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PLAN FOR WASTE PACKAGE DESIGN, FABRICATION AND PROTOTYPE TESTING FOR NNWSI

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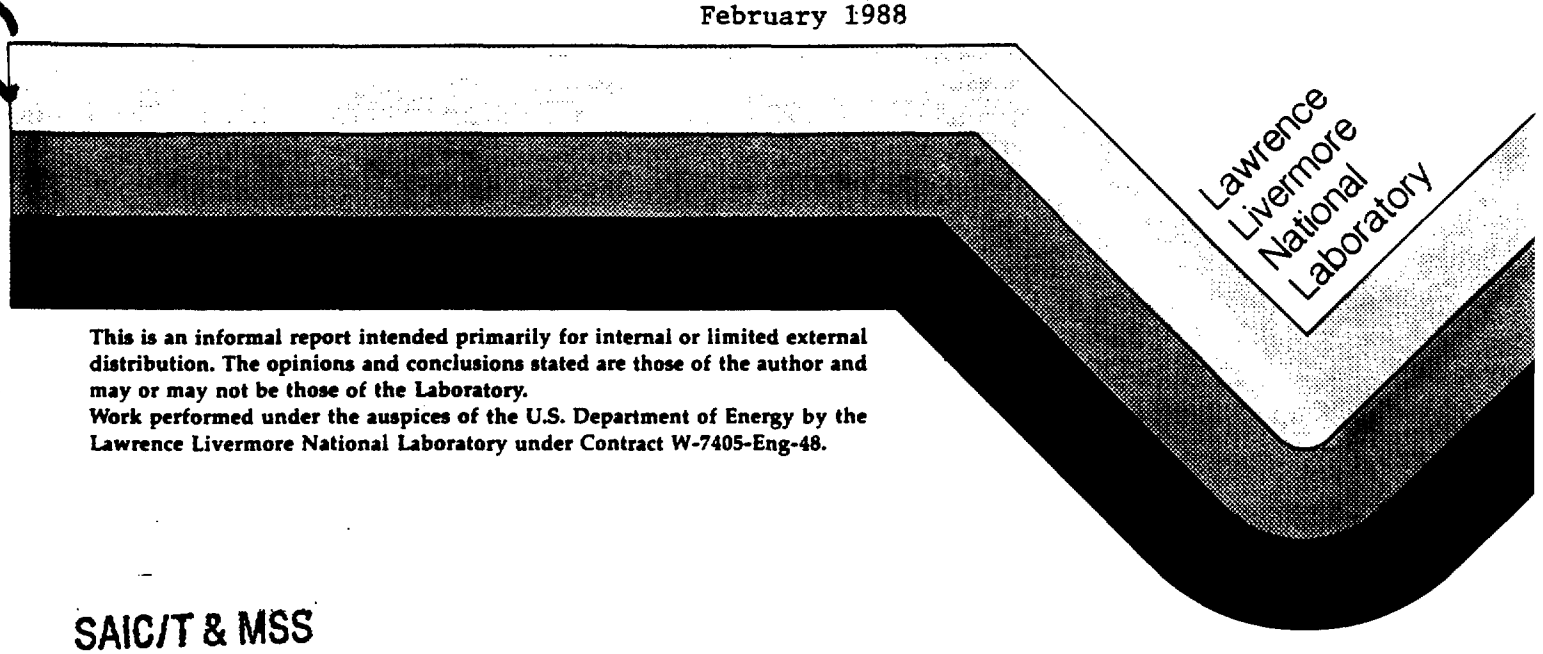

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This report is based on the Scientific Investigation Plan for NNWSI WBS Element 1.2.2.4.L, NNWSI Waste Package Design, Fabrication, and Prototype Testing Task. This SIP should be used as the reference document.

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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 QUALITY ASSURANCE

5.1 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 Design 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

5.2 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), TOPAZ2D - A Two-Dimensional Finite-Element Code for Heat Transfer Analysis, Electrostatic, and Magnetostatic Problems, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20824.

Shapiro, Arthur B. (1985), TOPAZ3D - A Three-Dimensional Finite Element Heat Transfer Code, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20484.

5.3 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

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