SEP 20 1993

Mr. Dwight E. Shelor, Associate Director
for Systems and Compliance
Office of Civilian Radioactive Waste Management
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Shelor:

SUBJECT: SUMMARY OF THE AUGUST 24, 1993, TECHNICAL EXCHANGE ON WASTE PACKAGE DESIGN CONCEPTS AND SUBSTANTIALLY COMPLETE CONTAINMENT

The purpose of this letter is to transmit the summary for the August 24, 1993, U.S. Nuclear Regulatory Commission/U.S. Department of Energy (DOE) technical exchange on waste package design concepts and substantially complete containment (SCC). The technical exchange was also attended by representatives of the State of Nevada and a representative of Nye County, Nevada. The purpose of the technical exchange was to hold discussions on DOE's interpretation of SCC and the use of SCC as a guide in design and to discuss the status/progress of DOE's waste package design effort.

Should you have any questions related to the summary or this letter, please contact Ms. Charlotte Abrams of my staff at (301) 504-3403.

Sincerely,

/s/

Joseph J. Holonich, Director
Repository Licensing and Quality Assurance
Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated (w/ attachment) FILED IN JACKET SAMS ACC#

cc: R. Loux, State of Nevada
T. J. Hickey, Nevada Legislative Committee
J. Meder, Nevada Legislative Counsel Bureau
C. Gertz, DOE/NV
M. Murphy, Nye County, NV
M. Baughman, Lincoln County, NV
D. Bechtel, Clark County, NV
D. Weigel, GAO
P. Niedzielski-Eichner, Nye County, NV
B. Mettam, Inyo County, CA
V. Poe, Mineral County, NV
F. Sperry, White Pine County, NV
R. Williams, Lander County, NV
L. Fiorenzi, Eureka County, NV
J. Hoffman, Esmeralda County, NV
C. Schank, Churchill County, NV
L. Bradshaw, Nye County, NV

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SUBJECT; SUMMARY OF THE AUGUST 24, 1993, TECHNICAL EXCHANGE ON WASTE PACKAGE DESIGN CONCEPTS AND SUBSTANTIALLY COMPLETE CONTAINMENT

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SUMMARY OF U.S. NUCLEAR REGULATORY COMMISSION AND
U.S. DEPARTMENT OF ENERGY TECHNICAL EXCHANGE ON
WASTE PACKAGE DESIGN CONCEPTS AND
SUBSTANTIALLY COMPLETE CONTAINMENT

On August 24, 1993, representatives of the Nuclear Regulatory Commission, U.S. Department of Energy (DOE), and State of Nevada Nuclear Waste Project Office participated in a technical exchange on substantially complete containment (SCC), and waste package/engineered barrier system design concepts. The purpose of the technical exchange was to discuss DOE's interpretation of SCC and the use of SCC as a guide in design and to discuss the status/progress of DOE's waste package design effort. Attendees also heard a presentation on DOE's plans for addressing NRC Site Characterization Analysis open items related to waste package concepts. The technical exchange agenda is included as Attachment 1 and the list of attendees is Attachment 2 to this summary. Copies of presenters' handouts are Attachment 3. Technical presenters representing DOE included staff from DOE's Yucca Mountain Project Office, and representatives of Lawrence Livermore National Laboratory and the Civilian Radioactive Waste Management System Management and Operating Contractor (M&O). NRC presenters included Division of High-Level Waste Management technical staff and representatives of the Center for Nuclear Waste Regulatory Analyses (CNWRA).

DOE technical presentations focused on current design efforts directed at evaluating waste package concepts during the Advanced Conceptual Design phase of the waste package development program. Designs under consideration include DOE's baseline design presented in the Site Characterization Plan, in addition to several multi-barrier concepts with small and large packages. Other DOE presentations included an overview of work directed toward materials testing and selection and the status of DOE testing and modeling efforts related to SCC.

The NRC presented a brief overview of its approach to reducing the uncertainty in SCC. NRC plans for development of guidance to clarify the meaning of SCC were highlighted. A discussion of CNWRA activities on the engineered barrier system program was also presented.

Following presentations, all parties had an opportunity for questions and discussion. In the closing comments, NRC and State of Nevada representatives noted that they were pleased with the information provided prior to and at the meeting, but highlighted the need for timely availability and transmittal of updated waste package information in the future. NRC representatives stated that they were pleased that DOE was moving toward a more robust design and requested a copy of the Engineered Barrier Design Requirements Document, when it is available.

The State of Nevada representative stated that the State continues to disagree with the NRC staff position regarding SCC. The State representative also expressed a concern that waste isolation performance credit may be given for a "robust" waste package that could be demonstrated, with reasonable assurance,

ENCLOSURE

to exceed the 300 to 1000 years performance objective. The state believes that the robust waste package may be used to compensate for uncertainties (arising from deficiencies) in the site and finds the robust design to be an unacceptable response to the resolution of site uncertainties.

Charlotte Abrams 9/20/93

Charlotte Abrams, Sr. Project Mgr.
Repository Licensing and Quality
Division of High-Level Waste
Management
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory Commission

Corrine Macaluso
Regulatory Integration Branch
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy

AGENDA
DOE/NRC TECHNICAL EXCHANGE
ON SUBSTANTIALLY COMPLETE CONTAINMENT AND WASTE PACKAGE/ENGINEERED BARRIER SYSTEM DESIGN CONCEPTS

August 24, 1993 at the NRC Phillips Building in Bethesda, MD

8:30	Welcome/Protocol/Opening Remarks	DOE, NRC, State, Counties (Stucker)
8:45	Overview of Substantially Complete Containment (SCC) • Basis for initial Consultative Draft-SCP and SCP approaches • Basis for current approach • Approach to resolution of NRC concerns	DOE (Stahl)
	Discussion	ALL
9:15	Status of SCC Activities • CNWRA activities and recommendations (Basis for SCC Elicitation)	NRC
	Discussion	ALL
9:25	Waste Package Development Program • Approach to meeting regulatory requirements • Waste package plan and waste package implementation plan • Schedule and milestones • Materials selection process • Multi-purpose canister (MPC) - waste package interface • Performance analysis	DOE (Benton)
	Discussion	ALL
10:25	BREAK	
10:40	Waste Package Design Concepts • SCP design • Multi-barrier concepts • MPC overpack concepts • Thermal considerations • Criticality considerations • Radiation considerations	DOE (Benton)
	Discussion	ALL

ENCLOSURE 1

11:40	LUNCH	
1:00	Approach to Testing/Materials Selection • Review of SCP functional requirements • Development of functional requirements for other design concepts • Materials selection	DOE (Fish)
	Discussion	ALL
1:45	Status of DOE Testing Effort Relative to SCC • Differences between corrosion-resistant and corrosion-allowance materials • Materials testing/selection for SCP design • Materials testing for the other design concepts	DOE (McCright)
	Discussion	ALL
2:45	Status of DOE Modeling Effort Relative to SCC • Total system performance assessments • Waste package performance models • Container corrosion models	DOE (Halsey)
	Discussion	ALL
3:30	BREAK	
3:45	Status of NRC Testing Effort	NRC
	Discussion	ALL
4:05	Status of NRC Modeling Effort	NRC
	Discussion	ALL
4:25	SCA Open Items Related to SCC • Comment No. 5 • Comment No. 47 • Comment No. 80 • Question No. 46 • Question No. 47	DOE (Stahl)
	Discussion	ALL
4:55	Closing Comments	DOE, NRC, State, Counties
5:15	Adjourn	

Enclosure 2

Attendees

August 24 Technical Exchange

Name	Affiliation	Phone #
H. MINWALLA	WESTIN	646-6710
Dean Stucken	DOE	702 794 7295
Charlotte Abrams	NRC	(301) 504-3403
PERRY Robinson	Winston & Strawn	(202) 371-5797
Steven E. LeRoy	M&O/Duke Eng.	(702) 794-7836
Vic Sgabbe	GAO	(202) 512-6937
Prasad Nair	CNWRA	(210)-522-5150
GUSTAVO CRAGNOLINO	CNWRA / SwRI	(210) 522-5539
Lester Berkowitz	M&O/TRW	(202) 488 2309
BILL HALSEY	L.L.N.L.	(510) 423-1133
KIEN CHANG	NRC	(301) 504-2525
Mike Lugo	M&O/TRW	(702) 794-7830
MacKaye Smith	DOE	(702 894-9537
Steve Saterlie	M&O/TRW	(702) 794-5376
Richard Memory	M&O/TRW	702-794-1837
Daniel Mc Cright	LLNL	510-422-7051
HUGH BENTON	M&O/BWFC	702-794-1891
Robert L. Fish	M&O/BWFC	702-794-1805
Steve Frishman	State of NV	702-687-3744
Ron Ballard	USNRC	301 504-3462
RICK WELLER	NRC	301-504-3458
Judy Treichel	NV Nuclear Waste TF	702-878-1885
Steve Nesbit	M&O / Duke Eng.	702-794-1910
Ray Wallace	U.S. Geol. Svy/HQ	202-586-1244

HAL CLEARY	WESTON	(202) 646-6728
David Stahl	M&O/BWFC	(702) 794-7778
Ellis D. Verink Jr.	NWTRB	(904) 392-8163
Bonnie Packer	TRW/M+O	703 204 8747
Frank Van Der Laan	TRW/M&O	(702) 794-7301
Jim York	Weston	202-646-6650
APRIL GIL	DOE/YMP	702 794-7622
Corinne Macduso	DOE/RW-331	(202) 586-2837
CARL DI BELLA	NWTRB	(703) 235-4473
JAMES J. RALEIGH	STS, INC	(301) 652-2500
Lem Reiter	NWTRB	(703) 231-4473
Chris Einberg	DOE/HQ	(202) 586-8869
Bernard J. Verna	DOE/YMP	702-794-7410
Gene Roseboom	USGS Dis Office	703-648-4422
ROBERT WAXMAN	US DOE/GC	(202) 586-6975
Judy Lancaster	Nye County	(202) 516-2504
DAN FEHRINGER	NWTRB	703-235-4473
Alan Benson	DOE/RW-22	202 586-9362
Herb Feinroth	Gamma Engineering	301-840-8415
John L. Russell	CNWRA	703) 979-9129
Charles Russomanno	DOE/RW-22	202 586 4347
Giorgio Gnugnoli	NRC/ACNW	301-492-9851
JOHN TRAPP	NRC/HLWM/GC	301-504-2509
DAVE DANCER	NRC/HLWM	301-504-2049
Raymond A. Mele	M&O/WCFS	202-488-2321
Charles Interrante	NRC/HLWM	301 504 1552

U.S. DEPARTMENT OF ENERGY

OCRWM

YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC TECHNICAL EXCHANGE SUBSTANTIALLY COMPLETE CONTAINMENT AND WASTE PACKAGE/ ENGINEERED BARRIER SYSTEM DESIGN CONCEPTS

OPENING REMARKS

PRESENTED BY

DEAN STUCKER

CHIEF, FIELD ENGINEERING BRANCH
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
LAS VEGAS, NEVADA

1022

AUGUST 24, 1993
BETHESDA, MD

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SCA: NRC STAFF VIEWS OF THE SCP

"The staff considers that the revised interpretation is an indication that DOE has taken a more conservative interpretation of the regulatory requirement, one more consistent with the staff's interpretation."

"However, the SCP has not demonstrated that this revised interpretation has sufficiently altered its plans for what must be demonstrated for compliance, or its strategy for demonstrating compliance."

(NUREG-1347, page 3-9)

SCA: STAFF REQUIREMENTS

MUTUAL UNDERSTANDING OF:

- Meaning of technological limitations and uncertainties
- Relationship between SCP goals and the technological limitations and uncertainties
- Effect of lack of quantitative measure of the technological limitations and uncertainties on DOE's compliance demonstration program

THE SCA RECOMMENDATIONS WERE SPECIFIC

- DOE performance goals should be consistent with the rule
- Proper balance of laboratory and in-situ testing
- A long-term waste package performance confirmation program

1989 - 1993: A PERIOD OF PROGRESS

- Characterization of the near-field environment initiated
- SNF/HLW testing initiated/ongoing
- Waste Package ACD initiated
  - WP conceptual designs under development
  - Container materials studies in progress
  - Fabrication/closure studies underway
- MPC Development initiated
- NRC staff position on SCC issued

DOE HAS CHANGED ITS PLANS SUBSTANTIALLY

- New performance goal - consistent with the rule
- New plans
  - Waste Package Plan, Rev. 1, March 1993
  - Waste Package Implementation Plan, Rev. 0, February 1993

DOE OBJECTIVES FOR THIS TECHNICAL EXCHANGE

- Discuss new performance goal/plans
- Discuss why we believe they are responsive to the Staff's recommendations
- Discuss why they will provide, when implemented, the information required to satisfy the SCC rule
- Outline approach to responding to open SCC-related SCA comments/questions
- Obtain NRC feedback on DOE's proposed responses to SCC-related SCA comments/questions

PRESENTATION OUTLINE

• Dave Stahl	SCC Overview
• Hugh Benton	Waste Package Development Program Waste Package Design Concepts
• Bob Fish	Testing/Materials Selection
• Dan McCright	Testing/Evaluation of EBS Materials
• Bill Halsey	Status of SCC-Related Modeling Program
• Dave Stahl	Approach to DOE Responses to Open SCA Items

Presentations will bring Staff up-to-date on DOE plans/progress

DOE BELIEVES THE PRESENTATIONS WILL PROVIDE:

- The understanding the staff called for in the SCA
- Confidence that DOE's Waste Package Program is established on a sound foundation
- Basis for closing open SCC-related SCA comments/questions

SUBSTANTIALLY COMPLETE CONTAINMENT AND WASTE PACKAGE/ENGINEERED BARRIER SYSTEM DESIGN CONCEPTS

DOE/NRC TECHNICAL EXCHANGE
AUGUST 24, 1993

Charlotte Abrams
US NRC

SINCE ISSUANCE OF THE SITE CHARACTERIZATION PLAN THERE HAS BEEN NO UPDATED INFORMATION PROVIDED ON THE YUCCA MOUNTAIN OFFICIAL REFERENCE ADVANCED CONCEPTUAL WASTE PACKAGE DESIGN

Comment 1, NRC review of PRs 6 and 7
May 5, 1993

LACK INFORMATION ON:

MATERIALS

DESIGN

EMPLACEMENT MODE

MATERIALS

PROGRESS REPORT 6 - REPORTS THREE MATERIALS RECOMMENDED FOR ADVANCED STUDY AND "OTHER" MATERIALS (UNNAMED) WILL BE STUDIED.

PROGRESS REPORT 7 - CITES A PAPER TO BE PUBLISHED ON SELECTION OF CANDIDATE CONTAINER MATERIALS.

DESIGN

THIN-WALLED CONTAINER DESIGN (SCP)

MULTIPURPOSE CANISTER (RECENT MEETINGS)

MULTIPLE-LAYERED WASTE PACKAGE

EMPLACEMENT MODE

HORIZONTAL BOREHOLE EMPLACEMENT

VERTICAL BOREHOLE EMPLACEMENT

HORIZONTAL DRIFT EMPLACEMENT

THE STAFF RECOGNIZES THAT ACTIVITIES RELATED TO WASTE PACKAGE MATERIALS, DESIGN, AND EMPLACEMENT CONFIGURATION ARE PRELIMINARY. THE STAFF SHOULD BE KEPT UP-TO-DATE ON WASTE PACKAGE ACTIVITIES IN FUTURE PROGRESS REPORTS AND THROUGH OTHER, LESS FORMAL, MECHANISMS.

U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/Engineered Barrier System Design Concepts

SCA Open Items Related to SCC

PRESENTED BY

Dr. David Stahl

Manager

Waste Package Performance Analysis

M&O/Las Vegas, Nevada

August 24, 1993

SCA COMMENT 5

NRC CONCERN:

- Explain how technological limitations and uncertainties and the Waste Package Designs impact demonstration of compliance with 10CFR 60.113 and describe plans for evaluating and reducing these impacts

PROPOSED DOE RESPONSE:

- Technological limitations relate to the ability to emplace waste packages without defects while uncertainties relate to the ability to define material interactions
- DOE plans to evaluate and reduce the impacts of these limitations and uncertainties on the demonstration of compliance with 10CFR 60.113 during the design process
- DOE plans are described in the Waste Package Implementation Plan and include the use of materials testing, environmental studies, fabrication studies, performance analysis, and performance assessment, and will include details on the performance confirmation program as they are developed

SCA COMMENT 5

PROPOSED DOE RESPONSE: (Continued)

- **Multi-barrier design approach will substantially improve containment and therefore will enhance demonstration of compliance by minimizing technological limitations and uncertainties**
  - **Use of corrosion-resistant and corrosion-allowance materials provide a more environmentally tolerant design**
  - **Probability of non-detected breach dramatically reduced**

SCA COMMENT 47

NRC CONCERN:

- Lack of information on tectonic events that could cause waste package rupture

PROPOSED DOE RESPONSE:

- Study Plan (8.3.1.8.2.1) on Analysis of Waste Package Rupture Due to Tectonic Processes and Events completed and sent to the NRC
- Studies will analyze tectonic processes and events, particularly those that involve displacements, that may have an impact on design and performance of waste packages and the EBS during postclosure
- Results of the study will be input into design activities for the waste package, EBS, and the repository

SCA COMMENT 80

NRC CONCERN:

- Inconsistency exists between the intent of SCC requirement and the SCP performance goals

PROPOSED DOE RESPONSE:

- DOE's interpretation of SCC is the same as that of the NRC staff
- The revised performance goal is no longer tied to release of radionuclides
- The revised performance goal is a mean waste package lifetime well in excess of 1,000 years

  - This is consistent with NRC's requirement for containment

- The multi-barrier approach with different materials and, hence, different failure modes, will add to confidence that goal will be met

SCA QUESTION 46

NRC CONCERN:

- Basis for stricter control of long half-life radionuclides for the containment period is not provided

PROPOSED DOE RESPONSE:

- CD-SCP and SCP design concept based on single, thin-walled container
- SCP goals were consistent with this design
- The revised performance goal is a mean waste package lifetime well in excess of 1,000 years
  - This is consistent with the SCC requirement
  - Performance goal is achieved through the use of designs with multiple barriers with different failure modes that enhance confidence that the SCC requirement will be met
- Revised performance goal, therefore, is no longer tied to release of radionuclides

SCA QUESTION 47

NRC CONCERN:

- Relationship of container failure to compliance with 10 CFR 60.113 must be demonstrated and plans for testing should be described

PROPOSED DOE RESPONSE:

- Initial DOE response was based on release of gaseous radionuclides from a single, thin-wall (SCP) design container
- Failure flow rates were taken from the ASME B&PV code, recognizing that testing will be performed at significantly lower allowable leakage
- Multi-barrier approach reduces impact on demonstration of compliance
- DOE's plans for demonstrating compliance and plans for testing are provided in the Waste Package Implementation Plan, including detailed materials testing and modeling programs, environmental studies, and performance assessments, as well as fabrication studies and prototype testing
- Longer waste package lifetimes will dramatically reduce release of gaseous radionuclides

OVERVIEW OF NRC APPROACH TO REDUCING THE UNCERTAINTY IN "SUBSTANTIALLY COMPLETE CONTAINMENT" (SCC)

DAVE DANCER
AUGUST 24, 1993

THE NATURE OF THE UNCERTAINTY IN SCC - THE TERM "SUBSTANTIALLY COMPLETE CONTAINMENT" NEEDS CLARIFICATION

- TO PERMIT ENGINEERED BARRIER SYSTEM (EBS) DESIGNERS TO RESPOND WITH AN ACCEPTABLE DESIGN

- TO PROVIDE NRC TECHNICAL REVIEWERS WITH A BASIS FOR THE DEVELOPMENT OF EBS EVALUATION CRITERIA

APPROACH TO SCC UNCERTAINTY REDUCTION

- REVIEW RULEMAKING RECORD FOR GUIDANCE ON THE INTENT OF SCC
- REVIEW THE EXPERIENCE WITH THE SCC CONCEPT
- DEVELOP TECHNICAL BASIS FOR GUIDANCE
- PREPARE GUIDANCE IN APPROPRIATE FORM (E.G. TECHNICAL POSITION, STAFF POSITION, REGULATORY GUIDE, RULE)
- INCORPORATE GUIDANCE IN THE LICENSE APPLICATION REVIEW PLAN

THE RULEMAKING RECORD

PROPOSED RULE (ISSUED JULY 1981)

- 60.111(b)(2)(i) CONTAINMENT OF WASTES

  "THE ENGINEERED SYSTEM SHALL BE DESIGNED SO THAT . . . THE WASTE PACKAGES WILL CONTAIN <u>ALL</u> RADIONUCLIDES FOR AT LEAST THE FIRST 1,000 YEARS AFTER PERMANENT CLOSURE."

- PURPOSE OF CONTAINMENT

  CONTAIN WASTES DURING PERIOD OF HIGH HEAT/RADIATION GENERATION WHEN UNCERTAINTIES INHERENTLY LARGE

- NO AMBIGUITY IN PROPOSED RULE

PUBLIC COMMENTS ON PROPOSED RULE

- 100% CONTAINMENT NOT LIKELY FOR LARGE NUMBER OF CONTAINERS
- 100% PERFORMANCE NOT JUSTIFIED TO MEET EPA STANDARD
- CONTAINMENT OF "ALL" RADIONUCLIDES FOR LONG PERIODS NOT DEMONSTRABLE
- NEED FOR 1,000-YEAR CONTAINMENT PERIOD NOT JUSTIFIED
- RULE MODIFIED IN RESPONSE TO COMMENTS

FINAL RULE (PROMULGATED JUNE 1983)

- 60.113(a)(1)(ii)

  ". . . THE ENGINEERED BARRIER SYSTEM SHALL BE DESIGNED . . . SO THAT CONTAINMENT OF HIGH-LEVEL WASTE WITHIN THE WASTE PACKAGES WILL BE <u>SUBSTANTIALLY COMPLETE</u> FOR A PERIOD TO BE DETERMINED BY THE COMMISSION . . . PROVIDED, THAT SUCH PERIOD SHALL BE NOT LESS THAN 300 YEARS NOR MORE THAN 1,000 YEARS AFTER PERMANENT CLOSURE OF THE GEOLOGIC REPOSITORY.

SIGNIFICANT DIFFERENCES BETWEEN PROPOSED RULE AND FINAL RULE

- 100% CONTAINMENT CHANGED TO SUBSTANTIALLY COMPLETE CONTAINMENT

- 1,000-YEAR CONTAINMENT PERIOD CHANGED TO RANGE (300-1,000 YEARS) TO REFLECT:

  1. AGE, NATURE OF WASTE

  2. UNDERGROUND FACILITY DESIGN

  3. SOURCES OF UNCERTAINTY

  4. APPLICABLE EPA STANDARDS

IMPORTANT CHARACTERISTICS OF FINAL RULE (STATEMENT OF CONSIDERATIONS)

- CONTAINMENT REQUIREMENT CLOSELY COUPLED TO ENGINEERED BARRIER SYSTEM (EBS) RELEASE RATE LIMIT:

  1. SHOULD NOT VARY INDEPENDENTLY

  2. ACT AS SYSTEM TO CONTROL RELEASES TO GEOLOGIC SETTING

- NO DIRECT TECHNICAL NEXUS TO EPA STANDARD

RATIONALE FOR FINAL RULE (NUREG-0804)

- "IT IS EXPECTED THAT CONTAINMENT OF THE WASTE WILL BE SUBSTANTIALLY COMPLETE, WITH RELEASES DURING THE CONTAINMENT TIME LIMITED TO A SMALL FRACTION OF THE INVENTORY PRESENT."

- "IT IS REALIZED THAT A SMALL FRACTION OF THE APPROXIMATELY 100,000 PACKAGES WILL BE BREACHED BEFORE 1,000 YEARS DUE TO VARIATIONS IN MATERIALS, MANUFACTURING PROCESSES, ETC., THAT CAN ONLY BE ESTIMATED USING STATISTICAL PROCEDURES."

