-20-8	Development of system model version II for analysis of anticipated and unanticipated events	6/87-10/87
I-20-9	Verification and validation of system model II	10/87-2/88
I-20-10	Analysis of advanced conceptual design with system model version II	2/88-9/88
I-20-11	Development of version III of system model for analysis of anticipated and unanticipated events	9/88-2/89
I-20-12	Verification and validation of system model version III	2/89-8/89
I-20-13	Analysis of license application design with system model III	8/89-7/90

5.4 Uncertainty analysis

The uncertainty methodology will incorporate model system versions. Therefore, reliability analysis of the waste package designs must be scheduled to allow for system model development. The final reliability analysis must await completion of all work that might impact system model process submodels.

The schedule for uncertainty analysis activities is as follows:

I-20-14	Development of uncertainty analysis methodologies for testing with the system model	11/86-11/90
I-20-15	Verification of suitability of uncertainty methods using system model version I	6/87-1/88
I-20-16	Development of uncertainty methodology incorporating the version II of the system model	1/86-9/88
I-20-17	Verification uncertainty methodology and application to analysis of advanced conceptual design	9/88-3/89
I-20-18	Refinement of uncertainly methodology and incorporation of final version of system model	3/89-10/89
I-20-19	Uncertainty analysis of license application design and derivation of source term for total system performance	10/89-1/91

5.5 Milestones

The only milestone for near-field flow and transport is presently as follows:

Title	Milestone	Date
Detailed flow and transport model documentation	P204	2/91

The level 1 and level 2 milestones for system model development are as follows:

1.	Design specification report on first version of system model	M276	10/86
2.	Report on system model I analysis of waste package conceptual designs	M260	6/87
3.	Report on system model II analysis of advanced conceptual designs	M263	7/88
4.	Final documentation of system model III and analysis of license application design	M268	1/91

Presently, there is only one level 1 milestone for uncertainty analysis:

Final report on waste package performance assessment and reliability analysis of license application design	M273	6/91

6.0 List of Activity Plans to Support this Study Plan

Waste package performance assessment activities will be grouped for production. As before, the groups will be: (1) development of the near-field hydrothermal flow and transport model; (2) development and application of the system model; and (3) development and application of the uncertainty analysis methodology. Production of these activity plans is prioritized with respect to their overall importance to waste package performance assessment. The following schedule presents production dates for activity plans.

6.1 Hydrothermal flow and transport model

Production Date for Activity Plans: 6/87

Activities Included in Plan:

Number	Title
I-20-1	Development of detailed near-field flow and transport model
I-20-2	Verification and validation of detailed flow and transport model
I-20-3	Sensitivity analysis of near-field flow and transport model
I-20-4	Analysis of source term attenuation in near-field host rock

6.2 Development and application of system model

Production Date for Activity Plans: 12/86

Activities Included in Plan:

Number	Title
I-20-5	Development of version I of system model
I-20-6	Verification and validation of system model version I

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification and Validation of System Model Version III

I-20-12

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL I

[signature] 8-13-86
Task or Subtask Leader

R.E. [signature] for J. Dronkers 8/13/86
Deputy Leader for QA

[signature] 8/13/86
NWMP Deputy Leader

[signature] for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Project Sponsor

Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ no	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ no	I
3.	Does the item or activity involve waste isolation? ___yes___ no	I
4.	Does the item or activity involve or affect retrievability? ___yes___ no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___yes___ no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ___yes___ no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification and Validation of System Model Version III

ACTIVITY NO.: I-20-12
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM 1.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

Number	Title
I-20-7	Testing of system model using waste package design concepts
I-20-8	Development of system model version II for analysis of anticipated and unanticipated events
I-20-9	Verification and validation of system model version II
I-20-10	Analysis of advanced conceptual design with system model version II
I-20-11	Development of version III of system model for analysis of anticipated and unanticipated events
I-20-12	Verification and validation of system model version III
I-20-13	Analysis of license application design with system model version III

6.3 Development and application of uncertainty methodology

Production Date for Activity Plans: 3/87

Activities Included in Plan:

Number	Title
I-20-14	Development of uncertainty analysis methodologies for testing with the system model
I-20-15	Verification of suitability of uncertainty methods using system model version I
I-20-16	Development of uncertainty methodology incorporating version II of the system model
I-20-17	Verification of uncertainty methodology and application to analysis of advanced conceptual design
I-20-18	Refinement of uncertainty methodology and incorporate final version of system model

Number	Title
I-20-19	Uncertainty analysis of license application design and derivation of source term for total system performance

APPENDIX

Quality Level Assignments

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes (no)	I
3.	Does the item or activity involve waste isolation? yes (no)	I
4.	Does the item or activity involve or affect retrievability? yes (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes (no)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes (no)	II

(III)

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification and Validation of Detailed Flow and Transport Model

ACTIVITY NO.: I-20-2
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Sensitivity Analysis of Near-Field Flow and Transport Model

I-20-3

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

7/24/86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ (no)	I
3.	Does the item or activity involve waste isolation? ___yes___ (no)	I
4.	Does the item or activity involve or affect retrievability? ___yes___ (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___yes___ (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ___yes___ (no)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ (no)	II
	(III)	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Sensitivity Analysis of Near-Field Flow and Transport Model

ACTIVITY NO.: I-20-3
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Analysis of Source Term Attenuation in Near-Field Host Rock

I-20-4

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

7/24/86
Task or Subtask Leader

R.E. Achert for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no (circled)	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no (circled)	I
3.	Does the item or activity involve waste isolation? yes no (circled)	I
4.	Does the item or activity involve or affect retrievability? yes no (circled)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no (circled)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no (circled)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no (circled)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no (circled)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no (circled)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no (circled)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no (circled)	II

III (circled)

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Analysis of Source Term Attenuation in Near-Field Host Rock

ACTIVITY NO.: I-20-4
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ____________________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Development of Version I of System Model

I-20-5

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

8/13/86
Task or Subtask Leader

R.E. for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

<u>LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS</u>

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? _yes________ (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes_____ (no)	I
3.	Does the item or activity involve waste isolation? __yes____ (no)	I
4.	Does the item or activity involve or affect retrievability? __yes____ (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? __yes____ (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? __yes____ (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety?_yes____ (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60?__yes____ (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components?__yes____ (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives?__yes____ (no)	II
11.	Can the item or activity cause major cost overrun or schedule slippage?__yes____ (no)	II
	(III)	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Version I of System Model

ACTIVITY NO.: I-20-5
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ____________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification and Validation of System Model Version I

I-20-6

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

8/13/86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification and Validation of System Model Version I

ACTIVITY NO.: I-20-6
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Testing of System Model Using Waste Package Design Concepts

I-20-7

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

8/13/86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

11-3-86
Project Sponsor

11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Testing of System Model Using Waste Package Design Concepts

ACTIVITY NO.: I-20-7
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Development of System Model Version II for Analysis of Anticipated and Unanticipated Events

I-20-8

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL II

[signature] 8/13/86
Task or Subtask Leader

R E [signature] for J. Dronkers 8/13/86
Deputy Leader for QA

[signature] 8/13/86
NWMP Deputy Leader

[signature] for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is ~~to~~ conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of System Model Version II for Analysis of Anticipated and Unanticipated Events

ACTIVITY NO.: I-20-8
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON LOGIC DIAGRAM 10.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification and Validation of System Model II

I-20-9

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL II

8-13-86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is ~~to~~ conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification and Validation of System Model Version II

ACTIVITY NO.: I-20-9
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON LOGIC DIAGRAM 10.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Analysis of Advanced Conceptual Design with System Model Version II

I-20-10

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL II

8-13-86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ (no)	I
3.	Does the item or activity involve waste isolation? ___yes___ (no)	I
4.	Does the item or activity involve or affect retrievability? ___yes___ (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___yes___ (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ___(yes)___ no	(II)
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Analysis of Advanced Conceptual Design with System Model Version II

ACTIVITY NO.: I-20-10
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON LOGIC DIAGRAM 10.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No waste package designs will occur in this activity.	
4.0 PROC. DOC. CONTROL	Nothing will be bought for this activity.	
7.0 CTL OF PUR MATERIALS	No materials will be purchased for this activity.	
8.0 I.D. & CTL OF MATERIALS	No samples are required for this activity.	
9.0 CONTROL OF PROCESSES	No special processes are required for this activity.	
10.0 INSPECTION	No inspections are required for this activity.	
11.0 TEST CONTROL	No tests are needed for this activity.	
12.0 CTL OF M & T EQUIP	No measuring or testing equipment are required.	
13.0 HANDLING, STOR. & SHIP.	Nothing will be handled, shipped or stored.	
14.0 INSP. TEST & OPER. STAT.	No status indicators are required for this activity.	
19.0 SOFTWARE QA	Yes, SQA Plan and Procedures to be developed.	

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Development of Version III of System Model for Analysis of Anticipated and Unanticipated Events

I-20-11

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL I

Kenneth Eggert 8/13/86
Task or Subtask Leader

R.E. [signature] for J. Dronkers 8/13/86
Deputy Leader for QA

L. Ballou 8/13/86
NWMP Deputy Leader

L. Ballou for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ no	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ no	I
3.	Does the item or activity involve waste isolation? ___yes___ no	I
4.	Does the item or activity involve or affect retrievability? ___yes___ no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___yes___ no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ___yes___ no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Version III of System Model for Analysis of Anticipated and Unanticipated Events

ACTIVITY NO.: I-20-11
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM 1.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification and Validation of System Model Version III

I-20-12

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL I

8-13-86
Task or Subtask Leader

R.E. [signature] for J. Dronkers 8/13/86
Deputy Leader for QA

[signature] 8/13/86
NWMP Deputy Leader

[signature] for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ no	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ no	I
3.	Does the item or activity involve waste isolation? ___yes___ no	I
4.	Does the item or activity involve or affect retrievability? ___yes___ no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___yes___ no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ no	II
10.	Does the item or activity involve a design phase for whicn the principle purpose is to conduct a comparative technical analysis of alternatives? ___yes___ no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification and Validation of System Model Version III

ACTIVITY NO.: I-20-12
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM 1.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Analysis of License Application Design with System Model Version III

I-20-13

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL I

8-13-86
Task or Subtask Leader

R E ... for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this ~~activity~~ to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Analysis of License Application Design with System Model III

ACTIVITY NO.: I-20-13
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM 1.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Development of Uncertainty Analysis Methodologies for Testing with the System Model

I-20-14

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

8/13/86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

11-3-86
Project Sponsor

11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no III	II

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Uncertainty Analysis Methodologies for Testing with the System Model

ACTIVITY NO.: I-20-14
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ____

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification of Suitability of Uncertainty Methods Using System Model Version I

I-20-15

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

8/15/86
Task or Subtask Leader

for J Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Project Sponsor

11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification of suitability of Uncertainty Methods Using System Model Version I

ACTIVITY NO.: I-20-15
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Development of Uncertainty Methodology Incorporating Version II of the System Model

I-20-16

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL II

7/24/86
Task or Subtask Leader

for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological·operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Uncertainty Methodology Incorporating Version II of the System Model

ACTIVITY NO.: I-20-16
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON LOGIC DIAGRAM 10.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification of Uncertainty Methodology and Application to Analysis of Advanced Conceptual Design

I-20-17

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL II

8/13/86
Task or Subtask Leader

RE [signature] for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

[signature] for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is ~~to~~ conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Verification of Uncertainty Methodology and Application to Analysis of Advanced Conceptual Design

ACTIVITY NO.: I-20-17
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON LOGIC DIAGRAM 10.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Refinement of Uncertainty Methodology and Incorporate Final Version of System Model

I-20-18

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL I

8/13/86
Task or Subtask Leader

R E for J. Dronkers 8/13/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L. D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes ______ no	I
2.	Does the item or activity involve or affect public radiologic health and safety? ____ yes ______ no	I
3.	Does the item or activity involve waste isolation? ____ yes ______ no	I
4.	Does the item or activity involve or affect retrievability? ____ yes ______ no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ____ yes ______ no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ____ yes ______ no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes ______ no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ____ yes ______ no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ____ yes ______ no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ____ yes ______ no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ____ yes ______ no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Refinement of Uncertainty Methodology and Incorporate Final Version of System Model

ACTIVITY NO.: I-20-18
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM 1.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL		Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS		No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS		No samples are required for this activity.
9.0 CONTROL OF PROCESSES		No special processes are required for this activity.
10.0 INSPECTION		No inspections are required for this activity.
11.0 TEST CONTROL		No tests are needed for this activity.
12.0 CTL OF M & T EQUIP		No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.		Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.		No status indicators are required for this activity.
19.0 SOFTWARE QA		Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Uncertainty Analysis of License Application Design and Derivation of Source Term for Total System Performance

I-20-19

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL I

7/24/86   for J. Dronkers 8/13/86

Task or Subtask Leader   Deputy Leader for QA

8/13/86   for L. D. Ramspott 8/13/86

NWMP Deputy Leader   NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86   James Blaylock 11/3/86

Project Sponsor   Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this ~~activity~~ activity to provide primary data for a license application? yes no	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes no	I
3.	Does the item or activity involve waste isolation? yes no	I
4.	Does the item or activity involve or affect retrievability? yes no	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes no	II
	III	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Uncertainty Analysis of License Application Design and Derivation of Source Term for Total System Performance

ACTIVITY NO.: I-20-19
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM 1.

QA ELEMENT	APPLIES IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No waste package designs will occur in this activity.
4.0 PROC. DOC. CONTROL	Nothing will be bought for this activity.
7.0 CTL OF PUR MATERIALS	No materials will be purchased for this activity.
8.0 I.D. & CTL OF MATERIALS	No samples are required for this activity.
9.0 CONTROL OF PROCESSES	No special processes are required for this activity.
10.0 INSPECTION	No inspections are required for this activity.
11.0 TEST CONTROL	No tests are needed for this activity.
12.0 CTL OF M & T EQUIP	No measuring or testing equipment are required.
13.0 HANDLING, STOR. & SHIP.	Nothing will be handled, shipped or stored.
14.0 INSP. TEST & OPER. STAT.	No status indicators are required for this activity.
19.0 SOFTWARE QA	Yes, SQA Plan and Procedures to be developed.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Development of Detailed Near-Field Flow and Transport Model

I-20-1

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

7/29/86
Task or Subtask Leader

for J. Dronkers 8/3/86
Deputy Leader for QA

8/13/86
NWMP Deputy Leader

for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Maxwell Blanchard 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ (no)	I
3.	Does the item or activity involve waste isolation? ___yes___ (no)	I
4.	Does the item or activity involve or affect retrievability? ___yes___ (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___yes___ (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ___yes___ (no)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ (no)	II
	(III)	

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Development of Detailed Near-Field Flow and Transport Model

ACTIVITY NO.: I-20-1
DATE: April 14, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ____________________

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL		
4.0 PROC. DOC. CONTROL		
7.0 CTL OF PUR MATERIALS		
8.0 I.D. & CTL OF MATERIALS		
9.0 CONTROL OF PROCESSES		
10.0 INSPECTION		
11.0 TEST CONTROL		
12.0 CTL OF M & T EQUIP		
13.0 HANDLING, STOR. & SHIP.		
14.0 INSP. TEST & OPER. STAT.		
19.0 SOFTWARE QA		

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: April 14, 1986

Meeting Attendees: J. Dronkers, L. Ballou, D. Becker, K. Eggert

Name(s) and Number(s) of Activity: Verification and Validation of Detailed Flow and Transport Model

I-20-2

S.I.P. Identification: Scientific Investigation Plan for Waste Package Performance Assessment (WBS Number 2.2.5) (DRAFT)

Additional Comments:

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF LEVEL III

[signature] 7/24/86
Task or Subtask Leader

R E [signature] for J Dronkers 8/13/86
Deputy Leader for QA

[signature] 8/13/86
NWMP Deputy Leader

[signature] for L.D. Ramspott 8/13/86
NWMP Leader

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

[signature] 11-3-86
Project Sponsor

James Blaylock 11/3/86
Project Sponsor Quality Manager

RETURN TO LLNL NWMP QA FILE

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.3.8.L

GEOCHEMICAL MODELING (EQ3/6)

LAWRENCE LIVERMORE NATIONAL LABORATORY

September, 1986

10/17/86

Larry D. Ramspott, Technical Project Officer — Date

10/16/86

John J. Dronkers, Deputy for Quality Assurance — Date

10-16-86

Donald O. Emerson, Principal Investigator — Date

Virginia Oversby, Technical Reviewer — Date

10/17/86

Project Sponsor Quality Manager — Date

10-17-86

Project Sponsor — Date

UCID-20864

GEOCHEMICAL MODELING (EQ3/6) PLAN
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT PROGRAM

W. F. McKenzie, T. J. Wolery, J. M. Delany, R. J. Silva,
K. J. Jackson, W. L. Bourcier, and D. O. Emerson.

Lawrence Livermore National Laboratory

August 28, 1986

TABLE OF CONTENTS

GEOCHEMICAL MODELING (EQ3/6) PLAN:
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT PROGRAM

ABSTRACT

This plan replaces an earlier plan (Isherwood and Wolery, 1984) for the Nevada Nuclear Waste Storage Investigations (NNWSI) Project. It includes activities for all repository projects in the Office of Geologic Repositories (OGR): NNWSI, the Basalt Waste Isolation Project (BWIP), the Salt Repository Project (SRP), and the Crystalline Project (CPO). Each of these projects is part of the Office of Civilian Radioactive Waste Management (OCRWM) Program. The scope of work for fiscal years 1986 to 1992 includes the work required to upgrade the geochemical codes and supporting data bases, to permit modeling of chemical processes associated with nuclear waste repositories in four geological environments: tuff, salt, basalt, and crystalline rock. Planned tasks include theoretical studies and code development to take account of the effects of precipitation kinetics, sorption, solid solutions, glass/water interactions, variable gas fugacities, and simple mass transport.

Recent progress has been made in the ability of the codes to account for precipitation kinetics, highly-saline solutions, and solid solutions. Transition state theory was re-examined resulting in new insights that will provide the foundation for further improvements necessary to model chemical kinetics. Currently there is an increased effort that is concentrated on the supporting data base. For aqueous species and solid phases, specific to nuclear waste, requisite thermodynamic values reported in the literature are being evaluated and for cases where essential data is lacking, laboratory measurements will be carried out. Significant modifications and expansions have been made to the data base. During FY86, the total number of species in the data base has almost doubled and many improvements have been made

with regard to consistency, organization, user applications, and documentation. Two Ridge computers using a RISC implementation of UNIX were installed and they are completely dedicated EQ3/6 machines. All codes have been re-written in FORTRAN 77 resulting in a more portable and efficient software package.

PREFACE

The critical need for the safe disposal of high-level radioactive waste material (HLW) was recognized by Congress in 1982 with the passage of the Nuclear Waste Policy Act (NWPA), which subsequently was signed into law by the President in January 1983. This act stated that it is the responsibility of the Federal government to dispose of HLW from both the civilian and military sectors. Most of the civilian HLW results from fissioning of nuclear fuel in reactors operated by electrical utilities. Radioactive products are contained in spent fuel. Utilities presently have about 13,000 tonnes of spent fuel in short-term storage facilities near the reactor sites, and about 2000 tonnes of additional spent fuel is being generated yearly. Presently, commercially generated spent fuel is not reprocessed for recovery of unfissioned uranium and plutonium. Most of radioactive material from previous reprocessing activities is liquid waste that is stored in tanks at West Valley, New York.

The NWPA established a fee of one mil/KWH on utilities that generate electricity generated from nuclear reactors to pay for the disposal and associated Federal management of HLW . The NWPA also established formal procedures for the evaluation and selection of repository sites, dictating that mined repositories should receive the primary emphasis. In addition, regulations regarding the construction, operation, and closure of repositories were to be issued and a timetable was provided for Federal agencies to meet in carrying out the program. The Department of Energy (DOE) is charged with the responsibility to provide for waste disposal and is scheduled to begin receiving wastes in 1998 at the first repository. In February 1985, the President approved that high-level defense wastes, created by military activities would be disposed of with the civilian waste.

Technical criteria to be used in the evaluation of license applications for a repository have been published by the Nuclear Regulatory Commission (NRC) (10 CFR 60, July 21, 1983). The DOE has issued guidelines for the recommendation of sites (10 CFR 960, December 6, 1984). Applicable environmental standards for HLW repositories have been established by the Environmental Protection Agency (40 CFR 191, August 15, 1985). Licensing procedures require the DOE to submit site-characterization reports to the NRC prior to characterizing sites that may be suitable for the disposal of HLW. The NRC is to analyze these reports and make appropriate comments to the DOE. However, the formal licensing process will begin with the submission of a license application to the NRC for a site that has been characterized by the DOE and recommended by the President for approval by Congress.

DOE rules for selecting sites for a first and a second repository are presented in 10 CFR 960 with the overall guidance provided in the NWPA. At present, the candidates for the first repository site include three rock types: tuff, basalt, and salt. Candidates for the second repository, which has been indefinitely postponed, (DOE News release, May 28, 1986) will likely include the addition of granite and shale to the three rock types being considered for the first repository. Each of the potential repository localities have different geologic settings and hydrological characteristics as well as rock type. Therefore, the assessment of hazards associated with HLW disposal at each site will require different studies.

