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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT
October 25, 1990

SUBJECT: 18th Water Reactor Safety Information Meeting
Hosted by the U.S. NRC
Organized by the Brookhaven National Laboratory

DATE/PLACE: October 22-24, 1990
Holiday Inn Crowne Plaza
Rockville, Maryland

AUTHOR: Wesley C. Patrick

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PERSON PRESENT: Wesley C. Patrick

BACKGROUND AND PURPOSE OF MEETING:

The purpose of this trip was to attend the subject conference to (a) present an invited paper on the subject "High-Level Nuclear Waste Research at the Center for Nuclear Waste Regulatory Analyses: A Progress Report" and (b) to participate in a special session of the conference on Waste Management Research.

SUMMARY:

The program for the conference is provided as Attachment 1 to this report. Two-page summaries of most of the papers presented are provided in "Transactions of the Eighteenth Water Reactor Safety Information Meeting", NUREG/CP-0113. A copy of this document is available in the Center library; the table of contents is provided as Attachment 2 to this report. Detailed proceedings, including each paper presented, will be published at a later date. A copy will be made available in the Center library.

Involvement in this three-day conference was limited to attendance at and participation in the special session on Waste Management Research, which was held the afternoon of October 23, 1990. As indicated in Attachment 1, the special session was divided topically into high-level waste and low-level waste.

M. Silberberg, who chaired the session, set the stage for the presentations that followed, elucidating the relationship between the licensing office and the research office of the NRC. J. Youngblood expanded upon this in his remarks, noting the requests for research provided via the Division of High-Level Waste Management user need letter.

G. Birchard provided a thorough review of the current NRC High-Level Waste Research Program Plan, which spans approximately five years. Areas of progress to date, the pre-1987 focus on the saturated zone, contracts being closed out, and transfer of work to the Center were noted.

Dr. Birchard's presentation was followed by a presentation by W. Patrick summarizing the research work ongoing at the Center. For each of the first six

projects approved by the NRC, the regulatory basis, associated technical issues, and general approach to the research was summarized. In addition, one or two examples of recent 'findings' were shown. Dr. J. Danko, University of Tennessee, expressed interest and concern regarding microbiologically influenced corrosion. G. Cragnolino has been in contact with him previously (at a conference last week) and should expect a follow-up call. The complete paper has been submitted to the organizing committee for publication, has been provided to the NRC for their use, and is being circulated internally to the staff of the Center.

The final paper in the high-level waste session was provided by Dr. T. McCartin. He summarized, in his words, the results of 15 years of performance assessment research at Sandia National Laboratory. The focus of the presentation was the SNL methodology (those interested should see B. Sagar for a copy of the schematic of that methodology and, as appropriate, an explanation thereof). The wide use of this methodology in many areas was highlighted. Note was made of the transfer of the work to the Center.

The second half of the special session dealt with low-level waste management. Following introductory remarks by R. Bangart, E. O'Donnell summarized the recently completed Low-Level Radioactive Waste Management Research Program Plan (see Attachment 3). Note that the full program plan has been published in NUREG form and is available in the Center library.

Dr. P. Reed provided a thorough summary of work on LLW classification and stability. A handout of his viewgraphs is provided as Attachment 4 to this report.

The final paper was given by Dr. T. Nicholson, who reported on the results of hydrogeology research that is being conducted in support of the LLW program. He highlighted current technical issues regarding fluid flow in the vadose zone, noting work ongoing at the University of Arizona and New Mexico State University. He established a tie to the Center through our work on the Jornada Trench experiment near Las Cruces, New Mexico, which is funded by the high-level waste program as part of INTRAVAL.

IMPRESSIONS/CONCLUSIONS:

The special session on Waste Management Research was quite well attended, particularly considering that the principal topic of the conference has historically dealt with nuclear power plant design, construction, and operations issues. International participation was particularly good.

There are already numerous conferences related to high-level nuclear waste management held annually. However, it may be appropriate to continue and possibly expand (to one day) involvement in this conference because it is one of a few such conferences which bring the reactor people (i.e. the waste generators) into contact with researchers in the field of waste disposal.

PROBLEMS ENCOUNTERED: None.

PENDING ACTIONS:

G. Cragnolino should expect a call from Dr. Danko regarding MIC. It may be appropriate for him to provide a brief seminar at the Center if his work is germane to what we have planned in the Integrated Waste Package Experiments area.

SIGNATURE

Wesley C. Patrick — Date 10/25/90

CONCURRENCE

Allen R. Whiting
Director SE&I — Date 10/25/90

ATTACHMENT 1

18 WRSM 1990

Held at
Holiday Inn Crowne Plaza
Rockville, Maryland
October 22-24, 1990

P•R•O•G•R•A•M

Allen J. Weiss, Meeting Coordinator
Brookhaven National Laboratory

MONDAY, OCTOBER 22, 1990

PLENARY SESSION

8:30 E.S. Beckjord, Director, RES, NRC
8:40 K.C. Rogers, Commissioner, NRC
9:10 H.J.C. Kouts, Defense Nuclear Facilities Safety Board

PLAZA I

1 Severe Accident Research I
Chairman: F. Eltawila

9:45 Opening Remarks, B. Sheron (NRC)

10:00 Review of Experimental Results on LWR Core Melt Progression, R. Hobbins et al. (INEL)

10:30 Results of the ACRR DF-4 BWR Control Blade-Channel Box Test, R. Gaunt, R. Gasser, R. Schmidt (SNL)

11:00 Experiment-Specific Analyses in Support of Code Development, L. Ott (ORNL)

11:30 Study of Possibilities of Use Containment Pressure Relief Filtration System for Mitigating the Consequences of a Beyond-Design Accident at NPP with VVER Type Reactor, V. Asmolov, E. Basanski, P. Slavyagin, O. Shakh (I.V. Kurchatov, Moscow)

12:00 Lunch

PLAZA II

2 Pressure Vessel Integrity
Chairman: C. Serpan

9:45 MEB Research Highlights, C. Serpan (NRC)

9:55 Heavy-Section Steel Technology Program Overview, W. Pennell (ORNL)

10:15 Potential Impact of Enhanced Fracture Toughness Data on Pressurized Thermal Shock Analyses, T. Dickson, T. Theiss (ORNL)

10:35 Multivariable Modeling of J-R Data, E. Eason, E. Nelson, J. Wright (M&CB)

10:55 Heavy-Section Steel Irradiation Program Overview, W. Corwin, et al.(ORNL)

11:35 Consequence Evaluation of Radiation Embrittlement, of Trojan Reactor Pressure Vessel Support, S. Lu (LLNL)

11:55 TMI-2 Vessel Investigation Project (VIP), Metallurgical Program, D. Diercks, L. Neimark (ANL)

12:15 Lunch

PLAZA III

3 Radiation Protection: BRC & Part 20
Chairman: D. Cool

9:45 USNRC Policy Statement on Below Regulatory Concern, D. Cool (NRC)

11:00 Overview of the Nuclear Regulatory Commission's Revised 10 CFR Part 20, H. Peterson, Jr. (NRC)

12:00 Lunch

BUFFET LUNCH - ATRIUM

12:00 - 1:30

TUESDAY, OCTOBER 23, 1990

PLAZA I

7 Aging and Components I
Chairman: J. Vora

8:30 NPAR Program - Overview and Accomplishments, M. Vagins (NRC)

8:40 Life Assessment Procedure for LWR Metal Containments, V. Shah, U. Sinha (INEL), S. Smith (MDC)

9:10 Developments in Risk Evaluation of Aging, W. Vesely, M. Hassan (SAIC)

9:40 Degradation Modeling with Applications to Aging and Maintenance Effectiveness Evaluation, P. Samanta, F. Hsu, M. Subudhi (BNL), W. Vesely (SAIC)

10:10 Break

10:30 Status - Risk Evaluation from Aging of Passive Components, J. Phillips, et al. (INEL)

11:00 Age-Dependent Risk-Based Methodology and its Application to Prioritization of NPP Components and to Maintenance for Managing Aging Using PRAs, I. Levy (PNL), W. Vesely (SAIC)

11:30 Studies of Aged Cast Stainless Steel from the Shippingport Reactor, O. Chopra, H. Chung (ANL)

12:00 Lunch

PLAZA II

8 Individual Plant Examination Program & Other Issues
Chairman: T. King

8:30 Individual Plant Examination Program - Summary and Status, J. Mitchell, J. Flack (NRC)

9:00 Individual Plant Examinations - An Industry Perspective, R. Ng (NUMARC)

9:30 Consideration of External Events in the Individual Plant Examination Program, J. Chen (NRC)

10:00 Break

10:15 Containment Performance Improvement Program, W. Beckner, et al. (NRC)

10:45 Summary and Status of Generic Issue Resolution, R. Baer, K. Kniel (NRC)

11:15 Source Term Update - Summary and Status, L. Soffer (NRC)

11:45 Discussion

12:00 Lunch

PLAZA III

9 Human Factors Research
Chairman: J. Persensky

8:30 Review of the Impact of Environmental Factors on Human Performance, D. Echeverria, V. Barnes, A. Bittner (HARC)

8:50 An International Comparison of Manpower and Staffing Regulation and Practice in Commercial Nuclear Power Plants: Changes over the Past Decade, B. Melber et al. (HARC)

9:10 Comparative Study of Alertness and Performance 8-Hour and 12-Hour Evening and Night Shifts for Nuclear Power Plant Operators, T. Baker (ICP)

9:35 Initial Examination of the Effects of Overtime and Shift Scheduling on Nuclear Power Plant Safety Performance, K. Baker, J. Olson (HARC), J. Montgomery (PNL)

9:55 Human Performance Information Management System: Inventory, Evaluation, and Assessment of NRC Data Sources, H. Burton, W. Banks (LLNL)

10:15 Break

10:30 Advanced Human-System Interface Design Review Guidelines, J. O'Hara (BNL)

10:55 Development of a Performance Indicator of the Effectiveness of Human-Machine Interfaces for Nuclear Power Plants, N. Moray (Univ. of IL)

11:15 A Computerized Safety Assessment and Post-Trip Analysis System for the Forsmark Unit 2 Control Room, Integrating a Real Time Expert System and a Modern Graphic Display System, F. Owre, S. Nilsen, E. Stokke (OECD Halden)

11:40 An Analysis of Reports of Procedure Violations in U.S. Nuclear Power Plants, V. Barnes, J. Olson (HARC)

12:00 Lunch

BUFFET LUNCH - ATRIUM

12:00 - 1:30

WEDNESDAY, OCTOBER 24, 1990

PLAZA I

13 Severe Accident Research III
Chairman: F. Eltawila

8:30 MELCOR Simulation of Long-Term Station Blackout at Peach Bottom, I. Madni (BNL)

8:55 Results of Recent ORNL Fission Product Release Tests, R. Lorenz, M. Osborne, J. Collins (ORNL)

9:20 Status of VICTORIA Development and Assessment, N. Bixler (SNL), T. Heames (SAIC)

9:45 SPARTA Project, V. Cerchia (ENEA)

10:10 Break

10:25 Large-Scale HDR-Hydrogen Mixing Experiments: Test Group E11, L. Valencia, L. Wolf (KfK)

10:50 Evaluation of Hydrogen Explosion Hazard, S. Dorofeev, A. Kochurko, B. Chaivanov (I.V. Kurchatov, Moscow)

11:15 ACE Program Phase C: Molten Corium Concrete Interaction (MCCI) and Corium Melt Coolability Experiments, B. Sehgal (EPRI), B. Spencer (ANL)

11:40 The Probability of Mark-I Liner Failure, T. Theofanous, et al. (UC Santa Barbara)

12:00 Lunch

PLAZA II

14 Earth Sciences
Chairman: E. Zurflueh

8:30 Introduction, E. Zurflueh (NRC)

8:35 Progress Report for the U.S. National Seismographic Network, R. Masse', R. Buland (USGS)

9:05 Cooperative New Madrid Seismic Network, R. Herrmann (St. Louis Univ.), A. Johnston (Memphis State Univ.)