EXPERIENCE WITH THE SCC CONCEPT

- DOE MISINTERPRETED SCC IN JANUARY 1988 CDSCP (PAGE 8.3.5.9.2) (E.G. UP TO 20% OF THE PACKAGES COULD FAIL IN THE FIRST 1000 YEARS)

- DOE DECEMBER 1989 BRIEFING TO NRC CITED NEED FOR CLARIFICATION OF SCC

- NWTRB THIRD REPORT (MAY 1991) EXPRESSED CONCERN ABOUT AMBIGUITIES AND LACK OF CLARITY IN SCC

TECHNICAL BASIS DEVELOPMENT FOR SCC

TECHNICAL FEASIBILITY ASSESSMENT PROJECT (JULY 1989 - SEP. 1990)

- THREE PRODUCTS:

  1. "TECHNICAL CONSIDERATIONS" REPORT

  2. "UNCERTAINTIES" REPORT

  3. "ALTERNATIVES" REPORT FOR RESOLVING SCC UNCERTAINTY

WASTE PACKAGE FAILURE MODELING/TESTING

- DETAILS TO BE DISCUSSED THIS AFTERNOON
- WILL ASSESS PERFORMANCE OF VARIOUS WP DESIGNS/MATERIALS AND VARIOUS ENVIRONMENTAL CONDITIONS
- WILL ASSESS WHAT STATE OF ART CAN ACHIEVE IN LIMITING WP FAILURES/RELEASES

LITERATURE REVIEW OF ENGINEERED STRUCTURES

- STUDY WILL ASSESS THE EXPERIENCE ON CONTAINMENT OF RADIOACTIVE OR HAZARDOUS MATERIALS BY BOTH ABOVE GROUND AND UNDERGROUND ENGINEERED STRUCTURES

- STUDY WILL INCLUDE THE PRACTICAL LIMITS OF MANUFACTURING PROCESSES AND QUALITY ASSURANCE ON CONTAINMENT RELIABILITY.

SCC GUIDANCE DEVELOPMENT

SCC GUIDANCE CHARACTERISTICS

- GOAL: DEVELOP NUMERICAL GUIDANCE TO CLARIFY THE MEANING OF SCC

- PREMISE: QUALITATIVE WORDS ALONE MAY BE INSUFFICIENT TO RESOLVE SCC UNCERTAINTY

- CONSTRAINTS:

  1. GUIDANCE SHOULD BE CONSISTENT WITH COUPLED EBS RELEASE LIMIT

  2. GUIDANCE SHOULD PRESERVE "CONTAINMENT" CONCEPT

  3. GUIDANCE SHOULD BE TECHNICALLY ACHIEVABLE, REFLECTIVE OF SCC AS A MINIMUM STANDARD

U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/Engineered Barrier System Design Concepts

Waste Package Development Program

PRESENTED BY

Hugh A. Benton

Manager

Waste Package/ Development

M&O/Las Vegas, Nevada

August 24, 1993

Outline

- Approach to meeting regulatory requirements
- Waste Package and Implementation Plans
- Requirements documents
- Design, testing, modeling, performance analysis interactions
- Processes for selecting options
- Interfaces
- Accomplishments and activities

WPD Program Constrained by 10 CFR 60 Requirements

- Substantially complete containment for at least 300 - 1000 years
- Releases after containment period $\leq$ 1 part in 10^5 per year
- Releases to accessible environment following closure within EPA standards
- Protection against radiation exposures and releases of radioactive material
- Waste retrieval option retained until NRC review of performance confirmation data

Waste Package Program

- Waste forms
  - Spent fuel
  - High-level waste glass
- Canisters
- Basket and containers
- Fillers and packing
- Air gaps (if in boreholes)
- Support structure
- Other material surrounding waste packages
- Backfill
- Near-field environment

Waste Package Development Goal

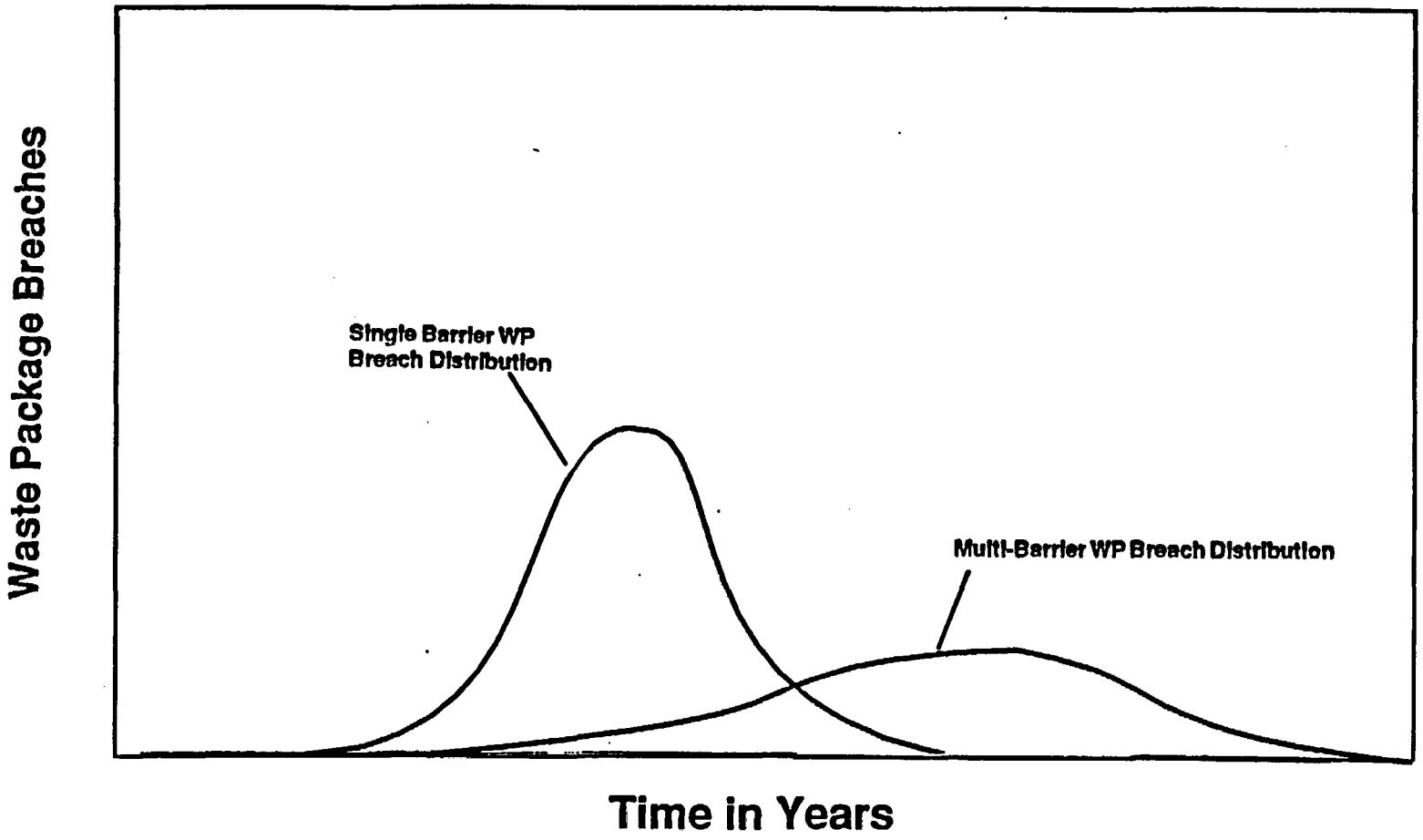
Achieve a design that:

- Meets Quality Assurance requirements
- Can be shown to meet regulatory requirements with sufficient margin for uncertainty of performance predictability
- Provides substantially complete containment for much longer than 1000 years
- Is compatible with the repository and the rest of waste management system
- Can be deployed at acceptable cost

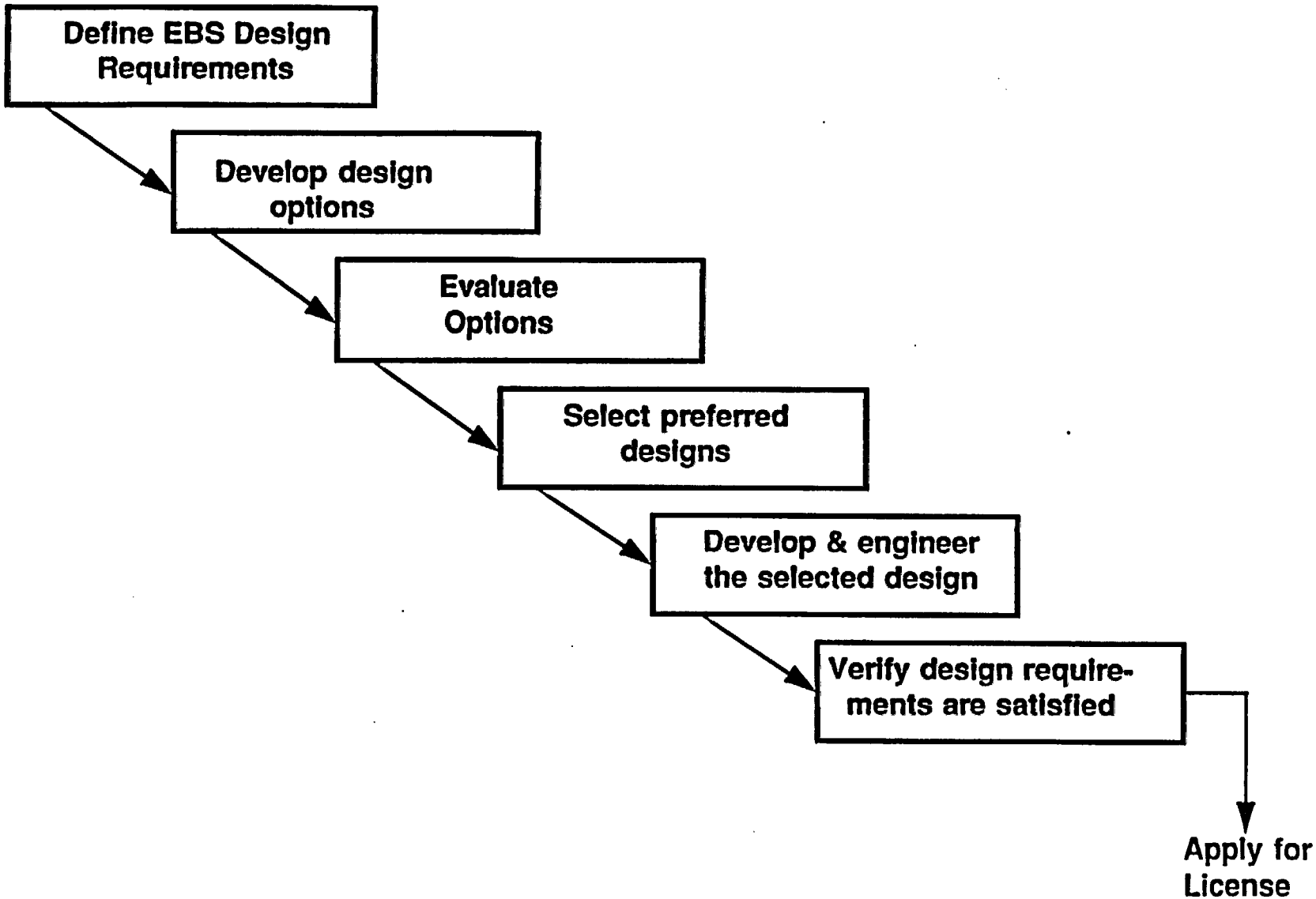
Waste Package Strategy

- The attainment of the development goal using an iterative system-engineering approach based on
  - A multi-barrier approach
  - The unsaturated nature of the Yucca Mountain site
  - Consideration of technical alternatives
  - Sufficient resolution of technical and regulatory uncertainties
  - Tolerance of broad range of thermal loads and other conditions

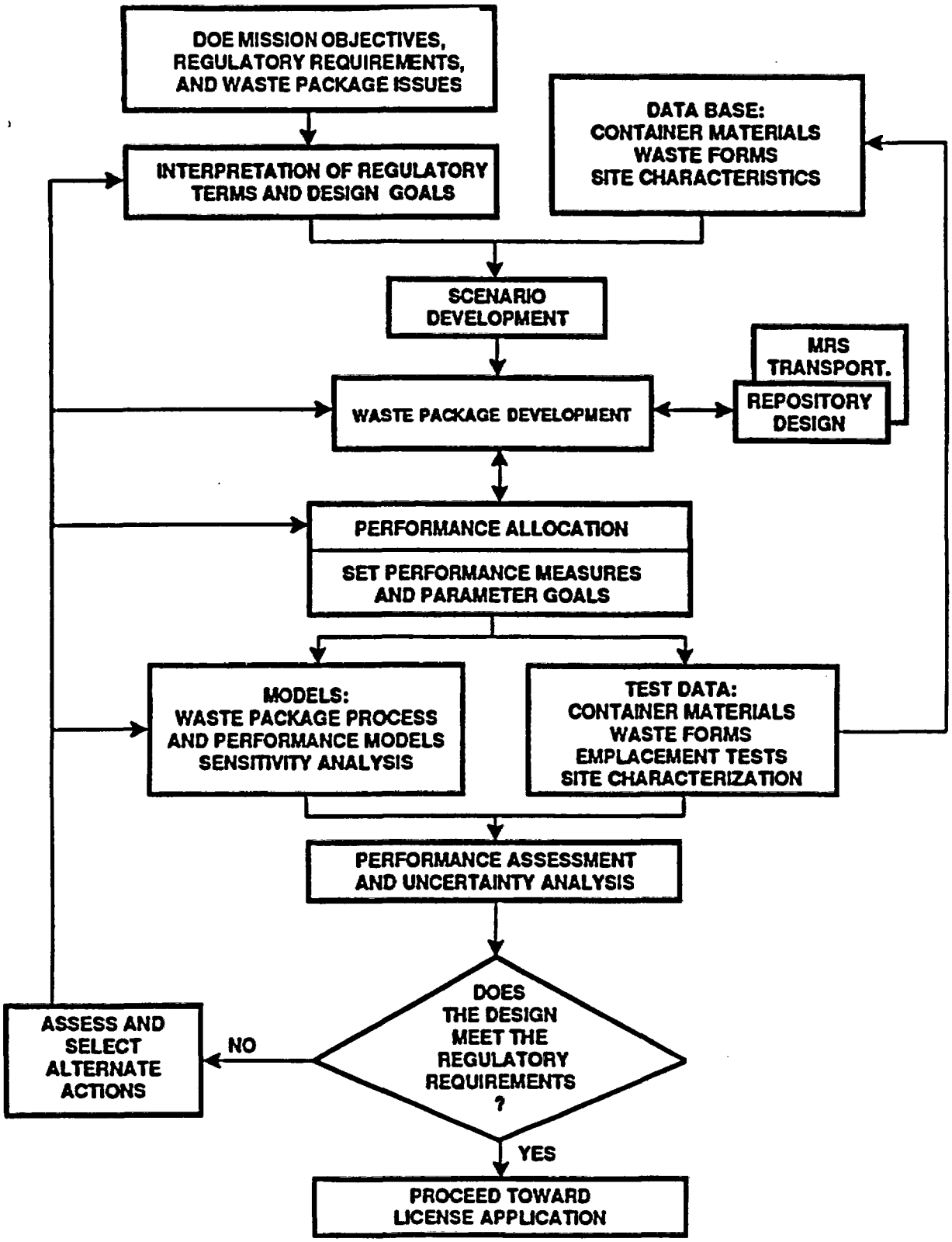
Qualitative Schematic Breach Distribution



A Systems Engineering Approach



Waste Package Regulatory Compliance Process



Plans

- Waste Package Plan - Issued August 1990
  - Provides overall Waste Package program for development of SCP designs
- Revised March 1993
  - Updates program to recognize other concepts
    - Multi-barrier waste package
    - Drift emplacement
- Waste Package Implementation Plan - Issued February 1993
  - Provides technical approach

Requirements Documents

CFR's

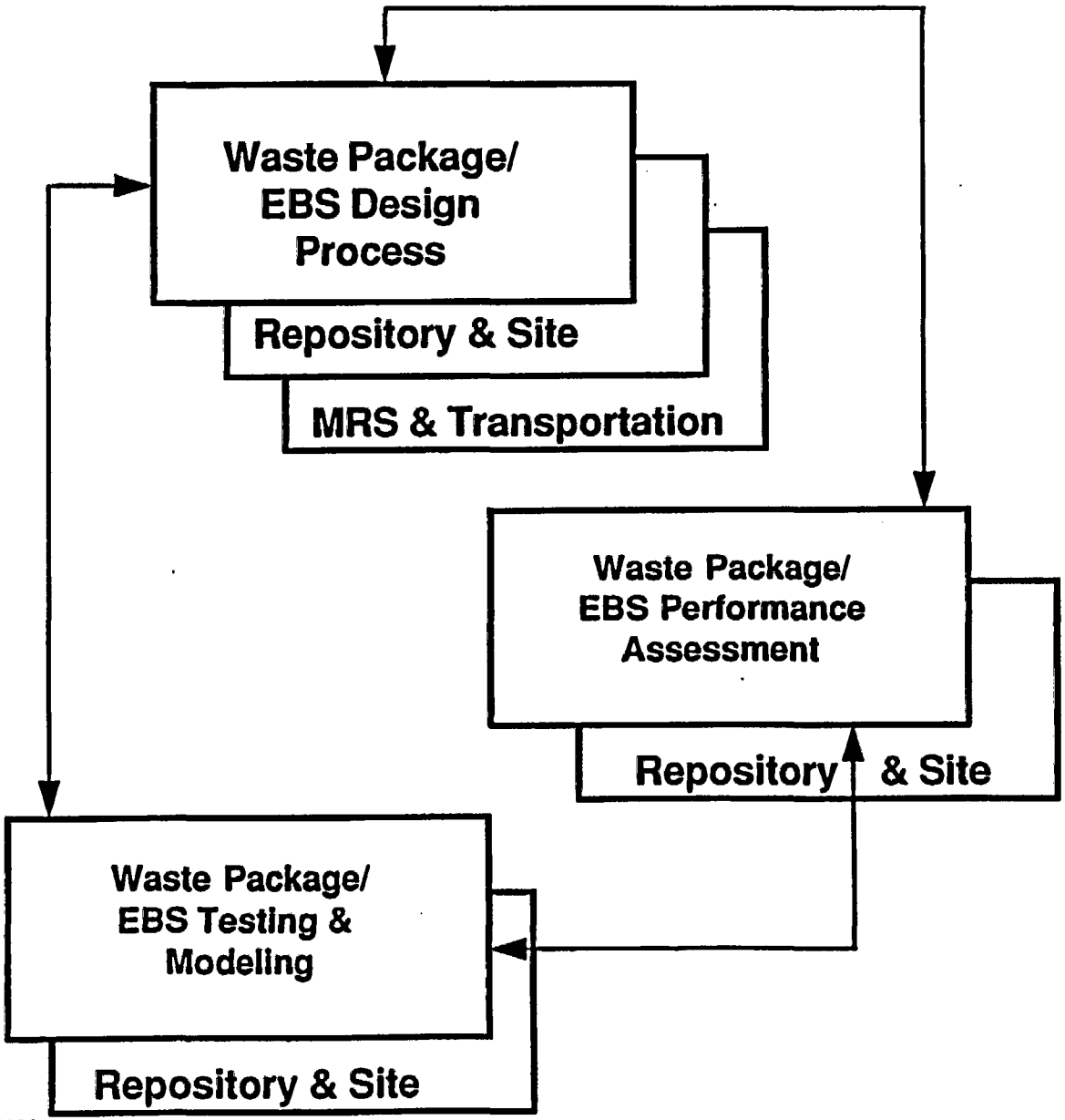
OCRWM
Requirements

MGDS
Requirements

Engineered Barrier
Requirements

Waste Package
Basis for Design

Major Process Interfaces



In Situ Heater Tests Can Resolve the Following Questions

(1) Whether heat conduction dominates heat flow

(2) Whether a region of above-boiling temperatures surrounding the repository corresponds to the absence of mobile liquid water at the Waste Package environment

(3) Whether fracture density and connectivity are sufficient to promote rock dry-out due to boiling and condensate shedding

In Situ Heater Tests Can Resolve the Following Questions

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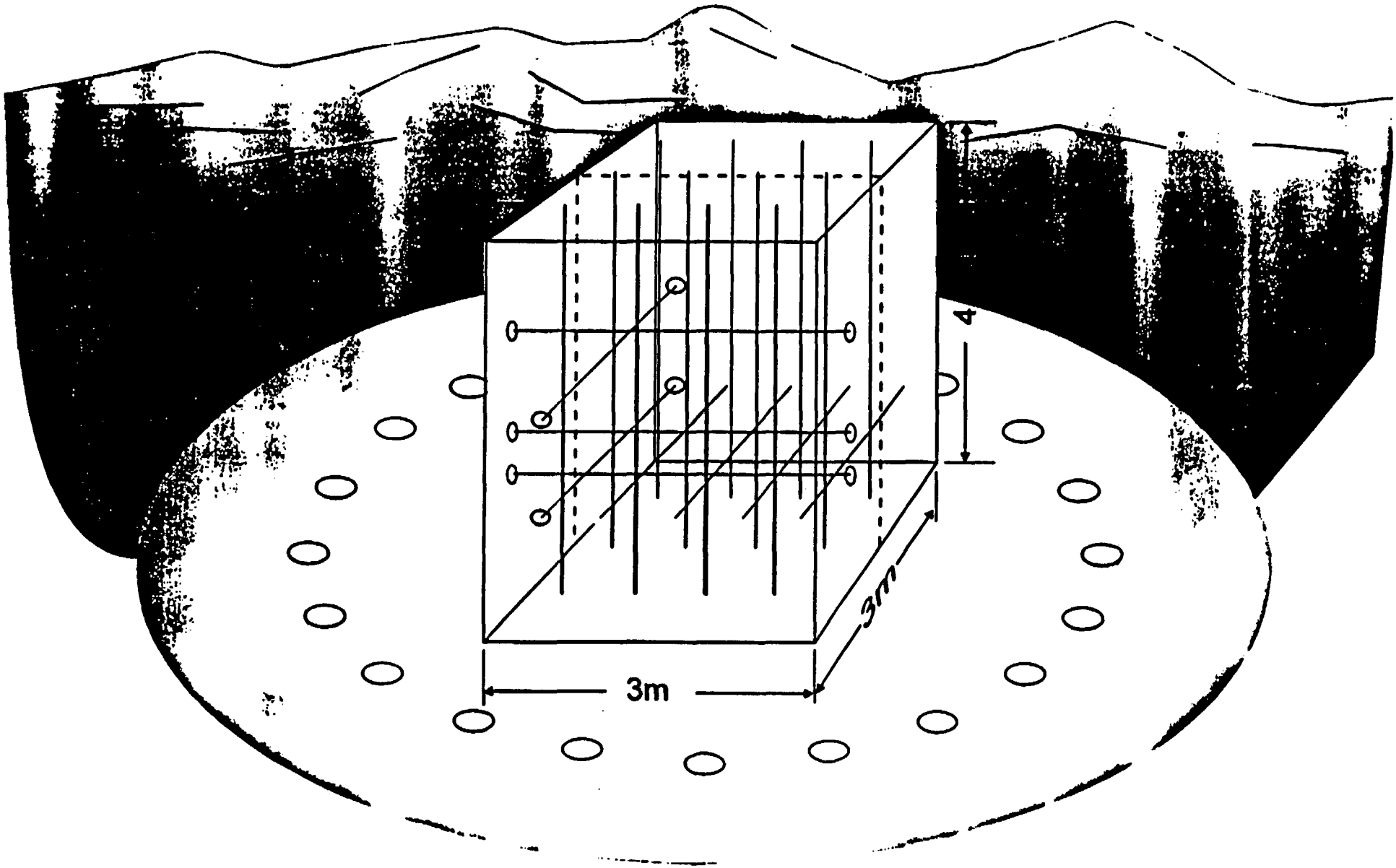
(3) Whether fracture density and connectivity are sufficient to promote rock dry-out due to boiling and condensate shedding

In Situ Heater Tests Can Resolve the Following Hpothesis Tests: (Continued)

(4) Whether re-wetting of the dry-out zone back to ambient saturation significantly lags behind the end of the boiling period