The NRC (10 CFR 60) "...anticipates that licensing decisions will be complicated by the uncertainties that are associated with predicting the behavior of a geologic repository over the thousands of years during which HLW may present hazards to public health and safety." In order to address this difficulty, the NRC required the DOE to incorporate multiple barriers in their repository design. An engineered barrier system consists of the waste package (waste form, containers, and any materials immediately surrounding the containers) and the underground facility (excluding shafts,

boreholes and their seals). The engineered barrier is required to compensate for the geological uncertainties, whereas the geological setting must be able to contribute significantly to isolation in order to compensate for uncertainties in the performance of the engineered barrier.

The requirement to predict materials performance and the geological environment over long periods of time is unprecedented. Field and laboratory experiments are carried out for only short periods of time relative to the period over which a repository must maintain integrity. Consequently, the prediction of radionuclide migration as part of the evaluation of potential repository sites must be made by models that extrapolate the data to longer times. The EQ3/6 software package is being modified and improved for the purpose of modeling the complex geochemical processes that result from interactions among the host rock, groundwater, air, and the engineered barrier.

1.0 REQUIREMENTS RESTRICTING RADIONUCLIDE MIGRATION

The goal to attain in geochemical modeling is the capability to simulate the processes of radionuclide release followed by migration away from the repository site. Requirements set by the NRC and the EPA restrict the potential migration of certain radionuclides to specific levels over defined periods of time. The EQ3/6 geochemical modeling codes must be developed, and the requisite thermochemical data obtained, to the extent that is necessary to address these regulatory requirements. An understanding of the necessary regulations is required to focus the development of the codes and the supporting data base.

1.1 NRC Performance Objectives for a HLW Repository

The NRC (10 CFR 60) has detailed four performance objectives for a repository. Two of the performance objectives are concerned with the

engineered barrier system (EBS) in a repository and the rule states in part that

> "...the engineered barrier system shall be designed, assuming anticipated processes and events, so that... (A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b) provided that such period shall not be less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and (B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure or such other fraction of the inventory as may be approved or specified by the Commission: provided that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste originally emplaced in the underground facility that remains after 1,000 years of radioactive decay" (10 CFR 60, section 60.113 (a) (1) (ii)).

The first performance objective for the EBS is the containment period, for which there will be a thermal pulse (from radioactive decay of HLW) that will cause an increase in temperature of the surrounding rock, water, and gas. This temperature increase will cause changes in both the fluid and rock compositions. When simulated by geochemical models, these changes will provide the characteristics of the fluid that may interact with and potentially cause a breach in the waste package.

The second performance objective for the EBS encompasses the radionuclide release rate. Geochemical modeling should be able to predict the release of radionuclides from the EBS following a breach of the container and/or any interactions involving the waste package, aqueous

fluids, gases, and surrounding rock. These calculations will not only determine if the requirements set by the NRC will be met, but can also serve as guidance for optimizing design characteristics and aid in choosing a safe repository site.

The third performance objective is for the undisturbed site. The NRC states: "The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission" (60.113 (a) (2)). Geochemical modeling will not be required for this performance assessment. However post-emplacement groundwater travel times will be coupled with geochemical modeling to address performance assessment for the total repository system.

The fourth performance objective is for the overall system and geochemical modeling is required for the performance assessment. The NRC states in part "...that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events" (60.112).

1.2 EPA Final Rule for Health and Safety for HLW Repositories

The EPA has issued requirements for environmental containment, individual protection, and groundwater protection. This final rule, 40 CFR 191, contains the standards referred to by the fourth performance objective set by the NRC.

The containment requirement limits the total quantities of radionuclides that are predicted to be released to the accessible environment over a period of 10,000 years. Cumulative releases from all significant processes and events must "have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1" of 40 CFR 191 and

"less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1". Geochemical modeling will provide input to performance assessment to the overall system. In other words: the fate of radionuclides will be determined as the containers are breached, and the HLW interacts with any aqueous fluids present, gases, and the surrounding rock as radionuclides migrate towards the accessible environment.

Oversby (1986) has identified the most important radionuclides to be considered by using a comparison of the NRC performance objectives for the EBS and the EPA requirements as the basis for the evaluation. The maximum allowed release rates were integrated over time for PWR spent fuel. These release rates were then compared to the EPA cumulative release rate limits, and with reasonable assumptions americium and plutonium were by far the most important. Thus, it is critical that the thermochemical properties of americium and plutonium be obtained so that modeling of the behavior these radionuclides under relevant repository conditions can be done.

1.3 Issues and Information Needs Addressed (7/10/86 Version)

The EQ3/6 Geochemical Modeling NNWSI Work Breakdown Structure (WBS) 1.2.3.8.L activities do not directly address particular issues or information needs. Rather, it provides techniques and data needed to resolve them. The issues and information needs related to WBS 1.2.3.8.L as well as the BWIP and Office of Nuclear Waste Isolation (ONWI, a division of Battelle Memorial Institute, serves as project manager for SRPO) activities are:

KEY ISSUE 1: Will the mined geologic disposal system at Yucca Mountain isolate the radioactive waste from the accessible environment after closure in accordance with the requirements set forth in 40 CFR Part 191, 10 CFR Part 60, and 10 CFR Part 960?

PERFORMANCE ISSUES AND INFORMATION NEEDS

ISSUE 1.1: Will the mined geologic disposal system meet the system performance objective for radionuclide releases to the accessible environment as required by 10 CFR 60.112 and 40 CFR 191.13?

1.1.1 Site information needed to calculate the releases of radionuclides to the accessible environment.

1.1.4 Calculational models to predict radionuclide releases to the accessible environment.

ISSUE 1.4: Will the waste package meet the performance objective for containment as required by 10 CFR 60.113?

1.4.3 Scenarios and models needed to predict the time to loss of containment and the ensuing degradation of the containment barrier.

1.4.4 Estimates of the rates and mechanisms of containment barrier degradation in the repository environment for anticipated and unanticipated processes and events.

1.4.5 Determination of the time to loss of substantially complete containment of the waste packages for anticipated and unanticipated processes and events.

ISSUE 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release rates as required by 10 CFR 60.113?

1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system.

1.5.4 Determination of the release rates of radionuclides from the engineered barrier systems for anticipated and unanticipated processes and events.

1.5.5 Determination of the amount of the radionuclides leaving the near-field environment of the waste package.

2.0 GEOCHEMICAL MODELING

2.1 Relation to Regulatory Requirements

Geochemical and transport models will play a critical role in determining migration rates for radionuclides away from a repository, and thereby determine whether HLW can be safely disposed of in geologic repositories for very long periods of time. The NRC considers estimates of aqueous concentrations of radionuclides under site specific conditions as being fundamental for predicting the release rates of radionuclides (U.S. Nuclear Regulatory Commission, 1984). Because of the complexity of the problem, the physical scale, and the long time period being considered for the release limit, 10,000 years, numerical simulations of the various processes are the only viable approach to the prediction of long-term performance. In a report prepared for the NRC (Coffman et al., 1984, p. 1-2) it has been pointed out that "in discharging its responsibility, the NRC must review DOE performance assessments and independently evaluate the likely performance assessments of each repository and waste package the DOE seeks to license. Computer models provide a framework for simulating the important processes expected to be active in a repository, thereby allowing assessment and prediction of the behavior of a waste isolation system. The

NRC is supporting the development of computer codes to be used to evaluate its HLW regulations and review of proposed nuclear waste management systems. Independently, the DOE is also developing and using computer codes for the assessment of repository sites and designs".

The NRC has taken the position that the results of computer model simulations by themselves will not be acceptable for demonstrating compliance with HLW regulations (NRC, 1985, p. 15). The NRC has stated that all predictive capabilities of computer codes will have to be validated with a substantial body of independent experimental data.

2.2 Geochemical Modeling

Geochemical modeling is an integrated approach that uses physicochemical principles of hydrogeochemical systems in order to interpret geologic processes such as water/rock interactions. Models are constructed utilizing theoretical concepts cast in mathematical representations. The computations grow increasingly complex for systems comprised of many components, as will be the case for any HLW geologic repository. Computers are necessary to solve the large number of coupled equations by numerical methods.

The first calculation of the distribution of major dissolved species in sea water was done in 1962 by Garrels and Thompson. This study pointed out the fact that the entire system must be considered when studying water/rock interactions. For example, the precipitation of calcium carbonate is dependent on the magnesium and sodium content of sea water as well as the calcium and carbonate concentrations. Magnesium forms an aqueous complex with carbonate, which is then unavailable to combine with the calcium ion needed for precipitation of calcite (calcium carbonate). Sodium chloride is the major component of salinity or ionic strength. This in turn affects the activity of all ions including both calcium and carbonate. It is the activity product (and not the analytical concentrations) of calcium and carbonate that determines whether precipitation or dissolution will occur. Only by considering all components in a system simultaneously can one address the distribution of species in solution and whether or not equilibrium with various solid phases exists.

Lack of thermochemical data was the limiting factor in early speciation calculations. Calculations were limited to natural waters no more concentrated than sea water and to approximately room temperature (Garrels and Christ, 1965). Helgeson (1964) was the first to estimate thermodynamic data for higher temperatures and used these estimates to calculate complexing involved in hydrothermal ore deposition. Nordstrom et al., (1979) reviewed more recent chemical models that have been developed for solving equilibrium calculations in aqueous systems. These models are all equivalent to the way that Garrels and Thompson set up the seawater problem, but may use different techniques for finding a mathematical solution.

Helgeson (1968, 1970) initiated computerized geochemical modeling for water/rock reactions and allowed the user to observe the series of changes in the chemical composition of a solution as well as the identification of solid phases being precipitated and dissolved from a given set of initial conditions (composition of water, composition of rock, temperature, pressure, etc.).

The geochemical modeling codes that are the most general and have the widest application are EQ3/6 developed by Wolery (1978) with later improvements by Wolery and others (e.g., Wolery, 1983; Wolery et al., 1984; Jackson and Wolery, 1985; Delany and Wolery, 1984; Delany, et al., 1986) at Lawrence Livermore National Laboratory (LLNL). This software package is operational and has successfully simulated many field and laboratory processes directly related to HLW repositories. Although a broad framework has been constructed for the geochemical models, much remains to be done to account for all potentially important processes associated with a HLW repository. These include advances in theory and code development, thermodynamic data, and kinetics and other coupled processes. Planned developments will broaden the capabilities of the codes to respond confidently to the necessary evaluation of radionuclide migration.

In addition to the three candidate repository site projects' planned utilization of EQ3/6 codes in performance assessment, Oak Ridge National Laboratory has recently brought the EQ3/6 software package on-line to provide the NRC with the ability to do independent evaluations of geochemical modeling done by the DOE (Kelmers et al., 1986).

2.3 EQ3NR, A Computer Program for Speciation-Solubility Calculations

EQ3NR (Wolery, 1983) calculates the thermodynamic state of an aqueous solution, which includes the degree of formation of ion pairs and complex aqueous species. Determination of the thermodynamic activities (concentrations corrected for non-ideality) of the species in solution, and a quantitative measure (saturation index or affinity) of the thermodynamic state of the solution (undersaturated, in equilibrium, or supersaturated) with respect to solid phases is made. This speciation-solubility calculation is useful as a method to test if a solution is in equilibrium with a particular solid phase. EQ3NR also serves to initialize the solution composition for reaction-path calculations made by the EQ6 code (EQ6 is discussed in the following section).

An example of calculations involving the determination of equilibrium would be the study of a sequence of water samples drawn at successive times from an autoclave in a rock/water interactions experiment. The state of over- or under-saturation with the minerals present in the original rock and/or those that may form as secondary phases can be computed. This can be used to check the consistency of reaction results with the supporting thermodynamic data, to determine whether or not an observed short term steady state is thermodynamically stable, and to identify new phases that may form (useful in guiding microprobe and other solids characterization work).

Speciation-solubility calculations of a fluid progressing along a known flow path can be used to construct models of chemical changes in aquifers, and allowing for inference of possible subsurface mineral-water interactions (see Parkhurst, Plummer, and Thorstenson, 1982). Speciation-solubility

calculations using EQ3NR are being done by the Basalt Waste Isolation Program to investigate the direction of groundwater flow in an area where the hydraulic gradient is too low to establish the flow direction by conventional hydrologic tests (G. C. Solomon, personal commun. 1986).

EQ3NR is also used to calculate the electrical imbalance of a fluid. This provides a useful check on the completeness and correctness of analytical measurements. At LLNL, electrical imbalance calculations using EQ3NR led to the replacement of a procedure for determining dissolved carbonate by alkalinity titration. A new technique that measures evolved carbon dioxide by absorption of an infrared beam is now used. EQ3NR can calculate the pH if one assumes electrical balance. This is usually not appropriate for complex solutions such as natural waters, because of uncertainties in the solution analysis. This type of calculation is useful for designing pH buffer solutions to be used in laboratory experiments (Knauss and Wolery, 1986). For example, the composition of buffer solution with a pH of 8.0 at 70°C contains 0.005 H_3BO_3 and a small amount of NaOH. EQ3NR can calculate the concentration of NaOH required.

A planned application of EQ3NR is to calculate the pH in brines and other concentrated salt solutions from coupled specific-ion electrode measurements. By replacing the reference electrode used in making pH measurements in dilute solutions with a chloride electrode, it is possible to measure pHCl (= pH + pCl). Liquid junction effects, which prevent the usual pH measurement technique from being used in concentrated solutions, are avoided by eliminating the usual reference electrode. Measurement of chloride concentration, along with the other usual components of solution analysis, allows pHCl to be split into pH and pCl. A speciation calculation is required to make the split and any pH scale can be chosen. The pH electrode could be paired off with a specific ion electrode other than chloride, say sodium, which would give the parameter pH/Na (= pH - pNa). This approach in concentrated solutions has yet to be proven and standard procedures remain to be developed, although it appears to be the only potential method for routinely determining pH in brines.

Reaction rates depend on the degree to which a reaction is out of equilibrium (see Wolery, 1986a, and references therein). Constructing rate laws and obtaining values for the necessary constants from experimental data require speciation-solubility calculations to evaluate this degree, usually expressed as a saturation index or thermodynamic affinity. Although the thermodynamic affinity depends on the activities of the species participating in the reaction, the reaction rate may depend on the activities of certain species through another factor appearing in the rate equation. The pH represents the activity of the hydrogen ion, and the activities of many other ions as well can be measured by single ion electrodes. At present, measurements using specific ion electrodes are limited to temperatures less than 100°C. Activities at temperatures greater than 100°C can only be determined by speciation calculations (EQ3NR).

EQ3NR can also calculate the concentration of a dissolved component, assuming that solubility equilibrium exists with a specific solid phase (i.e., that the saturation index is zero). This type of calculation yields the equilibrium concentration of a component if other solution parameters, such as pH, are known. Care must be taken to ensure that these types of calculations are properly interpreted. For example, if one knows the concentration of uranium in a solution, one could use the code to determine the saturation index of a specific uranium mineral. One might then ask the question, what would the concentration of uranium be if the solution were in equilibrium with this mineral. If the results of these calculations depend on, say pH, the question asked of EQ3NR is not necessarily the same as what would be the concentration of uranium if the mineral were allowed to equilibrate with the solution. The reason is that one would need to know the pH after equilibration, and this might change as a consequence of mineral/water interaction, just as the concentration of uranium would. EQ3NR can not calculate both the new uranium concentration and the new pH; it can only calculate the equilibrium concentration of uranium assuming that the old pH still holds. It is necessary to use EQ6 to calculate the reaction of a mineral with an aqueous solution.

2.4 EQ6, A Computer Program for Reaction-Path Modeling

EQ6 (Wolery, 1979, 1986b) calculates reaction paths and mass transfer in dynamically reacting systems by considering consecutive stages of partial equilibrium as equilibrium is approached and then attained. These calculations include such effects as changes in pH and redox potential, and changes in solute concentrations caused by the creation or consumption of the solvent (H_2O). EQ6 operates in more than one physical mode, but the basic one is the closed system (see section "Physical Systems and the Coupling of Geochemistry with Transport"). For example, during the dissolution of a mineral, there commonly occurs a sequential precipitation and dissolution of other solid phases before equilibrium is reached. EQ6 tracks that type of succession by noting both mineralogical composition and the aqueous phase speciation.

The approach in EQ6 is to dissolve an increment of a mineral into a "thermodynamically homogeneous" system composed of aqueous solution plus solids with which it is in equilibrium. The code recalculates the composition of the phases in this system and checks to see if any saturation relationships have changed. If so, the set of phases present may be changed. For example, if the solution becomes supersaturated with a mineral that is not present, it may be added to the system (precipitated). Usually the code adjusts the size of the reaction increment so as to accurately locate the position at which the new phase appears. The incrementing then continues. The reaction path ends when either all original reactant minerals have equilibrated or been totally consumed, or when a preset limit in terms of reaction progress, time, or number of increments is reached.

To make reaction-path calculations in a time framework, a rate law must be provided for each reaction that is not at equilibrium. In most calculations, these reactions represent mineral dissolution. Mineral precipitation is primarily modeled by assuming instantaneous precipitation upon reaching saturation. However, the code can also model precipitation according to specific rate laws (Delany, et al., 1986). When reaction-path

calculations are made without a time framework, the process is similar to a titration and is reported in terms of a reaction progress variable. This parameter describes how much mass transfer has occurred, as opposed to how much time has elapsed.

EQ6 uses the same speciation model as EQ3NR. Each code has its own speciation coding, although some routines are shared through the EQLIB library. The two codes also share a common thermodynamic data base. EQ3NR initializes EQ6 by providing a model for the aqueous solution at the start of the reaction path. EQ3NR only calculates the thermodynamic state of an aqueous solution. EQ6 must be used to calculate how that solution changes when it is reacted with other phases.

3.0 THEORY AND CODE DEVELOPMENT

The development of the EQ3/6 geochemical models involves incorporating conceptual models with a theoretical framework. These models simulate processes that may contribute to the potential transport of radionuclides from a HLW repository. There is an obvious need to interpret laboratory and field tests, which together with the predictive capabilities of the geochemical models, will provide the basis for the evaluation of potential repository sites.

3.1 Activity Coefficients

3.1.1 Background. In order to model many of the geochemical processes that may occur in and around HLW repositories and to interpret experimental studies over wide ranges of temperatures and solution compositions, it is essential to be able to calculate activity coefficients for aqueous solutes. Activity coefficients relate the concentrations of species in solution to their thermodynamic activities used in geochemical calculations. Activity coefficients are routinely calculated in EQ3/6 using Helgeson's (1969) B-dot equation. The B-dot equation is based on a simple, one-term extension of the Debye and Huckel model for dilute electrolytes combined with an ion association or "true speciation" concept. This

equation can be used to calculate activity coefficients for aqueous species in solutions up to relatively high temperatures, but it is generally useful only for solutions with ionic strengths less than about 1 molal. This constraint severely limits the utility of EQ3/6 in modeling chemical reactions, and precludes those conditions that might occur in and around a proposed salt repository. Consequently, recent and planned efforts sponsored by SRP, through the Office of Nuclear Waste Isolation (ONWI), have concentrated on extending the capability of the EQ3/6 codes to model the geochemistry of high ionic strength solutions.

3.1.2 Recent Progress. One approach for calculating activity coefficients in brines is based on a set of equations developed by Pitzer (e.g. 1973, 1975, 1979) which can be used for calculations in both dilute and very concentrated solutions. Pitzer's equations together with the empirical fit coefficients, which are necessary to evaluate these equations, have been incorporated in EQ3/6 (Jackson and Wolery, 1985). The fit coefficients required for Pitzer's equations, however, are scarce for most electrolytes at elevated temperatures and have not been determined at all for many of the actinide and lanthanide species. The reason for this is that the Pitzer method can be applied easily only to systems of strongly dissociated electrolytes. It is much more difficult to apply it to strongly associated electrolytes due to increased data requirements that involve a higher level of sophistication required to regress the data. An alternate approach to activity coefficients is based on hydration theory, a concept first advanced by Stokes and Robinson (1948). These equations have been extensively modified by Wolery and Jackson (1986), and have also been added to EQ3/6 as an option. It is hoped that this set of equations will accurately estimate activity coefficients at both high ionic strength as well as elevated temperatures. The hydration theory equations require use of two adjustable parameters: a hydration number and an ion size parameter. These parameters must be regressed from experimental data. In contrast to the parameters in Pitzer's equations, it appears that the parameters in the hydration theory equations may exhibit systematic variations among various solute species which will make it possible to estimate them using various correlation algorithms or from a variety of experimentally determined parameters.

3.1.3 Planned Work. An internally consistent set of hydration numbers and ion sizes, which can be used to approximate the compositional dependence of activity coefficients in compositionally complicated solutions, will be compiled. These efforts should greatly expand the capability of EQ3/6 to include the modeling of solutions with high ionic strengths over a range of temperatures and for a variety of solute components. Presently it is planned to retain each of the different options for calculating activity coefficients (B-dot equation, Pitzer's equations and hydration-theory equations) because each approach is useful for a certain range of conditions. In addition, it is planned to develop an EQ3/6 capability to use the equations of Helgeson et al. (1981) as modified by Wolery and Jackson (1986). This activity-coefficient model development has a special significance to the program-wide effort. This improvement will bridge the gap that exists between laboratory experiments conducted in dilute and concentrated solutions.

3.2 Solid Solutions

3.2.1 Background. Solid solutions are common in minerals. They have varying compositions but retain the same overall structure. For example, the mineral calcite ($CaCO_3$) contains primarily calcium ions bound in six-fold coordination with small amounts of strontium, barium, and magnesium ions replacing calcium on those sites without significantly changing the structure of the phase. Some degree of solid-solution behavior is universal in minerals found in nature. The mutual solubility of two end-member minerals in a solid-solution phase may be complete, or may be severely restricted. Regions of immiscibility exist where two phases of different composition coexist rather than there being a single homogenous phase.