9:35 Geodetic Measurement of Crustal Strain in the Eastern United States, W. Strange (NOAA)

10:05 Break

10:20 Seismic Study of Soil Dynamics at Garner Valley, California, R. Archuleta, S. Seale (UCSB)

10:50 New Evidence for Great Earthquakes in the Pacific Northwest, B. Atwater (USGS)

11:20 Paleoliquefaction Investigations Along the Atlantic Seaboard with Emphasis on the Prehistoric Earthquake Chronology of Coastal South Carolina, D. Amick, et al. (EBASCO)

11:50 Discussion

12:00 Lunch

PLAZA III

15 Accident Management
Chairman: N. Lauben

8:30 IAEA Accident Management Program, L. Kabanov (IAEA)

9:00 U.S. Accident Management Program, L. Shotkin (NRC)

9:30 Severe Accident Natural Circulation and Depressurization in PWRs, R. Dallman et al. (INEL)

10:15 Break

10:30 Assessment of Uncertainties in Severe Accident Management Strategies, W. Kastenberg et al. (UCLA)

11:00 Identification and Assessment of Containment and Release Management Strategies, J. Lehner, C. Lin, P. Neogy (BNL)

11:30 Failure of PWR-RHRs under Cold Shutdown Conditions: Experimental Results from the PKL Test Facility, R. Mandl, K. Umminger, J. Logt (Siemens, KWU)

12:00 Lunch

BUFFET LUNCH - ATRIUM

12:00 - 1:30

ATTACHMENT 2

NUREG/CP-0113

Transactions of the Eighteenth Water Reactor Safety Information Meeting

To Be Held at
Holiday Inn Crowne Plaza
Rockville, Maryland
October 22–24, 1990

Date Published: October 1990

Compiled by: Allen J. Weiss, Meeting Coordinator

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

CONTENTS

18th WATER REACTOR SAFETY INFORMATION MEETING
OCTOBER 22-24, 1990

Page

PREFACE. iii

Monday, October 22, 1990

SESSION 1
Severe Accident Research I
Chairman: F. Eltawila

Review of Experimental Results on LWR Core Melt Progression 1-1
R. Hobbins et al., (INEL)

Results of the ACRR DF-4 BWR Control Blade-Channel Box Test 1-3
R. Gaunt, R. Gasser, R. Schmidt (SNL)

Experiment-Specific Analyses in Support of Code Development 1-5
L. Ott (ORNL)

SESSION 2
Pressure Vessel Integrity
Chairman: C. Serpan

Heavy-Section Steel Technology Program Overview 2-1
W. Pennell (ORNL)

Potential Impact of Enhanced Fracture Toughness Data on Pressurized Thermal Shock Analyses 2-3
T. Dickson, T. Theiss (ORNL)

Multivariable Modeling of J-R Data 2-5
E. Eason, E. Nelson, J. Wright (M&CB)

Heavy-Section Steel Irradiation Program Overview 2-7
W. Corwin, et al.(ORNL)

Consequence Evaluation of Radiation Embrittlement of Trojan Reactor Pressure Vessel Support 2-9
S. Lu (LLNL)

TMI-2 Vessel Investigation Project (VIP), Metallurgical Program 2-11
D. Diercks, L. Neimark (ANL)

SESSION 3
Radiation Protection: BRC & Part 20
Chairman: D. Cool

USNRC Policy Statement on Below Regulatory Concern 3-1
D. Cool (NRC)

Overview of the Nuclear Regulatory Commission's
Revised 10 CFR Part 20 3-3
H. Peterson, Jr. (NRC)

SESSION 4
Severe Accident Research II
Chairman: F. Eltawila

The Debris Module: An Effective Tool for the Analysis of
Meltdown Progression in LWRs 4-1
R. Gasser, R. Gauntt (SNL)

Lower Head Failure Analysis 4-3
J. Rempe, G. Thinnes, C. Allison (INEL), A. Cronenberg (ESA)

ACE Program Phase A: Containment Filtration Experiments 4-5
M. Merilo (EPRI)

ACE Program Phase B: Iodine Behavior in Containment 4-7
R. Ritzman (EPRI)

An Integrated Structure and Scaling Methodology for
Resolving Technical Issues Relevant to Severe Accidents 4-9
G. Wilson (Technical Program Group)

Scaling Laws for Severe Accident Phenomena in BWRs 4-11
F. Moody, R. Muralidharan, S. Dua (GE)

Debris Dispersal from Reactor Cavity during Low Temperature
Simulant Tests of Direct Containment Heating (DCH) 4-13
S. Levy (S. Levy, Inc.)

Scaling Analysis for DCH 4-15
M. Pilch (SNL)

MELCOR Analysis of the TMI-2 Accident 4-17
E. Boucheron (SNL)

SESSION 5
Piping & NDE
Chairman: C. Serpan

Page

Progress in Improving NDE Reliability 5-1
S. Doctor, et al. (PNL)

Evaluation of Computer-Based NDE Techniques and Regional Support of Inspection Activities 5-3
T. Taylor, R. Kurtz, S. Doctor (PNL)

Advanced NDE Technologies and Characterization of RPV Flaw Distribution 5-5
S. Doctor, et al. (PNL)

Improved Eddy-Current Inspection for Steam Generator Tubing 5-7
C. Dodd, J. Pate (ORNL)

Environmentally Assisted Cracking in Light Water Reactors 5-9
J. Park, et al. (ANL)

Estimation of Fracture Toughness of Cast Stainless Steels in LWR Systems 5-11
O. Chopra (ANL)

Irradiation-Induced Sensitization in Austenitic Stainless Steel of In-Core Components 5-13
H. Chung et al. (ANL)

Short Cracks in Piping and Piping Welds 5-15
G. Wilkowski et al. (BCD)

Interfacing Systems LOCA (ISLOCA) Pressure Capacity Methodology and Davis-Besse Results 5-17
D. Wesley (Impell)

SESSION 6
Containment Testing & Structural Engineering
Chairman: J. Costello

Evaluation of the Leakage Behavior of Pressure-Unseating Equipment Hatches and Drywell Heads 6-1
M. Parks, H. Walther, L. Lambert (SNL)

Large-Scale Seismic Test Program at Hualien, Taiwan 6-3
H. Tang (EPRI), H. Graves (NRC), Y. Yeh (TPC)

Management of the Aging of Critical Safety-Related Concrete Structures in Light-Water Reactor Plants 6-5
D. Naus and C. Oland (ORNL), G. Arndt (NRC)

SESSION 6 (Cont'd.)

Page

Probabilistic Methods for Condition Assessment and Life Prediction of Concrete Structures in Nuclear Power Plants 6-7
B. Ellingwood and Y. Mori (Johns Hopkins Univ.)

Development of the Structural Materials Information Center 6-9
C. Oland and D. Naus (ORNL)

USNRC Structural Damping Research Program 6-11
J. Johnson et al. (EQE), J. Costello (NRC)

A Personal Computer Code for Seismic Evaluations of Nuclear Power Plant Facilities 6-13
J. Xu, A. Philippacopoulos (BNL), H. Graves (NRC)

SESSION 7
Aging and Components I
Chairman: J. Vora

Life Assessment Procedure for LWR Metal Containments 7-1
V. Shah, U. Sinha (INEL), S. Smith (MDC)

Developments in Risk Evaluation of Aging 7-3
W. Vesely, M. Hassan (SAIC)

Degradation Modeling with Applications to Aging and Maintenance Effectiveness Evaluation 7-5
P. Samanta, F. Hsu, M. Subudhi (BNL), W. Vesely (SAIC)

Status - Risk Evaluation from Aging of Passive Components 7-7
J. Phillips, et al. (INEL)

Age-Dependent Risk-Based Methodology and its Application to Prioritization of NPP Components and to Maintenance for Managing Aging Using PRAs 7-9
I. Levy (PNL), W. Vesely (SAIC)

Studies of Aged Cast Stainless Steel from the Shippingport Reactor . . 7-11
O. Chopra, H. Chung (ANL)

SESSION 8
Individual Plant Examination Program & Other Issues
Chairman: T. King

Individual Plant Examination Program - Summary and Status 8-1
J. Mitchell, J. Flack (NRC)

Individual Plant Examinations - An Industry Perspective 8-3
R. Ng (NUMARC)

SESSION 8 (Cont'd.)

Page

Consideration of External Events in the Individual Plant Examination Program 8-5
J. Chen (NRC)

Containment Performance Improvement Program 8-7
W. Beckner, et al. (NRC)

Summary and Status of Generic Issue Resolution 8-9
R. Baer, K. Kniel (NRC)

Source Term Update - Summary and Status 8-11
L. Soffer (NRC)

SESSION 9
Human Factors Research
Chairman: J. Persensky

Review of the Impact of Environmental Factors on Human Performance . . 9-1
D. Echeverria, V. Barnes, A. Bittner (HARC)

An International Comparison of Manpower and Staffing Regulation and Practice in Commercial Nuclear Power Plants: Changes Over the Past Decade 9-3
B. Melber et al. (HARC)

Comparative Study of Alertness and Performance on 8-Hour and 12-Hour Evening and Night Shifts for Nuclear Power Plant Operators 9-5
T. Baker (ICP)

Initial Examination of the Effects of Overtime and Shift Scheduling on Nuclear Power Plant Safety Performance 9-7
K. Baker, J. Olson (HARC), J. Montgomery (PNL)

Human Performance Information Management System: Inventory, Evaluation, and Assessment of NRC Data Sources 9-9
H. Burton, W. Banks (LLNL)

Advanced Human-System Interface Design Review Guidelines 9-11
J. O'Hara (BNL)

Development of a Performance Indicator of the Effectiveness of Human-Machine Interfaces for Nuclear Power Plants 9-13
N. Moray (Univ. of IL)

A Computerized Safety Assessment and Post-Trip Analysis System for the Forsmark Unit 2 Control Room, Integrating a Real Time Expert System and a Modern Graphic Display System 9-15
F. Owre, S. Nilsen, E. Stokke (OECD Halden)

SESSION 9 (Cont'd.)

Page

An Analysis of Reports of Procedure Violations in U.S. Nuclear Power Plants 9-17
V. Barnes, J. Olson (HARC)

SESSION 10
Aging and Components II
Chairman: W. Farmer

Mechanical Properties of Cables Exposed to Simultaneous Thermal and Radiation Aging 10-1
M. Jacobus (SNL), G. Fuehrer (SEA)

Recent Improvements in Check Valve Monitoring Methods 10-3
H. Haynes (ORNL)

USNRC Gate Valve Test Results Challenge Flexwedge Gate Valve, Motor Operator Sizing Equation 10-5
R. Steele, K. DeWall, J. Watkins (INEL)

Reactor Internals Degradation Mechanisms 10-7
K. Luk (ORNL)

Role of Recent Research in Improving Check Valve Reliability at Nuclear Power Plants 10-9
M. Kalsi et al. (Kalsi Eng.)