(5) Whether large-scale, buoyant, gas-phase convection may eventually dominate moisture movement

The large block test will provide valuable information pertaining to all five questions, particularly questions 2, 3, and 4

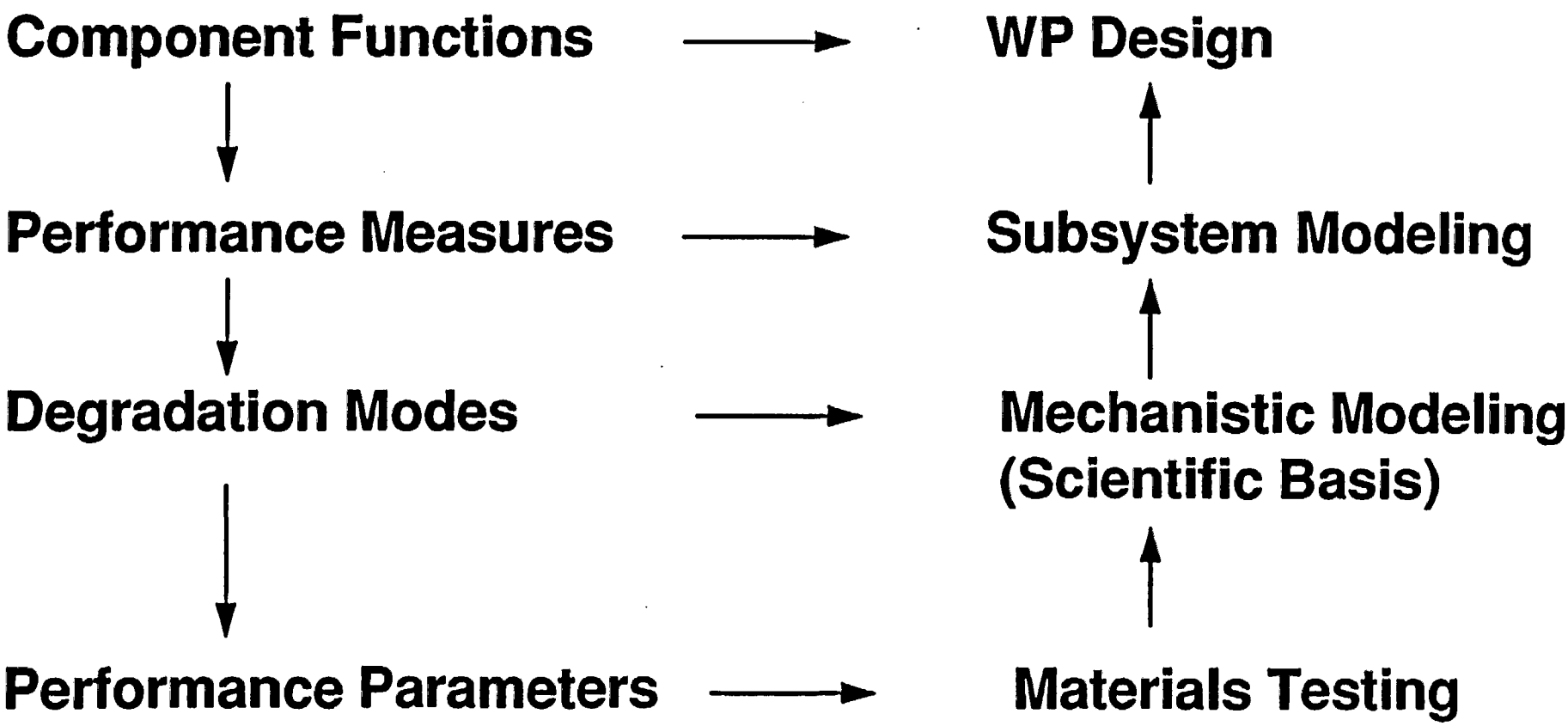


LGBLK.TST 126 7-26-93

Design Approach

- Start ACD with range of concepts
  - Small, thin-wall borehole emplaced
  - Multi-barrier, higher capacity, drift emplaced
    - Partially self-shielded
    - Self-shielded to personnel exposure limits
  - Multi-barrier, small, drift emplaced
  - Corrosion resistant plus corrosion allowance materials
- Variable thermal loading concept
  - Adjust waste package locations prior to backfill to optimize thermal loading
- Reduce concepts during LAD to one reference and one alternative design for detailed evaluation

Technical Approach for Waste Package Development



Interfaces

- MGDS System Studies
  - Thermal loading
  - Emplacement mode
  - Waste package performance allocation
- Multi-purpose canister
  - Compatible overpack
  - Thermal and criticality analyses
  - Material compatibility
- Closure and handling methods

Accomplishments to Date

- SCP design defined
  - Small diameter, thin-wall stainless steel containers
  - In vertical boreholes

- Developed other concepts including:
  - Larger multi-barrier waste packages
  - Corrosion allowance and corrosion resistant materials
  - Drift emplacement

- List of candidate containment barrier materials developed
  - Testing started

- Spent fuel oxidation and dissolution testing
  - Have 6 years of test data, testing continuing

- High Level Waste Glass characterized
  - Long-term tests continuing

- Waste package near-field environment partially characterized

Since the SCP, the Waste Package Program has emphasized five areas

- Characterization of rock near waste packages (geochemical, hydrological, and mechanical attributes)
- Characterization of spent fuel and HLW glass (pre-and post-emplacement attributes)
- Preliminary metallic container material surveys and tests
- Feasibility studies on metallic container fabrication and closure of SCP design
- Supporting multi-purpose canister and developing conceptual designs

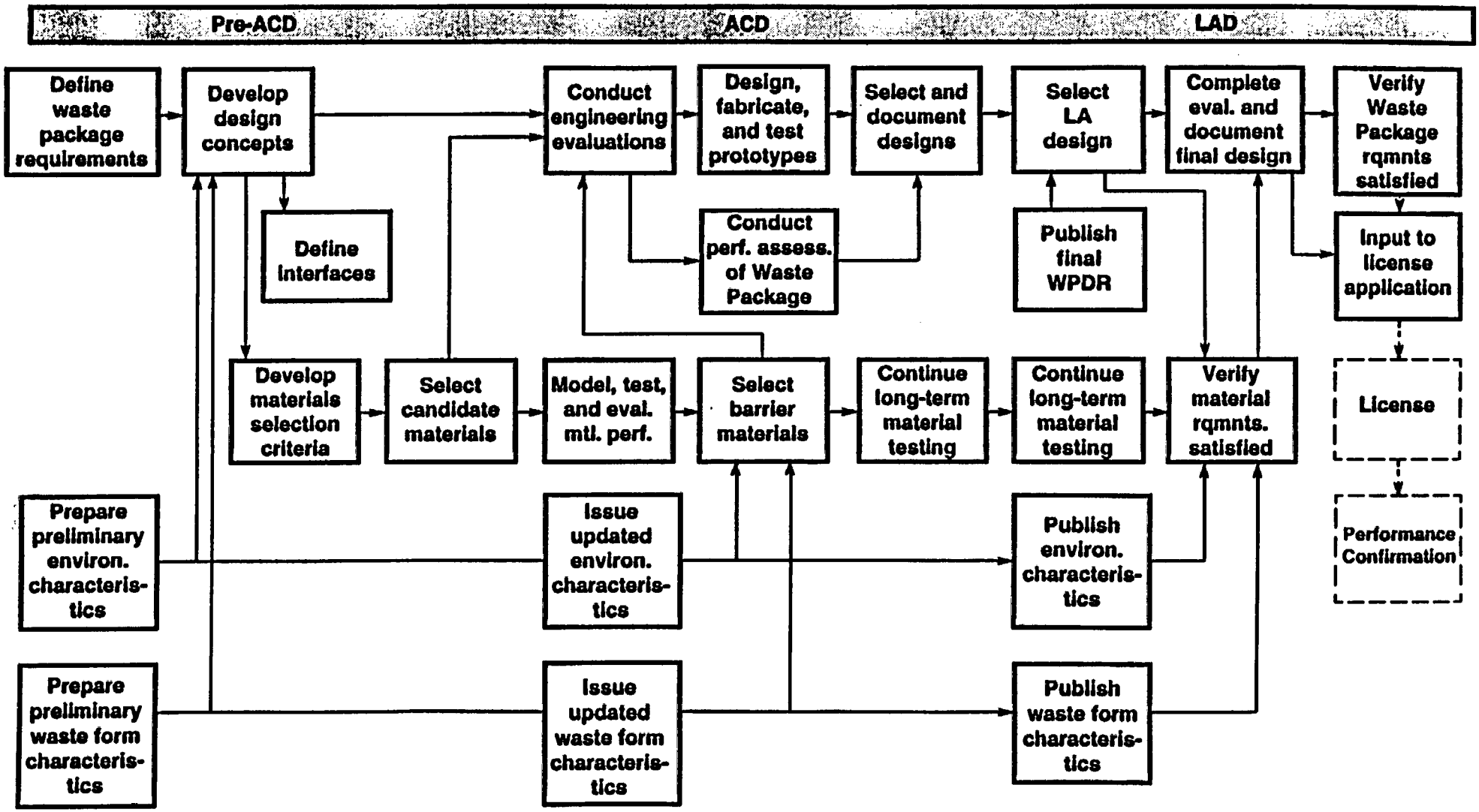
Current and Future Activities

- Complete Preliminary Design Basis
  - Environment, Waste Form, Materials Characterization Reports; Requirements Documents(s)
- Conduct waste form and metal barriers material studies
- Develop concepts for upcoming formal design phases
- Proceed with advanced conceptual design
  - Closely tied to site characterization and ESF

Design Activities During ACD Phase

- Evaluate design concepts for ACD based on analyses of
  - Containment capability
  - Radionuclide release performance
  - Thermal performance
  - Subcriticality margin
  - Handling and emplacement
  - Retrievability
  - Fabricability and structural integrity
  - Worker exposure

Waste Package Program



Preliminary Draft

U.S. DEPARTMENT OF ENERGY

OCRWM

YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/Engineered Barrier System Design Concepts

Waste Package Design Concepts

PRESENTED BY

Hugh A. Benton

Manager

Waste Package/EBS Development

M&O/Las Vegas, Nevada

August 24, 1993

Outline

- Description of design concepts
- Thermal loading impacts on design
- Thermal models
- Effects of fuel age
- Emplacement modes
- Criticality safety
- Radiation safety
- Shielding

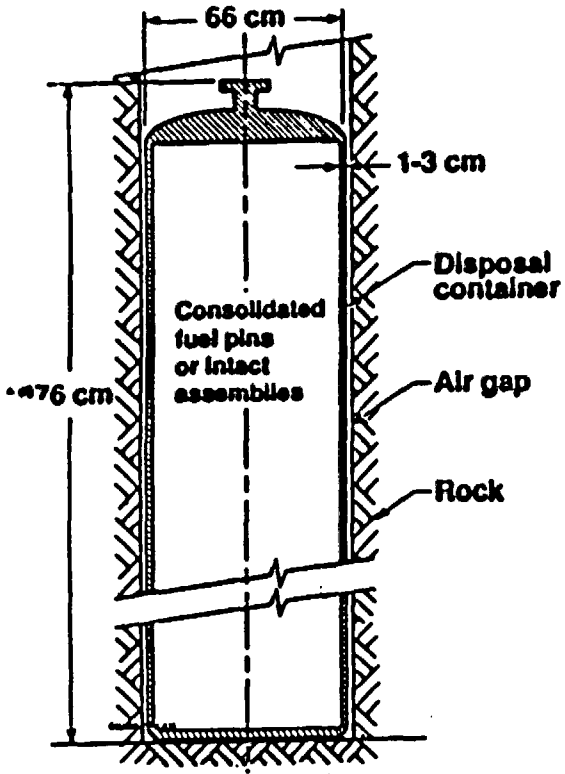
Waste Package
Advanced Conceptual Design Options

- Large metallic multi-barrier
  - Shielded
  - Partially shielded
- Small metallic multi-barrier
- Non-metallic multi-barrier
- Multi-purpose canister with overpack
- Multi-purpose unit
- SCP-CDR container

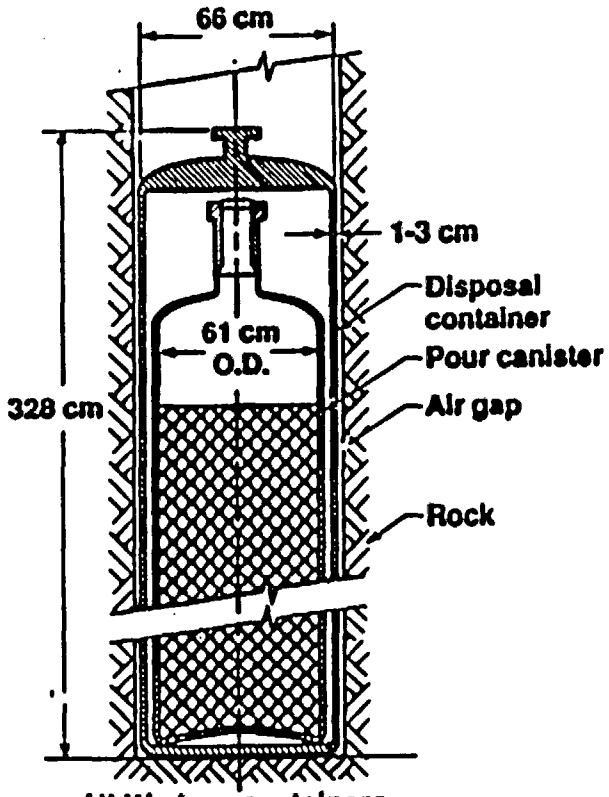
Waste Package Advanced Conceptual Design Options (Continued)

- High level waste glass canister with overpack
  - 1 Canister per waste package
  - 3 or 4 canisters per waste package