Solid-solution phases occur both as primary and secondary phases. Consequently, in order to compute chemical equilibrium and simulate reaction path models of rock/water interactions, it is necessary to take account of phases with variable compositions. The thermodynamic properties for many solid solutions can be calculated from the properties of its end members.

3.2.2 Recent Progress. Bourcier (1985) has improved the treatment of solid solutions in EQ3/6 by incorporating a new algorithm for molecular mixing. This model is mathematically equivalent to a single-site mixing model. The equations needed for modeling ideal random multiple-site mixing of solid solutions are being derived and incorporated into the codes. These equations are generally applicable to all randomly-mixed solid solutions. Also, the data base has been expanded to include calcite-structured solid solutions based on the model of Sverjensky (1985).

3.2.3 Planned Work. Most multiple-site solid solutions do not mix randomly. For those cases, ions on different types of crystallographic sites interact with each other and give rise to a preferential ordering of ions in the solid. An example of this is the "aluminum avoidance" behavior in the plagioclase solid solution, where aluminum ions avoid being nearest neighbors on the tetrahedral sites. For those non-random solid solutions, a separate set of equations must be derived, solved, and added to the code for each solid solution case. In order to build a comprehensive data base for solid solutions, a continuous effort must be made to obtain thermodynamic data for solid solutions and incorporate it into the code. Our emphasis will be on alteration minerals important in the waste environment: clays, micas, and zeolites. Mineral solid solutions may also be important sinks for trace elements in rock/water systems. Trace element substitution in solid solutions will be incorporated into the code using recent experimental data on partition coefficients and by using theoretical models, such as those of Sverjensky (1984, 1985). Incorporation of radionuclides as trace components in solid solutions may be an process that may be solubility limiting for some elements.

3.3 Kinetics

3.3.1 Background. Thermodynamic calculation of the equilibrium assemblage gives some indication of whether a given process (or reaction) will proceed. The equilibrium assumption is reasonable when geological time scales are considered, which are on the order of hundreds of thousands and millions of years. This has been supported by field observations of

equilibrium minerals assemblages found in many rocks. However, for periods of shorter duration, where temperatures are relatively low, equilibrium may not be reached, if reaction kinetics are sluggish. Both experimental and field data support cases where equilibrium is not reached (Lasaga and Kirkpatrick, 1981). There is thus a need to apply kinetics in cases where thermodynamics is of limited applicability. Time frames of interest for HLW repositories are from hundreds to thousands of years where equilibrium will not always be attained. It is also important to be able to model the laboratory experiments in real time in order to understand the factors that affect extrapolation to longer time intervals.

3.3.2 Recent Progress. A precipitation-kinetics option for the EQ6 geochemical reaction path code is available (Delany, et al., 1986). This option complements the pre-existing capability to model dissolution kinetics. Several precipitation rate laws have been programmed into EQ6 as well as options for transition state theory and "activity term" expressions. More realistic simulation of water/rock interactions are now possible. This is especially useful for comparison with short-term laboratory experiments. In addition, Wolery (1986a) re-examined transition state theory, which resulted in new theoretical insights. This work will provide the foundation for further improvements necessary to model chemical kinetics.

3.3.3 Planned Work. Presently data are available for the rates of precipitation for only a few few minerals (e.g., silica polymorphs, carbonates and some sulfates and phosphates). It appears possible to extract precipitation information from dissolution data (Rimstidt and Barnes, 1980), which is more abundant than precipitation rate data for silicate minerals. Efforts will be undertaken to evaluate this approach. Additionally, reconnaissance studies will be initiated to explore the effects of nucleation phenomena and poisoning by substances that inhibit precipitation.

3.4 Gas Phases

3.4.1 Background. Gases may be produced or consumed in aqueous geochemical systems during reactions involving the solid and fluid phases. As some quantities of various gases (e.g., oxygen, carbon dioxide, methane and hydrogen sulfide) are expected to be present in all potential repository sites, it is imperative that geochemical models attain the capability to include gases in the systems under consideration. Gas phase equilibrium is expressed in terms of fugacity ("thermodynamic partial pressure"). If a species is more concentrated in the gas phase than the aqueous phase, the fugacity of the gas phase can be assumed to control the fugacity of the aqueous phase. The paths and rates of chemical reactions in the aqueous phase can be altered by such constraints.

3.4.2 Recent Progress. A fixed-fugacity option has been added to the EQ6 geochemical reaction path code (Delany and Wolery, 1984). By permitting the fugacity of any gas to be set to a fixed value, the effect of rapid chemical exchange with a large external gas reservoir can be simulated. Groundwater systems that are both open and closed to the atmosphere as well as buffered laboratory experiments can be modeled.

3.4.3 Planned Work. A variable-fugacity model will be added to allow modeling of closed systems containing varying amounts of gases, such as unbuffered hydrothermal experiments. It will also be possible to treat a gas phase of finite mass.

3.5 Pressure Corrections

3.5.1 Background. Previously, all calculations were made at pressures along the liquid-vapor curve for pure water. The approach for incorporating pressure corrections into the codes is to use the present equilibrium constants along the liquid-vapor curve and to extrapolate these values up in pressure using molar volume data for the reaction and the relationship:

$$\ln K_{T,P} = \ln K_{Tr,Pr} - \frac{\Delta V_R^\circ}{RT}(P - P_r)$$

where Tr and Pr are the reference temperature and pressure (i.e. along the l-v curve) and ΔV_r° is the calculated molar volume change for the reaction. The molar volume of the reaction is determined from the molar volumes of all the constituents of the reaction.

3.5.2 Recent Progress. This effort has just begun.

3.5.3 Planned Work. In order to make these changes, the program MCRT must be modified so that it computes molar volume changes for reactions and writes this data into the file DATAO. The molar volume data are then read and used by EQTL to compute a polynomial to fit the equilibrium constants as a function of both temperature and pressure. Finally, EQNR and EQ6 must be modified to read the revised DATA1, DATA2, and DATA3 files and obtain pressure-corrected equilibrium constants from the revised fitting polynomial.

Work is in the progress to make the necessary modifications to the MCRT program. The MCRT program itself, and the subroutines DECOMP, DLTAQ1, DLTSOL, DLPSOL, AND DLPAQ1 must be modified to compute molar volume properties of reactions. The routines GRSOL and GRAQS must also be modified to correctly read in molar volume data from the MDA data file.

For computation of aqueous equilibria at elevated temperatures, the current activity coefficient subroutines must be modified to use the proper high-pressure Debye-Hückel parameters. These data are available in the program SUPCRT, and we are currently adding the necessary routines from SUPCRT into the MCRT code. This addition will also provide the capability for calculating high-temperature thermodynamic properties of ions and minerals internally in the MCRT code. Previously, they were obtained from running the SUPCRT program and placing them into the DATAO file using an editor.

3.6 Sorption

3.6.1 Background. Trace components are usually observed in precipitated, dissolved, or sorbed forms. Precipitation and dissolution reactions may be hindered by sluggish kinetics, thus leaving sorption an

important process to consider for reducing the concentrations of trace components or contaminants in solution. Sorption is thought to be particularly important when considering the transport of radionuclides in groundwater. Radionuclides may sorb onto surfaces of aquifers or colloids and retard radionuclide transport.

Sorption is one of several processes that affect the movement of dissolved radionuclides in ground waters. Several processes have been identified that retard their transport in solution: adsorption, ion exchange, membrane filtration, diffusion into pores, and chemical precipitation (Neretnieks, 1980). Sorption is a term that can include physical adsorption, chemisorption, and ion exchange processes. Modeling of sorption phenomena generally assumes that adsorption of trace quantities of radionuclides obey first-order reversible kinetics (Krishnaswami et al., 1982). Two principal models commonly used to explain reversible ion sorption reactions on natural surfaces are constant charge and constant potential models. At low concentration in a liquid, Henry's law is obeyed and the activity in solution is directly proportional to its concentration.

Langmuir (1918) was the first to develop a quantitative model for adsorption. He related the amount of a substance adsorbed on a surface in a fixed number of independent sites to the concentration. This model is called the Langmuir adsorption isotherm. Since that time, many sorption models have been developed, based on both theory and empirical observations. Some models also relate parameters such as pH, Eh, ionic strength, and valence state in solution to sorbed concentrations.

3.6.2 Recent Progress. This effort has just recently started.

3.6.3 Planned Work. Sorption is being considered for addition to the EQ3/6 code during FY86. The main objectives during this year are to investigate the fundamental principles that are involved in understanding adsorption column dynamics, to model batch adsorption systems, sorption kinetics, and equilibria, and provide a framework for the interpretation of experimental data. The addition of a sorption capability to the EQ6 code

will follow next year. This capability will be similar to the precipitation kinetics capability recently added to EQ6, and will consist of a representative sampling of sorption isotherms based both on theory and empirical observations. The actual isotherm to be used in a EQ6 run will be chosen by the user and indicated on the INPUT file. Also planned for inclusion are any site-specific sorption models developed for NNWSI. LANL is currently studying sorption characteristics of Topopah Spring Tuff.

3.7 Physical Systems and the Coupling of Geochemistry with Transport

3.7.1 Background. Geochemical interactions take place in physical systems where it is significant whether or not the system is open to any components, and if so, which ones. The EQ6 code now operates in more than one physical mode and additional modes are planned. The relation of these modes to the broader needs of the program will be discussed below.

The simplest physical system to treat using EQ6 is a thermodynamically homogeneous closed system. Thermodynamic homogeneity is defined as a static system without gradients in either temperature, pressure, or chemical potentials. The composition of the aqueous phase must be uniform. Other phases may be present, but they must be in equilibrium with the aqueous phase. EQ6 can solve parameters for these systems given the temperature, pressure, and bulk composition. It can identify the phases present and their compositions. By themselves, systems of this kind are of limited usefulness, but the ability to model them is a computational prerequisite to making more interesting calculations in more complex physical systems.

A more important mode is a closed system in which the phases are physically homogeneous but some reactions are out of equilibrium. Temperature and pressure are initially specified and uniform within the system, although they need not be constant with time or reaction progress. Driving forces are present to cause reactions that proceed toward equilibrium. It is possible to conceptualize such a system as consisting of a thermodynamically homogeneous subsystem, including an aqueous solution and one or more phases with which it is not in equilibrium. Progress toward

equilibrium can then be viewed as a titration process in which increments of the non-equilibrium phases are added to, or in some cases subtracted from, the thermodynamically homogeneous subsystem. Composition of the aqueous solution is then adjusted to satisfy internal equilibrium. Calculations of this kind can be used to model mineral/water reaction in closed systems, actual titration processes, and, by "reverse titrating" of water, processes of evaporation and boiling. Such calculations may or may not be directly related to a time framework, depending upon the availability of rate laws to describe the incrementing process in terms of time.

The closed system is an excellent representation of many experimental systems, such as Dickson rocking autoclaves. Much of the laboratory work being carried out in support of the OCRWM Program is being carried out in such systems. EQ6 can be used to model these experiments; the results can be related to basic thermodynamic data that can yield prediction of longer-term behavior with some degree of confidence. For example, short-term experiments may achieve apparent steady states that persist until the experiments are terminated. Geochemical modeling has shown that in a number of instances, these steady state conditions are thermodynamically metastable and probably cannot be expected to persist over the long time intervals required for repository performance assessment (Delany, 1986).

In contrast to closed systems, open systems imply some degree of transport, that is, movement of matter across system boundaries. Several kinds of open systems are possible, and it is useful to relate these to the closed system. The latter can be thought of as a model system at a positional node or box in a spatial framework, with the fluxes into or out of the box temporarily suspended or infinitesimal. A flow path, for example, could be represented by a series of boxes.

One type of open system is a box that is open to a large external gas reservoir, for example a beaker or flask open to the air. In such a system, as a dissolved gas such as CO_2 or O_2 is consumed or produced by chemical reaction in the box, an equivalent amount enters or leaves the box. The fugacity of such a gas is held constant. The reaction path representing the

geochemical interactions taking place within the box may be significantly changed by such an effect. This type of model is not only applicable to a simple benchtop experiment open to the atmosphere (or controlled by a constant source), but also to surficial weathering processes and processes in the unsaturated zone. The fraction of open space not occupied by water contains chemically reactive gas that appears to be much like air. EQ6 was recently modified to be able to model such systems (Delany and Wolery, 1984). With this code option, it is possible to calculate the affect of the presence of a gas reservoir. An important EQ6 application may be to use experimental data from laboratory experiments (conducted to characterize geochemical behavior in and about the proposed repository) to model the effects of a gas reservoir often not present in the laboratory systems.

It is possible to conceptualize a fully one-dimensional geochemical transport model by considering water moving through a sequence of boxes representing a flow path. The closed system calculational modeling capability would be used to solve for the chemistry in each box at each time step. Gas fugacities may be fixed, if desired. In the simplest case, fluid flow would be fixed, ignoring possible changes in flow due to mineral precipitation or dissolution. A temperature or pressure gradient could also be imposed.

At present, EQ6 does not have a full one-dimensional modeling capability. It only has a pseudo one-dimensional physical mode. A pseudo one-dimensional mode here refers to a model that focuses on a single packet of water or a single box. This mode in EQ6 tracks the evolution of a single package of water as it flows through a uniform reactant medium. System parameters such as temperature gradients and gas fugacities may be fixed, and product minerals removed from the system as they are formed. A full one-dimensional model would be required to allow precipitates to back react with the fluid or react with following packets of water.

An additional pseudo one-dimensional mode is planned. It focuses on the evolution of the contents of a box containing water and solids. Fluid of constant composition flows into the box and displaces fluid whose

composition has been modified by geochemical interactions in the box. Gas fugacities may be held constant. Part of the problem is to calculate the composition of the exiting fluid. The box can be thought of as the first box in a sequence. Alternatively, it can be conceptualized as a flow through leaching cell, an apparatus that is used in laboratory studies as part of the OCRWM Program. Thus, this capability will be useful in geochemical modeling of an additional important class of experiments.

These two pseudo one-dimensional modes allow a partial link of transport (fluid advection) with detailed geochemical models. By linking a sequence of boxes, a full one-dimensional model could be developed. The decision of whether or not to build such a model into EQ6 has not yet been made. EQ6 is a highly sophisticated tool for modeling geochemical interactions and is already a substantial code package, larger than many transport codes.

Solving the necessary chemistry equations in a single box may already involve simultaneous solution of hundreds of equations. A full one-dimensional model probably would represent the upper limit to transport development for the EQ6 code. Even with this treatment, the transport mechanism would be rudimentary compared to that which exists in current transport codes. These codes tend to treat geochemistry in a complementary rudimentary fashion.

The need for coupled geochemistry and transport models in the OCRWM Program is well established (e.g. Garven, 1984; Pearson, 1984; Cederberg, 1985; Lichtner, 1985). Geochemical interactions can be significantly affected by transport phenomena and vice versa. In the near field during the thermal-pulse period, dissolution and precipitation effects could have a significant effect on fluid flow. In the far field, geochemical interactions will probably have very little effect on fluid flow. Transport of radionuclides through both the near and far fields could be significantly affected by geochemical interactions such as sorption and precipitation.

The principle role of EQ3/6 is presently in the design and interpretation of laboratory experiments and in the interpretation of site geochemistry. The former involves both purely thermodynamic as well as kinetic modeling, and serves the important function of relating observations in complex systems to known basic data, such as solubility product constants. This is important for the identification of possible metastable assemblages in short-term experiments. The use of EQ3/6 in interpreting site geochemistry largely involves purely thermodynamic modeling and simulating rock/water interactions.

Although many effects may be included in a geochemical modeling calculation, it usually turns out that in any geochemical system only a small fraction of these effects dominate the results. Unfortunately, the identities of all of the dominant effects can usually be determined only after the calculation has been done with all of the possible effects included. For example, the mass balance of a dissolved component is usually 99% composed of only one to five species. The number of species included in the calculation may be quite large - for example, there are already dozens of aqueous species of uranium in the EQ3/6 data base. The set of dominant effects is not necessarily fixed, but may vary with such parameters as temperature, pressure, and fluid composition. If these change too much, the set of dominant effects may be changed. The possible effects of transport on these parameters and hence the set of dominant geochemical effects can be evaluated. It is expected that this can be accomplished primarily by reference to EQ6 calculations using the pseudo-one dimensional modes, and possibly the fully one dimensional mode. These should represent the transport effects sufficiently well to evaluate their effect on the identities of the dominant geochemical factors. If necessary, further justification for eliminating certain geochemical effects can be obtained by including a few that are thought unnecessary in a complete geochemistry-transport calculation.

3.7.2 Recent Progress. This effort has not started.

3.7.3 Planned Work. Modeling the behavior of the near-field environment will require a more sophisticated treatment of coupled geochemistry and transport. As planned, EQ3/6 will play an important role in interpreting the results of laboratory experiments and provide guidance for predicting long-term scenarios. This is viewed as necessary but not sufficient, because we do not plan to expand EQ3/6 into a sophisticated transport code. If EQ3/6 is not to be expanded to treat transport in more than a rudimentary fashion, the question arises as to what code will be used to make calculations in which both geochemistry and transport must be treated in more than a rudimentary way. It is anticipated that the need for such software will be met outside the EQ3/6 subtask by incorporating the improved descriptions of geochemistry generated by the subtask and by others using EQ3/6 into existing transport codes. Two approaches are possible. One is to carry out the geochemistry calculations utilizing subroutines. In this way, a scaled down version (in terms of reduced array dimensions and elimination of unnecessary supporting data and submodels) of EQ6 could be employed. The other approach would be to take the chemical equations and substitute them into the transport equations. Preliminary attempts of both approaches currently exist.

There are advantages in developing subroutines for geochemistry calculations. The geochemistry part of the model need not be extensively duplicated. New developments in modeling geochemical processes would quickly and more assuredly be included in the combined geochemistry-transport model. Most of the equations that describe geochemical interactions are fundamentally algebraic in nature. Substituting them into transport equations turns them into differential equations, and different numerical methods must then be employed. Errors in numerical integration of differential equations can be more devastating to chemistry equations than to transport equations. EQ3/6 is written to treat algebraic equations by algebraic methods. Only kinetic rate laws, which are inherently differential equations, are treated by numerical integration. Thus, duplication or partial duplication of the geochemistry submodels in EQ3/6 in a combined geochemistry - transport code would require not only parallel coding, but coding using different numerical methods.

4.0 THERMODYNAMIC DATA BASE

4.1 PURPOSE

The thermodynamic data base is a summary of the available thermodynamic data for aqueous species, solids, and gases in tabular form that are necessary to serve as input to the geochemical modeling codes EQ3NR and EQ6. The data base will be evaluated by testing predictions of host-rock phases, secondary phases, solution species, and total solution concentrations against the results of laboratory measurements made over a range of identified parameters that include: temperature, ionic strength, redox conditions, and solution composition. The user is responsible for determining the acceptability of the data base for its intended application.

The data base is structured to allow a convenient means for expansion, revision, and documentation as new data become available. The primary EQ3/6 data base is comprised of two data files. A master data file (MDAR) contains all species and data sources that have been considered by the EQ3/6 group. This data file is in direct access format and contains extensive comments and documentation. The second data file (DATAO) is generated in part from MDAR and contains thermodynamic values that have been selected for use by the EQ3/6 codes for actual calculations. A portion of DATAO that represents rock/forming minerals is taken from SUPCRT, a data base maintained at the University of California, Berkeley.

4.2 BACKGROUND

The two data files contain the standard thermodynamic data that are reported in the literature for solids, aqueous species, and gases. These values have been gathered from the available literature and inserted into the EQ3/6 data base format as an ongoing effort over several years. In general, the data base work has lagged behind code development. During FY85, a significant amount of time was spent reviewing and revising the thermodynamic data for the actinides. As a result of this work, an

experimental plan was developed to fill in thermodynamic values that are either lacking and to resolve inconsistentcies. This plan is designed to span a 5-year period.

Significant modifications with regard to consistency, organization, user information, and documentation are in progress. These changes affect the on-line maintenance of all the data base files, related data base manager codes, and thermodynamic codes. Recent revisions of the thermodynamic data for several of the aqueous and solid species of U, Am, and Pu have demonstrated the need for an experimental data base activity that would be able to provide data that is currently lacking for solubility limiting solid phases and/or solution species. Measurements will be made as a function of temperature, ionic strength, and oxidation state as required. The activity, which commenced in mid-FY86, has been divided into three sections: sensitivity analysis, development of thermodynamic data, and validation.

Two members of the EQ3/6 data base staff are participants on critical review teams for the International Thermodynamic Data Base, sponsored by the Nuclear Energy Agency (NEA). As a result of this work, the following principles have been accepted for the EQ3/6 data base.

1. Incorporate results of peer reviewed data. This will provide compatibility with CODATA (Committee on Data for Science and Technology) task group recommended key values and with NEA (Nuclear Energy Agency) as their data values are released.

2. Implement EQ3/6 data base methodology for new and existing data.

3. Create and maintain a data base library on the computer for all documented sources of thermodynamic data.

4.3 DATA BASE DEVELOPMENT

Sensitivity Analysis

A necessary part of this task is to meet the programmatic time constraints imposed by the NWPA. As a consequence of this, it is important that the number of experiments be limited by assigning priorities. Sensitivity analysis will: (1) identify reactions that can be neglected and (2) recommend additional experiments for improving and/or obtaining important thermodynamic data. The master EQ3/6 data base file now contains more than 1200 species. This program will evaluate the degree of importance various solution species have under different solution conditions. The precision needed for thermodynamic quantities will be determined for these species. The ranges of system parameters for which all thermodynamic data would be needed will also be determined.