Aging Assessment of Circuit-Breakers and Relays 10-11
J. Gleason (Wyle)

Effects of Aging on Calibration and Response Time of Nuclear Plant RTDs and Pressure Transmitters 10-13
H. Hashemian et al. (AMS)

SESSION 11
Organizational Factors and Reliability Assessment
Chairman: T. Ryan

Researching Organizational Factors 11-1
F. Coffman (NRC)

Team Performance Measures for Abnormal Plant Operations 11-3
J. Montgomery, D. Seaver, C. Holmes (PNL),
C. Gaddy (General Physics), J. Toquam (HARC)

Non-Nuclear Performance Indicators for NPP Application 11-5
E. Connelly, S. Van Hemel (Communications Tech. Applications),
P. Haas (Concord Assoc.)

SESSION 11 (Cont'd.)

Page

Amalgamation of Performance Indicators to Support NRC Senior Management Reviews 11-7
J. Wreathall, D. Schurman (SAIC), M. Modarres, A. Mosleh, N. Anderson (Univ. of MD)

Modeling the Effects of Dependency Between Humans and Hardware on Overall System Performance 11-9
N. Siu, C. Acosta (MIT)

Dependent Failure Analysis of NPP Data Bases 11-11
S. Cooper, E. Lofgren (SAIC), S. Wong, P. Samanta (BNL)

Conversion of a Mainframe Simulation for Maintenance Performance to a PC Environment 11-13
D. Gertman (INEL)

Human Factors Assessment in PRA using Task Analysis Linked Evaluation Technique (TALENT) 11-15
J. Wells, W. Banks (LLNL)

Human Factor Insights from International Event Reports 11-17
E. Swaton (IAEA)

SESSION 12
Waste Management Research
Chairman: M. Silberberg

Licensing Perspective: Utility of HLW Research to NRC's HLW Licensing Program . . . . . *
R. Browning (NRC)

NRC's HLW Research Program Plan 12-1
G. Birchard (NRC)

High Level Nuclear Waste Research at the Center for Nuclear Waste Regulatory Analyses: A Progress Report 12-3
W. Patrick (SWRI)

Development and Evaluation of a Performance Assessment Methodology for Analyzing the Safety of a Geologic Repository for HLW 12-5
T. McCartin, J. Randall, T. Margulies (NRC)

Licensing Perspective: Utility of LLW Research to NRC's LLW Licensing Program . . . . . *
R. Bangart (NRC)

Low-Level Radioactive Waste Research Program Plan 12-7
E. O'Donnell, J. Lambert (NRC)

SESSION 12 (Cont'd.)

Page

Low-Level Radioactive Waste Classification, Waste Form Stability, Failure Mechanisms, and Radionuclide Releases 12-9
P. Reed (NRC)

Hydrogeology Research 12-11
T. Nicholson (NRC)

SESSION 13
Severe Accident Research III
Chairman: F. Eltawila

MELCOR Simulation of Long-Term Station Blackout at Peach Bottom 13-1
I. Madni (BNL)

Results of Recent ORNL Fission Product Release Tests 13-3
R. Lorenz, M. Osborne, J. Collins (ORNL)

Status of VICTORIA Development and Assessment 13-5
N. Bixler (SNL), T. Heames (SAIC)

SPARTA Project 13-7
V. Cerchia (ENEA)

Large-Scale HDR-Hydrogen Mixing Experiments: Test Group E11 13-9
L. Valencia, L. Wolf (KfK)

ACE Program Phase C: Molten Corium Concrete Interaction (MCCI) and Corium Melt Coolability Experiments 13-11
B. Sehgal (EPRI), B. Spencer (ANL)

The Probability of Mark-I Liner Failure 13-13
T. Theofanous, et al. (UC Santa Barbara)

SESSION 14
Earth Sciences
Chairman: E. Zurflueh

Progress Report for the U.S. National Seismographic Network 14-1
R. Masse', R. Buland (USGS)

Cooperative New Madrid Seismic Network 14-3
R. Herrmann (St. Louis Univ.), A. Johnston (Memphis State Univ.)

Geodetic Measurement of Crustal Strain in the Eastern United States . . 14-5
W. Strange (NOAA)

Seismic Study of Soil Dynamics at Garner Valley, California 14-7
R. Archuleta, S. Seale (UCSB)

SESSION 14 (Cont'd.)

Page

New Evidence for Great Earthquakes in the Pacific Northwest 14-9
B. Atwater (USGS)

Paleoliquefaction Investigations Along the Atlantic Seaboard with Emphasis on the Prehistoric Earthquake Chronology of Coastal South Carolina 14-11
D. Amick, et al. (EBASCO)

SESSION 15
Accident Management
Chairman: N. Lauben

IAEA Accident Management Users Manual . . . . . *
R. Mauersberger (IAEA)

U.S. Accident Management Program 15-1
L. Shotkin (NRC)

Severe Accident Natural Circulation and Depressurization in PWRs . . . 15-3
R. Dallman et al.(INEL)

Assessment of Uncertainties in Severe Accident Management Strategies . 15-5
W. Kastenberg et al. (UCLA)

Identification and Assessment of Containment and Release Management Strategies 15-7
J. Lehner, C. Lin, P. Neogy (BNL)

Failure of PWR-RHRs under Cold Shutdown Conditions: Experimental Results from the PKL Test Facility 15-9
R. Mandl, K. Umminger, J. Logt (Siemens, KWU)

SESSION 16
Probabilistic Risk Assessment Topics
Chairman: H. VanderMolen

Accident Sequence Analysis for a BWR During Low Power and Shutdown Operations 16-1
D. Whitehead, T. Hake (SNL)

Status of the Surry Low Power and Shutdown PRA 16-3
T-L. Chu, R. Fitzpatrick (BNL)

Diablo Canyon Internal Events PRA Review: Methodology and Findings . . 16-5
R. Fitzpatrick, G. Bozoki (BNL)

Application of NUREG-1150 Methods and Results to Accident Management . 16-7
S. Dingman, T. Sype, A. Camp (SNL)

SESSION 16 (Cont'd.)

Page

Integrated Results of the Level 1 PRA Analysis for the LaSalle Plant . 16-9
A. Payne, Jr. (SNL)

Integrated Results of the Level 3 PRA Analysis for the LaSalle Plant . 16-11
T. Brown, L. Miller, A. Payne, Jr. (SNL)

Status of the Risk Evaluation from the Aging of Passive Structures . . *
M. Sattison (INEL)

SESSION 17
Seismic Engineering
Chairman: N. Chokshi

Overview of Seismic Design Margin Methodology Research 17-1
N. Chokshi (NRC)

Methodology for the Seismic Portion of the IPE and Coordination of Ongoing Seismic Issues 17-3
R. Kenneally, N. Chokshi (NRC)

Risk Insights from Seismic Margin Reviews 17-5
R. Budnitz (Future Resources Assoc.)

Seismic Testing and Evaluation of Relays - Past and Future 17-7
K. Bandyopadhyay, C. Hofmayer (BNL)

Seismic Component Fragility Data Base for IPEEE 17-9
K. Bandyopadhyay, C. Hofmayer (BNL)

Summary of Results Obtained from the Testing of Reinforced Concrete Shear Walls 17-11
C. Farrar, W. Baker (LANL)

The Effects of Reduced Structural Stiffness on Plant Risk and Margin . 17-13
M. Bohn, E. Klamerus (SNL), R. Kenneally (NRC)

SESSION 18
Thermal Hydraulics
Chairman: D. Bessette

Completion of Thermal-Hydraulic Code Development: TRAC-PF1/MOD2, RELAP5/MOD3, and TRAC-BF1/MOD1 18-1
L. Shotkin (NRC)

Nuclear Plant Analyzer Desktop Workstation 18-3
R. Beelman (INEL)

SESSION 18 (Cont'd.)

Page

Reactor System Analyses of Advanced, Passive LWR Designs 18-5
S. Modro, J. Miller, S. Sloan (INEL), G. Rhee (NRC)

UPTF Experiment: Full-Scale Tests on Countercurrent Flow Behavior in PWR Downcomer 18-7
P. Weiss, J. Liebert (Siemens-KWU)

UPTF Results with Respect to Selected Reactor Safety Issues 18-9
G. Rhee (NRC), R. Zipper (GRS), Y. Murao (JAERI)

Usefulness of a Reduced Pressure, Reduced Height Scaled Test Facility 18-11
M. diMarzo, K. Almenas, Y. Hsu (Univ. of MD)

BWR Stability Research Program 18-13
H. Scott (NRC)

Resolution of U.S. Regulatory Issues Involving BWR Stability 18-15
L. Phillips (NRC)

ATTACHMENT 3

LOW-LEVEL RADIOACTIVE WASTE RESEARCH PROGRAM PLAN

Edward O'Donnell, Janet Lambert

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Office of Nuclear Regulatory Research
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Washington, DC 20555

ABSTRACT

The Office of Nuclear Regulatory Research, has developed a strategy for conducting research on issues of concern to the U.S. Nuclear Regulatory Commission (NRC) in its efforts to ensure safe disposal of low-level radioactive waste (LLW). The resulting program plan has been published in NUREG-1380. The plan provides an integrated framework for the LLW research program to ensure that the program and its products are responsive and timely for use in NRC's LLW regulatory program. The plan addresses technical and scientific issues and uncertainties associated with the disposal of LLW, presents program goals and ways for achieving them, establishes a long-term strategy for conducting the confirmatory and investigative research needed to meet these goals, and includes schedules and milestones for completing the research. Areas identified for investigation include waste form and other material concerns, failure mechanisms and radionuclide releases, engineered barrier performance, site characterization and monitoring, and performance assessment. The plan includes projects that (1)-analyze and test actual LLW and solidified LLW under laboratory and field conditions to determine leach rates and radionuclide releases, (2)-examine the radiological and chemical characteristics of decommissioning waste from nuclear power stations,(3)-examine the short- and long-term performance of concrete-enhanced LLW burial structures and high-integrity containers, (4)-investigate the long term effectiveness of disposal unit covers in controlling water infiltration into disposal units, (5)- examine the information needed at time of closure for predicting future facility performance, (6)-attempt to develop a predictive model of the rate of radionuclide release at the boundary of waste disposal units, (7)-examine radionuclide transport behavior, pathways, uptake, and transfer coefficients of radionuclide releases from LLW disposal facilities, and (8)-attempt to predict water movement and contaminant transport through low permeability saturated media and unsaturated porous media.

INTRODUCTION

As the agency charged with the regulation of commercial low-level radioactive waste (LLW) disposal, the Nuclear Regulatory Commission's (NRC's) task is to establish and implement the framework for licensing all aspects of LLW

disposal facility siting, design, construction, operation, and closure to ensure that LLW disposal will present no undue risk to the public health and safety or the environment.

To meet its LLW disposal regulatory responsibilities, the NRC requires technical data and methods for evaluating the demonstrations made by license applicants that a proposed LLW disposal facility will isolate radioactive materials over the period of time that these wastes remain dangerous to the public. The data and methods that the NRC uses to review the submittals of license applicants must be independent of the assessment techniques and data bases developed by applicants in support of their submittals. The purpose of NRC's LLW research program is to furnish the independent data and methods as well as the technical understanding required by the LLW licensing office to ensure safe and effective radioactive waste management and disposal.