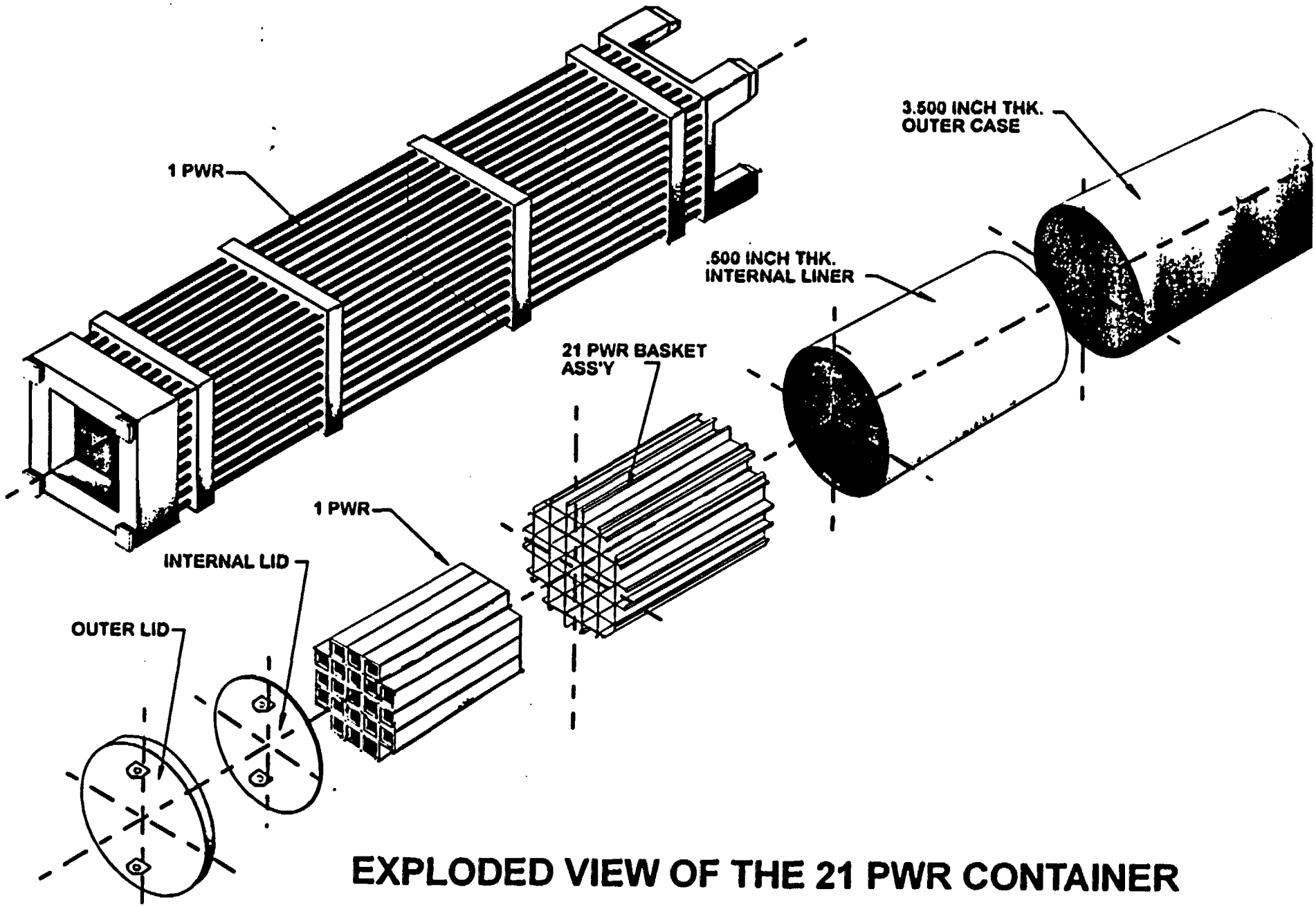
SCP Design



Spent fuel containers

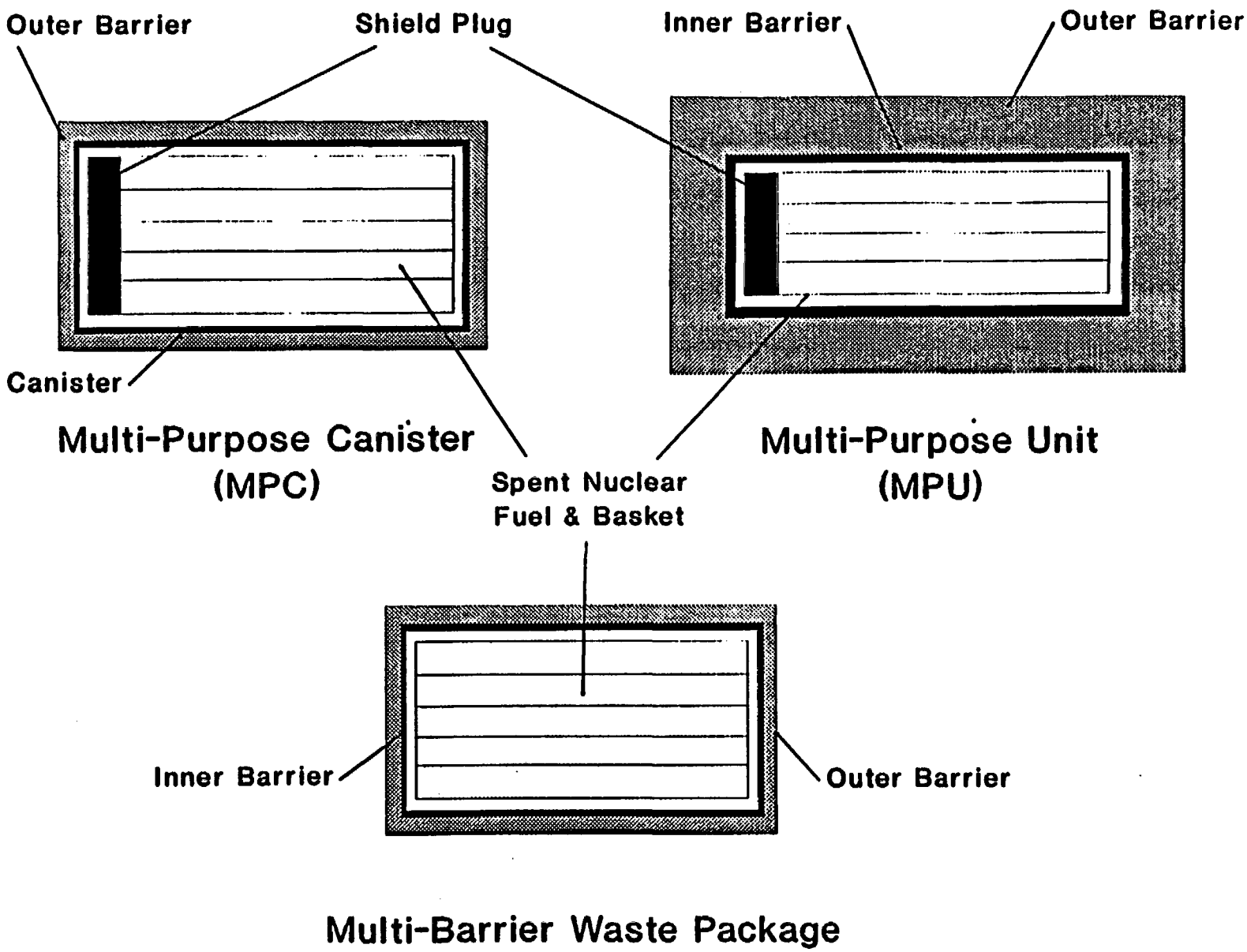


HLW glass containers

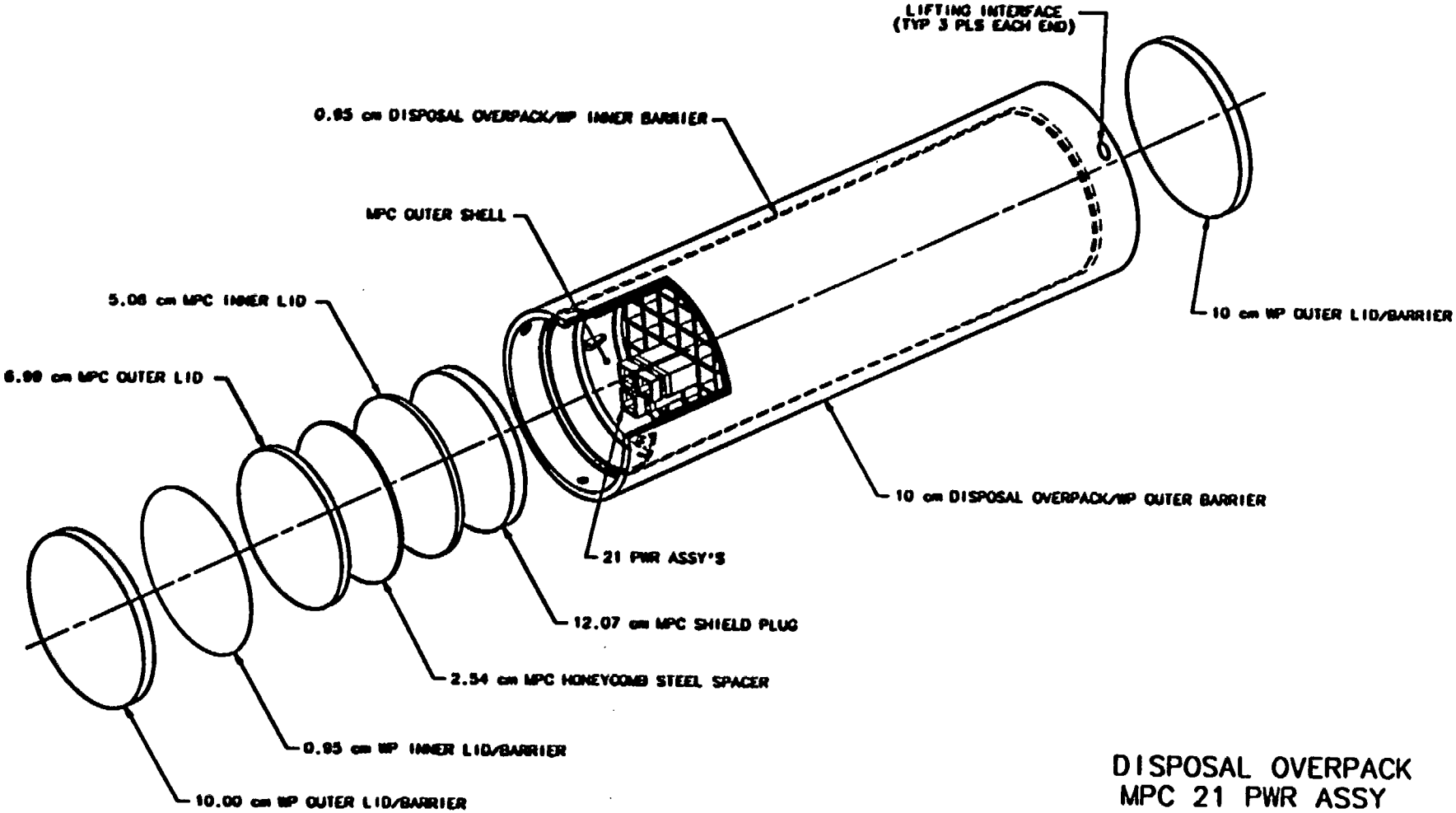


EXPLODED VIEW OF THE 21 PWR CONTAINER

Preliminary Draft



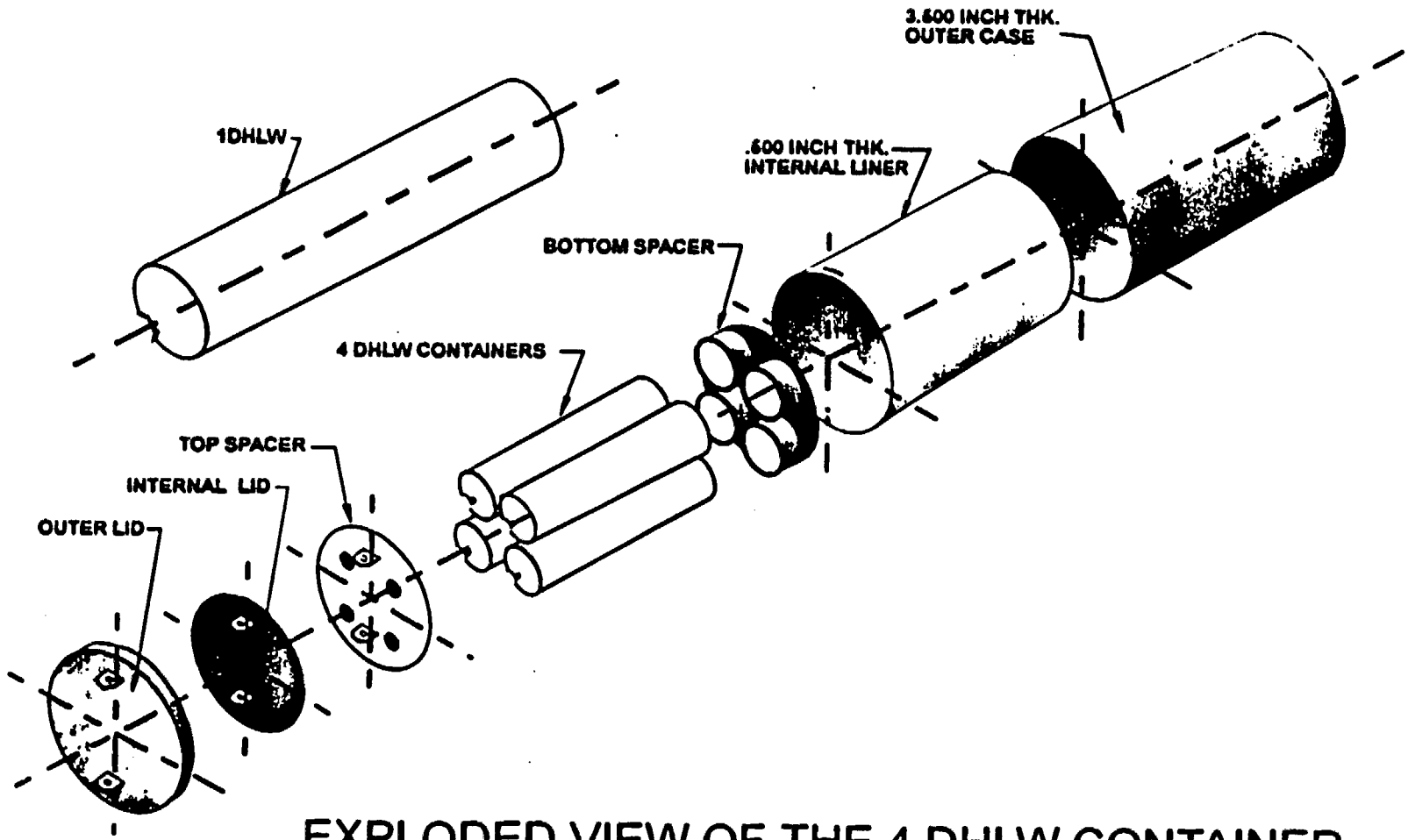
Preliminary Draft



DISPOSAL OVERPACK
MPC 21 PWR ASSY

Preliminary Draft

DEFENSE HIGH LEVEL WASTE
WASTE PACKAGE



EXPLODED VIEW OF THE 4 DHLW CONTAINER

4DHLW 122 CDR 4-23-93

Preliminary Draft

Thermal Loadings

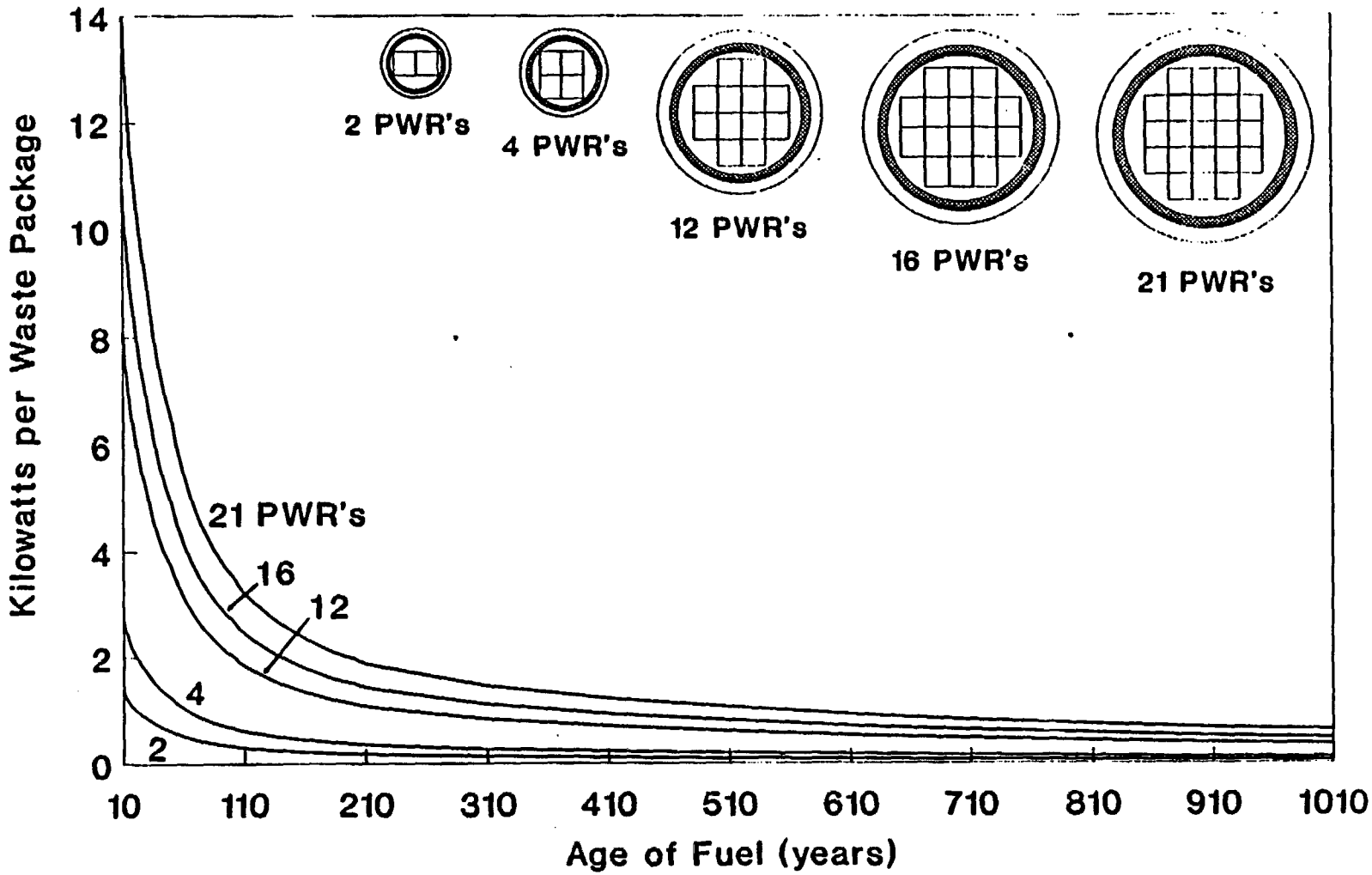
	Low Cold Repository	Medium High SCP - dry	High Extended dry
Waste Package Size	Small	Any	Any
Emplacement Mode	Any	Any	Drift
Full Range of MPC's	No	Yes	Yes
Emplaced Area	~ 2xSCP	SCP-1250acres	~1/2xSCP

Preliminary Draft

Factors Affecting Thermal Response of Disposal Device

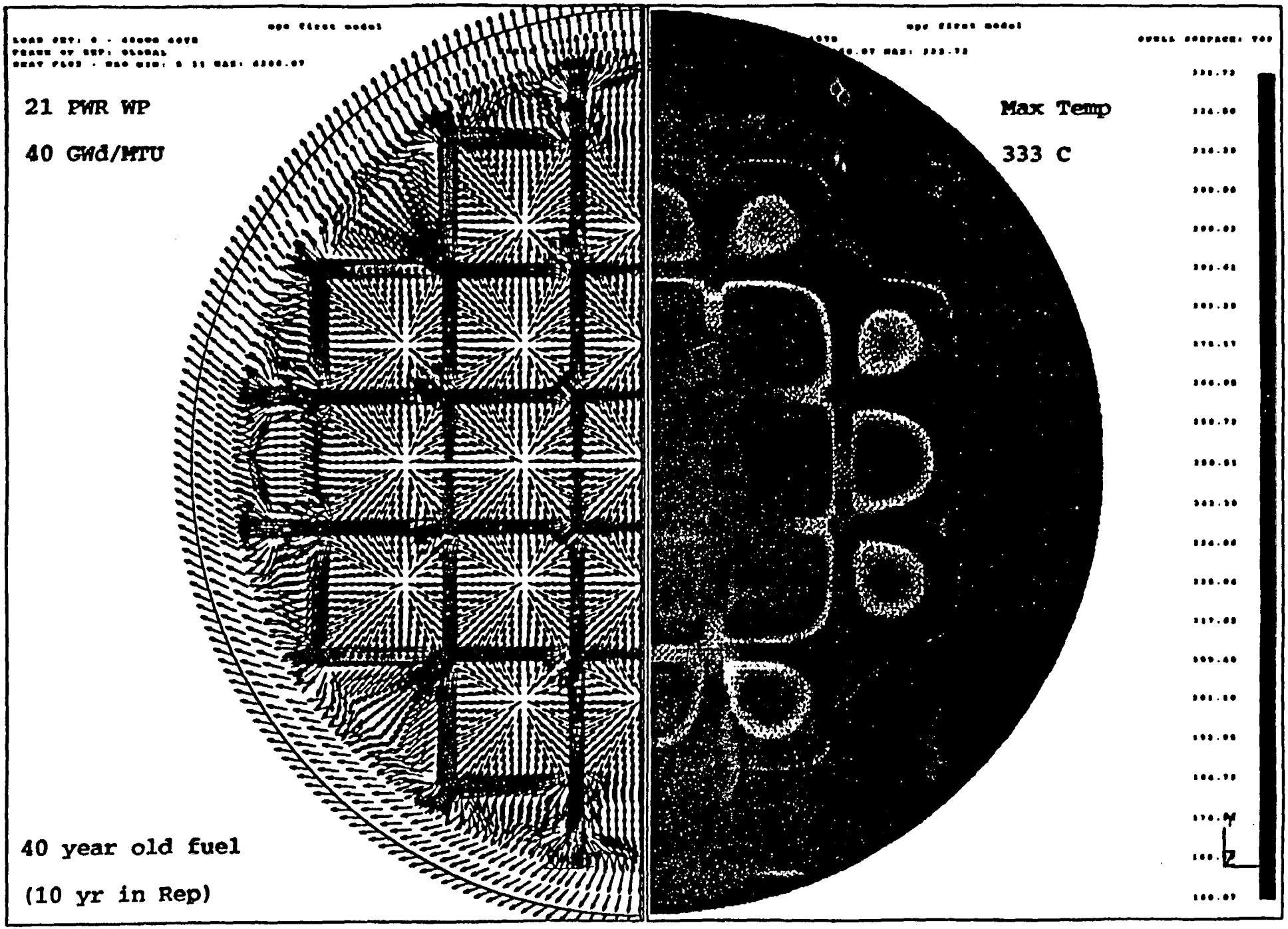
- Repository thermal loading, areal mass loading (AML)/areal power density (APD)
  - Drift size
  - Waste Package and drift spacing
  - Decay heat of spent nuclear fuel (SNF)
    - Time after discharge
    - Initial enrichment and burnup
    - Amount of SNF
- Materials of fabrication
- Design type
  - Flux trap
  - Burnup credit

Waste Package Heat Output



Burnup of 42.3 GWd/MTU

Preliminary Draft



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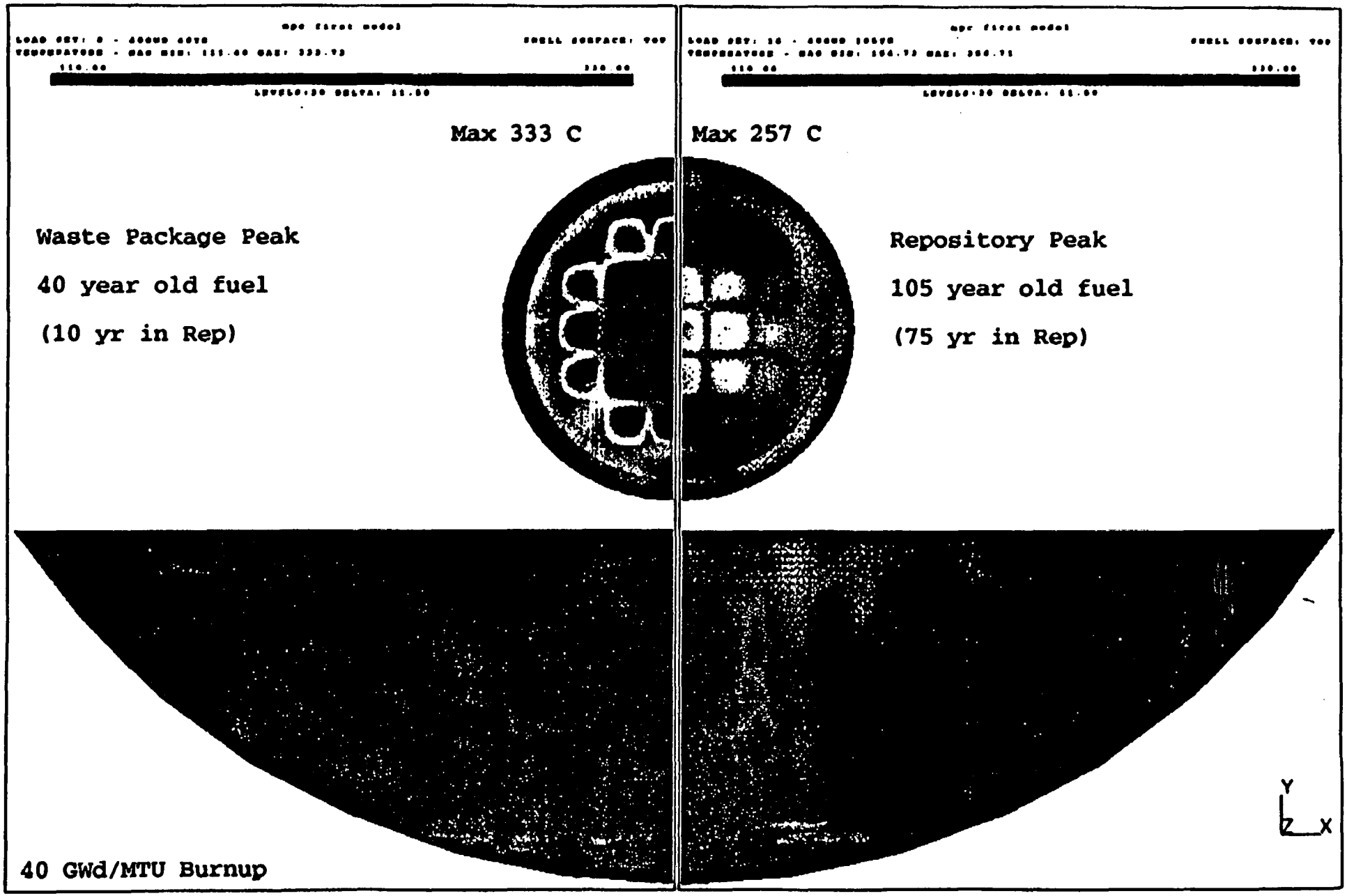
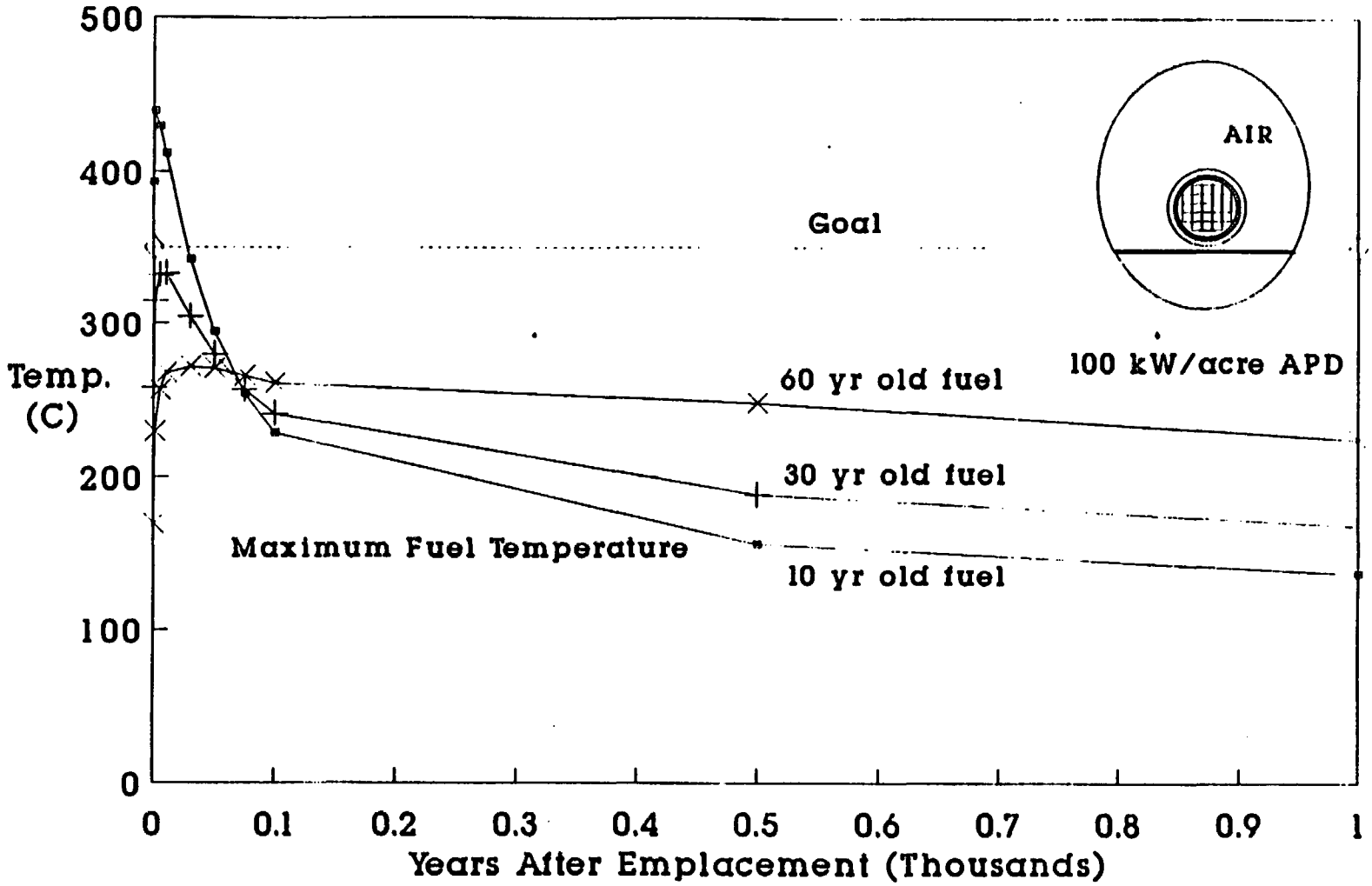