All sensitivity analysis tasks have been postponed until thermodynamic data for all important radionuclides have been entered into the data base from the available literature. During FY86, the thermodynamic data for neptunium solids and aqueous species are being reviewed and compiled to be incorporated into the EQ3/6 data base. Major emphasis is being given to species that may be significant in geochemical applications for radioactive waste disposal. Solids considered so far include oxides, hydroxides, phosphates, and carbonates; aqueous species include ions, anions, and complexes with the halides, phosphate, carbonate, and sulfate.

Compatibility with CODATA

CODATA values have been published for 125 chemical species (CODATA, 1978) and a preprint of a revision has been received that includes a number of additional compounds. The current EQ3/6 data base is consistent with most of the CODATA values although full compatibility has not been obtained.

To date, reports have been prepared comparing the 1978 CODATA values with the 1985 CODATA values and comparing these values (especially 1985) with the values found in MDAR.

Compatibility with International Thermodynamic Data Base

Aqueous and solid species for I, Pb, Tc, Cs, Sr, Ra, U, Np, Pu, and Am are being considered by NEA panels at this time. Most of this work is in the critical review process and has not yet been completed and released. NEA has also published standards on extrapolation to zero ionic strength, format for compilation and review processes, selected values for reference phases, treatment of uncertainties, and conventions with regard to notation, solution description, etc. (Muller, 1985). In order to incorporate these data into the EQ3/6 data base, the master data file will be reformatted to include additional species information that is required by the NEA format.

Data Evaluation and Maintenance

Several elements that are not currently in the data base, but which will be needed for modeling nuclear waste glass dissolution behavior, include Mo, Ti, Y, Zr, Te, Ce, Nb, Pd, Cm, and several lanthanide elements. Compilations of thermodynamic data exist for some of these elements (Eu, Mo) but additional evaluations and laboratory experiments are expected to be necessary for these elements. Critical reviews are also needed for values that have been entered into the data base but are yet to be evaluated, for example, thermodynamic values for species of C, Sn, Cr, Co, Se, Cs, I, Th, and Ra. Literature search and data collection tasks still need to be conducted for Sm and Pb before species of these elements can be inserted into the data base and a sensitivity analysis made. In some cases, the basic chemistry will have to be clarified before a thermodynamic assessment can be made.

The thermodynamic data for the rock-forming minerals has been taken from the SUPCRT compilation (Helgeson et al., 1978). SUPCRT is a FORTRAN code and supporting data base that calculates the thermodynamic properties of minerals, aqueous species, and gases at high temperatures. The SUPCRT data base stores the standard modal entropies, heat capacity power function coefficients, molar volumes, and enthalpy and Gibbs energy of formation for each mineral phase.

These thermodynamic values were extracted with high temperature/pressure phase equilibria constraints. The SUPCRT code generates a log K grid as a function of temperature for the dissociation reaction of each phase from 25-300°C. The log K values are then used as input to a SUPCRT formatter code (written at LLNL for the EQ3/6 data base by T. Wolery) to generate portions of EQ3/6 data blocks for the thermodynamic data file (DATA0).

The SUPCRT data base has been an integral part of the thermodynamic data base for minerals since 1978. The data has been updated with corrections as released by H. C. Helgeson at the University of California, Berkeley. The EQ3/6 thermodynamic data file contains thermodynamic data for many other solids and minerals in addition to that reported in SUPCRT. These data are generally documented and entered through the master data file (MDAR).

The work currently planned is to update SUPCRT by (1) updating values for molar heat capacities and calorimetric entropies with new experimental data that has been reported in the literature; (2) expanding the heat capacity fit equation ($H_T° - H_{298}° = A + BT + CT^2 + D/T + ET^{1/2} + FT_3$) to include more recent calorimetric data; and (3) evaluate the impact of CODATA values on the SUPCRT thermodynamic values.

Under consideration is replacing the SUPCRT data base with a new data base for rock-forming minerals. Berman et al. (1985) have reported data for 71 minerals, this new data base already contains many of the updated values we outlined above. They use linear programming techniques to ensure internal consistency between phase equilibrium, calorimetric, and volumetric data. This approach is similar to SUPCRT in that it uses constraints from phase equilibria data to derive thermodynamic properties of minerals. The authors also use a predictive Cp function (Berman and Brown, 1985) that is compatible with the high-temperature heat capacity limit predicted by lattice vibrational theory.

A continuing effort will be required to keep the data base current as new data become available. This will involve maintaining an archive of literature used to generate the data base and to continue to document the selection of values chosen for the data base.

4.4 Laboratory Measurements

The objective of this activity is to correct gaps or conflicts in the master EQ3/6 data file by making the necessary experimental measurements. Laboratory measurements will supply thermodynamic data on solids and solution species that are critical to the reliable prediction of radionuclide solution concentrations in waste repository settings where there are no reliable data, where serious discrepancies exist in published data, or where data of sufficient accuracy do not exist. The quality level assignment for data introduced from this activity will be identified in the data base.

Solubility Measurements

We propose to generate a resource body of data on possible controlling solid phases and to determine the free energies of solubility reactions needed by EQ3/6. Some redeterminations of existing data may be necessary because several values in the published literature are taken from experimental studies where the solid phases were not characterized. Additional data may be needed in some cases for amorphous and crystalline counterparts, especially if short-term solubility experiments are to be modeled successfully. To accomplish this activity, all solids must be well characterized both structurally and compositionally. This will be accomplished through the use of x-ray, infrared, and surface spectroscopy techniques for both synthetic and natural materials when possible.

The complete set of solution species and solid phases to be investigated over the life-time of the program is not as yet known since their identification is the object of the critical review, sensitivity analysis and validation of the EQ3/6 calculations. Our initial review of thermodynamic data for U, Pu and Am, and initial modeling studies of these elements in J-13 water in FY85-86 led to the following proposed research on these elements for FY86-88.

Uranium

The free energies for the solubility reactions of several uranyl silicate compounds that appear likely to form in dilute groundwater in the presence of spent fuel will be determined. These phases may be solubility limiting, but no experimental data presently exist. These solids are: soddyite, uranophane, Na-boltwoodite, and Ca-haiweeite.

Americium

We plan to determine the free energy of the solubility reactions of amorphous and crystalline $Am(OH)_3$. Also, we will investigate the nature of the solid phase that forms for pH values greater than about 9.

Plutonium

A number of important thermodynamic constants in the data base are highly unreliable, e.g. the Ksp values for $PuO_2(OH)_2(s)$ and $PuO_2(OH)(am)$. We propose to prepare and characterize the structure of $PuO_2(OH)_2$ and to measure the solubility product constant. Also, we plan to determine the solubility product constant of $PuO_2(OH)(am)$.

Speciation Experiments

Solubility product constants are not usually sufficient to predict accurate solution concentrations. This is because the formation of hydrolysis products and other complexes can increase apparent solubilities. Therefore, reliable formation constants for the major solution species that are likely to form under site-specific ground water conditions are needed to make accurate EQ3/6 calculations. A number of gaps and inconsistencies were identified for carbonate formation constants, particularly for Am(III) and Pu(IV). This is primarily because indirect methods that do not provide information on the nature of the solution species have commonly been used (e.g. nuclear counting methods). UV-visible near-IR spectroscopy can supply information for characterizing solution species and concentration levels. Initially, we will

be using standard absorption spectroscopy methods to investigate both oxidation state distributions and the nature of solution complexes. Attempts will be made to apply more sensitive laser techniques to these measurements. Carbonate complexation of americium will be studied in FY87 and plutonium in FY87-88.

Americium

We plan to investigate the carbonate complexation of Am^{+++} to verify the existence of bicarbonate and hydroxycarbonate complexes and to determine the relative importance of these complexes to the normal carbonates. If possible, formation constants will be obtained.

Plutonium

We will investigate the carbonate complexes of PuO_2^+ and attempt to obtain formation constants and plan to measure the first hydrolysis constant for PuO_2^+.

Laser-Induced Pulsed Photo-Acoustic Spectroscopy

The determination of waste radionuclide solubilities and speciation (i.e., oxidation state distributions, solution complexes, and ionic or colloidal forms) involves measurements that must be made in aqueous solutions of pH 7-9 (common to groundwaters). Many important waste radionuclides, particularly the actinides, are only sparingly soluble under these conditions and submicromolar concentrations are frequently encountered. While the nuclear counting methods usually provide the necessary sensitivity for the measurement of total concentrations, they provide no information on the nature of the solution species. Conventional UV-visible-near-infrared absorption spectroscopy can supply some information on solution species characterization, but generally lacks the necessary sensitivity. Thus, methods for the adequate characterization of solution species at submicromolar concentrations are not available. This limitation has led to serious gaps and conflicts in available

thermodynamic data on many of the waste radionuclides. The inadequacies of present techniques and the need for new, more sensitive methods for identifying solution species has been a subject for discussion at two recent workshops sponsored by DOE and NRC.

Within the last few years, a new laser technique has been developed for measuring very weak sample absorbance. The approach is to measure directly the deposited energy resulting from the absorption process rather than the more conventional method of measuring the attenuation in a light beam. This technique, pulsed photoacoustic spectroscopy, has been shown to be several orders of magnitude more sensitive than the conventional approach. Although applied to the study of gases and solids rather extensively, little has been reported on measurements involving aqueous solutions. Recently, a West German group has demonstrated that this technique can be applied to measurements of actinide speciation at submicromolar concentrations (Stumpe et al, 1984).

We are developing a pulsed photoacoustic (PA) spectroscopy system using the existing Nd-YAG pumped dye laser and associated computer-control instrumentation at LBL and will investigate the capabilities and sensitivity limitations of this system for characterizing waste radionuclide species in aqueous solutions. Since the application of PA spectroscopy to the study of aqueous solution species is still in the early stages of development, PA cells and associated preamplifiers tailored to the purpose are not yet commercially available. Therefore, our initial efforts would involve (1) experiments to determine optimum cell geometry and construction materials for efficient coupling of the cell liquid to the transducer for maximum signal to noise; (2) design and construction of PA cells based on the test results; and (3) design and construction of low-noise, high-impedance, high-frequency response preamplifiers tailored for use with the PA cells.

With the completed system, measurements of signal strength versus concentration of U, Np, and Pu in the submicromolar region would be made to determine usable detection limits. The final phase would involve tests to determine the capability of the system to distinguish ionic (complexed and uncomplexed), polynuclear, and colloidal forms of Pu at submicromolar levels.

Vibrational Spectroscopy

Frequently, a positive identification or characterization of the controlling solid phase in experimental measurements is lacking. This causes a serious problem when comparing the results of modeling studies with experimental measurements. The amount of solid material is often present in submilligram quantities (sometimes only surface layers) and it is frequently amorphous in nature. While x-ray spectroscopy can often be used to characterize submilligram amounts of crystalline material, multimilligram amounts are usually required for a chemical analysis of amorphous material.

We are generating a spectral library using Fourier transform infrared techniques to characterize phases that may be the controlling concentration in site-specific ground waters. Library spectra can be used to identify spectra of unknown solids from spent fuel and waste form dissolution experiments from their characteristic "finger prints." We plan to use this spectroscopic data, along with structural and elastic data to predict thermodynamic functions using a spectral-averaging model developed by Kieffer (1979a, b, c; 1980). This model is a FORTRAN code based on the theory of lattice vibrational properties of minerals, and observed trends in the high-temperature thermodynamic properties of silicates. These parameters are determined by the position and relative numbers of high-frequency modes. The entropy on the other hand is most sensitive to the low-frequency optic modes, generally observed in the far-infrared region. Model values of heat capacities and third law entropies have been shown to be in good agreement with experimental values at 298-1000°C for over 30 minerals. This method has been successful in predicting experimentally documented phase relations for a number of silicate and oxide systems. These data can then be used to calculate molar heat capacities and third law entropies. These quantities are needed to make thermodynamic calculations at temperatures above 25°C, and are stored directly in the EQ3/6 data base. At this time, quantitative spectral techniques are proposed for several uranyl silicate phases mentioned above.

4.5 User Guidelines for Validation of Data Base

The user has the responsibility for determining the acceptability of the data base for its intended application. This section outlines activities that serve as a guideline for users in that evaluation. This activity will involve both theoretical calculations using EQ3/6 and additional laboratory and field measurements aimed at confirming the validity of code predictions. Measurements of solution concentrations of the waste radionuclides as well as the identification and characterization of solid phases and solution species will be made over the range of system parameters expected in the proposed repository sites. Validation of rock/water systems at elevated temperatures can be conducted by comparison with existing literature. The majority of the inorganic components that form insoluble compounds and solution complexes in dilute ground waters are presently included in the data base. Many of these species have been qualitatively documented from previous EQ3/6 runs and presumably need only to pass the validation procedure. Additional complexes may need to be added to the data base as studies are completed with waste radionuclides that may be important depending on specific site characteristics. If any of these species are lacking thermodynamic characterization and need to be considered for the development portion of the data base, it will be critical that the validation staff work closely with the experimentalists to ensure that the necessary measurements are made. Because of the large number of solid phases and solution complexes that can conceivably form in groundwater-host rock interactions, this task must be sufficiently flexible to fill any gaps or conflicts in thermodynamic values on an as-needed basis. At this time, the site-specific solubility measurements of individual solid phases is being funded directly by each of the three project site tasks. The final data base will need to be validated by testing predictions of host-rock phases, secondary phases solution species, and total solution concentrations against the results of laboratory measurements made over a range of identified parameters that include: temperature, ionic strength, redox conditions, and solution composition. This validation work should complement measurements that are currently being made by the site tasks on specific systems.

5.0 MAINTENANCE, DOCUMENTATION, AND SUPPORT FUNCTIONS

5.1 Code Maintenance

Complex computer codes inevitably contain bugs. Bugs may be divided into four categories according to the nature of the effects they produce:

A The program crashes. For example upon attempting to divide by zero. Program termination is abnormal from the point of view of the operating system.

B The program fails. For example because an iterative calculation fails to converge. Program termination is normal from the point of view of the operating system.

C The program produces output that is normal in format, but the results are erroneous and are readily recognized as such by a knowledgeable user. For example, a result that should have a value within an order of magnitude of unity has a value of 1.e+30.

D The program produces erroneous data that appears to be normal. There is a high probability that the user will not catch the error, at least not right away.

A large portion of any code development effort normally is spent in fixing bugs, particularly types A and B. The discussion here will focus on the appearance of bugs in a version of a code that has been released by the developers for applications work. This program plan assumes that, as EQ3/6 is used in applications here at LLNL and elsewhere, bugs will be discovered and corrective action will be required. Fixing bugs takes time and money, because significant effort is usually required not only to change the code, but to diagnose the problem before changes are made and afterward to test the modified code. The EQ3/6 Software Quality Assurance Plan defines a procedure for resolving errors in released code (see "Software Quality Assurance, Section 6.0"). Bugs sometimes arise in the transfer of a code to a new

machine, due to differences in either the hardware or the operating system software. Even a change in the operating system software on a given machine may cause new bugs to appear. Increasing standardization of languages and operating systems is beginning to reduce the frequency of such problems, or at least offer the possibility of writing code in some manner that will reduce portability problems. Not all portability-related bugs can be caught prior to release of a code by the developers. Portability standards have been adopted for EQ3/6 development to help reduce the incidence of such problems.

Verification and validation activities are required as part of the EQ3/6 Software Quality Assurance Plan. However, testing, verification, and validation activities are necessarily finite. If a code is simple, or only solves a limited range of problems, a high degree of confidence may be achieved that all bugs have been eliminated. In the EQ3/6 package, this situation can be realized with the data base management code, MCRT. Less confidence is possible with codes that are more complex or solve a broader range of problems. The codes EQ3NR and EQ6 fall into this category. Part of our response to this problem in EQ3/6 development is the creation of verification libraries. As codes such as EQ6 are developed by the addition of new capabilities, test cases from these libraries will be periodically re-run to assure that new development has not compromised previous capabilities. Another method of bug detection is to encourage others to use the code and report problems that they may encounter.

Type C and D bugs may result from coding errors. However, they may also result from erroneous data on supporting data files. In the EQ3/6 Software Quality Assurance Plan, supporting data files and codes are both treated as "controlled items." Error resolution pertaining to such data files is handled much like that for coding errors.

Bugs of all types may result from errors in numerical integration or iterative procedures. Because these procedures are inherently inexact, special attention must be paid to the sizes of the errors. When such procedures are used in EQ3/6, problems of this kind are avoided in two ways. First, convergence tolerances, which are changeable by the user, are assigned

default values that are on the tight side. Second, if the error can be quantified in more than one way, each way is tested. For example, Newton-Raphson iteration is employed in both EQ3NR and other speciation-solubility codes. Most such codes test for convergence only the magnitudes of the residual functions; we also test the magnitudes of the correction terms.

5.2 Programming Improvements

A code may produce correct results, but still be deficient in terms of portability, efficiency, modularity, clarity, or new language or coding standards. EQ3/6 was originally written in extended FORTRAN 66 on CDC 6400, 6600, and 7600 computers, and was not especially portable to different kinds of machines. In recent years, there has been a considerable effort to increase portability and clarity, and adopt new programming standards. Some of these standards presaged adoption of the FORTRAN 77 language. EQ3/6 has recently been moved from CDC 7600 and Cray-1 computers, which have, respectively, 60- and 64-bit word sizes, to two dedicated Ridge computers, which are 32-bit UNIX machines. The big LLNL machines did not support a full FORTRAN 77. Hence, moving to the Ridge machines has permitted a move to full FORTRAN 77. FORTRAN 77, among other things, offers programming structures of the IF-THEN-ELSE-ENDIF type, which are clearer and less error prone than equivalent conditional GO TO structures. Another reason for moving EQ3/6 development to a 32-bit UNIX machine with FORTRAN 77 is that it increases portability as other users of EQ3/6 are now likely to run it on compatible (e.g., Ridge, VAX, PRIME, Sun).

Programming improvements can be separated into those which are mandatory and those which are enchacements. Some of the FORTRAN language changes were necessary to make EQ3/6 run on the new machines. Whether or not some other changes are truly necessary is less clear. Although there has been an effort in recent years to cut down the size of individual subroutines, a trend toward greater modularity, some internal pressure has developed to cut them even

further on grounds of easier documentation and future modification. Many conditional GO TO structures remain in the codes, and there is pressure to rewrite them on similar grounds, even though the structures are valid (but discouraged) under FORTRAN 77.

Other than language changes, there is also a clear need to increase the speed of the computations. The Ridge computers and similar machines are considerably slower than the CDC 7600 or the Cray-1, and activities are presently underway to reduce the execution times of the MCRT, EQ3NR, and EQ6 codes. As the codes have grown, there have also resulted pressures to change the ways that information is stored. For example, reaction coefficients in EQ3NR and EQ6 have been stored in arrays that contain a space for each master species on the data file. This scheme has an advantage in execution speed in that the coefficient for a given master species could be found without having to calculate its location in the array. When the number of master species was small, it also represented a not too inefficient means of storage. However, the number of master species is now large and the storage arrays are not only very large, but also sparse. The balance has shifted and it would now be more efficient overall to shift to a different storage scheme, one represented by a pair of smaller arrays: an element of one array would hold the coefficient, the corresponding element in the other would identify the corresponding master species.

An increase in storage efficiency is also possible for EQ3NR and EQ6. Some arrays, for example those that hold reaction coefficients, have only a few significant figures. Such arrays are currently double precision (REAL*8) on the Ridge machines, to match the single precision of the Cray-1 (equivalent to REAL*16). With some programming care, it should be possible to reduce these to REAL*4.

5.3 Installation of New Computing and Graphics Equipment

At the start of fiscal year 1985, the two codes EQ3NR and EQ6 would no longer fit into the small core memory of a CDC 7600, and all further development had to be done on the Cray-1. An expansion of computing needs by

LLNL's weapons programs reduced the allowable use of the LLNL Crays for EQ3/6 development and application to nearly zero. Thus, at this time the hardware resource necessary to work with the two largest codes in the package had vanished, the codes were written in a form of FORTRAN that was rapidly becoming archaic, the new form of FORTRAN was only partially available, and the codes were primarily written for long word length machines at a time when most users were working with short word length machines.

During 1985, the EQ3/6 group established, with NNWSI support, its own local computing system, based on a Ridge 32C and a Ridge 32S. The Ridge 32C was obtained second-hand, and significantly upgraded in memory, operating system, and disk space upon arrival at LLNL. These machines are being linked to an Ethernet system with other machines that belong to the Seismology group in the LLNL Earth Sciences Department. The purpose of this linking is to facilitate sharing of resources in local utilities development and peripheral hardware, to allow optimal usage of all machines, and to provide an insurance policy so work can continue if one or more computers go down. The EQ3/6 group has obtained, in addition to the two Ridge computers, a plotter and two laser printers. The system that has been put together can grow as necessary by the addition of more machines as needed.

It is anticipated that in two or three years the scope of EQ3/6 and related waste program calculation needs will require significantly more power to carry out all the applications calculations that are anticipated. A computer with the necessary power and within a reasonable price range now exists (the Convex C-1, described as "1/5 of a Cray," now costing about $600,000). Thus, it is reasonable to expect that in two years a machine of at least this power will be available, probably for less money, and that it will meet the necessary programmatic requirements. It is currently planned to add such a machine to the local network at about that time.

5.4 Code Manuals: Preparation and Updating

Code manuals published by LLNL are written to satisfy the requirements of NUREG-0856 and various DOE Project requirements, such as NNWSI SOP-03-02.