NRC's Office of Nuclear Regulatory Research (RES) has published a research plan for LLW (NUREG 1380) to ensure that the research program and its products are responsive and timely for use in the LLW regulatory program. This paper explains the regulatory and technical issues considered in developing NRC's LLW Research Plan and outlines the strategy for addressing those issues.

REGULATORY FRAMEWORK FOR DISPOSAL OF LLW

To regulate the safe disposal of LLW NRC must have a practical understanding of a complex set of scientific and technical variables, as well as the capability to apply this understanding in anticipating the outcome of their interactions. With this understanding and capability, the NRC staff should be able to evaluate the expected performance of a proposed LLW disposal facility against the performance objectives in 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," to determine whether the facility will be capable of isolating the hazardous components of LLW from the environment.

Part 61 contains procedural requirements, general performance objectives, and technical requirements applicable to any method of shallow land disposal of LLW. The performance objectives in Part 61 Subpart C specify that shallow land disposal facilities for LLW must be sited, designed, operated, closed, and controlled after closure in a manner that protects the general population from releases of radioactivity during and after operation, the workers on-site from releases during operation, and the inadvertent intruder from releases after closure. Section 61.41 provides the overall performance objective for the safe disposal of LLW in terms of doses--limiting the dose to any member of the public from any release to less than 25 millirems/yr for the whole body, 75 millirems/yr to the thyroid gland, and 25 millirems/yr to any other organ. The performance objectives are the basis for the performance assessment for any LLW disposal licensing decision and thus are the driving force for the research proposed in NUREG 1380.

The technical requirements in Part 61 Subpart D also serve as impetus for the LLW research program. The technical requirements are established for each stage in the life of a potential near-surface LLW disposal facility, including

the preoperational phase, operational phase, closure phase, observation and maintenance phase, and finally for the period of institutional control. One of the principal technical requirements driving the LLW research plan is paragraph 61.50(a)(2) which requires that an acceptable disposal site must be capable of being characterized, modeled, analyzed, and monitored. NRC must have the capability to independently model and analyze the disposal facility information presented by an applicant.

TECHNICAL ISSUES FOR LLW DISPOSAL

LLW disposal licensing decisions require a thorough understanding of the nature and form of the LLW intended for disposal, the surface and subsurface characteristics of the site where disposal is to occur, and how the various design features of the planned disposal facility will work with the site to enhance its isolation potential.

Clearly questions about the adequacy of a proposed LLW disposal facility begin with uncertainties regarding the characteristics and form of the LLW itself. The nature and form of LLW determine its potential source term and its potential for release of radioactivity or other hazardous materials, the overall long-term stability of the disposal site, the preferred engineered enhancements, and the likely pathways for release to the environment.

A fundamental problem in providing for safe disposal of LLW is that the term "low-level waste" refers to a wide range of radioactive wastes with an equally wide range of physical and chemical characteristics. All industries; hospitals; medical, educational, or research institutions; private or government laboratories; or facilities forming part of the nuclear fuel cycle (e.g., nuclear power plants, fuel fabrication plants) using radioactive materials as a part of their normal operational activities generate so-called low-level radioactive waste just as they generate other types of hazardous and nonhazardous wastes.

LLW consists of radioactive materials and other materials that have been in contact with the radioactive materials and thus are contaminated or suspected of being contaminated. It is generated in many forms, concentrations, and amounts. It ranges from trash that may be only slightly contaminated with radioactivity to highly radioactive materials such as activated structural components from nuclear power reactors. The form of the waste may be solid, liquid, or gaseous and it may include a variety of chemicals. LLW ranges in activity from thousands of curies per cubic meter to less than a few microcuries per cubic meter.

The LLW disposal site environment contributes another set of complex variables that, together with the characteristics of the LLW, must be understood in order to assess the performance of a proposed disposal facility. The site determines the physical and hydrologic environment into which the waste must be placed and in which it must maintain its integrity during the hazardous life of the LLW. Figure 1 is a schematic of a shallow land disposal facility. The schematic indicates some of the natural and engineered characteristics of the site that affect the stability and long-term performance of the individual

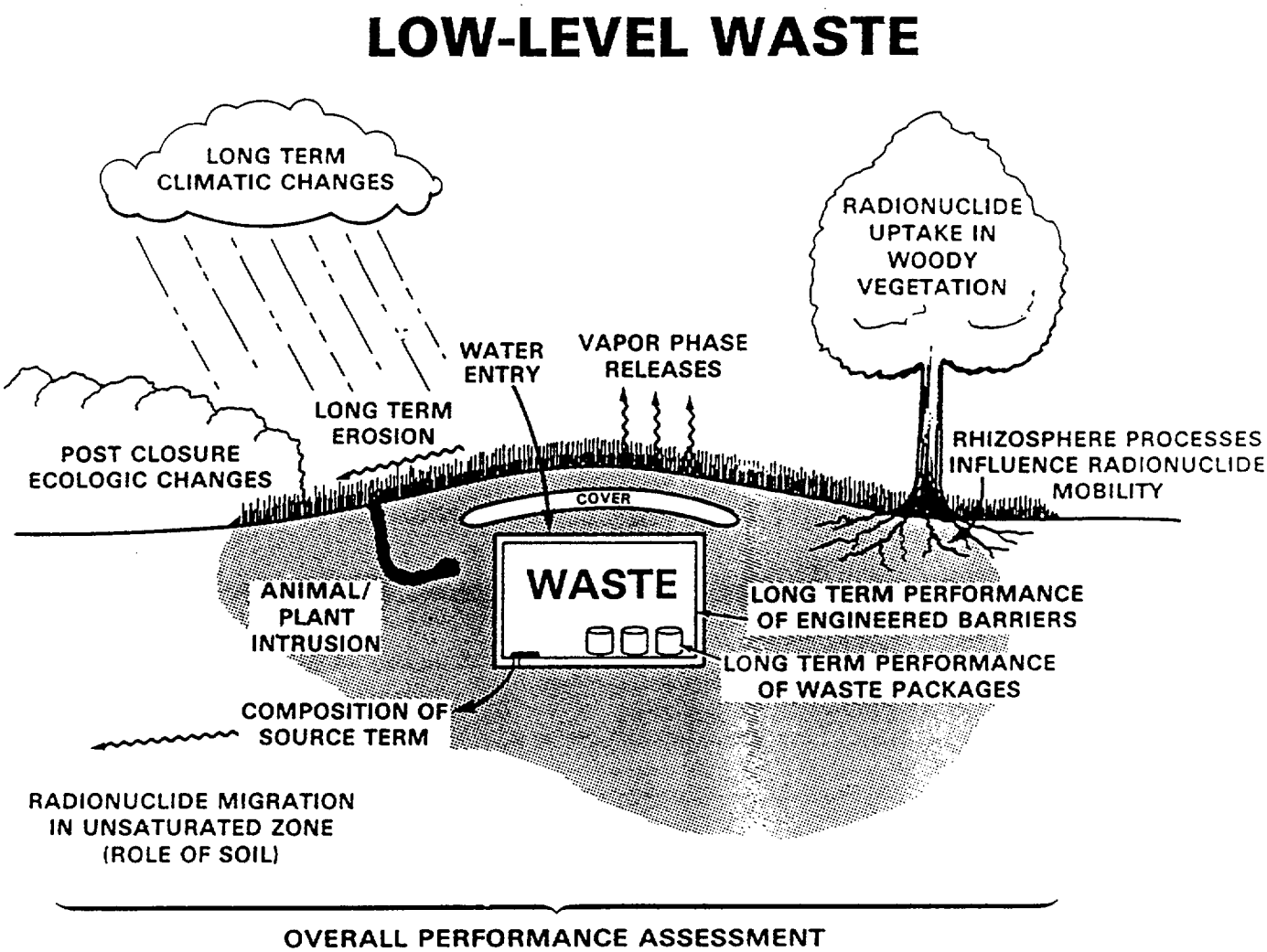

Figure 1 Technical uncertainties and research needs associated with low-level radioactive waste disposal.

The uncertainties begin with the radionuclide and chemical content of the waste and its long-term performance. Engineered barriers may be used to provide structural stability to the disposal facility, to contain waste, and to keep water from entering disposal units. Performance assessment entails evaluating everything from waste package degradation to water entry, performance of engineered barriers, role of the geologic environment in containing waste, radionuclide migration, and biologic uptake into the food chain to humans.