Preliminary Draft

Effect of Age at Emplacement

21 PWR at 40 GWd burnup

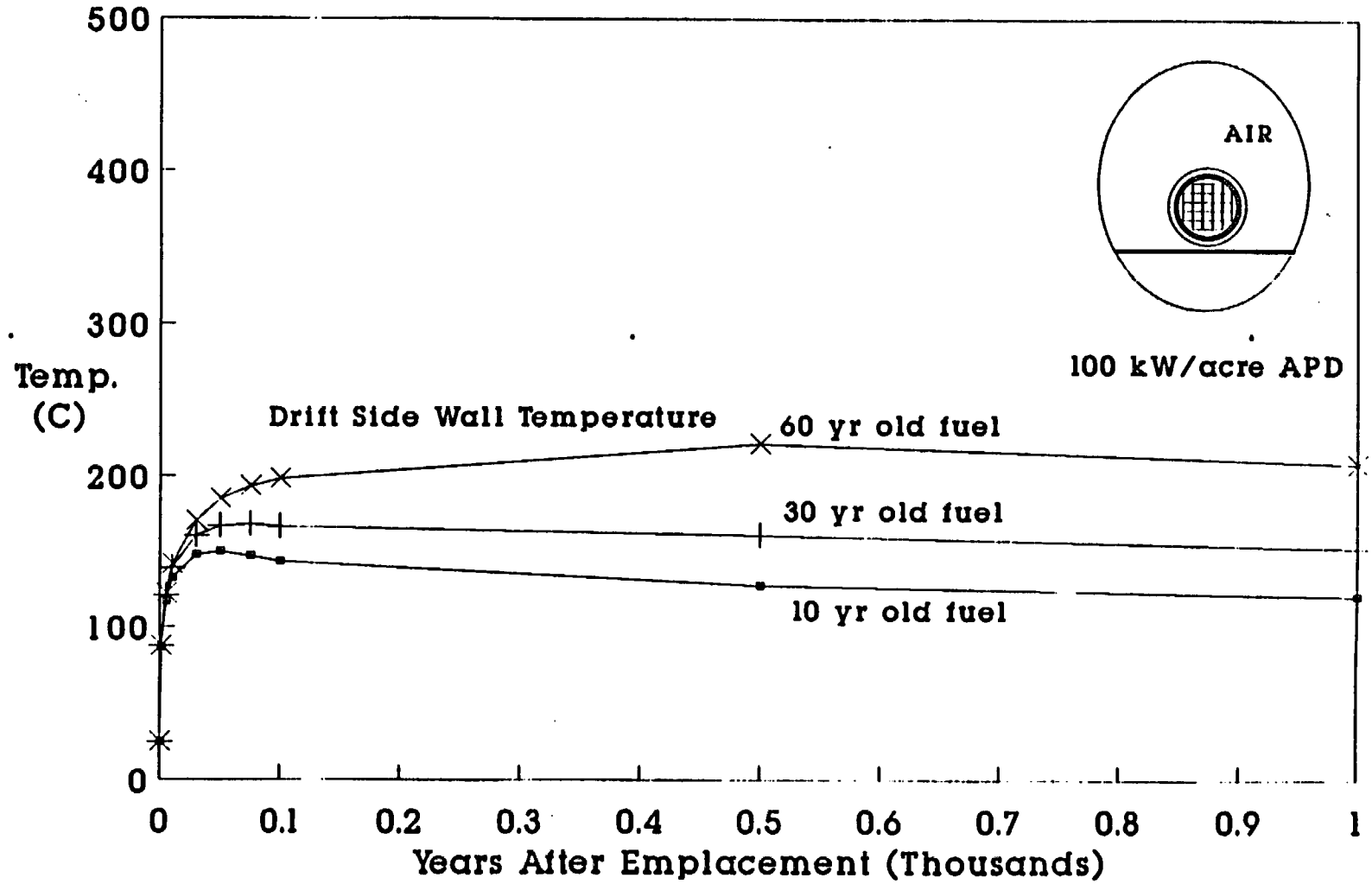


27ft dia drift

Preliminary Draft

Effect of Age at Emplacement

21 PWR at 40 GWd burnup



27ft dia drift

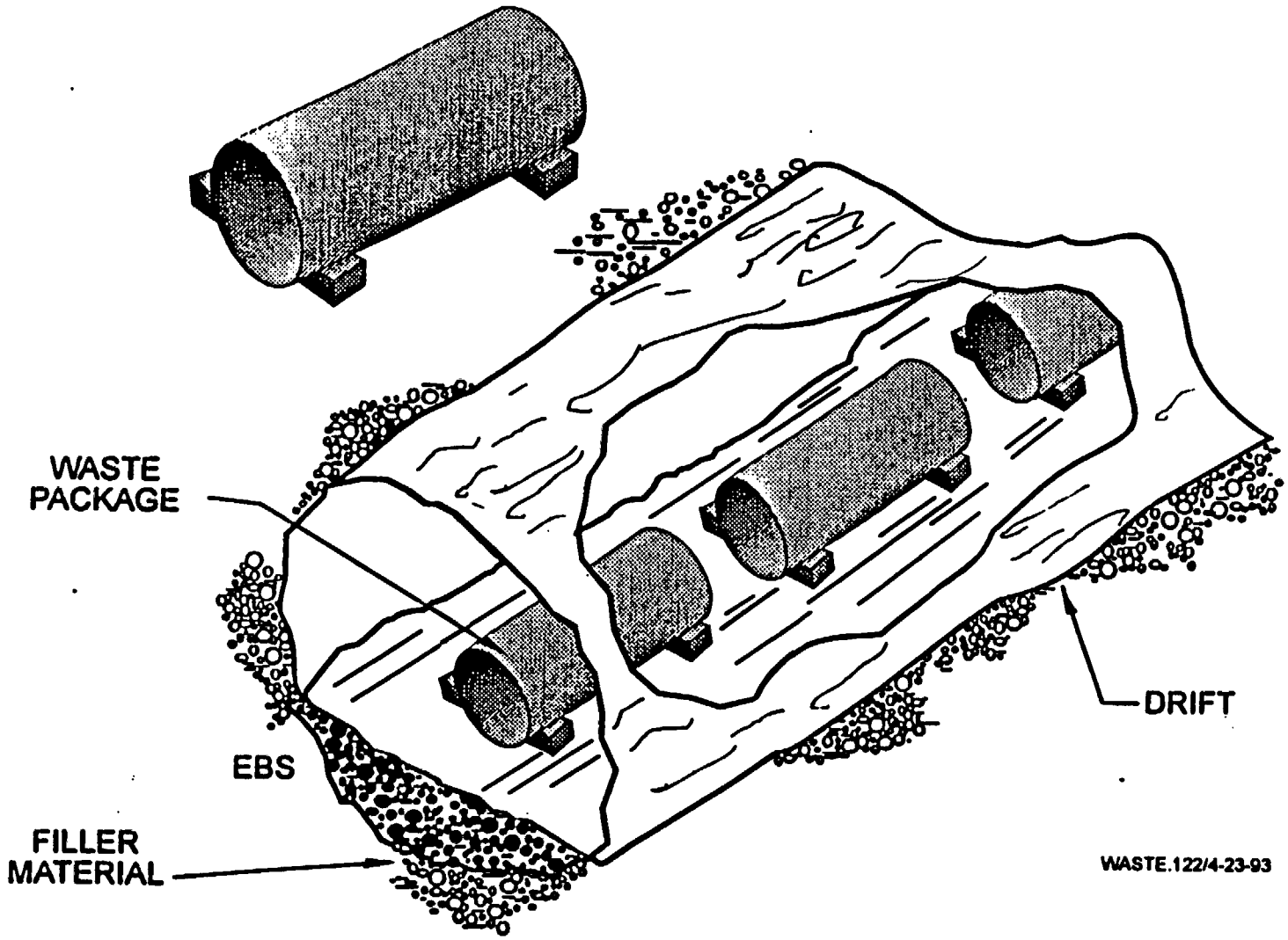
Preliminary Draft

Emplacement Modes

	Vertical Borehole	Short Horizontal Borehole	Long Horizontal Borehole	Drift
Waste Package Size	Small	Any	Any	Any
Heat transfer from Container	Poor	Poor	Poorest	Better as drift dia. increased
Emplacement drift air temperature in first 10 years (without ventilation)	High	High	Lower	Higher
Emplacement drift radiation levels (without shielding)	Low	Low	Lowest	Higher

Preliminary Draft

Drift-Emplaced Waste Package



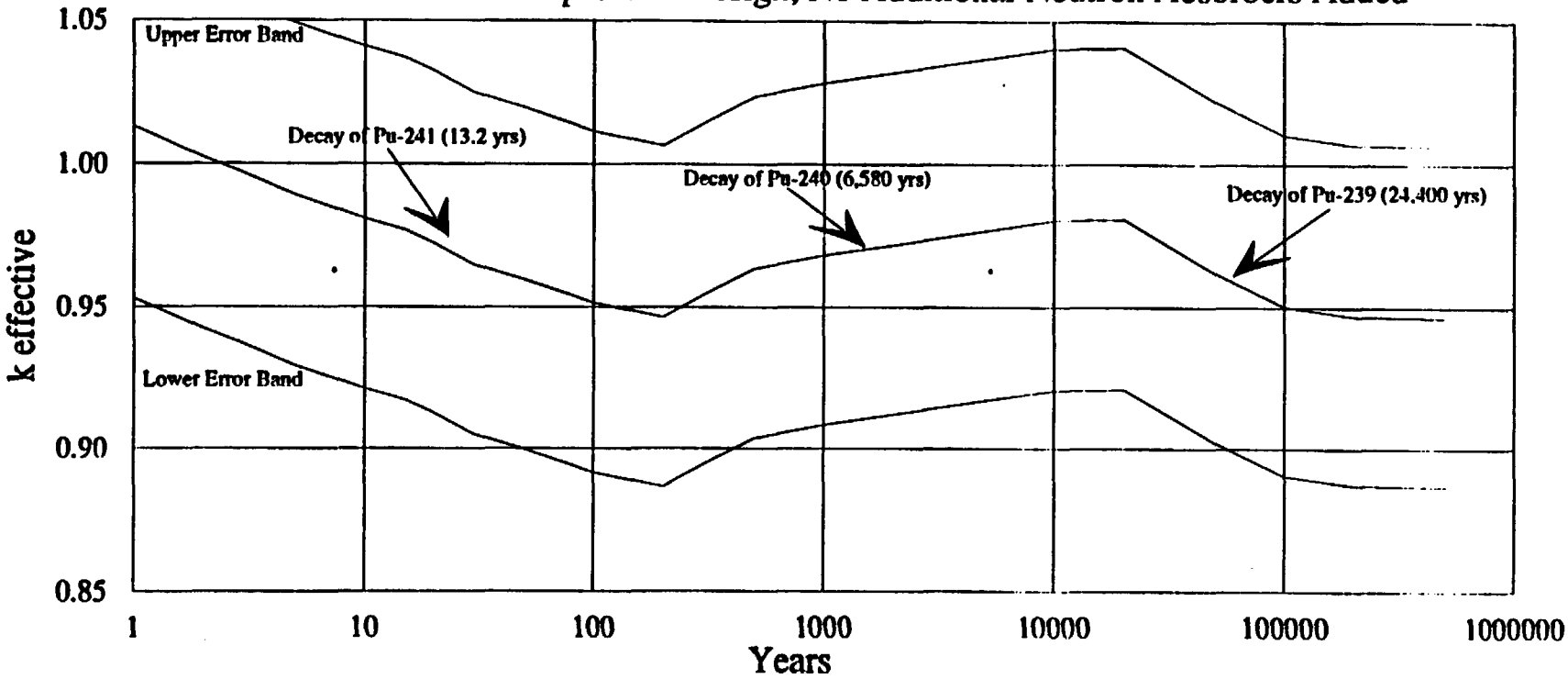
Criticality Safety

- Criticality accident not possible unless 2 unlikely, independent, and concurrent or sequential changes have occurred
- Each system designed for criticality safety under normal and accident conditions
- $K_{(eff)} \leq 0.95$ after allowing for
  - bias in method of calculation
  - uncertainty in experiments validating method

10 CFR 60.131(b)(7)

Time Effects On Criticality

21 PWR MPC Burnup Credit Design, No Additional Neutron Absorbers Added

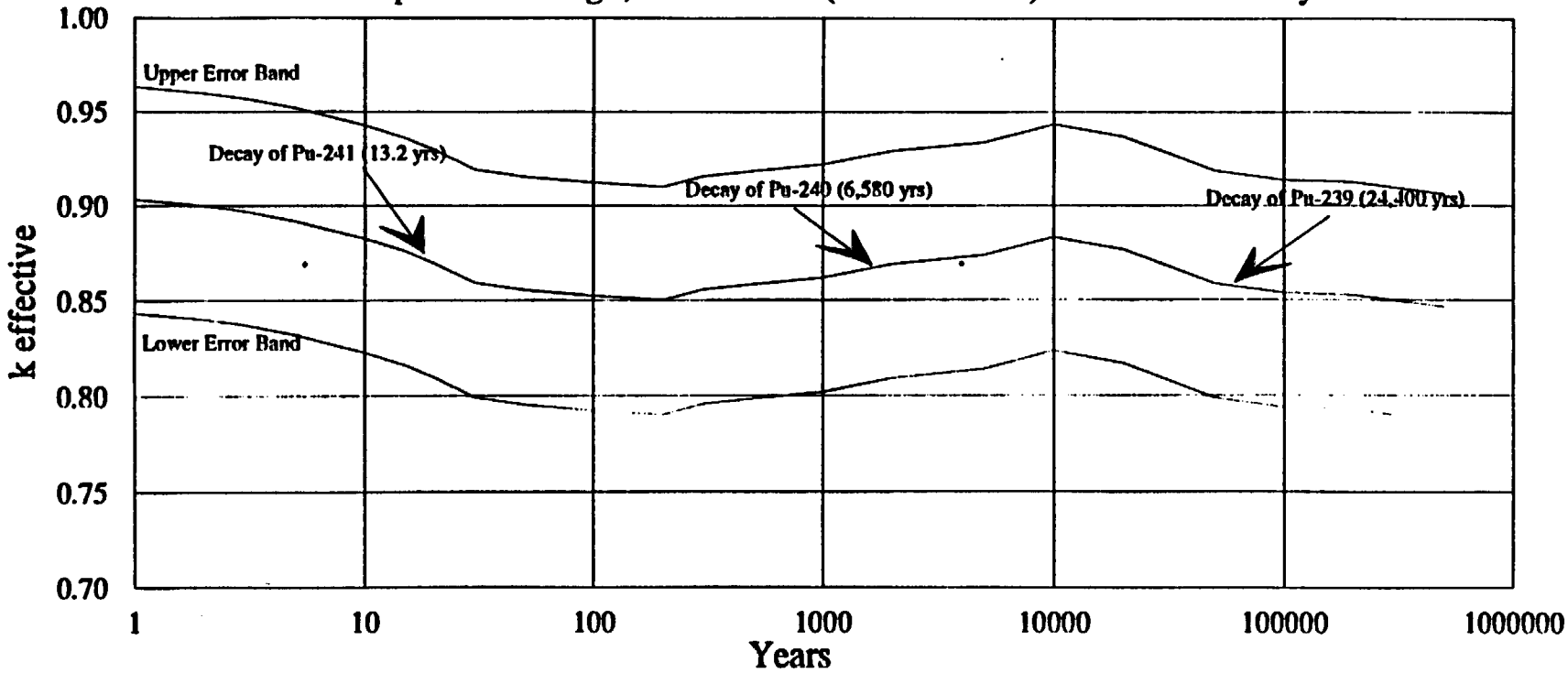


Fuel Type and Characteristics: BWFC 15 by 15, 20 GWD/MTU, 3.00% Initial Enrichment U-235

Preliminary Draft

Time Effects On Criticality

21 PWR MPC Burnup Credit Design, 4.5% Boron (0.972% B-10) in Al-B Criticality Control Material



Fuel Type and Characteristics: BWFC 15 by 15, 20 GWD/MTU, 3.00% Initial Enrichment U-235

Preliminary Draft

Radiation Protection

- Annual Work Hours: 2000 hours
- Annual Work Days: 250 days
- Annual Dose Limit: 5 rems
- DOE Administrative Control Level 2 rems
- Design Dose Rates at 2 meters:

  20 mrem/hr (1 hour per day for 250 days per year)
  2.5 mrem/hr (8 hours per day for 2000 hours per year)

Radiation Protection

- Maintain radiation doses, levels, concentrations of radioactive material in air in restricted areas below
  - 5 rems (0.05 Sv) per year or
  - 50 rems (0.5 Sv) total dose to any organ or tissue other than lens of the eye
- Which ever is more limiting

10 CFR 60.131(a)
10 CFR 20.1201(a)(1)(i) & (ii)

Radiation Safety - Shielding

Two strategies to meet target dose rates

- Fully shielding disposal overpack
  - Advantages
    - Intrinsic shielding available
  - Disadvantages
    - Shield useful small fraction of Waste Package's lifetime - 50 years of 1,000 to 10,000 year lifetime
      - Extra weight of shield materials
      - 21 PWR metallic multi-barrier Waste Package

Corrosion Barrier:	47 tonne (10cm)
Fully Shielded:	175 tonne (45cm)

Preliminary Draft

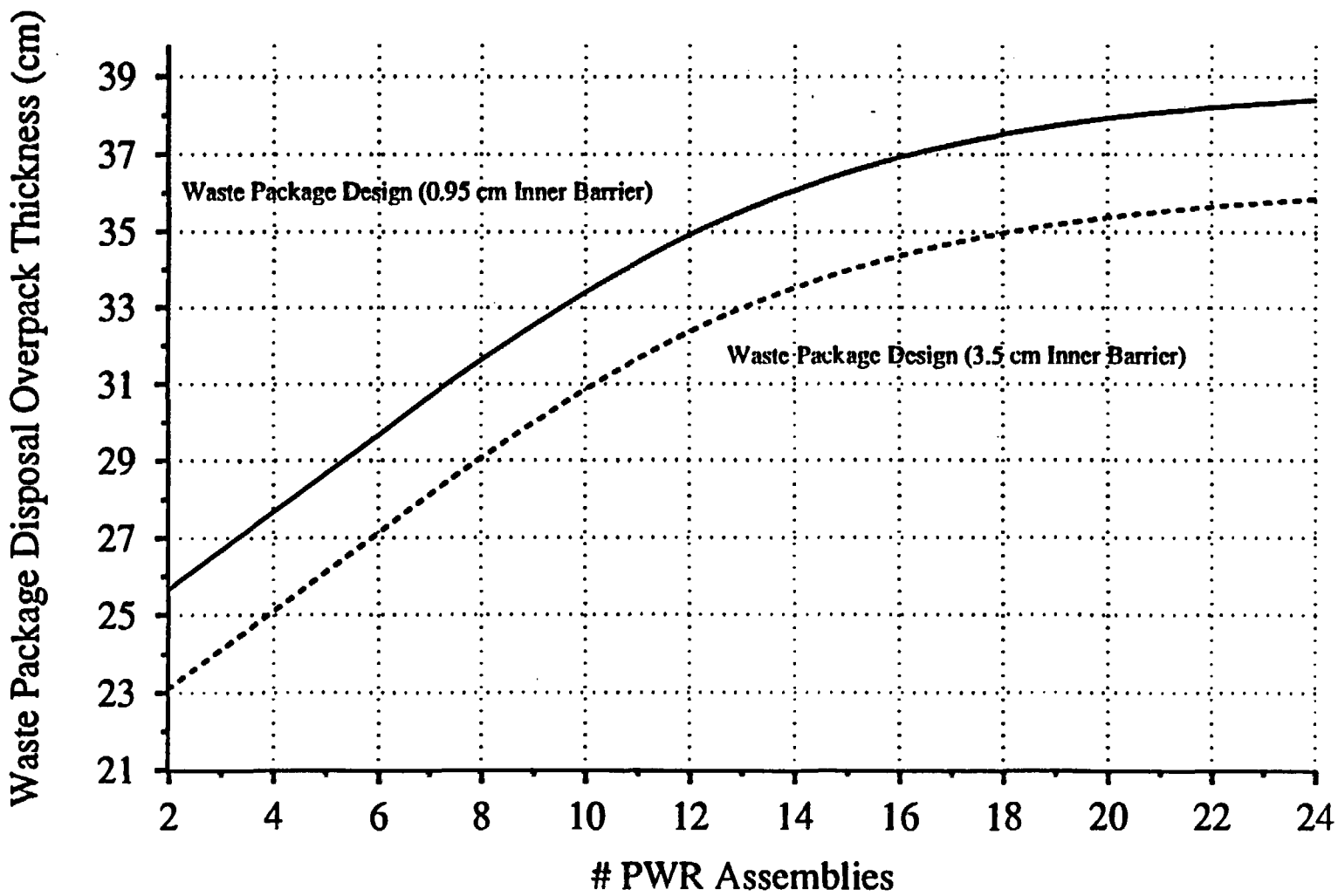
Radiation Safety - Shielding
(Continued)

- Emplacement transporter/shadow shielding
  - Advantages
    - Shields are reusable
    - Use of non-disposable shield materials allowed

      Less Weight

      Less Material
  - Disadvantage
    - No Intrinsic shielding

      Shadow shielding must be used for access



Preliminary Draft

Summary

Advanced Conceptual Design proceeding in accordance with Waste Package Plan (Revised) and Waste Package Implementation Plan

Test program will provide the scientific basis for Waste Package design

Conceptual designs will be developed and changed in response to test data and performance analysis

U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/Engineered Barrier System Design Concepts

Materials Testing and Selection

PRESENTED BY

Robert L. Fish

Manager

Waste Package Materials

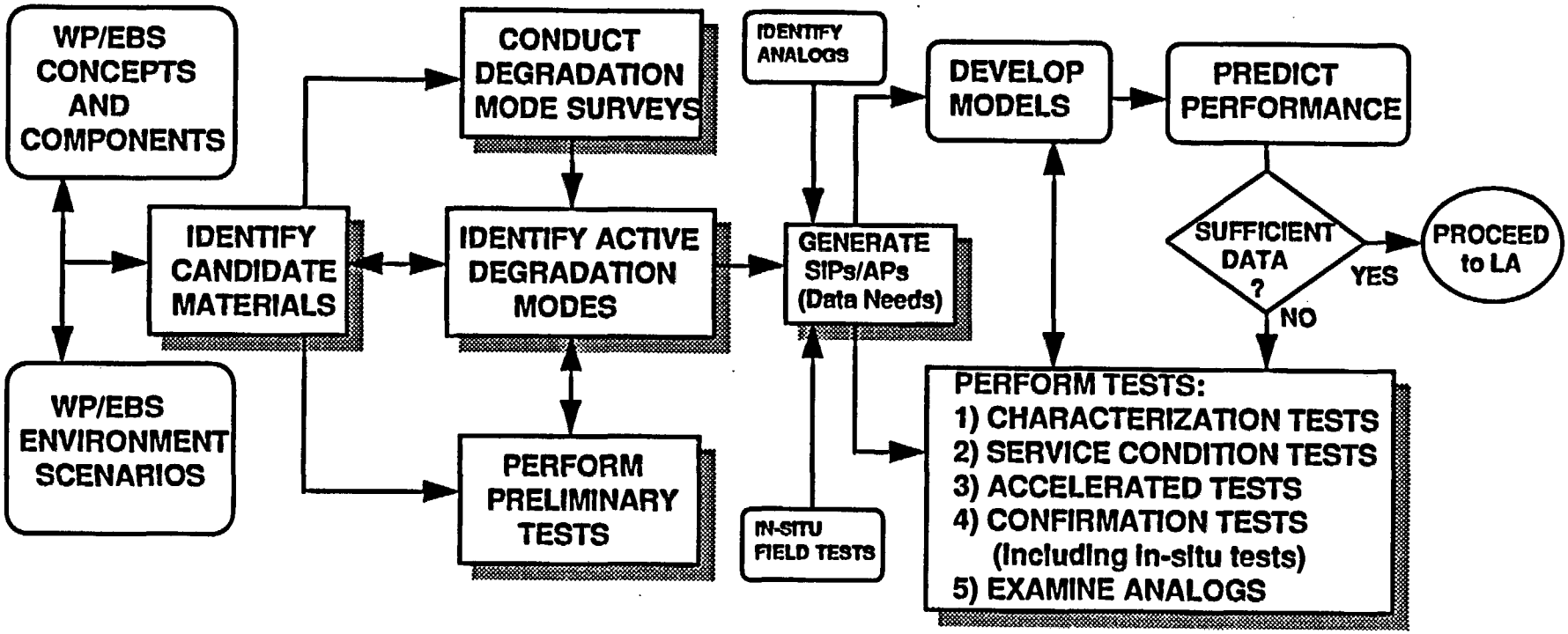
M&O/Las Vegas, Nevada

August 24, 1993

Outline

- Waste package materials test strategy
- Materials testing technical approach
- Materials selection process

Waste Package Materials Test Strategy



Containment Barrier Materials Testing Technical Approach

- Define functions of barrier (What)
- Identify performance measures (How well)
- Determine potential degradation modes (Related to PM's)
- Identify performance parameters (Measurements of degradation)