A main user manual is presently or will soon be available for each scientific/engineering code in the EQ3/6 package (Wolery, 1983, 1986b). Auxiliary user manuals, such as the report of Delany and Wolery (1984) on the fixed-fugacity option in EQ6, are used to cover special topics in greater detail and to document new improvements. Present plans call for putting all existing and future user manuals on the Ridge system, and making use of electronic publishing capabilities to maintain these manuals and keep them up to date.

5.5 Distribution of Codes, Manuals, and Publications

Distribution of codes is handled under existing DOE and LLNL regulations pertaining to unclassified software. When a new version of EQ3/6 is publicaly released, a copy of the software package and the documentation is deposited in the LLNL QA archive and the DOE's National Energy Software Center under the Center's "as is" release policy. The Center is the primary means of public distribution of EQ3/6. Copies are transmitted directly from LLNL to sponsoring agencies, sponsors' subcontractors, participating agencies and other national laboratories, and informal collaborators at universities and other public institutions who share relevant information or provide other feedback or services that enhance the success of the mission. In addition, pre-release copies of software may be transmitted to sponsors or others for review purposes.

An EQ3/6 Mailing List is maintained for the purpose of making announcements, updates, and distribution of EQ3/6 manuals and related reports that are published by LLNL. Distribution of manuals and other relevant LLNL reports is also carried out using various distribution lists that are required by DOE, LLNL, or the sponsoring Projects (NNWSI, SRP, BWIP). Additional copies of all documents may be obtained directly from LLNL, subject to availability, or from the National Energy Software Center and the National Technical Information Service.

5.6 General Assistance and Consulting

Current and anticipated use of EQ3/6 for the entire OCRWM Program (outside LLNL) encourages us to provide some effort directed toward general assistance and consulting activities. The most common assistance needed is hardware portability problems, advice on code options and use to solve specific problems, critiquing the results of specific calculations, and providing information on current developmental work that may affect future ability to perform desired calculations. Additional assistance is provided for examining reported code failures to determine whether the cause is due to code bugs or improper usage. If the problem lies in the latter, advice on the correct usage is given. If a bug is found, changes are made to the current development versions of both the codes and/or supporting data bases, (see section "Correcting Programming Bugs"). Temporary fixes may be recommended to allow work elsewhere to proceed, or LLNL may provide corrected software.

5.7 Peer Reviews

A formal peer review is provided for in the EQ3/6 Software Quality Assurance Plan as a means of approval for a public release (see below). No other examples of formal peer reviews are planned regarding EQ3/6 work. Informally EQ3/6 is subjected to the peer review of the geochemical community by outside use. This includes other programs at LLNL and in the academic community for applications to ore deposits, rock water interaction in mid-ocean ridges, and interactions in geothermal systems. Feedback is particularly encouraged by "informal collaborators" in universities.

6.0 SOFTWARE QUALITY ASSURANCE

EQ3/6 activities are governed by a quality assurance plan (LLNL, 1986) that is consistent with sponsor' requirements. This plan includes the development and maintenance of the EQ3/6 package, the application of software to critical calculations, export and import of software, and documentation of all activities. Development and maintenance of the package contains

guidelines for producing the necessary code documentation, coding standards, and error reporting and resolution. The plan also calls for formal peer review prior to release. Some elements dealing with system file maintenance, archival storage, and backup procedures have yet to be added to the plan.

The first plan element, "Requirements for Development and Use of Scientific and Engineering Software, (R19.1)," is a master requirements document. It contains an analysis of quality assurance problems that relate to scientific and engineering software, and an outline of the requirements documents and procedures that make up the rest of the plan. This document examines the most important problems that arise in the development of scientific software. This approach differs from that often employed in working level quality assurance plans for software development, which is to focus on the content of the "higher level" documents (such as NNWSI SOP-03-02). This type of "upward focus" approach, although more likely to require less work, would not provide a workable and efficient plan. Higher level requirements documents often neglect or do not emphasize the most important factors of software quality.

The EQ3/6 plàn has identified the two greatest problems in scientific software development: the lack of adequate documentation and the lack of adequate coding standards. The NRC (U.S. Nuclear Regulatory Commission, 1983) has called attention to the former in a very effective way, stimulating much attention to this problem in nearly all higher level requirements documents pertaining to software development in the Civilian Radioactive Waste Management (CRWM) Program. In contrast, very little attention has been paid to the issue of coding standards. The presence or adequacy of such standards can critically affect the portability of computer codes, the ability to efficiently continue development, and the frequency of errors. Adequate coding standards can also make documentation much easier.

We do not believe that a single very detailed set of standards is necessary for the entire CRWM Program. Although it may be useful to require adherence to some of the currently existing national or international language standards (e.g., FORTRAN 77). It is important to attain a level of

standardization within each code or code package to achieve desirable goals of portability, efficient ongoing development, and programming error reduction. Each development group should have its own set of more detailed standards. Plan element, R19.2, specifies the coding standards to be used for the development of EQ3/6. It requires adherence to the FORTRAN 77 language standards and specifies additional standards.

The EQ3/6 Software Quality Assurance Plan provides for a matrix system of controlling and documenting code development. One "axis" of this matrix is the configuration management system, the other is the "File Folder" (FF) system. The former is built around the concept of the "controlled item," which is a computer file subject to a configuration management tracking procedure. All source codes (including auxiliary library routines), primary versions of supporting data bases, and verification libraries are treated as controlled items. A controlled item is identified by a label consisting of a name, release number, machine letter, and stage number. If a controlled item is changed by so much as one byte, the configuration management system requires that it be reflected by changing either the machine letter (appropriate only under certain conditions) or by incrementing the stage number (appropriate for the vast majority of changes). An example of a full label is "eq6.3245R22," where eq6 is the code name, 3245 is a release number, R is a machine letter, and 22 is the stage number. Computer files are normally given by a shortened label in which the period is omitted and the release number is implied as the current development version (e.g., "eq6R22").

To modify a controlled item, a developer must have both "development rights" obtained by signing out the latest exact version from a development log and "authority" obtained from a "code development file folder". Development rights are held on a very short-term basis, between signing out the most recent version and signing back in a successor. They are also exclusive- only one developer may work on a controlled item at a time. Thus, development is linear and traceable. The plan allows for branch development, but generally discourages it.

A code development file folder (CDFF) is created for each development task affecting a code or code package. This system is designed to generate a records package to complement the development logs maintained for the controlled items. These logs are created by the Task Leader, who assigns associated "authority" to one or more developers. This authority may cover more than one controlled item in a package, and is held open until the FFs are closed (i.e., the work is thought to be complete). Requirements for the CDFF include a description of pertinent requirements, designs, and changes, as well as records pertaining to verification or validation.

The plan assumes that a sequence of consecutive development efforts will be undertaken, under a given release number (release numbers in the plan, following previous tradition, are four digit and increase monotonically but not by a constant increment). A set of CDFFs is opened for each line of development, and all must be closed prior to release of that line. After closure of all ordinary CDFFs, a special CDFF called "Release Package Integration" is opened to allow coordination of final testing and closing of any loose ends. When this FF is closed, a formal peer review is to be held. If the peer review turns up any problems that must be fixed before the code package is approved for release another special CDFF called "Review Response" may be opened to authorize the needed changes. The code package is then "approved," and distributed as described above.

In addition to "Release Package Integration" and "Review Response," a number of other special CDFFs exist for each development line. A "Maintenance" FF covers routine maintenance activities during the normal time of development. A "Post-Release Maintenance" FF covers such activities after the release of an "approved" code. After release of an "approved" code, an "Error Resolution" FF is opened, which remains open until the software development task is shut down.

The FF system is designed to be highly flexible. It presumes that most scientific software is developed by the approach that is formally known as "prototyping," as opposed to that which is referred to as "structured programming." Structured programming presumes that the situation is one in

which the requirements can be laid down at the start in essentially final form and the approach to meeting the requirements can be laid out largely in advance of doing the actual coding. The traditional QA approach is automatically to think of this approach when asked to deal with the software quality assurance problems of the CRWM Program. Unfortunately, it does not work well when the problem to be dealt with by the software is not very cut and dried, in terms of model/submodel adequacy, numerical methods adequacy, or both. The development of scientific software is usually much better addressed by prototyping, because it is usually the case that both model/submodel adequacy and often also numerical methods adequacy must be tested during code development, and it is often necessary for both the requirements of the work and the approach to meeting them to evolve as actual software development proceeds.

The EQ3/6 Software Quality Assurance Plan extends the FF system to cover other activities in addition to development. "Code Applications File Folders" (CAFFs) are used to document applications involving "critical calculations" that are to be used in direct support of a licensing application. Acquisition of outside codes are dealt with by "Acquisition" FFs, and subsequent evaluation by an "Evaluation" FFs. Code transfer (export) is not treated by formal FFs, although similar records packages are created. The EQ3/6 Software Quality Assurance Plan is a "form" driven system. Each entry to a FF or other records package is either on a specific form, or must be accompanied by a specific form. The system design is twofold to ensure standardization and help enforce the system.

The Task Leader is the FF manager. He is responsible for all procedures, approval of contributions, and setting priorities for code development work.

7.0 REFERENCES

Berman, R. G., and Brown, T. H., 1985, The heat capacity of minerals in the system $Na_2O-K_2O-CaO-MgO-FeO-Fe_2O_3-Al_2O_3-SiO_2-TiO_2-H_2O-O_2$: representation, estimation, and high temperature extrapolation. Contrib. Mineral. Petrology, v. 89, p. 168-183.

Berman, R. G., Brown, T. H., and Greenwood, H. J., 1985, An internally consistent thermodynamic data base for minerals in the system $Na_2O-K_2O-CaO-MgO-FeO-Fe_2O_3-Al_2O_3-SiO_2-TiO_2-H_2O-O_2$. Atomic Energy of Canada Limited, TR-377.

Bourcier, W. L., 1985, Improvements in the solid solution modeling capabilities of the EQ3/6 geochemical code, Lawrence Livermore National Laboratory, UCID-20587.

Bowers, T. S., and Taylor, H., 1985, Chemical and isotope mass transfer calculations pertaining to seafloor hydrothermal systems, Geophys. Res., v. 90, p. 12583-12606.

Cederberg, G. A., 1985, The effects of geochemical processes on the transport of contaminants in multicomponent systems: a modeling perspective, in International symposium on coupled processes affecting the performance of a nuclear waste repository, Lawrence Berkeley Laboratory, September 18-20, 1985, p. 71-76.

CODATA, 1978, CODATA Recommended Key Values for Thermodynamics, 1977, Report of the CODATA Task Group on Key Values for Thermodynamics, 1977, Jour. Chem. Thermodynamics, v. 10, p. 903-906.

Coffman, W., Vogt, D., and Mills, M., 1984, A Summary of Computer Codes for Waste Package Performance Assessment, NUREG/CR-3669, U.S. Nuclear Regulatory Commission, Washington, D.C.,

Delany, J. M., 1986, Reaction of Topopah Spring Tuff with J-13 water: A geochemical modeling approach using the EQ3/6 reaction path code. Lawrence Livermore National Laboratory, UCRL-53631.

Delany, J. M., and Wolery, T. J., 1984, Fixed-fugacity option for the EQ6 geochemical reaction path code, Lawrence Livermore National Laboratory, UCRL-53598, 20 p.

Delany, J. M., Puigdomenech, I., and Wolery, T. J., 1986, Precipitation kinetics option for the EQ6 geochemical reaction path code, UCRL-53642

Durham, W. B., Beiriger, J. M., Axelrod, M., and Tretteners, S., 1985, The effect of gamma irradiation on the strength and elasticity of Climax stock and Westerly granites, Lawrence Livermore National Laboratory, UCRL-92526.

Environmental Protection Agency, 1985, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes: Final Rule. 40 CFR Part 191 (Code of Federal Regulations), Federal Register Vol. 50, No. 182, September 19, 1985.

Garrels, R. M., and Thompson, M. E., 1962, A chemical model for seawater at 25°C and one atmosphere total pressure. Amer. Jour. Sci., v. 260, p. 57-66.

Garrels, R. M., and Christ, C. L., 1965, Solutions, Minerals, and Equilibria, Harper, and Row, New York, 450 p.

Garven, G., 1984, Research needs in water-rock interactions: effects on permeability and subsurface fluid flow, in Workshop on Fundamental Geochemistry Needs for Nuclear Waste Isolation, US DOE CONF8406134, p. 83-90.

Glass, R. S., 1981, Effects of radiation on the chemical environment surrounding waste canisters in proposed repository sites and possible effects on the corrosion process, Sandia National Laboratory, Albuquerque, SAND81-1677

Glassley, W. E., 1986, Reference waste package environment report, Lawrence Livermore National Laboratory, UCRL-53726.

Grasse, D., Kocar, W., Peirl, J., Moss, S. C., 1982, Diffuse x-ray scattering from neutron irradiated crystalline quartz, Rad. Effects, v.66, p. 61-71.

Helgeson, H. C., 1964, Complexing and Hydrothermal Ore Deposition, Pergamon, New York, 128 p.

Helgeson, H. C., 1968, Evaluation of irreversible reactions in geochemical processes involving minerals and aqueous solutions-I. Thermodynamic relations, Geochim. Cosmochim. Acta, v. 32, p. 853-857.

Helgeson, H. C., 1969, Thermodynamics of hydrothermal systems at elevated temperatures and pressures, Amer. Jour. Sci., v. 267, p. 729-804.

Helgeson, H. C., Brown, T. H., Nigrini, A., and Jones, T. A., 1970, Calculation of mass transfer in geochemical processes involving aqueous solutions, Geochim. Cosmochim. Acta, v. 34, p. 569-592.

Helgeson, H. C., Delany, J. M., Nesbitt, H. W., and Bird, D. K., 1978, Summary and critique of the thermodynamic properties of the rock-forming minerals, Am. Jour. Sci., 278A, p. 1-228.

Helgeson, H. C., Kirkham, D. H., and Flowers, G. C., 1981, Theoretical prediction of aqueous electrolytes at high pressures and temperatures: IV. Calculation of activity coefficients, osmotic coefficients, and apparent molal and standard and relative partial molal properties to 600 C and 5 kb, Am. Jour. Sci., v. 281, p. 1249-1516.

Hostettler, J. D., 1984, Electrode electrons, aqueous electrons, and redox potentials in natural waters. Amer. Jour. Sci., v. 284, p. 734-759.

Isherwood, D. J. and Wolery, T. J., 1984, EQ3/6 geochemical modeling task plan for Nevada Nuclear Waste Storage Investigations (NNWSI), Lawrence Livermore National Laboratory, UCID-20069, 39 p.

Jackson, K. J., and Wolery, T. J., 1985, Extension of the EQ3/6 computer codes to geochemical modeling in brines, Mat. Res. Soc. Symp. Proc., v. 44, p. 507-513.

Jenks, G. H., 1980, Review of information on the radiation chemistry of materials around waste canisters in salt and assessment of the need for additional experimental information, Oak Ridge National Laboratory, ORNL-5607.

Kelmers, A. D., Arnold, W. D., Blencoe, J. G., Meyer, R. E., Jacobs, G. K., and Whatley, S. K., 1986, Progress in evaluation of radionuclide geochemical information developed by DOE high-level nuclear waste repository site projects: Report for April-June, 1985, vol. 3, Oak Ridge National Laboratory, NUREG/CR-4236, ORNL/TM-9614, p. 11.

Kieffer, S. W., 1979a, Thermodynamics and lattice vibrations of minerals, 1, Mineral heat capacities and their relationships to simple lattice vibrational models: Rev. Geophys. Space Phys.,v. 17, p. 1-19

Kieffer, S. W., 1979b, Thermodynamics and lattice vibrations of minerals, 2, Vibrational characteristics of silicates: Rev. Geophys. Space Phys., v. 17, p. 20-34.

Kieffer, S. W., 1979c, Thermodynamics and lattice vibrations of minerals, 3, Lattice dynamics and an approximation for minerals with application to simple substances and framework silicates: Rev. Geophys. Space Phys., v. 17, p. 35-59.

Kieffer, S. W., 1980, Thermodynamics and lattice vibrations of minerals, 4, Application to chain and sheet silicates and orthosilicates, Rev. Geophys. Space Phys., v. 18, p. 862-886.

Knauss, K. G., and Wolery, T. J., 1986, Dependence of albite dissolution kinetics on pH and time at 25°C and 70°C, Lawrence Livermore National Laboratory, UCRL-89309.

Krishnaswami, S., Gravstein, W. C., and Turekian, K. K., 1982, Radium, thorium and radioactive lead isotopes in groundwaters: application to the in situ determination of adsorption-desorption rate constants and retardation factors: Water Resources Research, v. 18, p. 1633-1675.

Langmuir, I., 1918, Jour. Am. Chem. Soc., v. 40, p. 1361.

Lasaga, A. C., and Kirkpatrick, R. J., 1981, Kinetics of Geochemical Processes, Reviews in Mineralogy, v. 8, Mineralogical Society of America, p. 398.

Lawrence Livermore National Laboratory, 1986, EQ3/6 Software Quality Assurance Plan.

Lichtner, P. C., 1985, Continuum model for simultaneous chemical reactions and mass transport in hydrothermal systems, Geochim. Cosmochim. Acta, v. 49, p. 779-800.

Muller, A. B., 1985, International Chemical Thermodynamic Data Base for Nuclear Applications, Radioactive Waste Management and the Nuclear-Fuel Cycle, v. 6(2), p. 131-141.

Neretnieks, I., 1980, Diffusion in rock matrix: An important factor in radionuclide retardation?: Jour. Geophys. Res., v. 85, p. 4379-4397.

Nordstrom, D. K., Plummer, L. N., Wigley, T. M. L., Wolery, T. J., Ball, J. W., Jenne, E. A., Bassett, R. L., Crerar , D. A., Florence, T. M., Fritz, B., Hoffman, M., Holdren, G. R., Jr., Lafon, G. M., Mattigod, S. V., McDuff, R. E., Morel, F., Reddy, M. M., Sposito, G., and Thrailkill, J., 1979, A comparison of computerized chemical models for equilibrium calculations in aqueous systems, in E. A. Jenne (ed), Chemical Modeling in Aqueous Systems, American Chemical Society, Symposium Series 93, p. 857-892.

Oversby, V. M., 1986, Important Radionuclides in High Level Nuclear Waste Disposal: Determination Using a Comparison of the EPA and NRC Regulations. Submitted to Nuclear and Chemical Waste Management, UCRL-94222.

Parkhurst, D. J., Plummer, L. N., and Thorstenson, D. C., 1982, BALANCE - a computer program for calculating mass transfer for geochemical reactions in groundwater. U.S. Geol. Survey Water Resour. Invest. Rept. 82-14, 29 p.

Pitzer, K. S., 1973, Thermodynamics of electrolytes. I. Theoretical basis and general equations, Jour. Phys. Chemistry, v. 77, p. 268-277.

Pitzer, K. S., 1975, Thermodynamics of electrolytes, V. Effects of higher-order electrostatic terms, Jour. Solution Chemistry, v. 4, p. 249-265.

Pitzer, K. S., 1979, Theory: ion interaction approach, in Pytkowicz, R.M., ed., Activity Coefficients in Electrolyte Solutions, Volume I, CRC Press, p: 157-208.

Pearson, F. J., Jr., 1984, Linking flow and geochemical models: status and problems of developing a fully coupled model, in The Geochemistry of High-Level Waste Disposal in Granitic Rocks, AECL/CEC Workshop, September 12-16, 1983, AECL-8361, Atomic Energy of Canada Ltd., Pinawa, Manitoba, Canada.

Rimstidt, J. D., and Barnes, H. J., 1980, The kinetics of silica-water reactions, Geochim. Cosmochim. Acta, v. 44, p. 1683-1699.

Stokes, R. H., and Robinson, R. A., 1948, Ionic hydration and activity in electrolyte solutions, Am. Chem. Soc. Jour., v. 70, p. 1870-1878.

Stumpe, R., Kim, J.I., Schrepp, W., and Walther, H., 1984, Speciation of actinide ions in aqueous solution by laser-induced photo-acoustic spectroscopy, Appl. Phys., v. B34, p. 203-206.

Sverjensky, D. A, 1984, Prediction of Gibbs free energies of calcite-type carbonates and the equilibrium distribution of trace elements between carbonates and aqueous solutions, Geochim. Cosmochim. Acta, v 48, p. 1127-1134.

Sverjensky, D. A., 1985, The distribution of trace elements between sulfides, oxides, silicates and hydrothermal solutions, I. Thermodynamic basis, Geochim. Cosmochim. Acta, v. 49, p.853-864.

Thorstenson, D. C., 1984, The concept of electron activity and its relation to redox potentials in aqueous geochemical systems. U.S. Geol. Survey Open File Rept 84-072.

U.S. Nuclear Regulatory Commission, 1983, Disposal of High-Level Radioactive Wastes in Geologic Repositories. 10 CFR Part 60 (Code of Federal Regulations), U.S. Government Printing Office.

U.S. Nuclear Regulatory Commission, 1983, Final Technical Position on Documentation of Computer Codes for High-Level Waste Management, NUREG-0856, 12p.

U.S. Nuclear Regulatory Commission, 1984, Determination of Radionuclide Solubility in Groundwater for Assessment of High-Level Waste Isolation, Draft, Technical Position, November, 1984, Geochemistry Section, Geotechnical Branch, Division of Waste Management, U. S. Nuclear Regulatory Commission, 16 p.