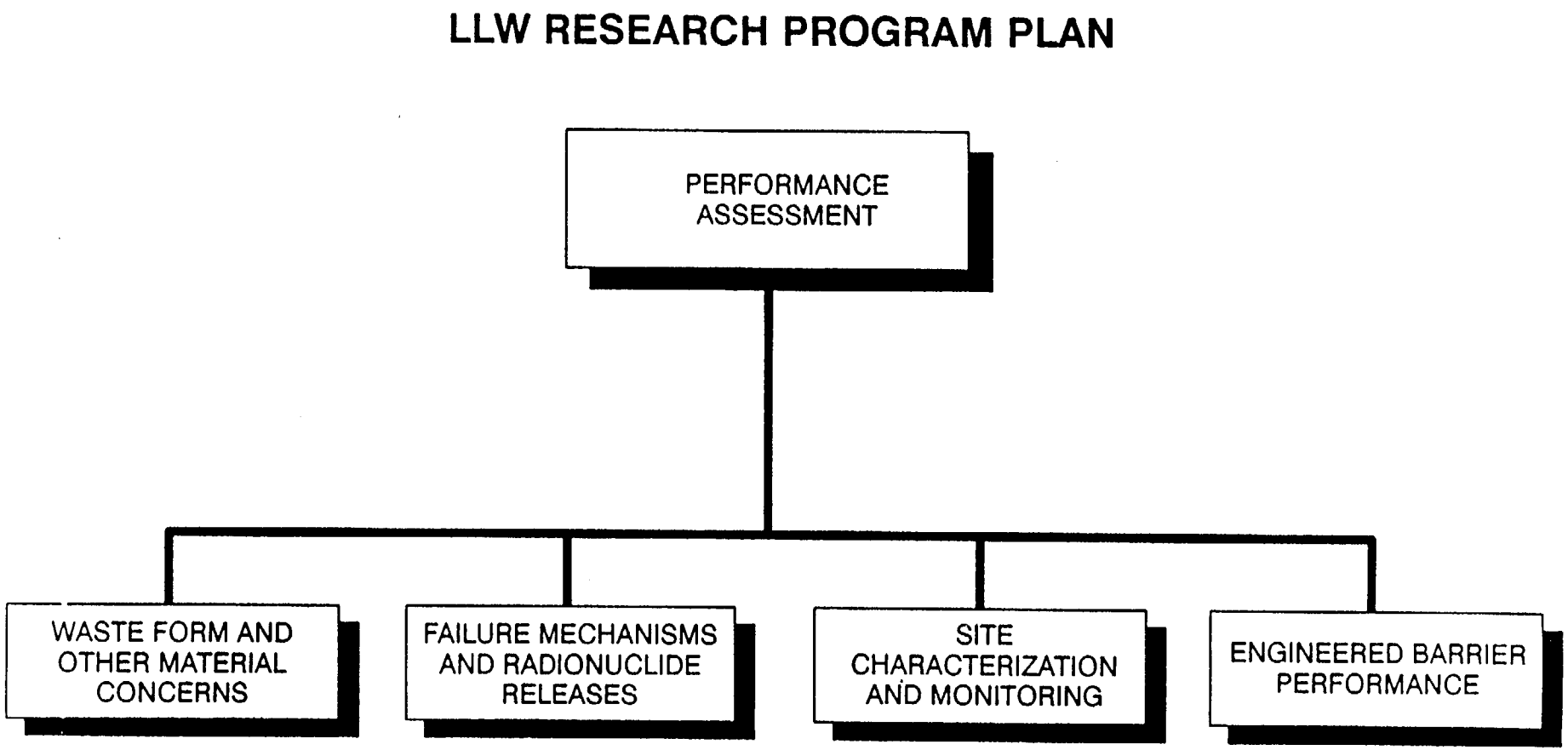

Figure 2. Program Element Structure

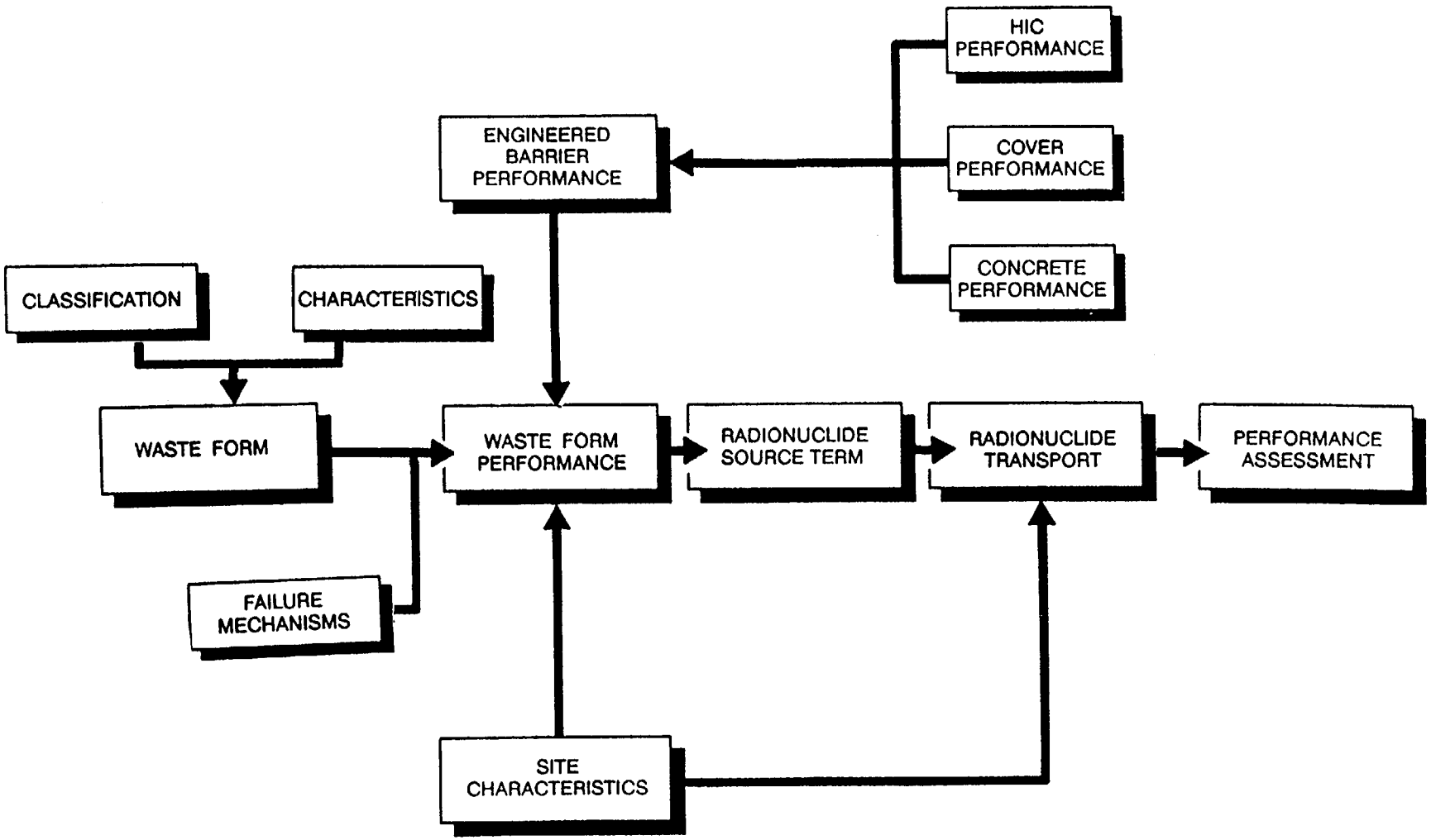

Figure 3. Overall LLW Research Integration

components as well as the overall LLW disposal facility. The major pathways for potential long-term radiological exposure to the public are also shown on the schematic and include potential leaching and transport of the waste by and into the ground water, deliberate or inadvertent human intrusion into the disposed waste, intrusion and dispersion by plants and animals, long-term erosion of the site by wind or water, and resulting radionuclide transport by surface water or the air.

RESEARCH PROGRAM STRATEGY

Most of the LLW research needs flow from the state of technical or scientific uncertainty in a specific area of disposal technology and reflect a recognition of the magnitude of the regulatory or licensing problems caused by the uncertainty. Consideration of the uncertainties and any corresponding threat to the public health and safety provides a basis for identifying research needs, for determining the level of research effort needed, and for determining when a specific piece of research has provided the required information or has reduced the level of uncertainty sufficiently for regulatory purposes.

Given the above, NRC has identified five major areas where research is considered important to provide information for LLW disposal licensing decisions. The areas are: (1)-Waste Form and other Material Concerns, (2)-Failure Mechanisms and Radionuclide Releases, (3)-Engineered Barrier Performance, (4)-Site Characterization and Monitoring, and (5)-Performance Assessment. Following is a discussion of the major issues in each of these areas and a discussion of the research which is planned to resolve the issues.

WASTE FORM AND OTHER MATERIAL CONCERNS

Waste Characterization

In order for NRC to predict the behavior of LLW in the disposal environment, it is necessary for NRC to know as much as possible about the waste. However, unresolved technical and scientific issues exist regarding (1)-the range of physical and chemical characteristics of commercial LLW, particularly the radiological and chemical characteristics of evaporator concentrates, decontamination waste, and decommissioning waste; (2)-the characteristics of the biological component of hospital/laboratory LLW; and (3)-the distribution and concentration of long-lived alpha and beta emitters in LLW from nuclear facilities.

To provide the necessary information, NRC plans to characterize low-level waste streams and solidified LLW for radionuclides and chemical content through the analysis of samples collected from actual operating nuclear power plants and other LLW generators. Various waste forms will be tested to determine if they comply with the guidance provided by the NRC branch technical position on radioactive waste classification and waste form and a proposed draft NRC regulatory guide on LLW form stability and manifest reporting.

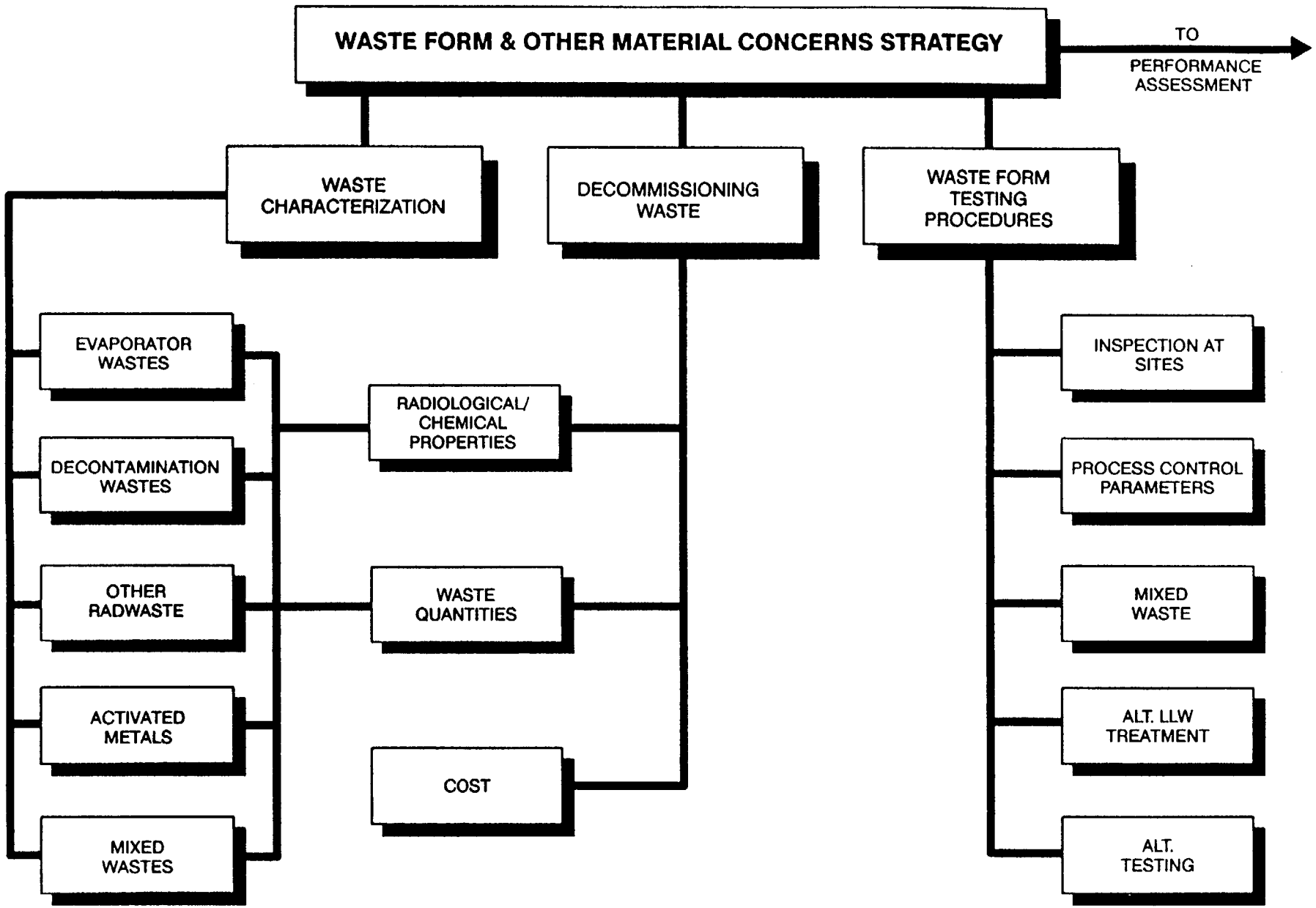

Figure 4 Research strategy for Waste Form and Other Material Concerns program element.

Testing Methods to Ensure Regulatory Compliance

Safe disposal of LLW requires that the LLW disposed of at NRC-licensed disposal facilities meets the requirements for waste form and characteristics established in 10 CFR Part 61. If the NRC is to be able to ensure compliance with Part 61, confirmatory information is needed for the following: (1)-reliability of existing methods for inspection of LLW at disposal facilities to verify compliance with Section 61.56 and disposal site requirements, (2)-identification of process control parameters critical to dewatering and solidification of LLW, (3)-reliability of methods for ensuring compliance with dewatering and solidification of LLW, (4)-reliability of methods for determination of compliance with mixed waste requirements, (5)-reliability of procedures for measurement of nonradiological hazardous material in LLW packages prior to disposal, (6)-alternative techniques for LLW treatment where conventional techniques are unacceptable, and (7)-reliability of existing screening tests on waste form.