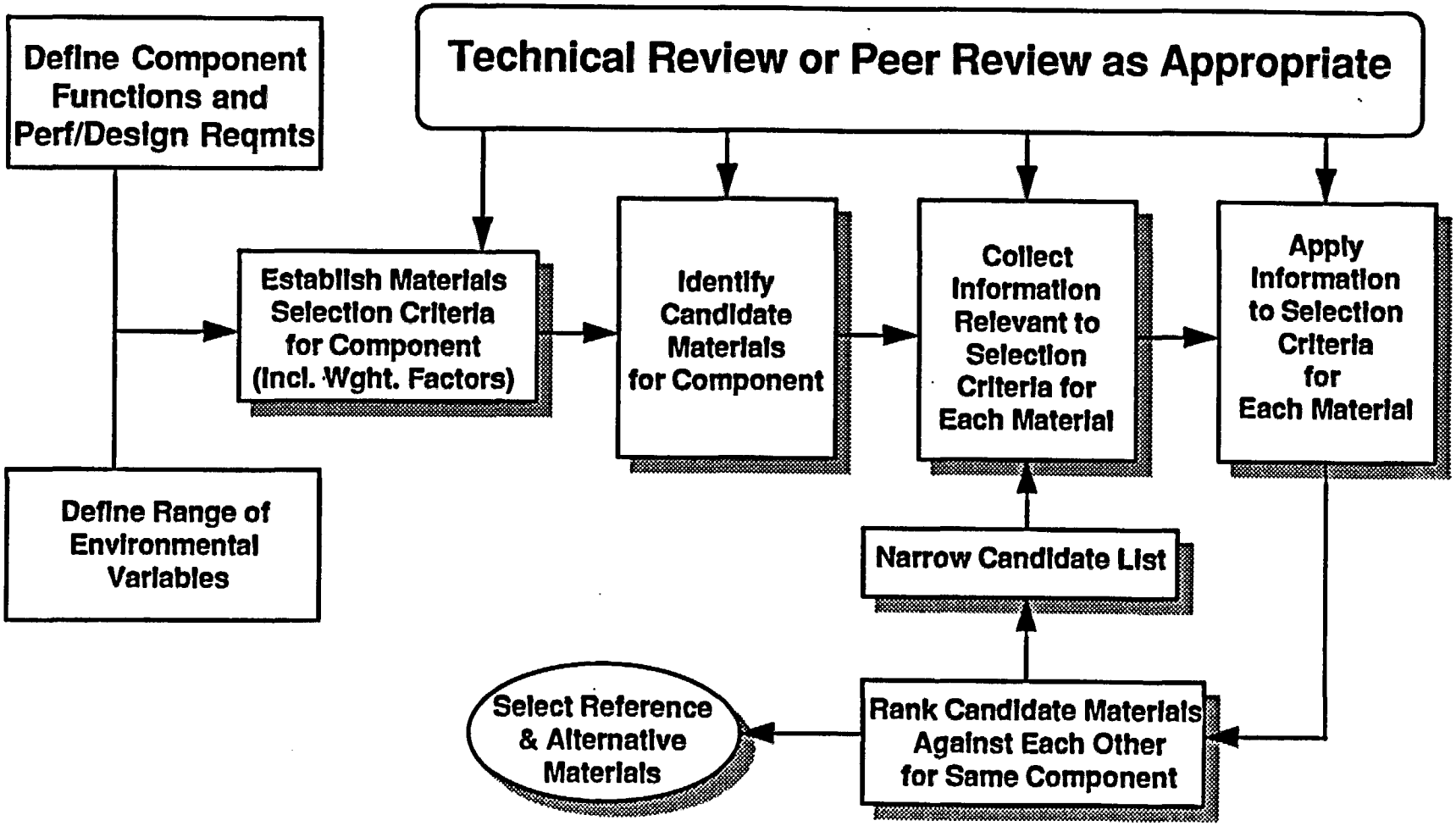
↓

Test Descriptions
Scientific Investigation Plan
Activity Plans

Technical Approach for Waste Package Container Materials Testing

Function of Container	Performance Measure	Degradation Mode	Performance Parameter
• Contain Radionuclides	• Fraction of containers breached	• Metallurgical instability (incl. weld & heat-affected zone) • Low-temperature oxidation • General aqueous corrosion • Microbiologically influenced corrosion (MIC) • Crevice corrosion • Pitting corrosion • Environmentally assisted cracking • Mechanical instability	• Phase transformations • Oxidation rates • General corrosion rates • MIC rates • Penetration rates • E_{crit} for pitting • E_{prot} for pitting • E_{corr} (open circuit) • Pit penetration rates • Crack propagation rates • Threshold stress intensity factors • Tensile properties • Creep properties • Fracture toughness (J_{IC})
• Limit radionuclide egress after container breach	• Release rate of radionuclides from containers	• Diffusion through corrosion products • Transport through cracks	• Diffusion coefficients of RNs in corrosion products • Diffusion coefficients of RNs in ground water • Crack geometry

WASTE PACKAGE MATERIALS SELECTION PROCESS



General Status of Materials Selection

- Candidate materials identified for thin-walled corrosion resistant container
- Additional information being collected (tests) on corrosion resistant materials
- Degradation mode survey and test initiation for iron-base/ materials
- Range of environments being defined for multi-barrier concept components
- Component functions, performance and design requirements being defined for multi-barrier design concept

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/ Engineered Barrier System Design Concepts

STATUS OF DOE TESTING EFFORT RELATIVE TO SUBSTANTIALLY COMPLETE CONTAINMENT

R. Daniel McCright
LLNL

Bethesda, MD

August 24, 1993

Outline of Presentation

- Design implications on materials - configuration and thermal
  - corrosion allowance and corrosion resistant materials
- Materials testing/selection for SCP design
- Multi-barrier concepts — materials testing and evaluation
- Summary

Design Implications on Materials

Waste Package Configuration Features Relevant to Materials Selection and Evaluation

- Single vs. multiple barrier
- Corrosion allowance vs. corrosion resistant metals/alloys
- Radiolytic shielded vs. non-shielded (thick vs. thin)
- All metal vs. metal/ceramic
- Packing materials vs. air gap
- Filler materials vs. empty space

Comparison of Corrosion Allowance vs. Corrosion Resistant Materials

Corrosion Allowance	Corrosion Resistant
• Moderate to high general aqueous corrosion rate	• Very low general aqueous corrosion rate
• Corrosion products offer little or modest protection	• Either noble metal, or protected by adherent, coherent passive film
• Localization effects handled as multiplying factor of general rate	• When attacked, corrosion is highly localized
• Degradation mode is known	• Degradation mode is stochastic
• Performance prediction is fairly easy	• Performance prediction is more problematic; may have long induction time
• Usually use in thick sections	• Usually use in thin sections
• Design for "wastage" of lost material	• Design to keep localized corrosion at a very low probability
• Examples: carbon and alloy steel, cast iron, copper and copper-base alloys (in some cases)	• Examples: stainless steels, nickel-base alloys, titanium, copper and copper-base alloys (in some cases)

YMP is Revisiting Thermal Limitations in 1988 Site Characterization Plan (SCP)

- Higher thermal loads offer advantages
  - extended dry conditions — higher confidence in longer containment period
  - larger, more robust, but fewer waste packages — occupy less space in Yucca Mountain
  - in-drift emplacement — savings in amount of excavation
- Must consider geologic, geochemical, hydrologic implications of high thermal loads
- Major discussion on thermal loading at NWTRB meeting — July 1993

Container Material Responses Categorized into Hydrothermal Regimes

	Container Surface Temperature		
	30-60°C*	60-120°C*	120-300°C*
Dry <70% relative humidity*	low temperature oxidation	low temperature oxidation	low temperature oxidation metallurgical changes
Wet	general corrosion localized corrosion stress corrosion	general corrosion localized corrosion stress corrosion	not applicable
		usually more serious localized and stress corrosion	
		"cold" repository	*SCP thermal strategy* / *Extended dry thermal strategy*

- Rather arbitrary boundaries between thermal regimes
- Quantity and quality of water contacting container determine attack severity

*approximate

Materials Testing/Selection for SCP Design

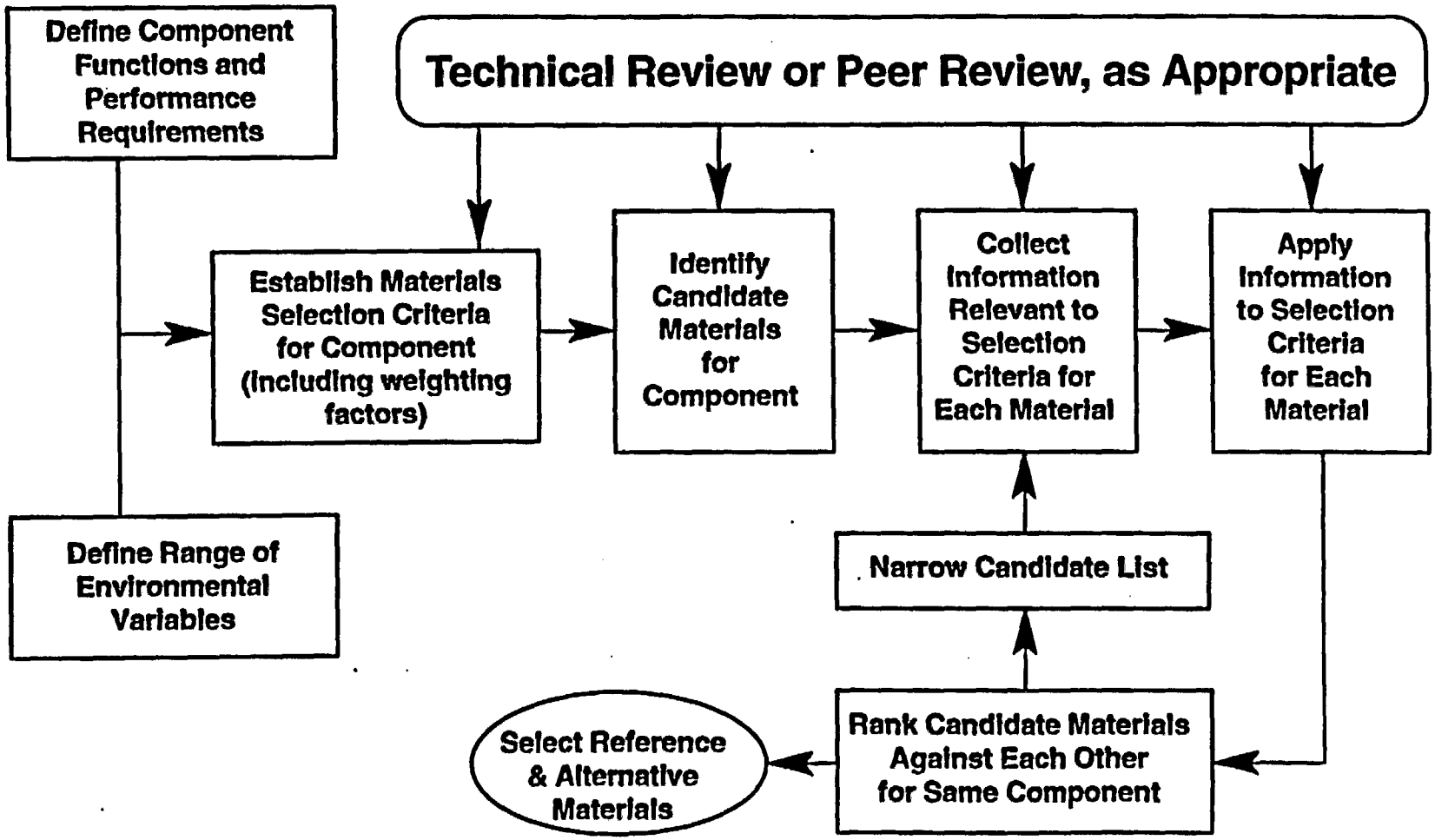
Features of the SCP Waste Package Conceptual Design (1991)

- Single metal barrier (approximately 1-3 cm thick) functions as the disposal container
- Disposal container surrounds spent fuel assemblies or vitrified waste in stainless steel pour canister
- Not radiation shielded
- Vertical emplacement in boreholes
- No packing material
- Peak disposal container temperatures

  ~ 220°C (spent fuel packages)

  ~ 140°C (vitrified waste packages)

Waste-Package Materials Selection Process



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Container Material Selection Process for SCP Conceptual Design

- Selection process
  - Performance considerations (corrosion, compatibility, mechanical properties)
  - Engineering considerations (fabricability, cost, experience base)
- Recommended materials
  - Nickel-rich Alloy 825 (UNS N08825)
  - Nickel-base Alloy C-4 (UNS N06455)
  - Titanium Grade 12 (UNS R53400)

Multi-barrier Concepts

One Multiple-Barrier Waste-Package Design Concept is a Corrosion-Resistant Container Overpacked with a Corrosion-Allowance Material

- **Example:** Alloy 825 inner barrier, carbon steel outer barrier

- **Principle:** Outer barrier slowly oxidizes and if wet, corrodes to protect inner barrier.

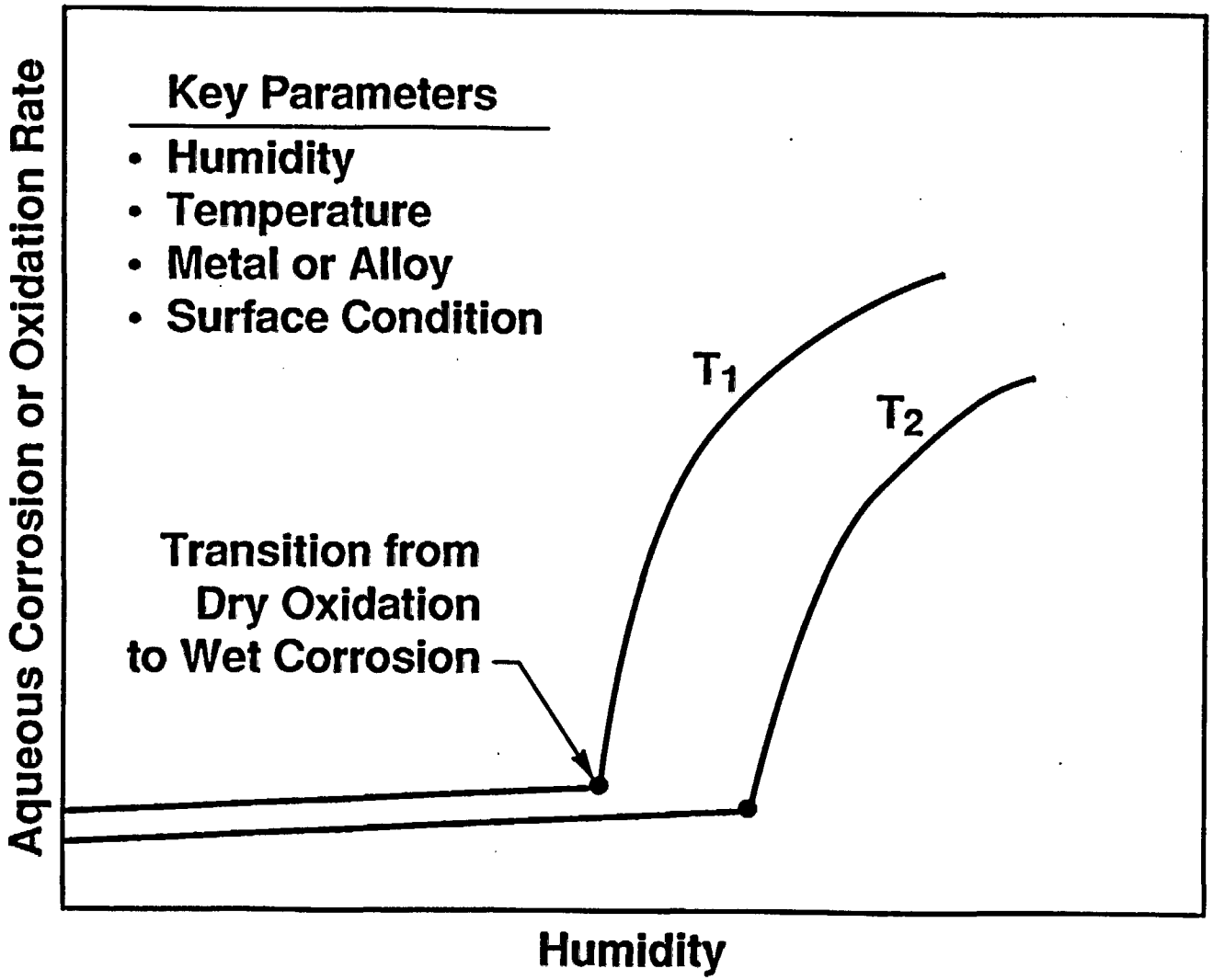
  As long as some steel remains, inner barrier is galvanically protected in a wet environment.

  Eventually, inner barrier "stands on its own" when steel is consumed.

Performance of Steel Barrier is Very Sensitive to Moisture

- Oxidation of carbon steel is slow
  - Extrapolations from high temperature data indicate rates of 0.002-0.1 μm/yr in repository thermal environment
  - Thick overpack would endure for more than 10,000 years
- Aqueous corrosion of carbon steel is more rapid
  - Measured rates of 0.01-0.5 mm/yr
  - Localized corrosion factor (2-4 times general corrosion rate)
  - Carbon steel overpack could be penetrated in several decades to several centuries, if wet

Atmospheric Exposure of Metals Indicates Transition from Oxidation to Aqueous (Wet) Corrosion



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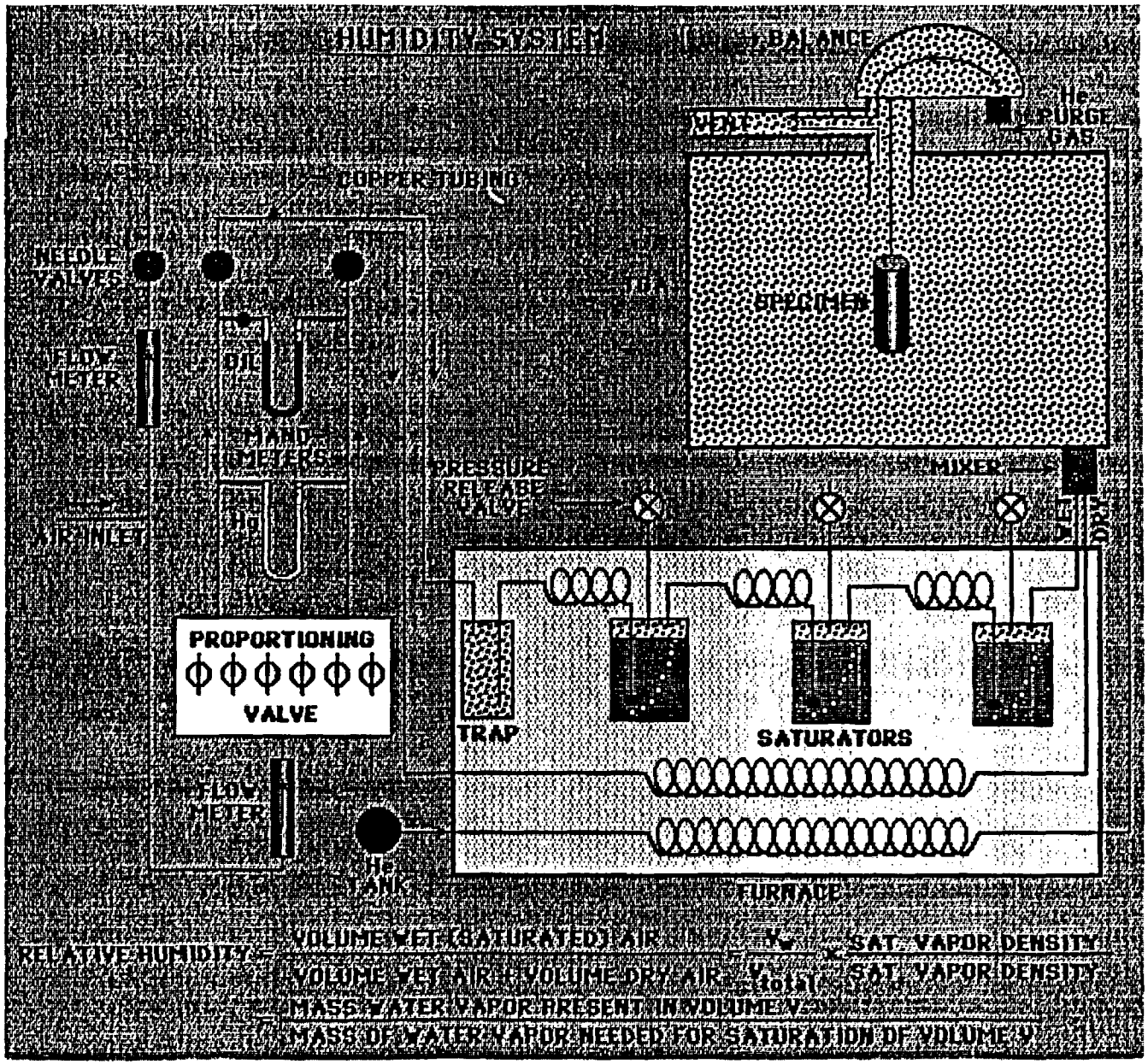
Color Schematic of Humidity System



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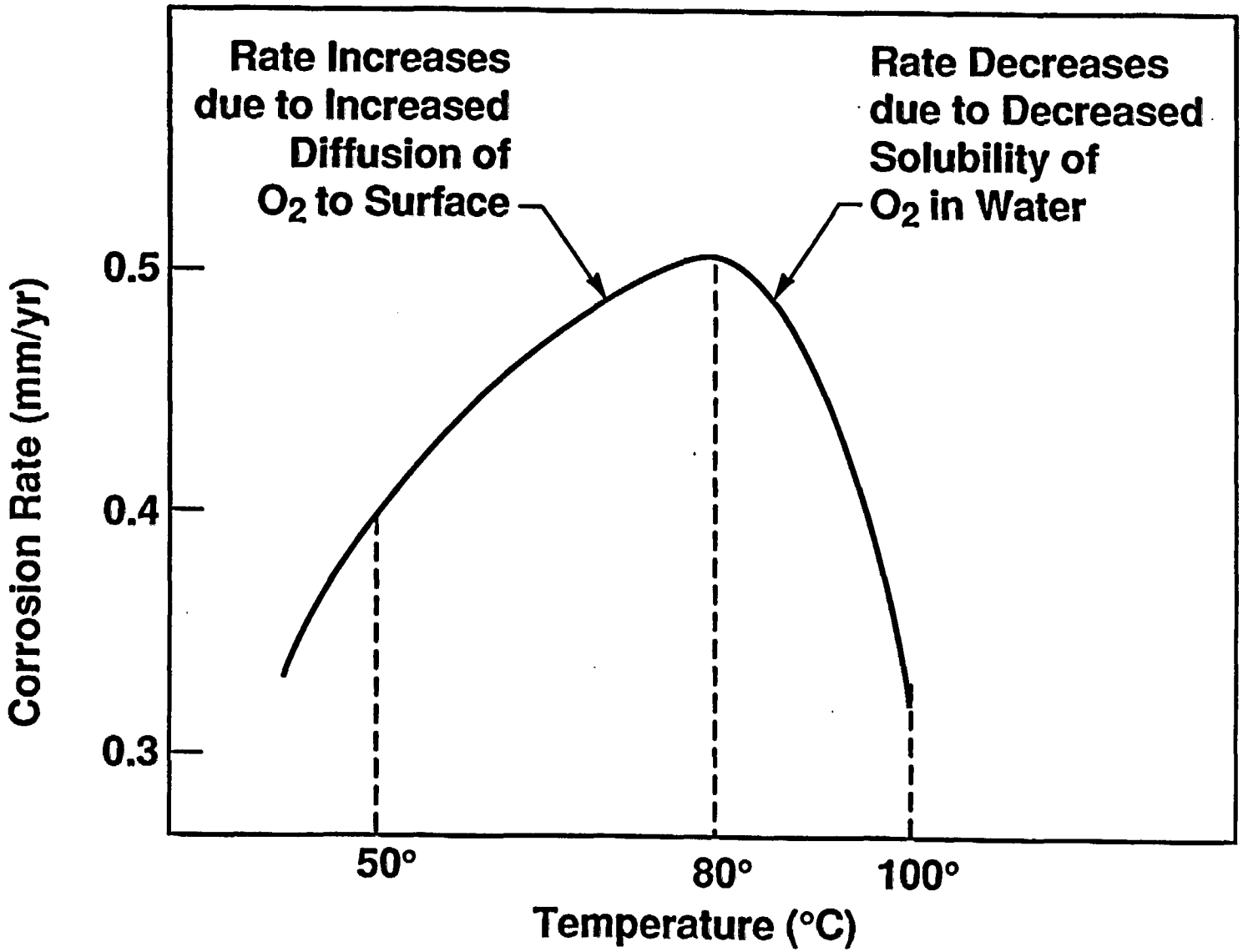
Corrosion of Carbon Steel in Neutral-pH Water Shows a Maximum