U.S. Nuclear Regulatory Commission, 1985, Generic Technical Position, Waste Package Reliability Analysis, August, 1985, Engineering Branch, Division of Waste Management, U. S. Nuclear Regulatory Commission, 22 p.

U.S. Nuclear Regulatory Commission, 1986, Determination of Radionuclide Sorption for High-Level Nuclear Waste Repositories, Technical Position, January, 1986, Geochemistry Section, Geotechnical Branch, Division of Waste Management, U. S. Nuclear Regulatory Commission, 15 p.

Van Konynenburg, R. A., 1984, Radiation doses in granite around emplacement holes in the spent fuel test - climax (Final Report), Lawrence Livermore National Laboratory, UCRL-53580

Van Konynenburg, R. A., 1986, Radiation chemical effects in experiments to study the reaction of glass in a gamma-irradiated air, ground water, and tuff environment, Lawrence Livermore National Laboratory, UCRL-53719.

Wilcox, T. P., and Van Konynenburg, R. A., 1981, Radiation dose calculations for geologic media around spent fuel emplacement holes in the Climax Granite, Nevada Test Site, Lawrence Livermore National Laboratory, UCRL-53159

Wolery, T. J., 1978, Some chemical aspects of hydrothermal processes at mid-oceanic ridges - a theoretical study. I. Basalt-seawater reaction and chemical cycling between the oceanic crust and the oceans. II. Calculation of chemical equilibrium between aqueous solutions and minerals, 1978, Ph.D. dissertation, Northwestern University.

Wolery, T. J., 1979, Calculation of chemical equilibrium between aqueous solution and minerals: the EQ3/6 software package, Lawrence Livermore National Laboratory, UCRL-52658, 41 p.

Wolery, T. J., 1983, EQ3NR, A computer program for geochemical aqueous speciation-solubility calculations: User's guide and documentation, Lawrence Livermore National Laboratory, UCRL-53414, 191 p.

Wolery, T. J., 1986a, Some forms of transition state theory including non-equilibrium steady state forms, and their application in geochemistry, Lawrence Livermore National Laboratory, UCRL-94221.

Wolery, T. J., 1986b, EQ6, A computer program for reaction-path modeling of aqueous geochemical systems: User's guide and documentation, UCRL, in preparation.

Wolery, T. J., Isherwood, D. J., Jackson, K. J., Delany, J. M., and Puigdomenech, I., 1984, EQ3/6: Status and applications, Lawrence Livermore National Laboratory, UCRL-91884, and in Jacobs, G. K. and Whatley, S. K., 1985, Proceedings of the conference on the application of geochemical models to high-level nuclear waste repository assessment held at Oak Ridge Tennessee, October 2-5, 1984, NUREG/CP-0062, ORNL/TM-9585, p. 54-65.

Wolery, T. J., and Jackson, K. J., 1986, Activity coefficients in aqueous salt solutions. I. The ion size problem, manuscript in preparation.

Wood, B.J., and Walther, J.V., 1983, Rates of hydrothermal reaction, Science, v. 222, p. 413-415.

8.0 MILESTONES AND DELIVERABLES

8.1 BWIP: In Support of WBS 1.1.3 and 1.1.2 (FY86)

Increased Pressure Capability for EQ3/6

The deliverable will be met with submission of a letter report to BWIP. This project is the modification of the EQ3/6 geochemical modeling software package for application to aqueous systems involving basalt at the BWIP site. The first activity is to modify the EQ3/6 codes and data base to incorporate pressure-corrections to the thermodynamic data. The modification will enable BWIP to model fluid speciation and fluid/rock interactions at any pressure between 1.013 and 300 bar, at temperatures between 0° and 300°C.

8.2 NNWSI: WBS 1.2.3.8.L (FY86-90)

Level II

M343 Complete Draft MCRT User's Manual

This deliverable will be met with submission of a draft manual report to WMPO-NV. The user's manual will satisfy NRC's documentation requirements for computer codes. It will contain a description of the data processing routine used in the EQ3/6 code package, and the data base files which contain the thermodynamic data and their sources.

P331 Status Report on Data Base

This deliverable will be met with submission of a letter report to WMPO-NV. This report will include progress on data base activities for FY86, and all changes and additions made to selected species will be documented. Topics that will be included are; the addition of neptunium to the EQ3/6 data base, recommendations for experimental work as a result of evaluation of data for uranium, americium and neptunium.

P330 EQ3/6 Code Release

This deliverable will be met with a formal release of the EQ3/6 Software Package. The codes and supporting data bases will satisfy NUREG-0856, NNWSI SOP-03-02, and OGR Guidance on Computer software Control requirements. The release will be by magnetic tape to WMPO-NV and the National Software Distribution Center at Argonne.

P332 Issue Revised Data Base and User's Manual

This report will be met by a formal release of the EQ3/6 Data Base. The release will be by magnetic tape with distribution to WMPO-NV and the National Software Distribution Center at Argonne. This release will be CODATA compatible and contain significant format changes. A draft data base user's manual will also be submitted that describes EQ3/6 data base procedures and methods of evaluation, and use of the direct access data base manager codes.

P333 Draft EQ3/6 User's Manual

This deliverable will be met by submission of a draft summary report to the WMPO-NV. This report will include summarizing all code options from the EQ3/6 User's Manual and supplementary reports. This report will be written for EQ3/6

P334 Issue Final Data Base

This deliverable will be met by a magnetic tape release to WMPO-NV. The data base release will include all the supporting data files and documentation.

P399 Complete Final EQ3/6 User's Manual

This deliverable will be met by submission of a summary report to the WMPO-NV. This report will include summarizing all code options from the EQ3/6 User's Manual and supplementary reports. This report will be written for EQ3/6 applications users.

Level III

C317 Complete Precipitation Kinetics Addition to EQ6

This deliverable will be met by submission of a draft report to the WMPO-NV. The report include an added code capability to model precipitation kinetics in complex systems that include nucleation. A description of the code option, input and output file modifications, and sample test cases will be included. Supplemental documentation will be included.

C319 Interim Report on Modeling Sorption with EQ3/6

This deliverable will be met by a letter report. This report will contain background data on equilibrium sorption mechanisms, the necessary theory and recommendations on the addition of selected mechanisms to the EQ6 code.

C800 Final Report on Uranium - EQ3/6 Data Base

This deliverable will be met with submission of a draft report to the WMPO-NV. The report will be prepared for UCRL distribution and will contain a critical review of the chemistry and thermodynamics of both aqueous and solid species of uranium. All species data will be compatible with the NEA critical compilation on uranium (currently in draft form). This report will summarize the final data values based on existing results and those from the EQ3/6 laboratory and sensitivity analysis program.

C395 Report on Equilibrium Sorption Modeling

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will describe the EQ6 capability to model various sorption mechanisms. A description of the code option, supporting equations and supporting data base will be included along with input and output file changes and sample problems. This document will be a supplementary EQ6 manual.

D301 Final Report on Solid Solutions Model

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will describe the EQ3/6 capabilities to handle complex mineral solid solutions. It will contain a brief outline of selected solution models that have been incorporated into the codes, examples of input and output files and sample problems. This document will be a supplementary EQ6 manual.

C393 Final Report on Variable Fugacity Model

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will describe the codes capability to model systems open to gases with variable fugacities. This capability will allow modeling of systems that contain varying amounts of gases such as unbuffered hydrothermal experiments. It will contain an outline of code changes, examples of input and output files, and example problems. This document will represent a supplementary EQ6 manual.

C801 Final Report on Americium - EQ3/6 Data Base

This deliverable will be met with submission of a draft report to the WMPO-NV. The report will be prepared for UCRL distribution and will contain a critical review of the chemistry and thermodynamics of both aqueous and solid species of americium. All data base values will be compatible with the NEA critical compilation on americium (currently in draft form). This report will summarize the final data values based existing results and those from the EQ3/6 laboratory and sensitivity analysis program.

C394 Final Report on Flow Model Extension

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will describe an extension to the EQ6 reaction path code that will allow the code to trace the chemical evolution of a packet of fluid in a dynamic system. It will contain an outline of code changes, examples of input and output files, and sample problems. This document will be a supplementary EQ6 manual.

C809 Complete Sorption Modeling

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will describe the EQ6 capability to model kinetics as well as equilibrium sorption mechanisms. A description of the code options, supporting equations and supporting data base will be included along with input and output file changes and sample problems. This document will be a supplementary EQ6 manual.

C802 Final Report on Plutonium -EQ3/6 Data Base

This deliverable will be met with submission of a draft report to the WMPO-NV. The report will be prepared for UCRL distribution and will contain a critical review of the chemistry and thermodynamics of both aqueous and solid species of plutonium. All data base values will be documented. This report will summarize the final data values based on existing results and those from the EQ3/6 laboratory and sensitivity analysis program.

C806 Interim Report on Results of Validation Studies

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will outline the experimental program that has been set up for the EQ3/6 Data Base Expansion Program. It will detail the techniques and procedures used to determine thermodynamic values. This report will mainly concern experiments in progress on the actinides, U, Am, Pu, Np.

C302 Ridge Computer system Fully Operational

Completed.

C307 Software QA Procedures

Completed.

C303 All Codes Running on the Ridge

Completed.

C304 EQ3/6 Code Release

This deliverable will be met by a letter documenting to WMPO-NV the submission of magnetic tapes to the National Software Distribution Center at Argonne and programmatic users. This release will include the Pitzer Activity Coefficient Option, the Precipitation Kinetics Option, and an improved Solid Solution Option.

C803 Final Report on Neptunium and Technetium - EQ3/6 Data Base

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will update the critical review of the chemistry and thermodynamics of technetium completed by J.A. Rard (UCRL-53440), and the NEA compilation on neptunium (currently in draft form). This report will summarize the final data values based on the above reports and those from the EQ3/6 laboratory and sensitivity analysis program.

C804 Canister Materials - EQ3/6 Data Base Report

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will outline the experimental results that have been obtained for metals important to the OCRWM Waste Package activities at the first repository projects. Experiments on these materials are designed to follow the program set up for the actinides in the EQ3/6 Data Base Expansion Program. It will detail the techniques and procedures used to determine thermodynamic values. This content of this report will depend on the canister specifications currently being formulated.

C807 Report on Rock-Water Validation Studies

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will contain results of EQ3/6 runs in rock-water systems. It will summarize the validation of common rock-water systems from peer reviewed experimental systems existing in the literature. Most rock-water systems can be validated without additional experimental measurements. Any gaps or inconsistencies will be recommended for investigation by the EQ3/6 Data Base Laboratory Program. All results will be summarized in the Final Report on Validation Studies.

C805 Complete Laboratory Measurements on Less Abundant Radionuclides

This deliverable will be met with submission of a draft report to the WMPO-NV. This report will outline the experimental results that have been obtained for radionuclides with allowed release rates set by 0.1% of the calculated release rate limit (see Oversby, 1986). It will use the same techniques and procedures used to determine thermodynamic values set up for the actinides in the EQ3/6 Data Base Expansion Program.

C808 Final Report on Validation Studies

This deliverable will be met by submission of a draft report to the WMPO-NV. This report will summarize the validation of the EQ3/6 code for the actinides, less abundant radionuclides, canister materials and rock-water systems. It will contain sample input and output files and satisfy requirements set forth in the EQ3/6 QA Plan (Draft date 2/14/86).

8.3 ONWI: In Support of WBS 1.2.3 (FY86-87)

Activity Coefficients I(2)

A paper has been submitted to the American Journal of Science entitled: "Activity Coefficients in Aqueous Salt Solutions. I. The Ion Size Problem." The primary purpose of this paper was to document the ion size averaging technique which we have already built into the hydration theory equations and to compare this technique with the treatment of ion size parameters in other activity coefficient equations. A discussion of the requirements of thermodynamic consistency was included as was an introduction to improvements on the equations of Helgeson et al. (1981)* in ternary (as well as more compositionally complex) aqueous solutions.

Pitzer Coefficient Data Update(3)

The versions of the Pitzer data files currently used by EQ3/6 need to be updated to include data which have become available subsequent to Pitzer's (1979) compilation on which they are based. The updated versions of the Pitzer data files contain both updated values for aqueous species in previous released versions of the data files and data for species not previously included in them.

Code Release(4)

A magnetic tape containing a new version of the EQ3/6 package released. This release includes all the codes in the package and features the capability to do calculations using Pitzer's equations at 25°C. The code release is accompanied by current versions of the appropriate data files.

---

* The equations used by Helgeson et al. (1981) to calculate the activity coefficients of dissolved species in aqueous solutions are collectively referred to in this report as the "Part IV" equations.

Thermodynamics of Solutions(5)

An article submitted to the American Journal of Science tentatively entitled "On the Thermodynamics of Solutions." This paper develops many of the fundamental thermodynamic equations, definitions and relationships which will be used in the subsequent papers in this series (e.g., Milestones #2, 17, 18 and 19).

Pitzer Term Tabulation Option(6)

This project entails modification of the subroutine in EQLIB which reads the Pitzer interaction coefficients from the DATA1 and DATA2 files. The modification is designed to tally the number of interaction coefficients loaded into the EQ3NR and EQ6 codes from the data files for each of the aqueous species present in the model. The modified subroutine will generate information to be written onto the OUTPUT file and will be activated by turning on a print option switch. The principle use of this new option will be to help in evaluating whether or not a particular species is adequately represented by the interaction coefficients in the data files. It should serve to prevent accidental misuse of the Pitzer activity coefficient option. The culmination of this project will be documented in a letter report submitted to ONWI.

pH in Brines(7)

A letter report entitled "Approaches to Dealing with pH in Brines." This letter report covers two milestones delayed from FY85. One covers the methodology for measuring pH in brines (the pHCl and mineral saturometry methods). The other takes care of activity coefficient scale conversions (equivalent to pH scales).

Construction of EQ3/6 Subroutines to Evaluate the Part IV Activity Coefficient Expressions(8)

The Part IV activity coefficient expression offers an alternative to the hydration theory option and Pitzer's equations for calculating activity coefficients in relatively concentrated aqueous solutions. In addition, the Part IV equations can be used at elevated temperatures for a wide variety of aqueous species. The new subroutines will take advantage of

the Part IV equations corrected to account for variable ion sizes as described in the "ion size paper" (Milestone #2). A progress report on the new subroutines written to evaluate the Part IV expressions will document the completion of this milestone.

Brine Modifications II(9)

A draft version of a UCRL report which will be forwarded to ONWI is tentatively entitled "EQ3/6 Modifications for Geochemical Modeling of Brines. II. Hydration Theory Equations." This code document will represent an extension of a portion of the information contained in an earlier letter report to ONWI by K. Jackson and T. Wolery entitled "Hydration Theory Modifications to the EQ3/6 Geochemical Modeling Code: Verification and Validation Studies." This will be a supplementary user's guide for the EQ3/6 codes.

Activity Coefficients II(10)

A journal article entitled "Activity Coefficients in Aqueous Salt Solutions. II. Hydration Theory Models for Electrolyte Solutions" will be submitted to document this milestone. The scope of this paper will be to evaluate the hydration theory model for aqueous activity coefficients at 25°C. This report will expand on some of the principles mentioned briefly in an earlier letter report to ONWI ("Hydration Theory Modifications to the EQ3/6 Geochemical Modeling Code: Verification and Validation Studies") by K. Jackson and T. Wolery.

Compilation of Data Files for the Part IV Equations(11)

This project is comprised of two steps. The first is the assembly of data files containing the appropriate coefficients for use in evaluating the Part IV activity coefficient equations. (These data will have to be manipulated to make it compatible with the form of the equations which will be used by the EQ3/6 codes.) The second step involves modifications to the EQ3/6 codes so they can read these data.

Data Base Update(12)

A magnetic tape release containing updated versions of all of the thermodynamic data files which support EQ3/6 calculations and the new data base pre-processing codes will be forwarded to ONWI. This data base update will be consistent with the work of the EQ3/6 data base effort funded by the Nevada Nuclear Waste Storage Investigation (NNWSI) and will represent a major upgrade of the current data base. Included in this effort is a plan to ensure CODATA compatibility and internal consistency for the thermodynamic parameters.

pH Options in EQ3/6(13)

A code document ("EQ3/6 Options for Dealing with pH and Related Quantities") will be submitted to ONWI which will detail the installation and use of the various pH options available in the EQ3/6 code package. This document is closely related to (and dependant upon) the more theoretically oriented paper which comprises Milestone #5, but concentrates more on the ways in which pH is computed by EQ3NR and EQ6 and details how each of these options is evoked.

Preliminary Analysis of Salton Sea Data Package from University of California, Riverside (UCR)(14)

Contingent on receiving a set of data from UCR, and in conjunction with P. Cloke of ONWI and A. Williams of UCR, the suitability of the Salton Sea Geothermal Field data for use in validation exercises for the EQ3/6 geochemical modeling codes and as natural analog for waste disposal in a salt repository will be evaluated. Completion of this milestone will be documented in a letter report submitted to ONWI.

Code Release(15)

A magnetic tape release containing a new version of the EQ3/6 code package which will have the capability to calculate activity coefficients in high ionic strength solutions at elevated temperatures (up to about 300°C) using the hydration theory option. This code release will be accompanied by current versions of the EQ3/6 data files which will contain a preliminary hydration theory data set.

Installation of the Part IV Routines into EQ3/6(16)

The subroutines described in the letter report which constitutes Milestone #6 will be installed in the EQ3NR and EQ6 codes. This progress report will document the code modifications necessary to install the Part IV capabilities and outline how to use this EQ3/6 activity coefficient option. Preliminary results of runs used to verify this activity coefficient option will be included as will an analysis of how results from these equations compare with results calculated using other EQ3/6 activity coefficient options.

Activity Coefficients III(17)*

A draft version of a journal article tentatively entitled "Activity Coefficients in Aqueous Salt Solutions. III. Extension of Hydration Theory Models to High Temperatures," by K. Jackson and T. Wolery will be submitted to ONWI to document this milestone. This paper represents the culmination of a series of articles detailing the theoretical development of the hydration theory equations for calculating aqueous activity coefficients and documents the ability of these equations to be extended to high temperatures along the liquid vapor saturation curve for water.

Analysis of Salton Sea Data Package from University of California, Riverside (UCR)(18)

This milestone represents the second of two scheduled studies of data collected by the UCR group at the Salton Sea Geothermal Field. As with the first analysis in this series, the work will be performed in conjuction with P. Cloke of ONWI and A. Williams of UCR and will concentrate on the potential use of Salton Sea data for validation of the EQ3/6 ability to model geochemical reactions involving brines at elevated temperatures. This deliverable will be documented in a letter report to ONWI.

Part IV Verification and Validation(19)

A letter report submitted to ONWI will document verification studies for the Part IV activity coefficient option in EQ3/6. Discussion of modeling runs intended to partially validate this option will also be included.

Brine Modification III(20)

A supplementary user's guide for the addition of the Part IV equations to EQ3/6 will be submitted to ONWI in the form of a draft version of a UCRL report. This report will contain detailed instructions for the use of the Part IV activity coefficient option in EQ3/6 as well as documentation for the code changes involved in their implementation.

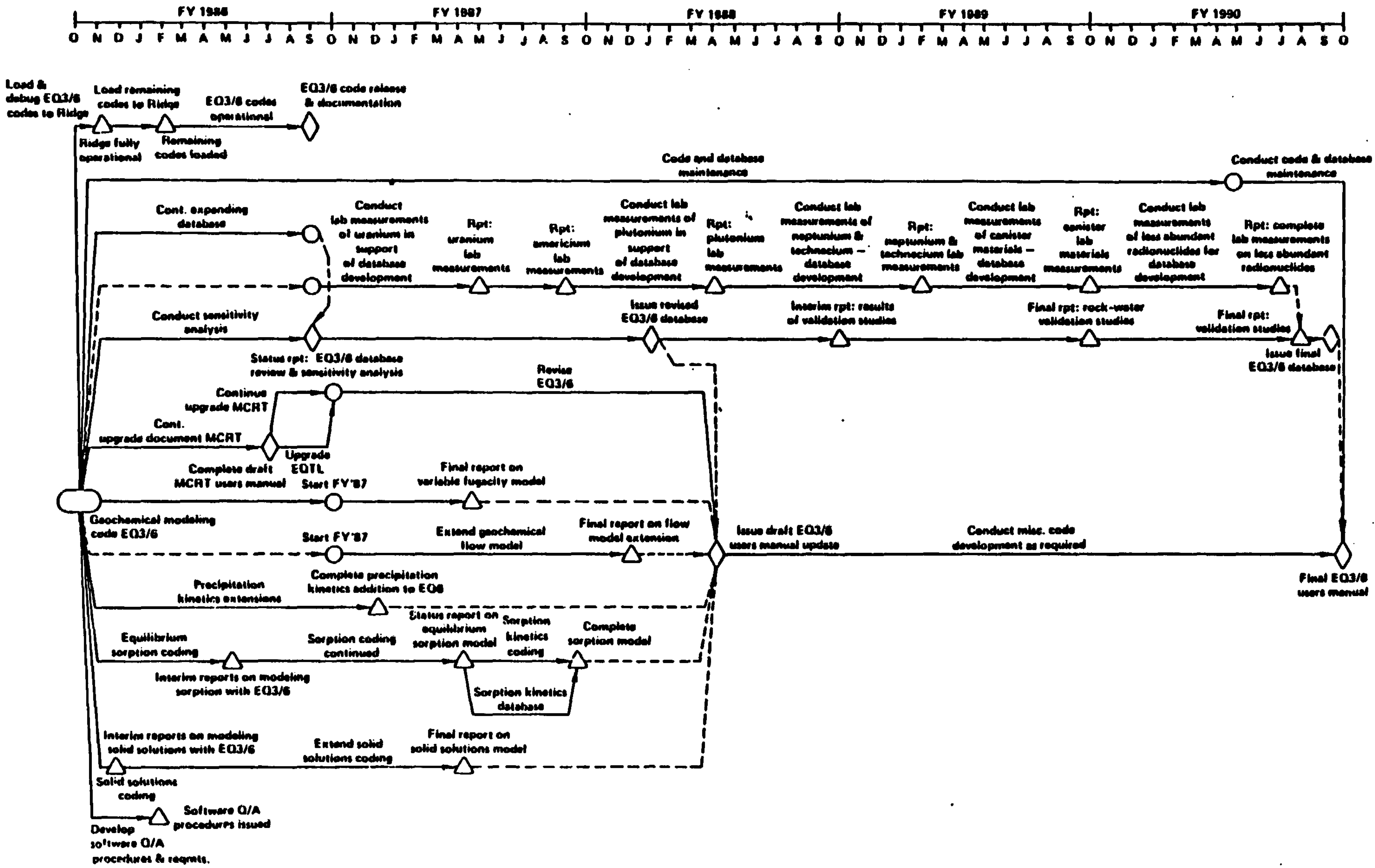
Part IV Code Release(21)

A magnetic tape containing a new version of the EQ3NR and EQ6 codes will be forwarded to ONWI. These code versions will include the capability to use the Part IV equations to calculate activity coefficients and will be accompanied by the appropriate date files.