The strategy for evaluating test methods will be to assess existing methods through literature reviews backed by confirmatory laboratory work to establish the validity of existing test methods.

Decommissioning of Nuclear Facilities

Decommissioning of nuclear power plants will begin in the near future and will produce large amounts of LLW for disposal at commercial disposal facilities. The current level of knowledge regarding desommissioning waste is not extensive. Areas of uncertainty regarding decommissioning wastes include (1)-the accuracy of the information for generation of decommissioning wastes because of the paucity of information available, (2)-the technology of decommissioning of nuclear facilities, particularly the safety and costs of decommissioning, and (3)-the distribution and concentration of radioactivity from decommissioning with the greatest concern being activation products at nuclear power plants.

In order to provide the desired information, NRC plans to sample and analyze products from the decommissioning of actual power plants. Attention will be given to (1)-characterizing the distribution, curie quantity, and isotopes remaining prior to dismantlement/decontamination as well as the type and quantities of radioactive decommissioning waste, (2)-determining estimates of unit cost for various decommissioning activities, and (3)-assessing all information acquired from actual decommissioning operations to present an overview of the technology, safety, and costs for decommissioning all nuclear facilities with special emphasis on power reactors.

FAILURE MECHANISMS AND RADIONUCLIDE RELEASES

Waste Form Performance

LLW intended for disposal may take a variety of forms and each may interact differently with the disposal environment. Thus the characteristics of the waste form will contribute significantly to the overall performance of a

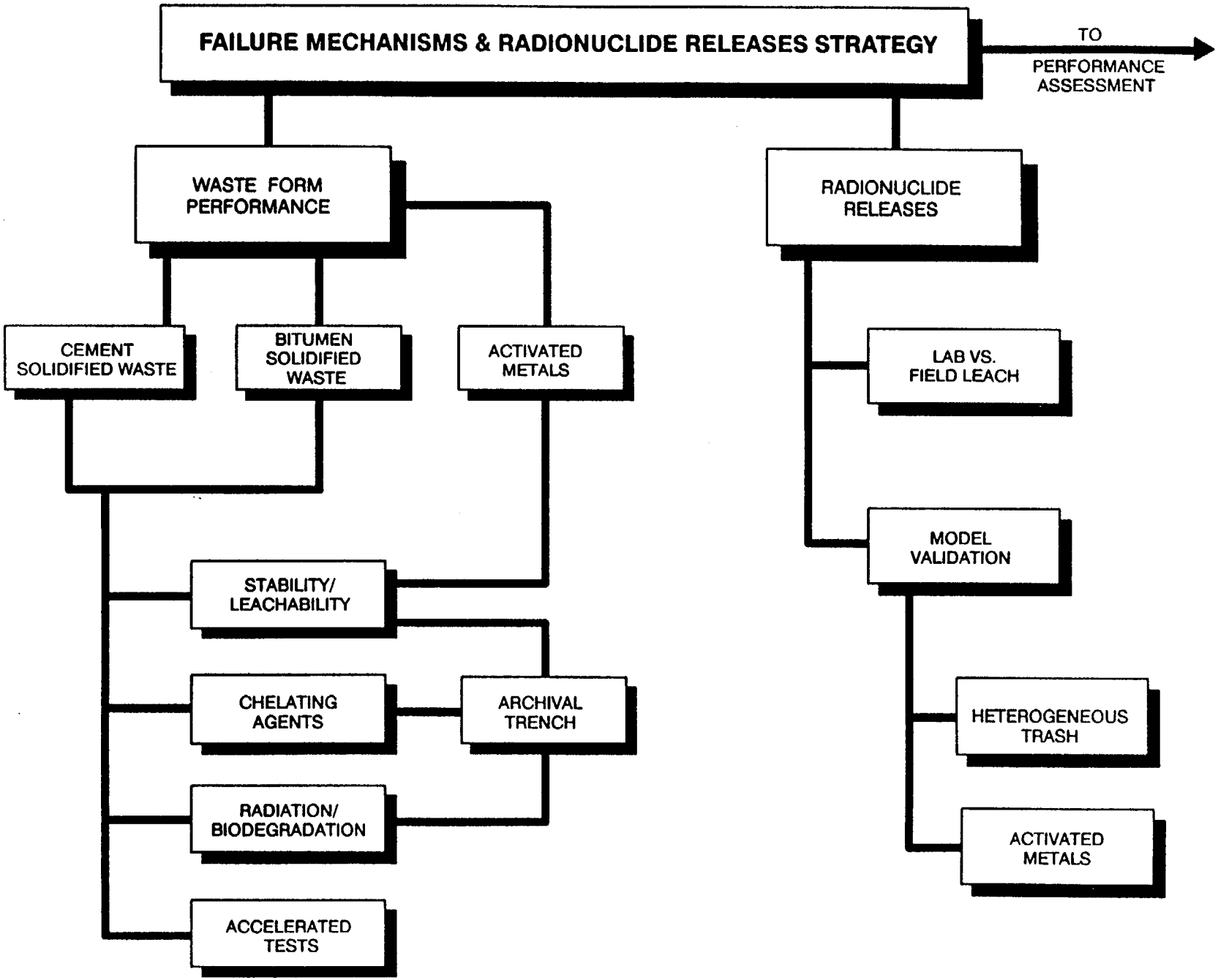

Figure 5 Research strategy for Failure Mechanisms and Radionuclide Releases program element.

disposal facility. In evaluating the performance of various waste forms, uncertainty lies in (1)-the long-term performance of commercial LLW waste forms under disposal conditions; (2)-the effect of chelating agents and nonradiological constituents on the release and transport of radionuclides from LLW, especially decontamination wastes; and (3)-the leachability of activated metals from nuclear power stations and decommissioned nuclear facilities.

NRC plans to reduce uncertainties in these areas by conducting small-scale laboratory tests on actual solidified LLW waste forms from nuclear facilities followed by large-scale field tests in lysimeters. The proposed program focuses on four lines of investigation: (1)-stability/leachability of solidified waste forms; (2)-the effect of chelating agents and other waste constituents on decontamination LLW releases; (3)-the effect of chemicals, radiation, and biodegradation on solidified LLW; and (4)-the leachability of activated metals.

Radionuclide Releases

Tests to determine the potential release of radionuclides and other hazardous materials from different LLW forms have typically been conducted in laboratories. As a result, there is a need to (1)-understand the relationship of laboratory leaching studies to actual field conditions that control radionuclide releases, and (2)-validate the models for releases of radionuclides to the environment from LLW disposal facilities, particularly those dealing with high-volume heterogeneous trash and high-activity activated metals. Additional information is necessary to determine the regulatory applicability and usefulness of these tests and models.

NRC plans to characterize the physical and chemical processes that control releases of radionuclides, chelating agents, and other hazardous materials from LLW and then to develop mechanistic models that describe these processes. Emphasis will be given to (1)-relating the results of laboratory leaching studies to actual field conditions that control releases, and (2)-validating models for radionuclide releases from high-volume heterogeneous trash and high-activity activated metals.

ENGINEERED BARRIER PERFORMANCE

Long-Term Performance of High-Integrity Containers

Various styles and kinds of high-integrity containers (HIC) may be used for LLW disposal. There are outstanding questions regarding the performance of these containers and their the long-term capability of maintaining structural integrity and containing radionuclides. In particular, the effects of radiation on high-integrity containers, and the effect of biodegradation and microbial activity on high-integrity containers are not well understood.

NRC's strategy for resolving these questions is to conduct accelerated testing on a variety of materials, initially at a small scale. Promising HIC materials will then be tested at a large scale, with accelerated testing and

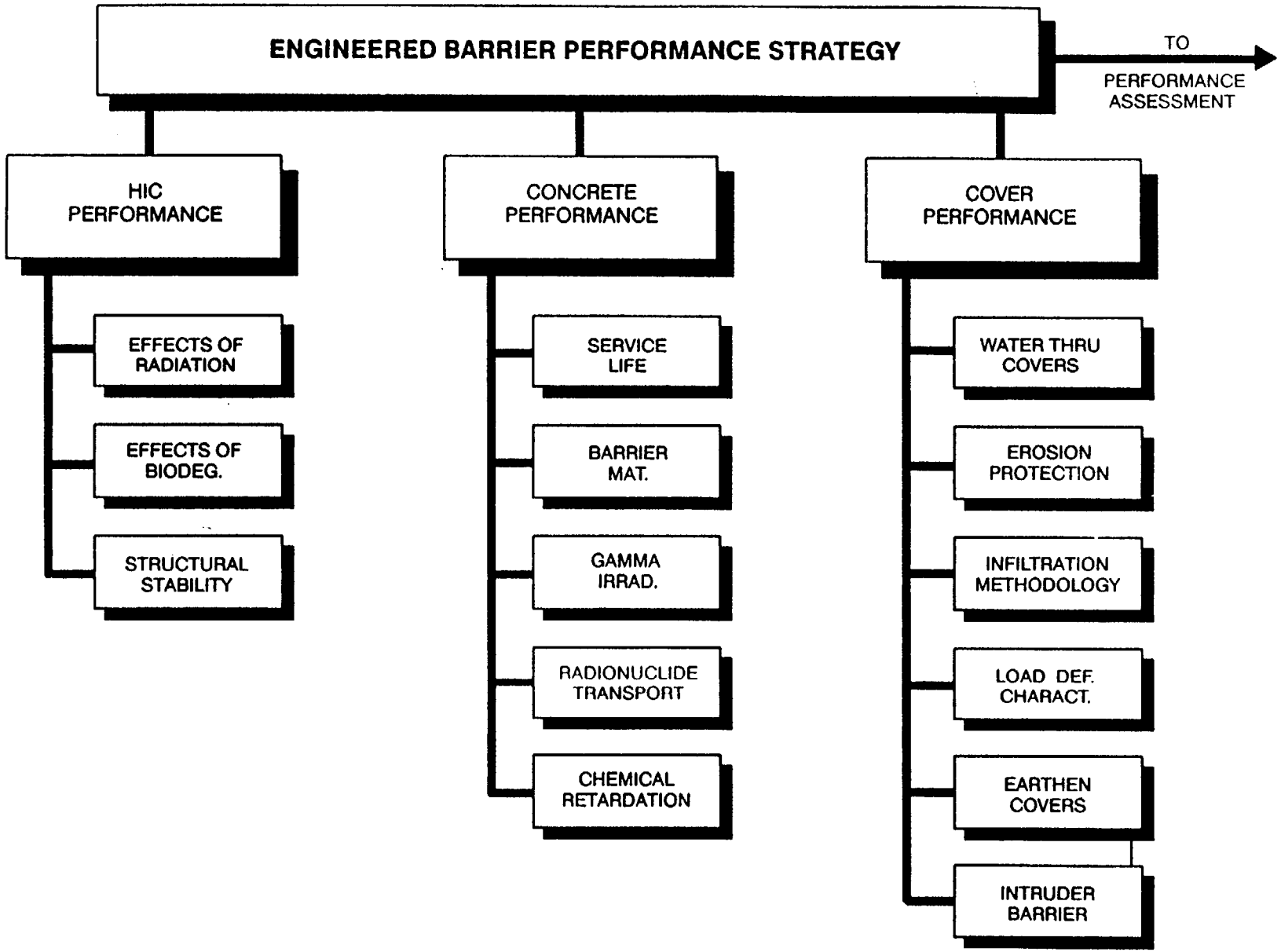

Figure 6 Research strategy for the Engineered Barrier program element.

long duration testing of replicate samples. Additional tests would be conducted on replicate samples to determine the ability of the materials to withstand structural loading and chemical/radiolytic attack.