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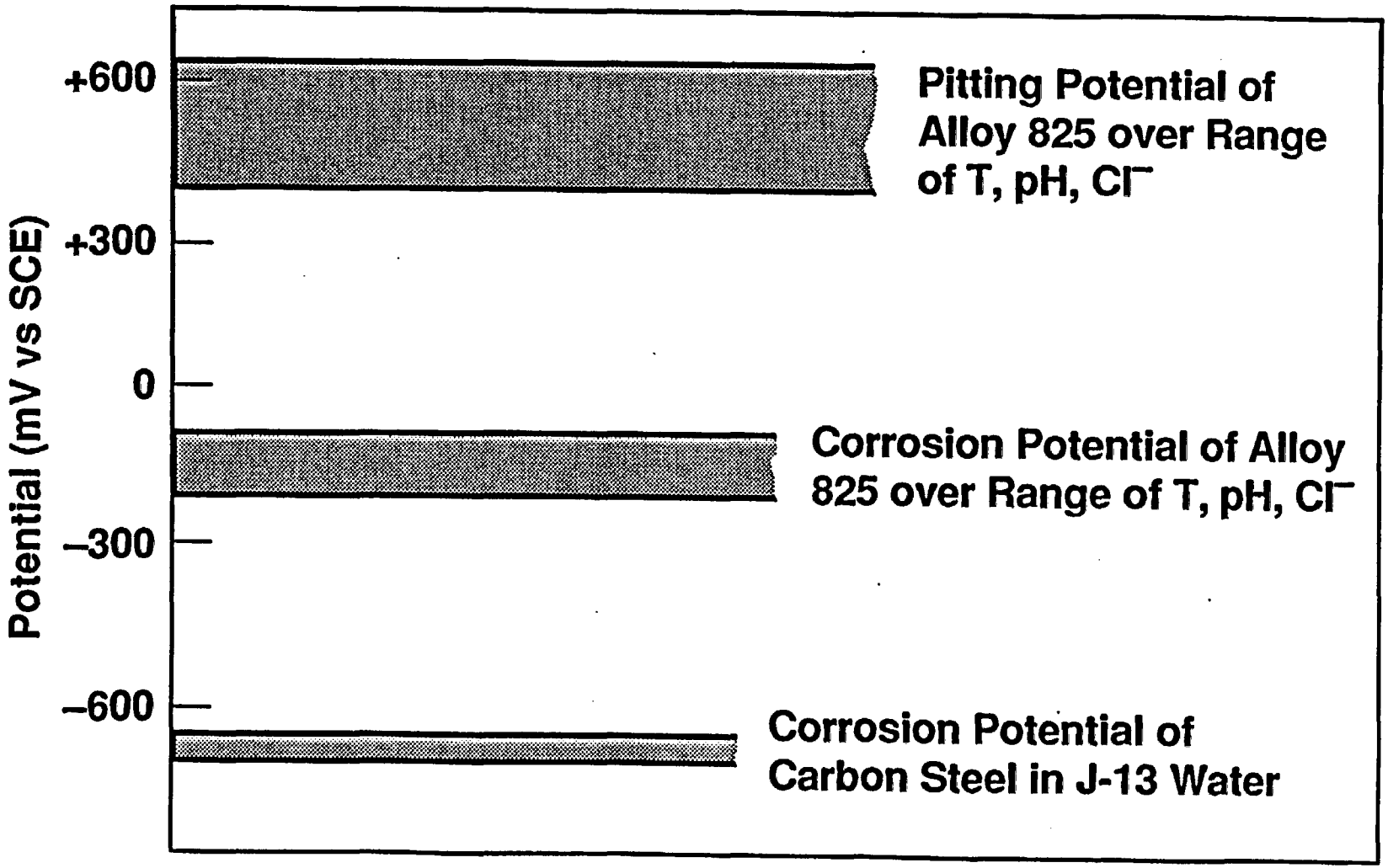
Carbon Steel will Protect Alloy 825 from General and Pitting Corrosion



DCLLMLMC13.125.NWTRB/7-13/14-93

Testing and Evaluation of Multi-Barrier Concepts Activities

- Corrosion Allowance Material (Outer Barrier)
  - Degradation mode survey (in progress)
  - Transition from oxidation to corrosion (near future)
  - Slow crack growth (near future)
  - Microbiological induced corrosion effects (future)
- Corrosion Resistant Material (Inner Barrier)
  - Degradation mode survey (completed)
  - Localized corrosion — modeling and experimental confirmation
  - Slow crack growth (current)
  - Crevice corrosion studies/tests (planning)
  - MIC effects (future)

Materials Testing Yields Performance Parameters

Current and near-future work:

- Oxidation rates for low-temperature oxidation
- General corrosion rates for general aqueous corrosion
- E_{crit}, E_{prot}, E_{corr}, pit penetration rates for pitting corrosion
- Crack propagation rates, threshold stress intensity factors for environmentally assisted cracking

Summary

Summary

- Differences between corrosion allowance and corrosion resistant materials enumerated
- Brief treatment on selection of corrosion resistant materials for SCP CD presented
- Transition from dry oxidation to wet corrosion is a key performance issue
  - corrosion allowance: from a very low rate to a rather high rate
  - corrosion resistant: from a very low rate to possible onset of localized attack
- Principle of multi-barrier concept "defense in depth" illustrated
- Testing program will yield important performance parameters for demonstration of substantially complete containment

DOE-NRC TECHNICAL EXCHANGE
SUBSTANTIALLY COMPLETE CONTAINMENT AND WASTE PACKAGE/
ENGINEERED BARRIER SYSTEM DESIGN CONCEPTS

Status of DOE Modeling Relative to SCC

WILLIAM G. HALSEY
LLNL

BETHESDA MD.

August 24, 1993

Outline

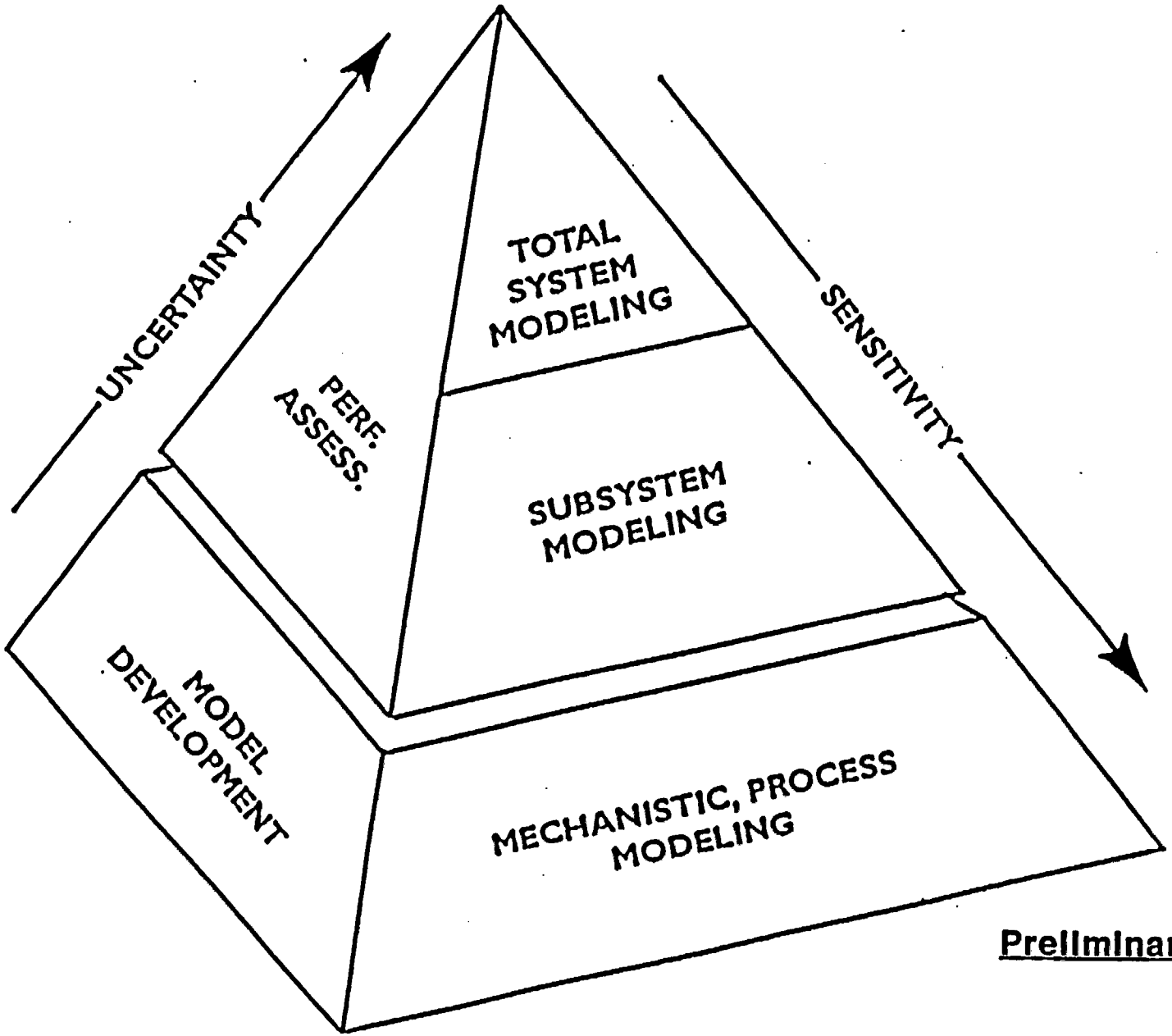
Performance Assessment
- Model Hierarchy
- EBS Subsystem PA

Waste Package Performance Modeling
- Near Field Environment
- Container
- Waste Form

Container Performance Models
- Corrosion
- Other

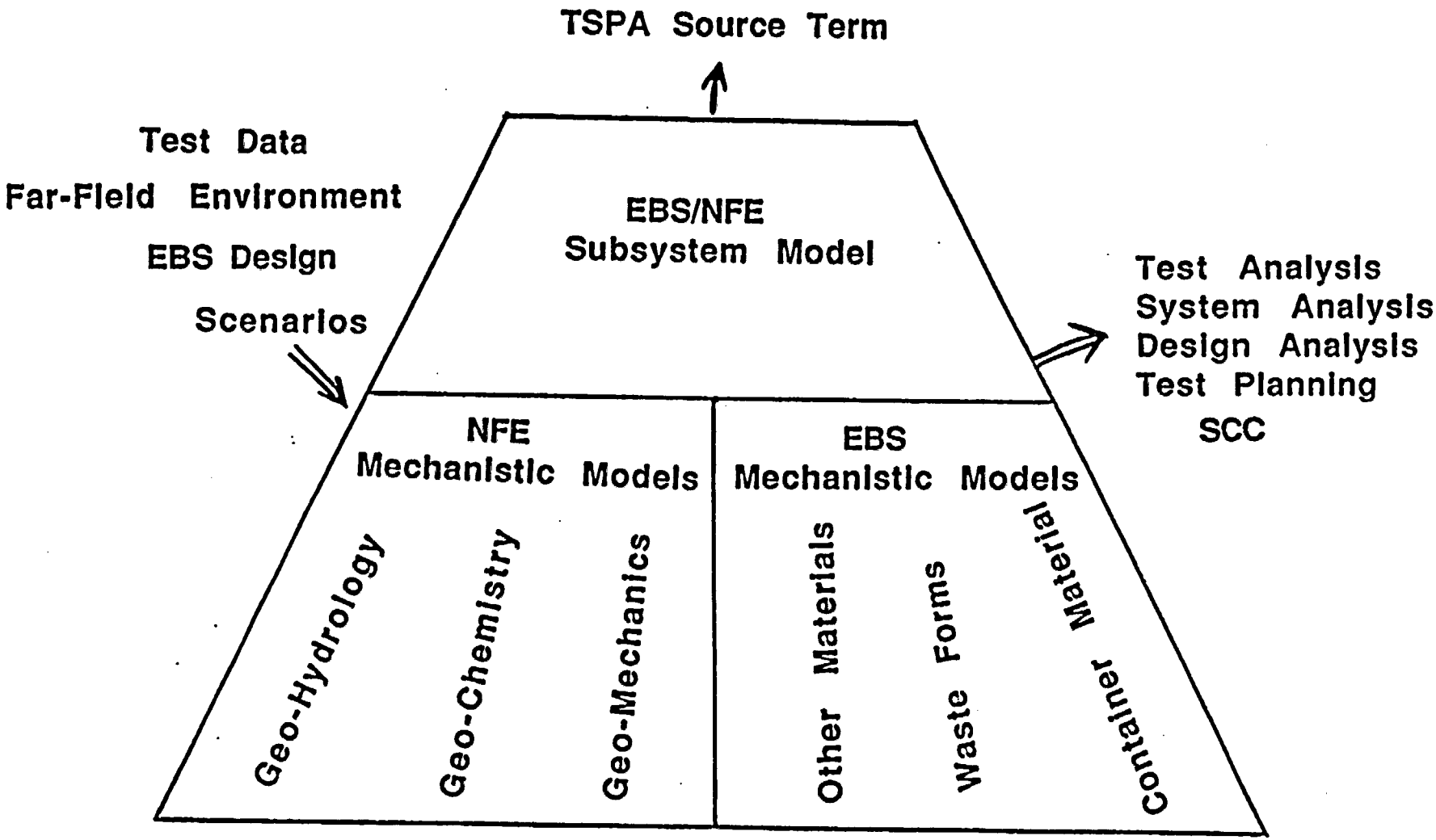
Summary

Hierarchy of Performance Assessment Models



Preliminary Draft

EBS/NFE Subsystem PA Models



Preliminary Draft

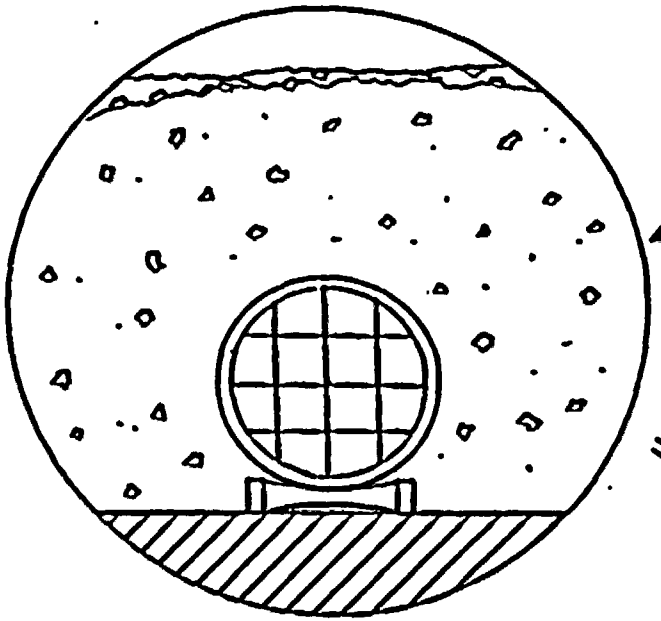
Engineered Barrier/Near Field Environment Performance Analysis

Engineered Barrier System

Design
waste package/repository
thermal evolution
backfill, seals
man-made materials
etc.

Waste Package Container
design, materials
degradation modes
time distribution of failure
evolution of isolation loss
etc.

Waste Forms
radionuclide inventory
water contact evolution
alteration (oxid., dissol.)
radionuclide mobilization
speciation,etc.



Near Field Environment
hydrothermal evolution
WP water contact modes
water contact time distribution
water contact spatial distribution
water composition
etc.

Radionuclide Transport
gaseous transport
advective transport
diffusive transport
retardation, decay
etc.

Source Term
time history of radionuclide release from EBS/NFE

Preliminary Draft

Example Waste Package Performance Models

Previous Models:

AREST - Analytical source term model. Ensemble containment failure from specified container failure distribution.

PANDORA - Detailed description of single waste package performance. Container failure distributions for multiple degradation modes.

Recent Models:

YMIM - Modular EBS/NFE model. Mechanistic container failure models for multiple degradation modes dependent on few group temperature, water contact and chemistry.

RIP - Deterministic WP model in a stochastic integrated system model. Few group representation of NFE and EBS. Container failure distributions specified for multiple degradation modes.

Future Models:

AREST2 - Integrated EBS/NFE source term model. Mechanistic environment dependent container degradation models.

Preliminary Draft

Container Performance Modeling Addresses SCC

Mechanistic Containment Failure Modes

Mechanical Failure:

Failure of container wall or closure due to mechanical load such as rock fall, tectonic event, etc.

Corrosion Failure:

- Dry Oxidation
- General Aqueous Corrosion
- Aqueous Localized Corrosion
- Stress Corrosion Cracking
- Microbiologically Influenced Corrosion
- Hydrogen Effects

Other Containment Failure Modes

"Premature" Failure:

Early, non-aqueous waste package failure due to flawed construction, closure, emplacement, etc. (Probabilistic)

Preliminary Draft

Current Developments (TSPA-2)

TSPA-1 vs TSPA-2

Feature/Process	TSPA-1 (1991)	TSPA-2 (current)
Waste package	Small, thin wall	Small thin wall Large multiple material
Emplacement	Borehole	Borehole In drift
Thermal Loading	Implicit 57 kw/acre	Explicit: 28.5, 57, 114 kw/acre
Container performance	Arbitrary failure history Isothermal after 1000 yr.	Deterministic Temperature dependent Oxidation, General aqueous corr. Stochastic localized corrosion
Waste form performance	Isothermal, arbitrary rate	Temperature dependent Oxidation, Alteration, Dissolution
Near Field Environment	Isothermal, 'ambient'	Coupled hydrothermal modeling Temperature dependent Dry out effects Reflux effects

Preliminary Draft

Near Field Environment Modeling
(TSPA-2)

- Temperature dependent.
- Water flow represents both ambient percolation flux and hydrothermally driven effects such as dry-out and refluxing.
- Abstracted from VTOUGH analyses for representative conditions.
- Few group representation of spatial variation from center to edge of repository. Log-normal representation of localized flux heterogeneity.
- Transient geochemical effects not currently incorporated.

Preliminary Draft

Dry Oxidation Modeling
(TSPA-2)

- Dry oxidation rate extrapolated from high temperature data for iron and steel.
- Arrhenius temperature dependence.
- Primarily used for early time oxidation of thick steel overpack.
- Key question: at what temperature-saturation conditions to switch to aqueous processes.

Preliminary Draft

Aqueous General Corrosion Modeling
(TSPA-2)

- Aqueous corrosion rate with a selectable pitting factor to represent localized rate variations.
- Selectable average rates, default values extracted from iron and steel corrosion data.
- Temperature relationship fitted to a quadratic shape with a maximum rate at a selectable temperature (such as 80°C).
- Primarily used for wet corrosion of thick steel overpack.

Preliminary Draft

Aqueous Localized Corrosion
(TSPA-2)

- Combined representation of pitting and crevice corrosion.
- Abstracted from a stochastic pitting model (Henshall) which represents pit birth, growth and death probabilistically, with distributions normalized to fit pit depth data for austenitic corrosion resistant materials.
- Container failure time extracted via extreme value statistics over the active area of container surface.
- Temperature dependence fitted to an Arrhenius relationship of growth rate.
- Median, upper bound or lower bound growth rates selectable.

Preliminary Draft

Other Degradation Mode Modeling

- "Premature" Failure
- Environmentally Assisted Cracking
  - Stress Corrosion Cracking
    - transgranular
    - intergranular
  - Hydrogen Embrittlement
- Microbiologically Influenced Corrosion
- Delayed Ceramic Fracture
- Other

Modeling of these degradation modes is on hold awaiting ACD design details, material selection, environmental definition and funding.

Preliminary Draft

Summary

- Several EBS/NFE models have been developed, and are beginning to incorporate more mechanistic details such as hydrothermal water contact, temperature dependence, and specific corrosion processes.

- The primary purpose of these models is subsystem design and test analysis and to produce a source term for TSPA.

- Analysis of SCC is not currently the focus of EBS model development.

- More detailed SCC analysis will be possible in the future. Important developments will include: waste package design details, container material specification, improved mechanistic models and improved definition of the near-field environment.

ACTIVITIES ON THE ENGINEERED BARRIER SYSTEM (EBS) PROGRAM AT THE CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

PRESENTED AT THE
U.S. DEPARTMENT OF ENERGY — U.S. NUCLEAR REGULATORY COMMISSION
TECHNICAL EXCHANGE ON SUBSTANTIALLY COMPLETE CONTAINMENT
AND WASTE PACKAGE/ENGINEERED BARRIER SYSTEM DESIGN CONCEPTS

Presented by

Prasad Nair
Gustavo Cragnolino

AUGUST 24, 1993

ENGINEERED BARRIER SYSTEM (EBS)

- ACTIVITIES
  - EVALUATE THE QUANTIFICATION OF THE 'SUBSTANTIALLY COMPLETE CONTAINMENT' REQUIREMENT FOR THE WP
  - EVALUATE THE 'GRADUAL RELEASE RATE' REQUIREMENT FOR THE EBS
  - DEVELOP EBS PERFORMANCE-RELATED COMPLIANCE DETERMINATION METHODOLOGY
  - SUPPORT ITERATIVE PERFORMANCE ASSESSMENTS
  - EVALUATE WASTE FORM DATA ADEQUACY FOR EBS MATERIALS

NOV-22-93 MON 10:07 FROM: U.S. NUC WASTE REG ANA ID: 2106225159 PAGE 5

ENGINEERED BARRIER SYSTEM (EBS)

- EXPERIMENTAL RESEARCH PROJECTS
  - DEVELOP A PHENOMENOLOGICAL UNDERSTANDING OF CORROSION OF CONTAINER MATERIALS
  - DEVELOP TEST METHODS TO EVALUATE LONG-TERM MATERIAL PERFORMANCE
  - QUANTIFY THE IMPORTANCE OF REPOSITORY ENVIRONMENTAL FACTORS RELEVANT TO MATERIAL DEGRADATION
  - ASSESS MATERIAL RELATED FACTORS PERFORMANCE OF CLASSES OF WP MATERIALS
  - DEVELOP INTEGRATED WP TESTS TO EVALUATE THE EFFECTS OF NEAR-FIELD ENVIRONMENT (E.G., GEOCHEMICAL, THERMOHYDROLOGICAL) ON WP BEHAVIOR
  - SUPPORT DATA NEEDS FOR MODEL DEVELOPMENT

AUG-23-93 10:57 FROM: CAR NUC WASTE REG ANA ID: 2105225155 PAGE 4

EBS ELEMENT ACTIVITIES IN HLW

- DETAILED MODELS SUPPORTING ITERATIVE PERFORMANCE ASSESSMENT ITERATIONS: CORROSION, GRADUAL RELEASE, WASTE PACKAGE ENVIRONMENT

- SUBSTANTIALLY COMPLETE CONTAINMENT EXAMPLE PROBLEM REFLECTS CONCEPTS DEVELOPED IN DETAILED MODELING

EBS ELEMENT ACTIVITIES IN HLW

LOCALIZED CORROSION

- GENERAL CODE WITH MULTIPLE CHEMICAL SPECIES AND REACTIONS
- EQUILIBRIUM BY GIBBS FREE ENERGY MINIMIZATION (MARIANA)
- ACTIVE / PASSIVE TRANSITION
- EQUATIONS FOR MODERATELY CONCENTRATED SOLUTIONS
- USED FOR DEFENSE OF CRITICAL POTENTIALS
- CLOSE COORDINATION WITH RESEARCH PROGRAM

SUBSTANTIALLY COMPLETE CONTAINMENT EXAMPLE PROBLEM (SCCEX)

- SIGNIFICANT DEPARTURE FROM CURRENT MODELS OF WP BEHAVIOR
- ACCOUNTS FOR THERMAL LOADING STRATEGY
- BALANCE OF DRIPPING AND EVAPORATION OF GROUNDWATER
- NEW PREDICTIONS FOR WASTE PACKAGE ENVIRONMENT RESULTING IN CONCENTRATED AQUEOUS SOLUTIONS
- CORROSION POTENTIAL AS KEY MATERIAL/ENVIRONMENTAL PARAMETER FOR MECHANISTIC MODELING OF WASTE PACKAGE CORROSION IN CONJUNCTION WITH CRITICAL POTENTIAL FOR LOCALIZED CORROSION
- PROBABILISTIC

INTEGRATED WASTE PACKAGE EXPERIMENTS PROJECT

- OBJECTIVES
  - UNDERSTAND IMPORTANT PARAMETERS AFFECTING LONG-TERM PERFORMANCE OF WASTE PACKAGE MATERIALS
  - ASSESS METHODOLOGIES USED TO PREDICT LONG-TERM PERFORMANCE
  - PERFORM CONFIRMATORY TESTS TO ASSESS DOE DATA