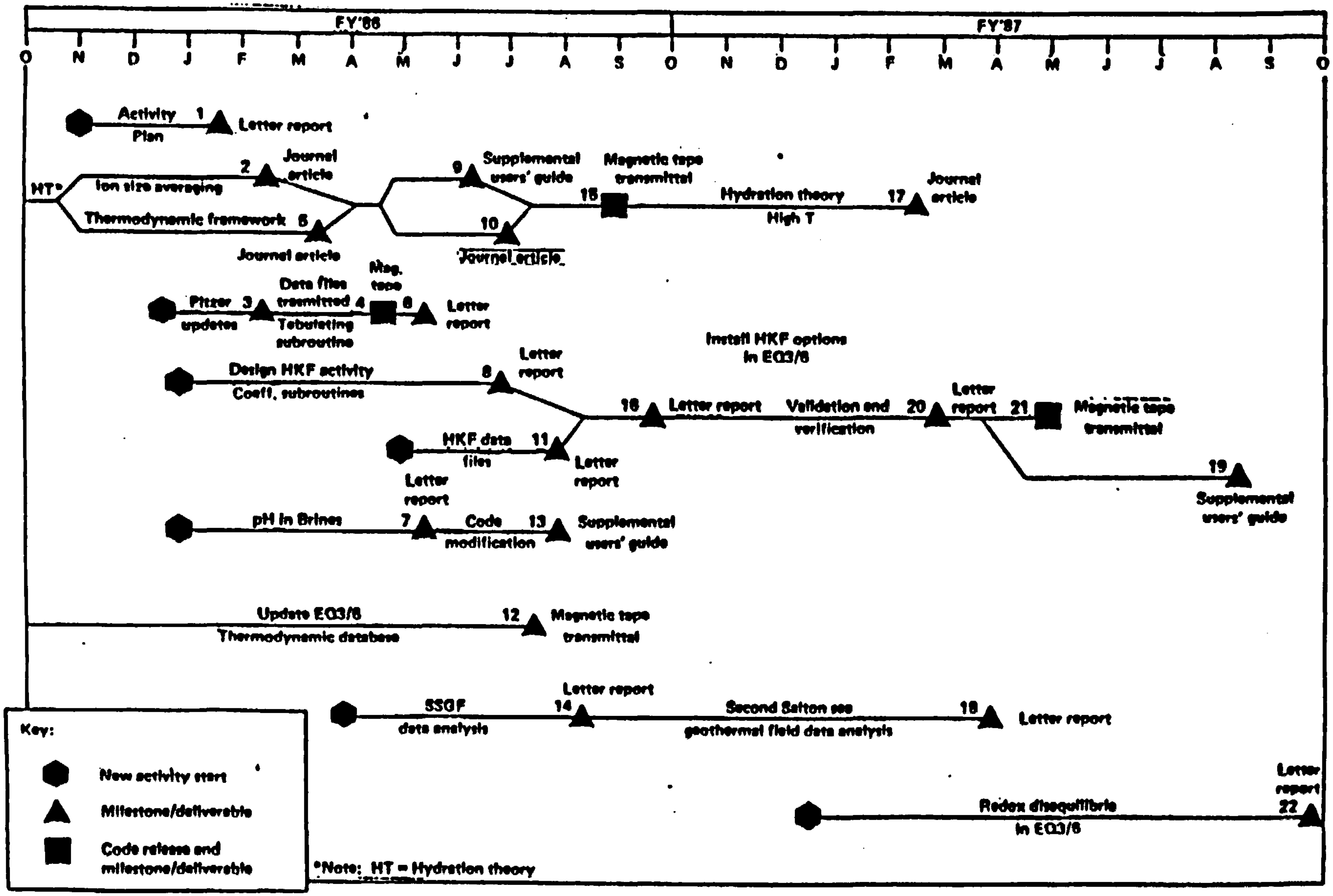
Redox Disequilibria(22)

A letter report will document the code modifications necessary to allow EQ6 to maintain the redox pairs in solution in a disequilibrium state. These code modifications will be consistent with the EQ3NR capabilities to model aqueous solutions which are not in chemical equilibrium with respect to redox reactions.

NNWSI NETWORK FOR WBS 1.2.3.8.L



ONWI NETWORK FOR FY86-87



QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of Panel Meeting: May 15, 1986

Meeting Attendees: L. Ballou, J. Dronkers, D. Emerson, W. McKenzie, L. Ramspott, and Tom Wolery

Name(s) and Number(s) of Activity: EQ3/6 Model Development
J-20-7 (NNWSI WBS 1.2.3.8.L)

S.I.P. Identification: UCID-20864

Additional Comments: This is one of the four major activities into which Geochemical Modeling EQ3/6 (NNWSI WBS 1.2.3.8.L) has been divided. This activity is described in UCID-20864, Part 3.0 "Theory and Code Development" which consists of a total of 9 subactivities.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF II

D.O. Emerson	9/12/86	John F. Dronkers	9/12/86
Task or Subtask Leader	Date	Deputy Leader for QA	Date
L. Ballou	9/12/86	L. Ramspott	9/12/86
NWMP Deputy Leader	Date	NWMP Leader	Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Maxwell Blanchard	10-17-86	James Blaylock	10/17/86
Project Sponsor	Date	Project Sponsor Quality Manager	Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: EQ3/6 Model Development

ACTIVITY NO.: J-20-7 (NNSWI WBS 1.2.3.8.L)

DATE OF PANEL MEETING: May 15, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON CHECKLIST Step 11 This activity could cause cost and schedule overruns of more than 50%.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	No waste package design.
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P. 4.0 Procurement Document Control.
7.0 CTL OF PUR OF MATERIALS	Yes	033-NWMP-R 7.0 Control of Purchased Materials, Parts and Components
8.0 I.D. & CTL OF MATERIALS	No	No samples involved.
9.0 CONTROL OF PROCESSES	No	No special proceedures.
10.0 INSPECTION	No	No inspection involved.
11.0 TEST CONTROL	No	No tests involved.
12.0 CTL OF M & T EQUIP	No	No M&T equipment involved.
13.0 HANDLING, STOR. & SHIP.	No	No items are involved.
14.0 INSP. TEST & OPER. STAT.	No	No status indicators needed.
19.0 SOFTWARE QA	Yes	See attached list of Requirements

CROSS REFERENCE

Activity: EQ3/6 Model Development
NNWSI WBS 1.2.3.8.L
LLNL Activity Number: J-20-7

	SOP-02-01 Requirement		Where addressed (UCID-20864 text or other documentation)
1.	para 3A.1.1, subpara 1	1.	Part 1.0 (Overview specific) Part 1.3 (Issues hierachy) Part 3.0 Part 8.2 (WBS)
2.	para 3A.1.1, subpara 2.	2.	Part 3.0
3.	para 3A.1.1, subpara 3.a	3.	Part 2.3 (EQ3NR) Part 2.4 (EQ6) Part 3.0
4.	para 3A.1.1, subpara 3.b	4.	Part 3.0 Part 8.0 (Other projects)
5.	para 3A.1.1, subpara 3.c	5.	Part 8.2
6.	para 3A.2	6.	See attached sheets
7.	para 3A.3.1	7.	Review documentation on file with QA
8.	para 3A.3.2	8.	See QA procedure 22
9.	para 3A.4	9.	See QA procedures for EQ3/6 Task
10.	para 3A.5	10.	See QA procedure 19.4
11.	para 3A.6	11.	See QA procedure 19.8
12.	para 3A.7	12.	See QA procedure 22

List of EQ3/6 QA Requirements and Procedures

NUMBER	TITLE	DRAFT TO BE COMPLETED
033-NWMP-R19.1 (EQ3/6),	Requirements for Development and Use of Engineering Software (EQ3/6 Task)	9/15/86
033-NWMP-R19.2 (EQ3/6),	Coding Standards for FORTRAN Computer Codes	9/15/86
033-NWMP-R19.3 (EQ3/6),	Acquisition and Evaluation of Computer Codes	9/15/86
033-NWMP-R19.4 (EQ3/6),	Development of Computer Codes	9/15/86
033-NWMP-R19.5 (EQ3/6),	Verification and Validation of Computer Codes	9/15/86
033-NWMP-R19.6 (EQ3/6),	Documentation of Computer Codes	9/15/86
033-NWMP-R19.7 (EQ3/6),	Peer Review of Computer Codes	9/15/86
033-NWMP-R19.8 (EQ3/6),	Transfer of Computer Codes	9/15/86
033-NWMP-R19.9 (EQ3/6),	Preparation and Review of Computer Code Applications	9/15/86
033-NWMP-R19.10 (EQ3/6),	Error Reporting and Resolution	9/15/86
033-NWMP-R19.11 (EQ3/6),	Standards for Directory Structures	9/30/86
033-NWMP-R19.12 (EQ3/6),	Backup Storage for Computer Codes	9/30/86

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of Panel Meeting: May 15, 1986

Meeting Attendees: L. Ballou, J. Dronkers, D. Emerson, W. McKenzie,
L. Ramspott, and Tom Wolery

Name(s) and Number(s) of Activity: EQ3/6 Data Base Development
J-20-8 (NNWSI WBS 1.2.3.8.L)

S.I.P. Identification: UCID-20864

Additional Comments: This is one of the four major activities into which Geochemical Modeling EQ3/6 (NNWSI WBS 1.2.3.8.L) has been divided. This activity is described in UCID-20864, Part 4.0 "Thermodynamic Data Base".

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF III

D.O. Emerson 9/12/86
Task or Subtask Leader Date

John J. Dronkers 9/12/86
Deputy Leader for QA Date

L. Ballou 9/12/86
NWMP Deputy Leader Date

L. Ramspott 9/12/86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Maxwell Blanchard 10-17-86
Project Sponsor Date

James Blaylock 10/17/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: EQ3/6 Data Base Development

ACTIVITY NO.: J-20-8 (NNWSI WBS 1.2.3.8.L)

DATE OF PANEL MEETING: May 15, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON CHECKLIST ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	
4.0 PROC. DOC. CONTROL	No	
7.0 CTL OF PUR OF MATERIALS	No	
8.0 I.D. & CTL OF MATERIALS	No	
9.0 CONTROL OF PROCESSES	No	
10.0 INSPECTION	No	
11.0 TEST CONTROL	No	
12.0 CTL OF M & T EQUIP	No	
13.0 HANDLING, STOR. & SHIP.	No	
14.0 INSP. TEST & OPER. STAT.	No	
19.0 SOFTWARE QA	No	

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of Panel Meeting: May 15, 1986

Meeting Attendees: L. Ballou, J. Dronkers, D. Emerson, W. McKenzie, L. Ramspott, and Tom Wolery

Name(s) and Number(s) of Activity: EQ3/6 Documentation and Code Release
J-20-9 (NNWSI WBS 1.2.3.8.L)

S.I.P. Identification: UCID-20864

Additional Comments: This is one of the four major activities into which Geochemical Modeling EQ3/6 (NNWSI WBS 1.2.3.8.L) has been divided. This activity is described in UCID-20864, Part 5.4 Code Manuals: Preparation and Updating and 5.5 Distribution of Codes, Manuals, and Publications.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF II

D.O. Emerson 9/12/86
Task or Subtask Leader Date

[signature] 9/12/86
Deputy Leader for QA Date

[signature] 9/12/86
NWMP Deputy Leader Date

L. Ramspott 9/12/86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Maxwell Blanchard 10-17-86
Project Sponsor Date

James Blaylock 10/17/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: EQ3/6 Documentation and Code Release

ACTIVITY NO.: J-20-9 (NNWSI WBS 1.2.3.8.L)

DATE OF PANEL MEETING: May 15, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON CHECKLIST Step 11. The activity could cause cost and schedule overruns or more than 50%.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	No waste package design.
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Procurement Document Control.
7.0 CTL OF PUR OF MATERIALS	Yes	033-NWMP-R 7.0 Control of Purchased Materials, Parts and Components.
8.0 I.D. & CTL OF MATERIALS	No	No samples involved.
9.0 CONTROL OF PROCESSES	No	No special procedures.
10.0 INSPECTION	No	No inspection involved.
11.0 TEST CONTROL	No	No tests involved.
12.0 CTL OF M & T EQUIP	No	No M&T equipment involved.
13.0 HANDLING, STOR. & SHIP.	No	No items are involved.
14.0 INSP. TEST & OPER. STAT.	No	No status indicators needed.
19.0 SOFTWARE QA	Yes	See attached list of Requirements.

CROSS REFERENCE

Activity: EQ3/6 Documentation and Code Release
NNWSI WBS 1.2.3.8.L
LLNL Activity Number: J-20-9

	SOP-02-01 Requirement		Where addressed (UCID-20864 text or other documentation)
1.	para 3A.1.1, subpara 1	1.	Part 1.0 (Overview specific) Part 1.3 (Issues hierachy) Part 3.0 Part 8.2 (WBS)
2.	para 3A.1.1, subpara 2.	2.	Part 3.0
3.	para 3A.1.1, subpara 3.a	3.	Part 2.3 (EQ3NR) Part 2.4 (EQ6) Part 3.0
4.	para 3A.1.1, subpara 3.b	4.	Part 3.0 Part 8.0 (Other projects)
5.	para 3A.1.1, subpara 3.c	5.	Part 8.2
6.	para 3A.2	6.	See attached sheets
7.	para 3A.3.1	7.	Review documentation on file with QA
8.	para 3A.3.2	8.	See QA procedure 22
9.	para 3A.4	9.	See QA procedures for EQ3/6 Task
10.	para 3A.5	10.	See QA procedure 19.4
11.	para 3A.6	11.	See QA procedure 19.8
12.	para 3A.7	12.	See QA procedure 22

List of EQ3/6 QA Requirements and Procedures

NUMBER	TITLE	DRAFT TO BE COMPLETED
033-NWMP-R19.1 (EQ3/6),	Requirements for Development and Use of Engineering Software (EQ3/6 Task)	9/15/86
033-NWMP-R19.2 (EQ3/6),	Coding Standards for FORTRAN Computer Codes	9/15/86
033-NWMP-R19.3 (EQ3/6),	Acquisition and Evaluation of Computer Codes	9/15/86
033-NWMP-R19.4 (EQ3/6),	Development of Computer Codes	9/15/86
033-NWMP-R19.5 (EQ3/6),	Verification and Validation of Computer Codes	9/15/86
033-NWMP-R19.6 (EQ3/6),	Documentation of Computer Codes	9/15/86
033-NWMP-R19.7 (EQ3/6),	Peer Review of Computer Codes	9/15/86
033-NWMP-R19.8 (EQ3/6),	Transfer of Computer Codes	9/15/86
033-NWMP-R19.9 (EQ3/6),	Preparation and Review of Computer Code Applications	9/15/86
033-NWMP-R19.10 (EQ3/6),	Error Reporting and Resolution	9/15/86
033-NWMP-R19.11 (EQ3/6),	Standards for Directory Structures	9/30/86
033-NWMP-R19.12 (EQ3/6),	Backup Storage for Computer Codes	9/30/86

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of Panel Meeting: May 15, 1986

Meeting Attendees: L. Ballou, J. Dronkers, D. Emerson, W. McKenzie, L. Ramspott, and Tom Wolery

Name(s) and Number(s) of Activity: EQ3/6 Code Maintenance
J-20-10 (NNWSI WBS 1.2.3.8.L)

S.I.P. Identification: UCID-20864

Additional Comments: This is one of the four major activities into which Geochemical Modeling EQ3/6 (NNWSI WBS 1.2.3.8.L) has been divided. This activity is described in UCID-20864, Part 5.1 Code Maintenance.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF II

D.O. Emerson 9/12/86
Task or Subtask Leader Date

9/12/86
Deputy Leader for QA Date

9/12/86
NWMP Deputy Leader Date

L. Ramspott 9/12/86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO SUBTASK LEADER

Maxwell Blanchard 10-17-86
Project Sponsor Date

James Blaylock 10/17/86
Project Sponsor Quality Manager Date

RETURN TO LLNL NWMP QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: EQ3/6 Code Maintenance

ACTIVITY NO.: J-20-10 (NNWSI WBS 1.2.3.8.L)

DATE OF PANEL MEETING: May 15, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL II

CITE "YES" ITEM ON CHECKLIST Step 11. The activity could cause cost and schedule overruns or more than 50%.

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	No waste package design.
4.0 PROC. DOC. CONTROL	Yes	033-NWMP-P 4.0 Procurement Document Control
7.0 CTL OF PUR OF MATERIALS	Yes	033-NWMP-R 7.0 Control of Purchased Materials, Parts and Components
8.0 I.D. & CTL OF MATERIALS	No	No samples involved.
9.0 CONTROL OF PROCESSES	No	No special proceedures.
10.0 INSPECTION	No	No inspection involved.
11.0 TEST CONTROL	No	No tests involved.
12.0 CTL OF M & T EQUIP	No	No M&T equipment involved.
13.0 HANDLING, STOR. & SHIP.	No	No items are involved.
14.0 INSP. TEST & OPER. STAT.	No	No status indicators needed.
19.0 SOFTWARE QA	Yes	See attached list of Requirements

CROSS REFERENCE

Activity: EQ3/6 Code Maintenance
NNWSI WBS 1.2.3.8.L
LLNL Activity Number: J-20-10

	SOP-02-01 Requirement		Where addressed (UCID-20864 text or other documentation)
1.	para 3A.1.1, subpara 1	1.	Part 1.0 (Overview specific) Part 1.3 (Issues hierachy) Part 3.0 Part 8.2 (WBS)
2.	para 3A.1.1, subpara 2.	2.	Part 3.0
3.	para 3A.1.1, subpara 3.a	3.	Part 2.3 (EQ3NR) Part 2.4 (EQ6) Part 3.0
4.	para 3A.1.1, subpara 3.b	4.	Part 3.0 Part 8.0 (Other projects)
5.	para 3A.1.1, subpara 3.c	5.	Part 8.2
6.	para 3A.2	6.	See attached sheets
7.	para 3A.3.1	7.	Review documentation on file with QA
8.	para 3A.3.2	8.	See QA procedure 22
9.	para 3A.4	9.	See QA procedures for EQ3/6 Task
10.	para 3A.5	10.	See QA procedure 19.4
11.	para 3A.6	11.	See QA procedure 19.8
12.	para 3A.7	12.	See QA procedure 22

List of EQ3/6 QA Requirements and Procedures

NUMBER	TITLE	DRAFT TO BE COMPLETED
033-NWMP-R19.1 (EQ3/6),	Requirements for Development and Use of Engineering Software (EQ3/6 Task)	9/15/86
033-NWMP-R19.2 (EQ3/6),	Coding Standards for FORTRAN Computer Codes	9/15/86
033-NWMP-R19.3 (EQ3/6),	Acquisition and Evaluation of Computer Codes	9/15/86
033-NWMP-R19.4 (EQ3/6),	Development of Computer Codes	9/15/86
033-NWMP-R19.5 (EQ3/6),	Verification and Validation of Computer Codes	9/15/86
033-NWMP-R19.6 (EQ3/6),	Documentation of Computer Codes	9/15/86
033-NWMP-R19.7 (EQ3/6),	Peer Review of Computer Codes	9/15/86
033-NWMP-R19.8 (EQ3/6),	Transfer of Computer Codes	9/15/86
033-NWMP-R19.9 (EQ3/6),	Preparation and Review of Computer Code Applications	9/15/86
033-NWMP-R19.10 (EQ3/6),	Error Reporting and Resolution	9/15/86
033-NWMP-R19.11 (EQ3/6),	Standards for Directory Structures	9/30/86
033-NWMP-R19.12 (EQ3/6),	Backup Storage for Computer Codes	9/30/86

Scientific Investigation Plan

for

NNWSI WBS Element 1.2.6.9.1.5
NNWSI WBS Element 1.2.6.9.2.5
NNWSI WBS Element 1.2.6.9.4.5

NNWSI EXPLORATORY SHAFT INVESTIGATIONS: ENGINEERED BARRIER SYSTEM TESTING

LAWRENCE LIVERMORE NATIONAL LABORATORY

July, 1986

10-20-86
Lawrence D. Ramspott, Technical Project Officer for NNWSI

10-16-86
John J. Dronkers, Deputy for Quality Assurance

10-16-86
Jesse L. Yow, Jr., Principal Investigator

William E. Glassley, Technical Reviewer

10-16-86
Dale G. Wilder, Technical Reviewer

10-30-86
Project Sponsor Quality Assurance Manager

Project Sponsor

NNWSI WBS 1.2.6.9.x.5 ENGINEERED BARRIER SYSTEM TESTING

1. Objectives and Issues Addressed

These activities are directed toward planning and implementing major tests of the near field waste package environment in the candidate repository horizon as part of the NNWSI Exploratory Shaft (ES) in situ testing program. Waste package environment tests will be configured to provide site specific data on near field hydrologic, thermal, mechanical, and chemical phenomena during a complete, accelerated thermal cycle in the rock mass. While near field hydrologic phenomena (movement of water in rock pores or fractures) are of primary interest, thermal and mechanical phenomena are also of interest because of their roles in driving or influencing water migration. Chemical phenomena are important because of their potential influence on hydrologic behavior and because of possible effects on components of the engineered barrier system.