Long-Term Concrete Performance

Since a number of States are considering LLW disposal facility designs which incorporate concrete structures, it is important to understand how the concrete will perform under disposal conditions. Unresolved issues concerning the performance of concrete include (1)-predicting service life for concrete structures, (2)-the performance of barrier materials used in concrete, (3)-the effect of gamma irradiation on concrete, (4)-mathematical modeling of radionuclide transport through concrete, and (5)-the degree of chemical retardation provided by concrete, particularly with new concrete formulations.

Much like the research strategy for evaluating the anticipated performance of HICs, NRC plans to conduct accelerated tests on a variety of concrete formulations, initially on a small scale, then moving to tests on a larger scale for the most promising formulations NRC plans to emphasize determining (1)-the service life of materials, (2)-the performance of barrier materials added to concrete, (3)-the degree of chemical retardation provided by concrete, and (4)-mathematical models for predicting radionuclide movement through concrete.

Long-Term Cover Performance

In licensing a LLW disposal facility, the NRC must be able to assess how the cover will contribute to the overall performance of the facility. Outstanding issues regarding the evaluation of cover performance include (1)-control of water entry through covers, particularly when there is subsidence, (2)-the distance over which a capillary barrier is effective; (3)-the reliability of existing methods used for determining compliance of LLW disposal facility earthen liners and covers with regulatory requirements; (4)-the erosion protection design criteria for long-term stabilization of LLW disposal facilities; (5)-the reliability of existing infiltration evaluation methods for determining compliance with design specifications; (6)-the load deformation responses of components that contribute to the successful performance of an LLW disposal facility; and (7)the long-term performance of engineered barriers against inadvertent intrusion.

NRC's strategy for resolving these uncertainties regarding the performance of the covers at LLW disposal facilities has been and continues to be focused on humid region problems where there is potential for infiltration of significant amounts of water through covers. Testing is being done under carefully controlled conditions in the field in large-scale lysimeters following initial small-scale laboratory tests and modeling of cover performance. Emphasis is being given to managing infiltration with or without subsidence acting on the cover. Other areas of future investigation include (1)-evaluating the reliability of existing methods for determining compliance of LLW earthen covers and liners with regulatory requirements, (2)-determining erosion protection design criteria for long-term stabilization of covers,

(3)-determining load deformation responses of components that contribute to cover performance, and (4)-determining the long-term performance of intruder barriers.

SITE CHARACTERIZATION AND MONITORING

Site Characterization

As previously stated, the NRC must be able to evaluate assertions made by a LLW disposal facility lisence applicant that the intended site will be acceptable under Part-61. In addition, the NRC must be able to ensure that the hydrologic and geochemical properties of the site controlling contaminant transport are measured and understood prior to issuance of a license. This means that both the surface water hydrology of the site and the ground-water hydrology of the site (including both the saturated and unsaturated zones) and the ground-water chemistry must be adequately characterized. With respect to determining surface-water hydrology for a site, unresolved issues remain including (1)-estimation of long-return flooding (e.g., 500-year flood) beyond the period of record, (2)-estimation of drainage changes due to natural processes or human activities over the long term (100-300 years), and (3)-determination of erosion and land-form modifications over the long term.

With respect to evaluating the saturated zone hydrology, additional information is needed in the areas of (1)-determining the steady-state and transient water tables for the site, (2)-determining the impact of the engineered facility on existing ground-water flow paths, and (3)-determining the long-term impact of regional/local ground-water use on an LLW disposal facility.

In the case of characterizing the unsaturated zone hydrology, issues that remain outstanding include (1)-determining hydraulic and pneumatic properties of heterogeneous unsaturated sediments, (2)-determining ambient moisture content and hydraulic potential of heterogeneous unsaturated sediments, and (3)-delineating liquid and vapor pathways in unsaturated sediments because of nonuniform moisture content and pressure heads.

With regard to ground-water chemistry, additional information regarding the complex interaction of leachate with the natural ground water is needed.

Monitoring

An applicant for an LLW disposal license must collect information about the proposed site to determine if the site is suitable. The monitoring information or data collected at the site must provide an accurate description of the site. In general, more information on physical processes and monitoring techniques is available for the saturated zone than the unsaturated zone. The principal uncertainty is in the validity of measurement techniques for the unsaturated zone.

More specifically, additional information is needed in the areas of (1)-determining the effect of spatial variability on monitoring strategies;

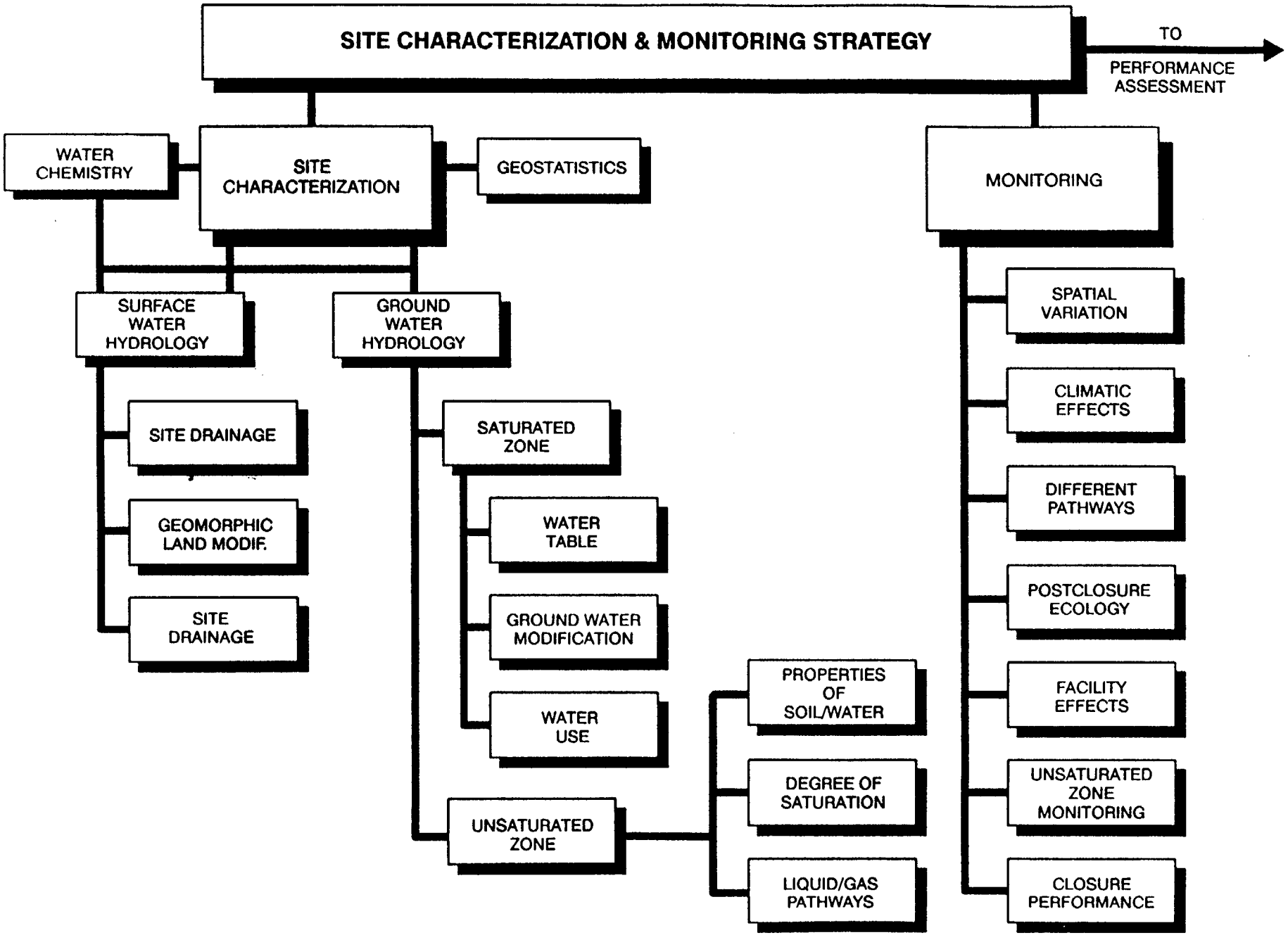

Figure 7 Research strategy for the Site Characterization and Monitoring program element.

(2)-determining the overall monitoring strategy for each of the pathways; (3)-determining the effect of engineered barriers on monitoring strategies; (4)-accounting for the extreme variability of the natural ground-water flow system in the unsaturated zone; (5)-accounting for the complex interaction among contaminant chemistry, the concrete in the engineered system, and the natural ground-water flow system; (6)-determining information needed to predict performance at time of closure; (7)-determining post-closure ecologic changes acting on LLW disposal facilities; and (8)-determining long-term climatic changes.

The strategy for meeting needs for site characterizion and monitoring is to focus on (1)-determining what information is needed for predicting contaminant transport to insure that that information will be gathered during site characterization and as part of monitoring during operation, and (2)-establishing methods for providing early warning of contaminant movement from beyond the boundary of disposal units. The greatest uncertainty is in characterizing and monitoring low-permeability saturated media and unsaturated porous media. Consequently greatest emphasis will be given to these areas.

PERFORMANCE ASSESSMENT

Performance Assessment Pathway Model Evaluation

To help assess the performance of a proposed facility and to evaluate the applicants' assertions regarding the requirements in 10-CFR-Part-61, the NRC intends to use models predicting the interactions of the waste and the site. The principal issue that requires investigation is the validity of the models used. More specifically, it is necessary to (1)-determine an overall methodology for assessing the contribution of various pathways (air, water, etc.) for different scenarios; (2)-be able to account for engineered barriers in the evaluation of different scenarios; (3)-determine the effect of field-scale heterogeneity on the prediction of site behavior; (4)-gather relevant, accurate data on surface water drainage and flood assessment into available models and calibrate for the site; and (5)-gather relevant, accurate data into available ground-water models on saturated and unsaturated flow and transport and calibrate for the site.

Resolution of performance assessment issues will require technical information and predictive models resulting from research on waste form and waste package performance, failure mechanisms, radionuclide releases, engineered barrier performance, and site characterization. With regard to scenario evaluation, the strategy will be to develop a methodology for assessing (1)-the contributions of various scenarios, (2)-the effect of field-scale heterogeneity on the prediction of site behavior, and (3)-the ability to account for engineered barriers in the evaluation of different scenarios.