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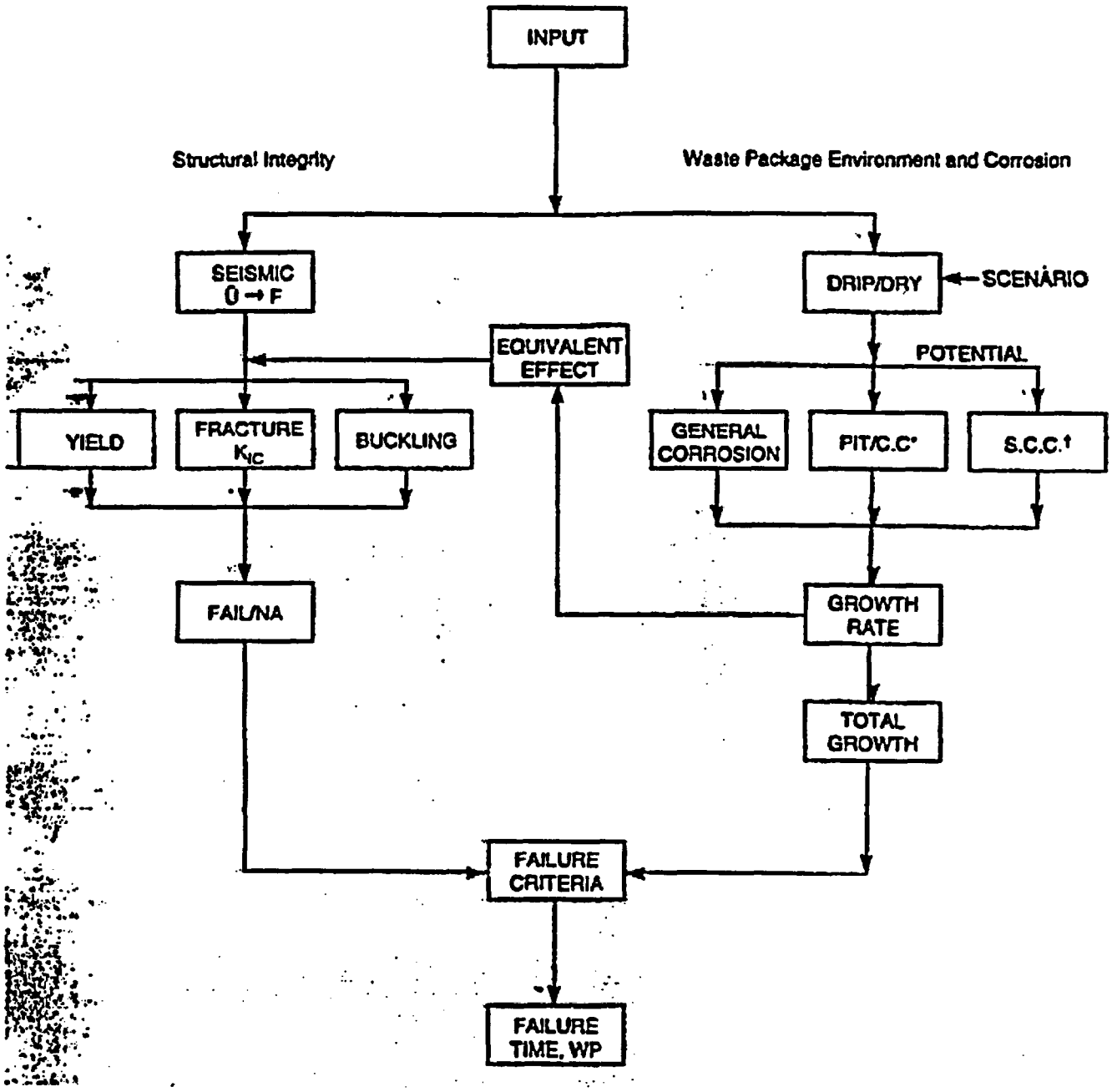
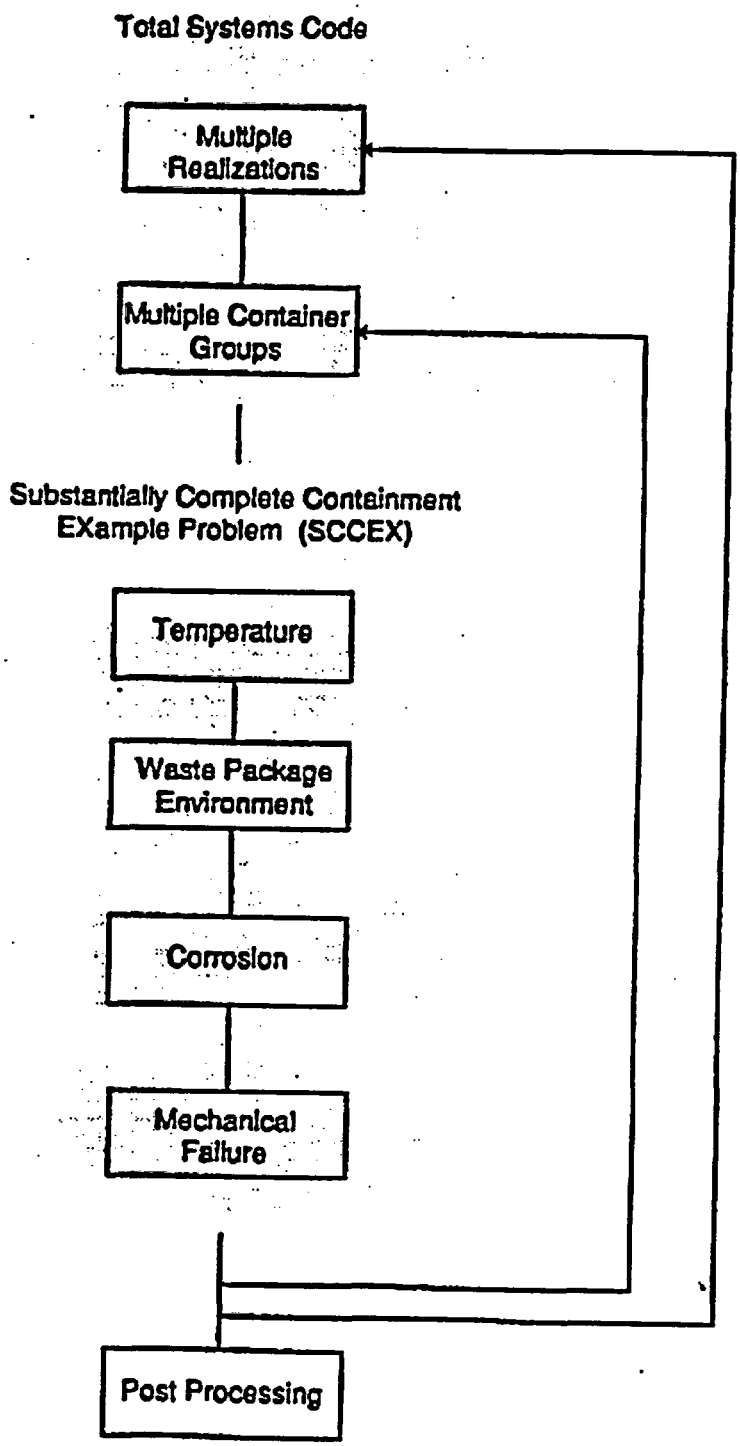
INTEGRATED WASTE PACKAGE EXPERIMENTS PROJECT

- TECHNICAL APPROACH
  - CONFIRMATORY AND EXPLORATORY STUDIES
  - STUDY CLASSES OF MATERIALS
  - PRIORITIZE ENVIRONMENTAL FACTORS USING SCREENING TESTS
  - PROVIDE DATA COMPATIBLE WITH MECHANISTIC MODELS DEVELOPED IN EBS PROGRAM
  - GUIDE LONG-TERM TESTING STRATEGIES

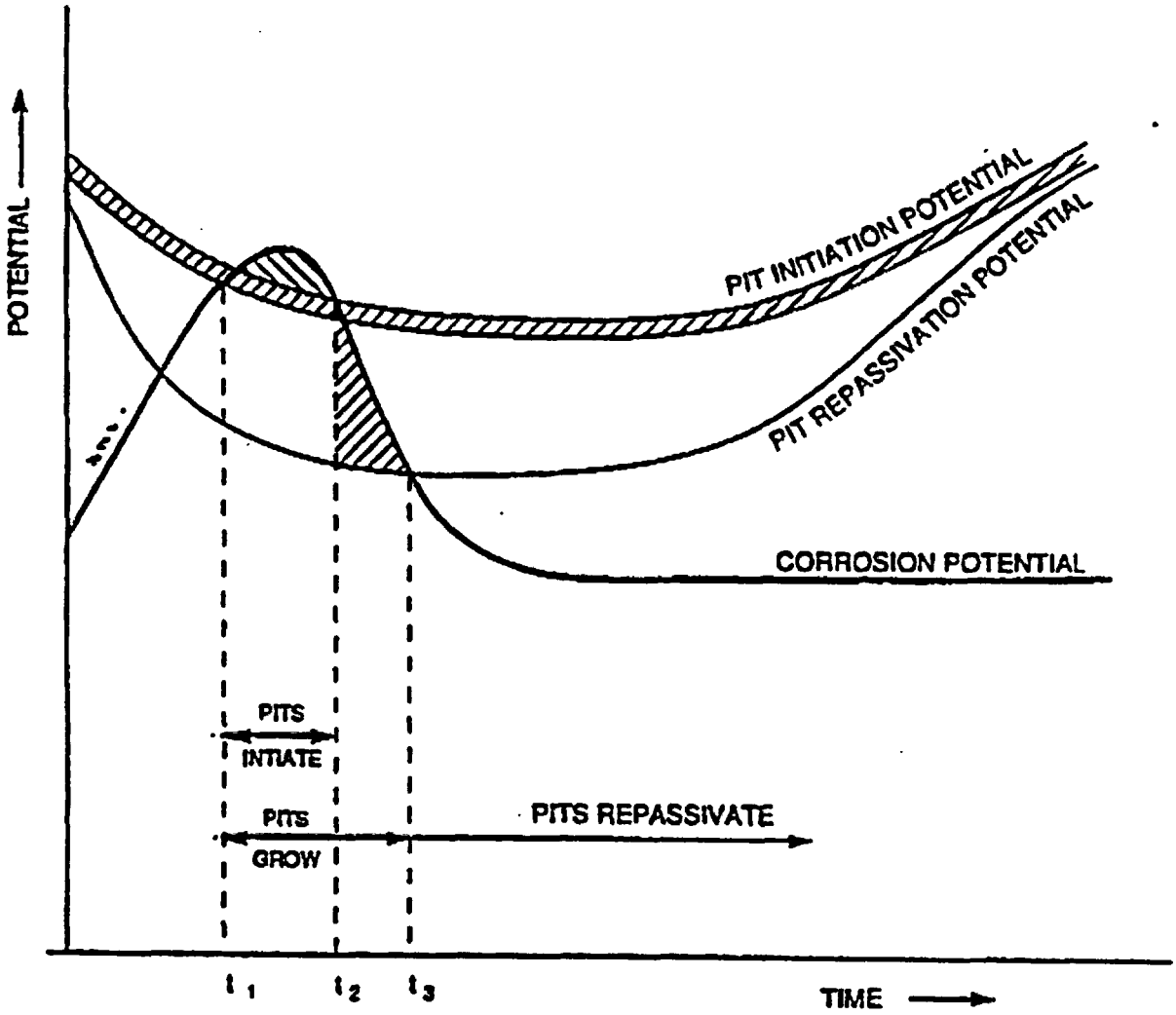


*C.C. = Crevice Corrosion
†S.C.C. = Stress Corrosion Cracking

Flow diagram of computer codes



Schematic of probabilistic calculations



Schematic Illustration of the Use of Corrosion, Pitting, and Repassivation Potential to Predict the Performance of a Container.

U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/Engineered Barrier System Design Concepts

Overview of Substantially Complete Containment

PRESENTED BY

Dr. David Stahl

Manager

Waste Package Performance Analysis

M&O/Las Vegas, Nevada

August 24, 1993

OVERVIEW OF SUBSTANTIALLY COMPLETE CONTAINMENT

BASIS FOR INITIAL CD-SCP AND SCP APPROACHES FOR COMPLIANCE WITH 60.113

- 10 CFR 60.113(a)(1)(ii)(A) states that

  "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;"

- NRC Staff Position 60-001 states that

  "The requirement in 10 CFR 60.113(a)(1)(ii)(A) for substantially complete containment of high-level waste ... is a minimum performance requirement which is not intended, and should not be interpreted, as a cap on the waste package lifetime or a limitation on the credit that can be taken (in engineered barrier system and overall repository system performance assessments) if the waste package is designed to provide containment in excess of 1,000 years."

Overview of Substantially Complete Containment

Basis for Initial CD-SCP and SCP Approaches for Compliance with 60.113

- CD-SCP and SCP design concept based on single, thin-walled container
- Waste package failure performance goals were established to meet SCC and release requirements
- Goals were further subdivided into time and temperature regions to show that requirements were met

Preliminary Draft

OVERVIEW OF SUBSTANTIALLY COMPLETE CONTAINMENT

BASIS FOR CURRENT APPROACH

- ACD design concepts based on double-walled waste package, although SCP design is carried along as a reference
  - Emphasis is on corrosion-resistant container overpacked by thick-walled, corrosion-allowance container
- SCC requirement as given in 10 CFR 60 permits the NRC to determine if design complies with reasonable assurance
- A more specific containment performance goal, which will be part of the basis for design, has been developed to guide the design effort

Preliminary Draft

OVERVIEW OF SUBSTANTIALLY COMPLETE CONTAINMENT

BASIS FOR CURRENT APPROACH
(Continued)

- For corrosion-resistant materials, the dominant degradation mode is localized corrosion
  - Initiation is usually a random process
  - Performance prediction is difficult
  - Rates are usually rapid after the process is initiated
  - Degradation mode surveys have been performed for the six candidate alloys plus titanium alloys
- For corrosion-allowance materials, the dominant degradation mode is general corrosion (atmospheric and aqueous)
  - Permits performance prediction
  - Rates are usually parabolic (protective)
  - Some rates are linear (non-protective)
  - Degradation mode surveys have been performed for copper-based alloys and has been initiated for iron-based materials

Overview of Substantially Complete Containment

Approach to Resolution of NRC Concerns

- In NUREG-1347, NRC expressed concern regarding inconsistencies between their requirements and the performance goals and recommended that the goals be consistent with the intent of the SCC requirement
- The focus of the new design concepts (see PR 8) is on containment and the integrity of the waste package during the containment period, which is consistent with the NRC recommendation
- The revised performance goal will not be based on release of radionuclides
- The revised performance goal is a design mean waste package lifetime well in excess of 1,000 years

  - This is reflected in the barrier functions and performance measures

Overview of Substantially Complete Containment

APPROACH TO RESOLUTION OF NRC CONCERNS
(Continued)

- The multi-barrier approach with both corrosion-resistant and corrosion-allowance materials will provide confidence that the revised performance goal and, hence, the SCC requirement will be met
- The DOE design effort, materials evaluations and environmental studies conducted by LLNL, fabrication studies, performance analyses, performance assessments, and a future waste package performance confirmation program are directed toward achieving a long-lived waste package that will meet the SCC requirement
- This approach should provide the basis for closing of several SCA Open Items (Comment 5, Comment 47, Comment 80, Question 46, and Question 47)

Preliminary Draft

SUBSTANTIALLY COMPLETE CONTAINMENT AND WASTE PACKAGE/ENGINEERED BARRIER SYSTEM DESIGN CONCEPTS

DOE/NRC TECHNICAL EXCHANGE
AUGUST 24, 1993

Charlotte Abrams
US NRC

LACK INFORMATION ON:

MATERIALS

DESIGN

EMPLACEMENT MODE

MATERIALS

PROGRESS REPORT 6 - REPORTS THREE MATERIALS RECOMMENDED FOR ADVANCED STUDY AND "OTHER" MATERIALS (UNNAMED) WILL BE STUDIED.

PROGRESS REPORT 7 - CITES A PAPER TO BE PUBLISHED ON SELECTION OF CANDIDATE CONTAINER MATERIALS.

DESIGN

THIN-WALLED CONTAINER DESIGN (SCP)

MULTIPURPOSE CANISTER (RECENT MEETINGS)

MULTIPLE-LAYERED WASTE PACKAGE

EMPLACEMENT MODE

HORIZONTAL BOREHOLE EMPLACEMENT

VERTICAL BOREHOLE EMPLACEMENT

HORIZONTAL DRIFT EMPLACEMENT

THE STAFF RECOGNIZES THAT ACTIVITIES RELATED TO WASTE PACKAGE MATERIALS, DESIGN, AND EMPLACEMENT CONFIGURATION ARE PRELIMINARY. THE STAFF SHOULD BE KEPT UP-TO-DATE ON WASTE PACKAGE ACTIVITIES IN FUTURE PROGRESS REPORTS AND THROUGH OTHER, LESS FORMAL, MECHANISMS.

U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

DOE-NRC Technical Exchange on Substantially Complete Containment and Waste Package/Engineered Barrier System Design Concepts

SCA Open Items Related to SCC

PRESENTED BY

Dr. David Stahl

Manager

Waste Package Performance Analysis

M&O/Las Vegas, Nevada

August 24, 1993

SCA COMMENT 5

NRC CONCERN:

- Explain how technological limitations and uncertainties and the Waste Package Designs impact demonstration of compliance with 10CFR 60.113 and describe plans for evaluating and reducing these impacts

PROPOSED DOE RESPONSE:

- Technological limitations relate to the ability to emplace waste packages without defects while uncertainties relate to the ability to define material interactions
- DOE plans to evaluate and reduce the impacts of these limitations and uncertainties on the demonstration of compliance with 10CFR 60.113 during the design process
- DOE plans are described in the Waste Package Implementation Plan and include the use of materials testing, environmental studies, fabrication studies, performance analysis, and performance assessment, and will include details on the performance confirmation program as they are developed

SCA COMMENT 5

PROPOSED DOE RESPONSE: (Continued)

- **Multi-barrier design approach will substantially improve containment and therefore will enhance demonstration of compliance by minimizing technological limitations and uncertainties**

  - **Use of corrosion-resistant and corrosion-allowance materials provide a more environmentally tolerant design**

  - **Probability of non-detected breach dramatically reduced**

SCA COMMENT 47

NRC CONCERN:

- Lack of information on tectonic events that could cause waste package rupture

PROPOSED DOE RESPONSE:

- Study Plan (8.3.1.8.2.1) on Analysis of Waste Package Rupture Due to Tectonic Processes and Events completed and sent to the NRC
- Studies will analyze tectonic processes and events, particularly those that involve displacements, that may have an impact on design and performance of waste packages and the EBS during postclosure
- Results of the study will be input into design activities for the waste package, EBS, and the repository

SCA COMMENT 80

NRC CONCERN:

- Inconsistency exists between the intent of SCC requirement and the SCP performance goals

PROPOSED DOE RESPONSE:

- DOE's interpretation of SCC is the same as that of the NRC staff
- The revised performance goal is no longer tied to release of radionuclides
- The revised performance goal is a mean waste package lifetime well in excess of 1,000 years

  - This is consistent with NRC's requirement for containment

- The multi-barrier approach with different materials and, hence, different failure modes, will add to confidence that goal will be met

SCA QUESTION 46

NRC CONCERN:

- Basis for stricter control of long half-life radionuclides for the containment period is not provided

PROPOSED DOE RESPONSE:

- CD-SCP and SCP design concept based on single, thin-walled container
- SCP goals were consistent with this design
- The revised performance goal is a mean waste package lifetime well in excess of 1,000 years
  - This is consistent with the SCC requirement
  - Performance goal is achieved through the use of designs with multiple barriers with different failure modes that enhance confidence that the SCC requirement will be met
- Revised performance goal, therefore, is no longer tied to release of radionuclides

SCA QUESTION 47

NRC CONCERN:

- Relationship of container failure to compliance with 10 CFR 60.113 must be demonstrated and plans for testing should be described

PROPOSED DOE RESPONSE:

- Initial DOE response was based on release of gaseous radionuclides from a single, thin-wall (SCP) design container
- Failure flow rates were taken from the ASME B&PV code, recognizing that testing will be performed at significantly lower allowable leakage
- Multi-barrier approach reduces impact on demonstration of compliance
- DOE's plans for demonstrating compliance and plans for testing are provided in the Waste Package Implementation Plan, including detailed materials testing and modeling programs, environmental studies, and performance assessments, as well as fabrication studies and prototype testing
- Longer waste package lifetimes will dramatically reduce release of gaseous radionuclides

OVERVIEW OF NRC APPROACH TO REDUCING THE UNCERTAINTY IN "SUBSTANTIALLY COMPLETE CONTAINMENT" (SCC)

DAVE DANCER
AUGUST 24, 1993

APPROACH TO SCC UNCERTAINTY REDUCTION

- REVIEW RULEMAKING RECORD FOR GUIDANCE ON THE INTENT OF SCC
- REVIEW THE EXPERIENCE WITH THE SCC CONCEPT
- DEVELOP TECHNICAL BASIS FOR GUIDANCE
- PREPARE GUIDANCE IN APPROPRIATE FORM (E.G. TECHNICAL POSITION, STAFF POSITION, REGULATORY GUIDE, RULE)
- INCORPORATE GUIDANCE IN THE LICENSE APPLICATION REVIEW PLAN

THE RULEMAKING RECORD

PROPOSED RULE (ISSUED JULY 1981)

- 60.111(b)(2)(i) CONTAINMENT OF WASTES

  "THE ENGINEERED SYSTEM SHALL BE DESIGNED SO THAT . . . THE WASTE PACKAGES WILL CONTAIN <u>ALL</u> RADIONUCLIDES FOR AT LEAST THE FIRST 1,000 YEARS AFTER PERMANENT CLOSURE."

- PURPOSE OF CONTAINMENT

  CONTAIN WASTES DURING PERIOD OF HIGH HEAT/RADIATION GENERATION WHEN UNCERTAINTIES INHERENTLY LARGE

- NO AMBIGUITY IN PROPOSED RULE

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DOE/NRC TECHNICAL EXCHANGE
AUGUST 24, 1993

Charlotte Abrams
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- CD-SCP and SCP design concept based on single, thin-walled container
- SCP goals were consistent with this design
- The revised performance goal is a mean waste package lifetime well in excess of 1,000 years
  - This is consistent with the SCC requirement
  - Performance goal is achieved through the use of designs with multiple barriers with different failure modes that enhance confidence that the SCC requirement will be met
- Revised performance goal, therefore, is no longer tied to release of radionuclides

SCA QUESTION 47

NRC CONCERN:

- Relationship of container failure to compliance with 10 CFR 60.113 must be demonstrated and plans for testing should be described

PROPOSED DOE RESPONSE:

- Initial DOE response was based on release of gaseous radionuclides from a single, thin-wall (SCP) design container
- Failure flow rates were taken from the ASME B&PV code, recognizing that testing will be performed at significantly lower allowable leakage
- Multi-barrier approach reduces impact on demonstration of compliance
- DOE's plans for demonstrating compliance and plans for testing are provided in the Waste Package Implementation Plan, including detailed materials testing and modeling programs, environmental studies, and performance assessments, as well as fabrication studies and prototype testing
- Longer waste package lifetimes will dramatically reduce release of gaseous radionuclides

OVERVIEW OF NRC APPROACH TO REDUCING THE UNCERTAINTY IN "SUBSTANTIALLY COMPLETE CONTAINMENT" (SCC)

DAVE DANCER
AUGUST 24, 1993

APPROACH TO SCC UNCERTAINTY REDUCTION

- REVIEW RULEMAKING RECORD FOR GUIDANCE ON THE INTENT OF SCC
- REVIEW THE EXPERIENCE WITH THE SCC CONCEPT
- DEVELOP TECHNICAL BASIS FOR GUIDANCE
- PREPARE GUIDANCE IN APPROPRIATE FORM (E.G. TECHNICAL POSITION, STAFF POSITION, REGULATORY GUIDE, RULE)
- INCORPORATE GUIDANCE IN THE LICENSE APPLICATION REVIEW PLAN

THE RULEMAKING RECORD

PROPOSED RULE (ISSUED JULY 1981)

- 60.111(b)(2)(i) CONTAINMENT OF WASTES

  "THE ENGINEERED SYSTEM SHALL BE DESIGNED SO THAT . . . THE WASTE PACKAGES WILL CONTAIN <u>ALL</u> RADIONUCLIDES FOR AT LEAST THE FIRST 1,000 YEARS AFTER PERMANENT CLOSURE."

- PURPOSE OF CONTAINMENT

  CONTAIN WASTES DURING PERIOD OF HIGH HEAT/RADIATION GENERATION WHEN UNCERTAINTIES INHERENTLY LARGE

- NO AMBIGUITY IN PROPOSED RULE