Geotechnical and hydrologic instrumentation will be deployed to monitor selected near field environmental parameters in situ. Pre-test and post-test rock and water samples will be analyzed for changes in mineralogy and chemistry. These activities will provide data for integration with laboratory scale measurements and for use in validating model calculations. Overall, this work will directly address Information Need 1.10.4 and, indirectly, Information Needs 1.4.3 and 1.5.3 (NNWSI Issues Hierarchy of July 10, 1986). However, these activities do not include testing of an actual prototype waste package because of the relatively short duration of the tests.

Additional details about the Waste Package Environment Tests are included in the NNWSI Exploratory Shaft Test Plan, and in the conceptual test plan that is attached.

2. Principal Investigator

Jesse L. Yow, Jr., Lawrence Livermore National Laboratory

3. Statement of Work

This statement primarily describes work to be done in FY 1987. Work to be accomplished in subsequent years is reflected in Section 9 and in the attached conceptual test plan, and will be covered in more detail in future revisions of this Scientific Investigation Plan (SIP).

3.1 Develop detailed engineering test plans for the waste package environment tests. This includes scoping analyses for test design, and preparation of procedures for specific portions of the work that will be defined in the course of work statement items 3.2 and 3.3. The performance of this work is measured at level of effort.

3.2 Evaluate, calibrate, and prepare geophysical and conventional techniques for measuring rock mass hydrologic responses to thermal perturbation as a function of time and location in the near field environment. This work includes development of plans for conducting prototype instrument and geophysical technique evaluations, and is subject to performance measurement.

3.3 Evaluate and prepare techniques for measuring rock mass thermal and mechanical responses to thermal perturbation as a function of time and location in the near field environment. This will include development of plans for conducting prototype instrument evaluations; work may also be initiated in geochemical techniques. The performance of this work is measured at level of effort.

4. <u>Data, Materials, or Techniques Needed</u>
(Referenced to items listed in Section 3)

4.1 Data: Thermomechanical, hydrologic, and geologic data will be needed for use in analyses and scoping calculations. All such data will be obtained from sources (e.g., the NNWSI Reference Information Base or the tuff data base) that allow the quality of the data to be determined; the quality of the data will be determined and verified prior to use. Results from analyses and calculations will be used to develop plans for the installation and operation of the waste package environment tests, and to guide the preparation of measurement techniques. The needed data will be obtained from the LLNL Waste Package task and from the work of the U.S. Geological Survey (USGS), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL).
Materials: None needed.
Techniques: Scoping calculations will be made with numerical models capable of solving thermal, hydrologic, and thermomechanical problems.

4.2 Data: Thermal, mechanical, geophysical, and geologic data are needed for the Topopah Spring (Tpt) test horizon to define the environment in which instruments must operate. All such data will be obtained from sources (e.g., the NNWSI Reference Information Base or the tuff data base) that allow the quality of the data to be determined; the quality of the data will be determined and verified prior to use. These data will be obtained from LLNL work or from USGS or SNL work. Performance capabilities, specifications, and requirements for calibration, installation, and operation must also be determined for each instrument type. Physical data needed for verifying results of the measurement techniques will be obtained during prototype tests.
Materials: Tpt samples are needed for determining material properties for calibrating geophysical instrumentation.

Prototype instruments will be procured or fabricated for evaluation.

Techniques: Instruments will be evaluated using methods developed at LLNL or refined from other sources. High frequency electromagnetic measurements and other geophysical measurements will be made using methods developed or refined at LLNL. This may involve a combination of computer simulations, laboratory (bench scale) trials, and prototype field trials in NNWSI test facilities.

4.3 Data: Thermal, mechanical, hydrologic, and geochemical data are needed for the Tpt test horizon to define the environment in which instruments must operate. All such data will be obtained from sources (e.g., the NNWSI Reference Information Base or the tuff data base) that allow the quality of the data to be determined; the quality of the data will be determined and verified prior to use. These data will be obtained from LLNL work or from USGS or SNL work. Performance capabilities, specifications, and requirements for calibration, installation, and operation must also be determined for each instrument type.

Materials: Prototype instruments will be procured or fabricated for evaluation.

Techniques: Instruments will be evaluated using methods developed at LLNL or refined from other sources. This will involve laboratory (bench scale) trials and field trials in NNWSI test facilities.

5. Location of Work Performed

Work activities will be formulated at LLNL and carried out by LLNL or LLNL subcontractor personnel. While many instrument evaluation activities will be conducted at LLNL or at the facilities of LLNL subcontractors, some prototype testing will be done in the G-Tunnel test facility at NTS. After prototype tests are complete, the waste package environment tests will be conducted in the Exploratory Shaft facilities at Yucca Mountain.

6. Quality Assurance Requirements

Quality Assurance requirements are being met under the provisions of the LLNL Nuclear Waste Management Project Quality Assurance Program Plan. Work involved in the waste package environment tests has been divided into activities for assignment of quality assurance levels under provisions of the plan. Copies of the quality assurance level assignment sheets are attached; an annotated list of activities follows:

Q-20-1 Develop test plans. This activity is described in Section 3.1 of this Scientific Investigation Plan (SIP).

S-20-1 Evaluate test components in support of component selection. This activity is described in Sections 3.2 and 3.3 of this SIP.

S-20-2 Perform scoping calculations in support of test plan development. This activity is described in Section 3.1 of this SIP.

S-20-3 Procure or manufacture test components. This activity is described in Sections 4.2 and 4.3 of this SIP, and is included in the planned achievements of Section 9.

S-20-4 Perform instrument and test component calibrations. This activity is included in the planned achievements of Section 9, and will be described more fully in Section 3 in future revisions of this SIP. The level of quality assurance will be assigned to this activity at the time of these future revisions.

S-20-5 Installation of test components. This activity is included in the planned achievements of Section 9, and will be described more fully in Section 3 in future revisions of this SIP. The level of quality assurance will be assigned to this activity at the time of these future revisions

S-20-6 Collect and analyze material samples. This activity is included in the planned achievements of Section 9, and will be described more fully in Section 3 in future revisions of this SIP. The level of quality assurance will be assigned to this activity at the time of these future revisions

S-20-7 Conduct test, and record and archive data. This activity is included in the planned achievements of Section 9, and will be described more fully in Section 3 in future revisions of this SIP. The level of quality assurance will be assigned to this activity at the time of these future revisions

S-20-8 Reduce and analyze test data, and report test results. This activity is included in the planned achievements of Section 9, and will be described more fully in Section 3 in future revisions of this SIP. The level of quality assurance will be assigned to this activity at the time of these future revisions.

7. Application of Results

Results of the prototype testing performed as part of items 3.2 and 3.3, above, will be used in developing plans for field tests in the Exploratory Shaft at Yucca Mountain. Field test results will be used in defining the waste package environment (WBS 2.2.2), in waste package design (WBS 2.2.4), and in waste package performance assessment (WBS 2.2.5) as described in Section 1.

Additional development of the rationale and application of this work is provided in the test concept document that is attached.

8. Schedule

Start Date: In progress. Estimated End Date: 1992.

9. Past and Expected Achievements

Significant Achievements to Date

A conceptual test plan for the waste package environment tests has been formulated and included in Revision 1 of the Exploratory Shaft Test Plan (ESTP). Moisture characterization experiments have been conducted at the G-Tunnel test facility at NTS and in a sand pit test bed at LLNL; these provide trials of geophysical techniques that are candidates for moisture content measurements in the waste package environment tests. These and other parts of work accomplished to date are reflected by published reports:

Concept for Waste Package Environment Tests in the Yucca Mountain Exploratory Shaft (LLNL UCID 20450)

Preliminary Evaluation of Alterant Geophysical Tomography in Welded Tuff (LLNL UCRL 92229)

Report on the PLUS Family, A Set of Computer Programs to Evaluate Analytical Solutions of the Diffusion Equation (LLNL UCID 20680)

A Monte Carlo Investigation of a Proposed Screen for NX-Borehole Jack Data (LLNL UCRL 94087)

Thermomechanical Scoping Calculations for the Waste Package Environment Tests (LLNL UCID 20758)

Planned Achievements for FY87 and Later Years

* Design and conduct tests of geotechnical, hydrologic, and geophysical measurement techniques in preparation for the waste package environment tests proposed for the ES. This will lead to development of calibration procedures for each type of instrument to be used in the waste package environment tests, as listed below.

* Complete scoping calculations and analyses, revise the conceptual test plan, and develop detailed engineering test plans for waste package environment tests that reflect design conditions anticipated for a repository at Yucca Mountain.

* Develop specifications and procedures for calibration, installation, and operation of test components.

* Fabricate or procure test components, and install and conduct waste package environment tests.

* Analyze test data and report results.

10. Milestones and Deliverables

Most of the near term dates for milestones and deliverables are contingent upon approval of quality assurance level assignments for the associated activities. All of the dates in the out years depend on development of the overall ES schedule. This list is subject to change between revisions of this SIP.

Analysis of the effects of boreholes on the hydrothermal environment in the waste package environment tests.

Report on expected hydrothermal phenomena in the waste package environment tests.

Analysis of apparent fracture width during imbibation or boiling during waste package environment tests.

Analysis of the hydrologic effects of drilling fluids on core samples from waste package environment tests.

Report on laboratory evaluation and calibration of the NX borehole jack (X704).

Report on geotomographic methods for monitoring rock mass moisture changes.

Calibration methods for geophysical techniques used in the waste package environment tests.

Report on stability of USBM borehole deformation gauges in stress monitoring applications.

Report on conventional methods for monitoring rock mass moisture changes.

Calibration methods for stress monitoring instrumentation.

Instrumentation for monitoring rock mass deformation.

Calibration methods for moisture monitoring instrumentation.

Complete hardware for waste package environment tests (M611).

Begin installation of waste package environment tests (D401).

Preliminary report on 1st waste package environment test (D425).

Preliminary report on 2nd waste package environment test (D427).

Preliminary report on 3rd waste package environment test (D429).

Preliminary report on 4th waste package environment test (D455).

Final report on waste package environment tests (M650).

11. Cost

Budgets for FY 1987 work are summarized below; budgets for following years are given in the LLNL WPAS for WBS 1.2.6. The budgets below do not contain any contingency amounts.

WBS 1.2.6.1.L	Management and QA	300 k$
WBS 1.2.6.9.L	ESTP and Prototype testing	1000 k$
WBS 1.2.6	Total for FY 1987	1300 k$

12. Performance

The performance measure of each portion of the work in FY87 is described in Section 3, above.

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Procure or manufacture test components

ACTIVITY NO.: S-20-3
DATE: July 31, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III We will control QA level by pre-installation performance evaluation and calibration
CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
4.0 PROC. DOC. CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
7.0 CTL OF PUR MATERIALS	No	This is a Level III activity. Good professional and scientific practices apply.
8.0 I.D. & CTL OF MATERIALS	No	This is a Level III activity. Good professional and scientific practices apply.
9.0 CONTROL OF PROCESSES	No	This is a Level III activity. Good professional and scientific practices apply.
10.0 INSPECTION	No	This is a Level III activity. Good professional and scientific practices apply.
11.0 TEST CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
12.0 CTL OF M & T EQUIP	No	This is a Level III activity. Good professional and scientific practices apply.
13.0 HANDLING, STOR. & SHIP.	No	This is a Level III activity. Good professional and scientific practices apply.
14.0 INSP. TEST & OPER. STAT.	No	This is a Level III activity. Good professional and scientific practices apply.
19.0 SOFTWARE QA	No	This is a Level III activity. Good professional and scientific practices apply.

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes (no)	I
3.	Does the item or activity involve waste isolation? yes (no)	I
4.	Does the item or activity involve or affect retrievability? yes (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes (no)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes (no)	II
	III	

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: 7-31-86

Meeting Attendees: J. Yow, L. Ballou, J. Dronkers

Name(s) and number(s) of Activity: S-20-1/WBS 2.6.9.4.5
Evaluate test components in support of component selection

S.I.P. Identification: Engineered Barrier System Testing

Additional Comments:

This includes laboratory and field trials of components and techniques leading to selection of components and development of procedures. This includes prototype testing.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF III

Jesse L. Yow Jr. 10-16-86
Task or Subtask Leader Date

John H. Dronkers 10-21-86
Deputy Leader for QA Date

L. Ballou 10-16-86
NWMP Deputy Leader Date

J. Ramspott 10-20-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

[illegible] 10-30-86
Project Sponsor Date

James [illegible] 10/2[illegible]
Project Sponsor Quality Manager

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Perform scoping calculations

ACTIVITY NO.: S-20-2
DATE: July 31, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
4.0 PROC. DOC. CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
7.0 CTL OF PUR MATERIALS	No	This is a Level III activity. Good professional and scientific practices apply.
8.0 I.D. & CTL OF MATERIALS	No	This is a Level III activity. Good professional and scientific practices apply.
9.0 CONTROL OF PROCESSES	No	This is a Level III activity. Good professional and scientific practices apply.
10.0 INSPECTION	No	This is a Level III activity. Good professional and scientific practices apply.
11.0 TEST CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
12.0 CTL OF M & T EQUIP	No	This is a Level III activity. Good professional and scientific practices apply.
13.0 HANDLING, STOR. & SHIP.	No	This is a Level III activity. Good professional and scientific practices apply.
14.0 INSP. TEST & OPER. STAT.	No	This is a Level III activity. Good professional and scientific practices apply.
19.0 SOFTWARE QA	No	This is a Level III activity. Good professional and scientific practices apply.

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: 7-31-86

Meeting Attendees: J. Yow, L. Ballou, J. Dronkers

Name(s) and number(s) of Activity: S-20-2/WBS 2.6.9.4.5
Perform scoping calculations

S.I.P. Identification: Engineered Barrier System Testing

Additional Comments:

This includes scoping calculations, sensitivity studies, and analyses performed in support of Activity Q-20-1.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF III

Jesse L. Yow Jr. 10-16-86
Task or Subtask Leader Date

John J. Dronkers 10-21-86
Deputy Leader for QA Date

L. Ballou 10-16-86
NWMP Deputy Leader Date

L. Ramspott 10-20-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Timothy P. [illegible] 10-30-86
Project Sponsor Date

James [illegible] [illegible]
Project Sponsor Quality Manager

RETURN TO LLNL NNWSI QA FILE

QUALITY LEVEL ASSIGNMENT APPROVAL SHEET

Date of the Panel Meeting: 7-31-86

Meeting Attendees: J. Yow, L. Ballou, J. Dronkers

Name(s) and number(s) of Activity: Q-20-1/WBS 2.6.9.1
Develop test plan

S.I.P. Identification: Exploratory Shaft Test Plan

Additional Comments:

This includes conceptual, engineering, and operation test plans.

APPROVE QUALITY ASSURANCE LEVEL DETERMINATION OF I

Jesse L. Yow Jr. 10-16-86
Task or Subtask Leader Date

John J. Dronkers 10-21-86
Deputy Leader for QA Date

L. Ballou 10-16-86
NWMP/Deputy Leader Date

L. Ramspott 10-20-86
NWMP Leader Date

AFTER NWMP LEADER APPROVAL RETURN TO DEPUTY LEADER FOR QA WITH COPY TO TASK OR SUBTASK LEADER

Timothy P. Grant 10-30-86
Project Sponsor Date

James B. Ranford 10/30/86
Project Sponsor Quality Manager

RETURN TO LLNL NNWSI QA FILE

NWMP QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Develop test plans

ACTIVITY NO.: Q-20-1
DATE: July 31, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL I

CITE "YES" ITEM ON LOGIC DIAGRAM Step 5

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	This activity is controlled by element 6.
4.0 PROC. DOC. CONTROL	No	This activity is controlled by element 6.
7.0 CTL OF PUR MATERIALS	No	This activity is controlled by element 6.
8.0 I.D. & CTL OF MATERIALS	No	This activity is controlled by element 6.
9.0 CONTROL OF PROCESSES	No	This activity is controlled by element 6.
10.0 INSPECTION	No	This activity is controlled by element 6.
11.0 TEST CONTROL	No	This activity is controlled by element 6.
12.0 CTL OF M & T EQUIP	No	This activity is controlled by element 6.
13.0 HANDLING, STOR. & SHIP.	No	This activity is controlled by element 6.
14.0 INSP. TEST & OPER. STAT.	No	This activity is controlled by element 6.
19.0 SOFTWARE QA	No	No software developed as part of test plans.

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? ___yes___ (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? ___yes___ (no)	I
3.	Does the item or activity involve waste isolation? ___yes___ (no)	I
4.	Does the item or activity involve or affect retrievability? ___yes___ (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? ___(yes)___ no	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? ___yes___ no	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? ___yes___ no	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? ___yes___ no	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? ___yes___ no	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? ___yes___ no	II
11.	Can the item or activity cause major cost overrun or schedule slippage? ___yes___ no	II
	III	

NNWSI QUALITY ASSURANCE ELEMENT ASSIGNMENT

ACTIVITY: Evaluate test components in support of component selection

ACTIVITY NO.: S-20-1
DATE: July 31, 1986

QUALITY ASSURANCE ELEMENTS 1, 2, 3A, 5, 6, 15, 16, 17, 18, 21, AND 22 APPLY TO ALL WORK DONE AT QUALITY ASSURANCE LEVEL I OR II.

QA LEVEL III

CITE "YES" ITEM ON LOGIC DIAGRAM ______

QA ELEMENT	APPLIES	IF NO - JUSTIFICATION IF YES - LIST NEEDED PROCEDURES
3B.0 DESIGN CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
4.0 PROC. DOC. CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
7.0 CTL OF PUR MATERIALS	No	This is a Level III activity. Good professional and scientific practices apply.
8.0 I.D. & CTL OF MATERIALS	No	This is a Level III activity. Good professional and scientific practices apply.
9.0 CONTROL OF PROCESSES	No	This is a Level III activity. Good professional and scientific practices apply.
10.0 INSPECTION	No	This is a Level III activity. Good professional and scientific practices apply.
11.0 TEST CONTROL	No	This is a Level III activity. Good professional and scientific practices apply.
12.0 CTL OF M & T EQUIP	No	This is a Level III activity. Good professional and scientific practices apply.
13.0 HANDLING, STOR. & SHIP.	No	This is a Level III activity. Good professional and scientific practices apply.
14.0 INSP. TEST & OPER. STAT.	No	This is a Level III activity. Good professional and scientific practices apply.
19.0 SOFTWARE QA	No	This is a Level III activity. Good professional and scientific practices apply.

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP ATTRIBUTE LEVEL

1. Is it the intended purpose of this activity to provide primary data for a license application? yes I
no

2. Does the item or activity involve or affect public radiologic health and safety? yes I
no

3. Does the item or activity involve waste isolation?
yes I
no

4. Does the item or activity involve or affect retrievability?
yes I
no

5. Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data?
yes I
no

6. Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes I
no

7. Can the item or activity have a major impact on non-radiological or occupational health and safety? yes II
no

8. If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes II
no

9. Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes II
no

10. Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes II
no

11. Can the item or activity cause major cost overrun or schedule slippage? yes II
no

III

LOGIC DIAGRAM FOR ASSIGNING QUALITY ASSURANCE LEVELS

STEP	ATTRIBUTE	LEVEL
1.	Is it the intended purpose of this activity to provide primary data for a license application? yes (no)	I
2.	Does the item or activity involve or affect public radiologic health and safety? yes (no)	I
3.	Does the item or activity involve waste isolation? yes (no)	I
4.	Does the item or activity involve or affect retrievability? yes (no)	I
5.	Can the failure of the item or activity cause a failure of a QA Level I item, or irretrievable loss of QA Level I data? yes (no)	I
6.	Does the activity involve a design phase which is to be conducted immediately prior to application for a NRC license, procurement or construction? yes (no)	I
7.	Can the item or activity have a major impact on non-radiological or occupational health and safety? yes (no)	II
8.	If the item or activity were to fail or is performed inadequately could repository workers be exposed to radiation or radioactive contamination levels in excess of the limits expressed in 10CFR60? yes (no)	II
9.	Does the item or activity have a major impact on the non-radiological operation, reliability or maintainability of engineered systems, structures, or components? yes (no)	II
10.	Does the item or activity involve a design phase for which the principle purpose is to conduct a comparative technical analysis of alternatives? yes (no)	II
11.	Can the item or activity cause major cost overrun or schedule slippage? yes (no)	II
	III	