Radionuclide Source Term

A major part of performance assessment is determining the radionuclide source term. Calculating the source term requires that the releases of radionuclides and chemicals leached during waste form and waste package degradation be

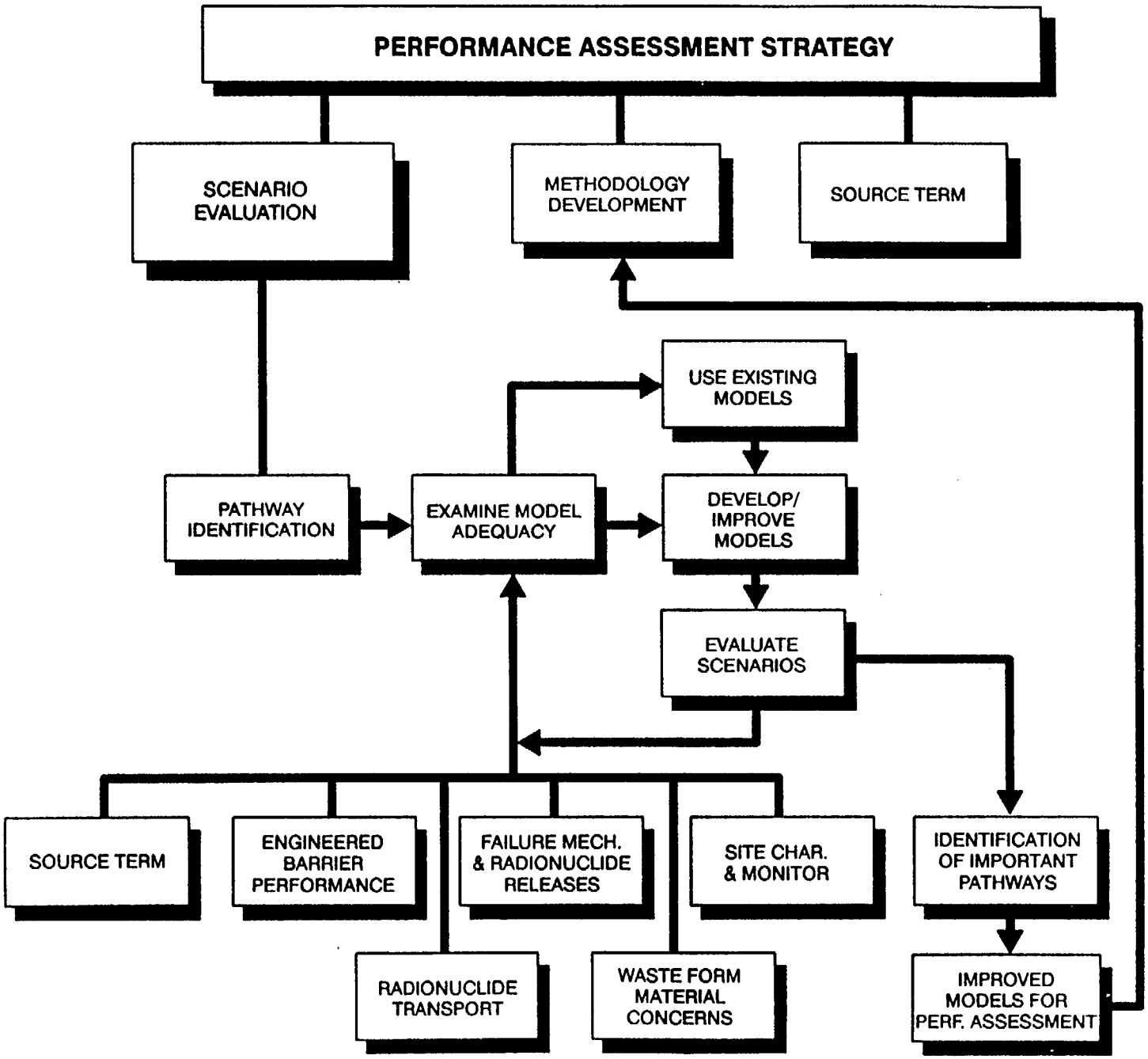

Figure 8 Research strategy for the Performance Assesment program element.

modeled.

With regard to source term model development, issues that must be resolved include (1)-accounting for the range of radiological and chemical characteristics of LLW, (2)-developing a systematic disposal unit model from inventories of disposal sites, (3)-determining the important parameters and processes influencing radionuclide release and transport, and (4)-benchmarking a source term model against lysimeter tests and in-situ data.

With regard to the assessment of waste form degradation, the most outstanding issue is determining the corrosion mechanisms and rates, particularly for high-integrity containers.

For the assessments of waste form leaching, areas where the NRC needs additional information include (1)-determining mechanisms and rates of leaching, (2)-determining release from partially failed containers, and (3)-coupling diffusion models with dissolution models.

To resolve uncertainties regarding the source term, NRC plans to use modeling combined with laboratory test data on waste form and package performance to quantify the release of radionuclides and other contaminants, including chelating agents, to the boundary of the disposal unit.

Transport of Radionuclides and Chemicals at LLW Disposal Sites

The last test of the potential performance of an LLW facility will be how far and how fast radionuclides will move through the site and into the environment after a source term becomes available.

In deciding whether or not to license LLW disposal facilities, the NRC will have to be able to understand and quantify radionuclide transport under unsaturated and saturated flow conditions. Uncertainties that must be resolved in this area include (1)-the relative importance of mechanisms (e.g., surface complexation, ion exchange model, precipitation/ dissolution, physical and chemical sorption, matrix diffusion) controlling retardation; (2)-the relationship of laboratory measurements of retardation to field measurements; (3)-the role played by soil composition in controlling radionuclide movement; (4)-the role played by nonradiological waste package components in enhancing radionuclide transport; (5)-the role played by biotic processes in enhancing radionuclide movement considering the complexity of organic ligands produced in the rhizosphere of vegetation and the role played by microbes in metal corrosion and in changing the chemistry of ground-water systems; (6)-the role of organic complexants and microparticulates in radionuclide migration; (7)-the transport behavior of C-14 and H-3, particularly in applying Regulatory Guide 1.109 methodology for determining environmental parameters, especially C-14 transfer coefficients for transport through soil and transpiration to the atmosphere; and (8)-validation of radionuclide retardation/transport models to understand the transport of chemicals and radionuclides at LLW disposal sites.

NRC's research strategy is to quantify mechanisms controlling movement and to

ascertain the role played by soil composition, biotic processes, organic complexes, and microparticulates. Radionuclide retardation/transport models will be validated against laboratory, large-scale lysimeter data, and field data on radionuclide releases from actual disposal facilities, including DOE facilities and foreign sites. NRC will trace the movement of releases from the boundary of disposal units into the accessible environment, with a goal of developing a complex hydrochemical transport code.

CONCLUSION

The research program described in this paper and set out in NRC's NUREG-1380, "Low-Level Radioactive Waste Research Program Plan," presents the baseline LLW research program for FY-1990 and beyond. It is intended that this baseline plan will be a living document for a stable program with a framework that is sufficiently flexible to permit revisions arising from program changes that may be needed during the course of the research program. The program plan will be revisited annually in the spring in conjunction with the annual updating of the NRC's Five Year Plan.

During FY-1990, in preparation for the first update of this plan, we expect to emphasize interactions with (1)-the Department of Energy's LLW program and (2)-the appropriate State organizations in order to refine and clarify both the critical LLW disposal issues and the approach NRC is taking to resolving these issues.

In addition, NRC plans to use the research conducted by other agencies like USGS and EPA and other countries as a resource to complement, augment, and enhance the research described in NUREG-1380.

ATTACHMENT 4

NRC'S LOW-LEVEL RADIOACTIVE WASTE RESEARCH PROGRAM PLAN

LOW-LEVEL RADIOACTIVE WASTE CLASSIFICATION, CHARACTERISTICS, WASTE FORM STABILITY, AND RADIONUCLIDE RELEASES

HOLIDAY INN CROWN PLAZA
ROCKVILLE, MARYLAND
OCTOBER 23, 1990

PHILLIP R. REED

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U. S. NUCLEAR REGULATORY COMMISSION

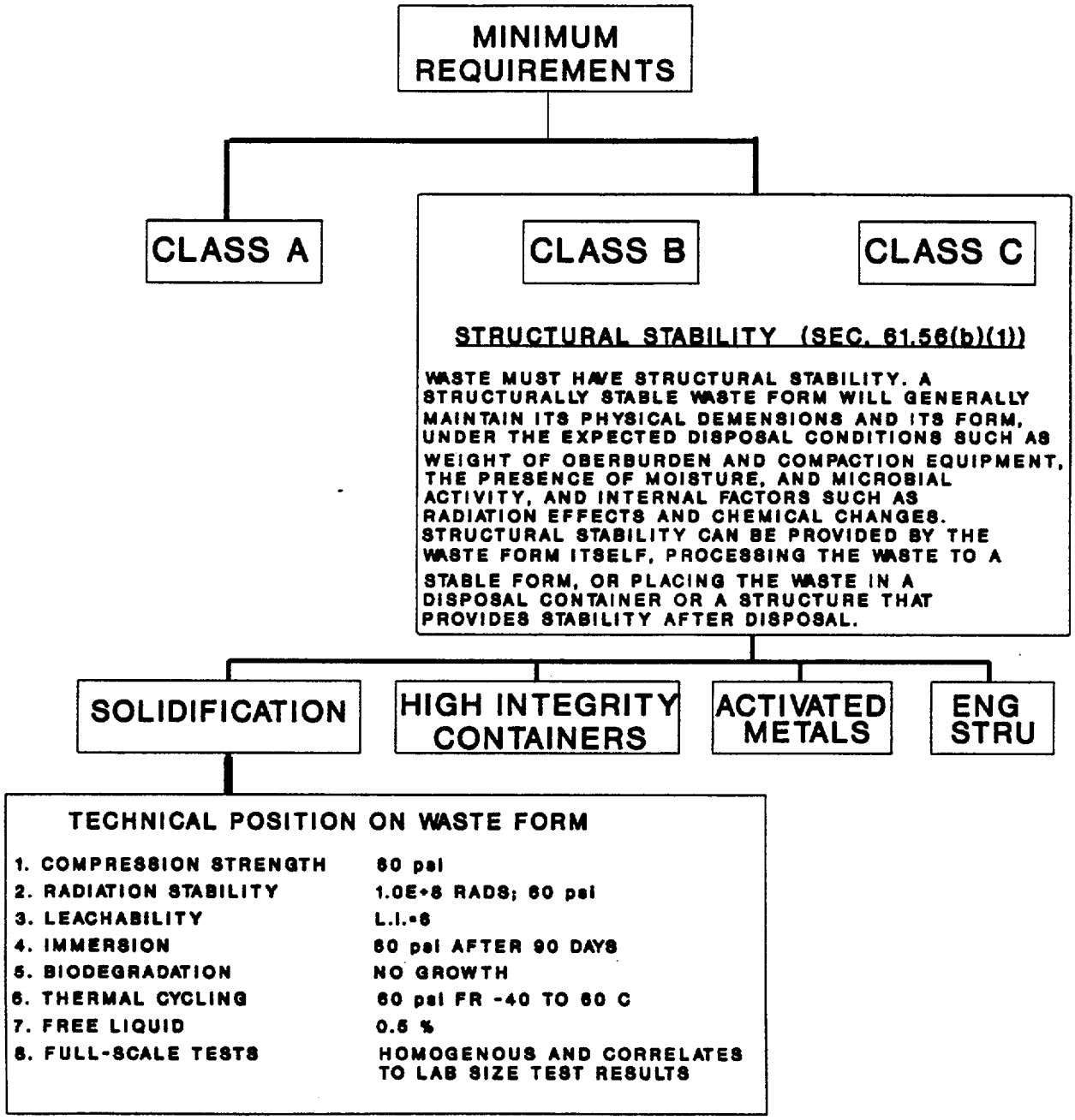
PRESENTATION TOPICS

- REGULATORY OBJECTIVES
- REGULATORY NEEDS
- RESEARCH STRATEGY
- REGULATORY APPLICATIONS
- RESEARCH PROGRAM STATUS
- RESEARCH RESULTS
- FY91 NEW STARTS

18WRSM1.CHT 10-90

RADIOACTIVE WASTE DISPOSAL REQUIREMENTS

WASTE CLASSIFICATION AND WASTE FORM STABILITY



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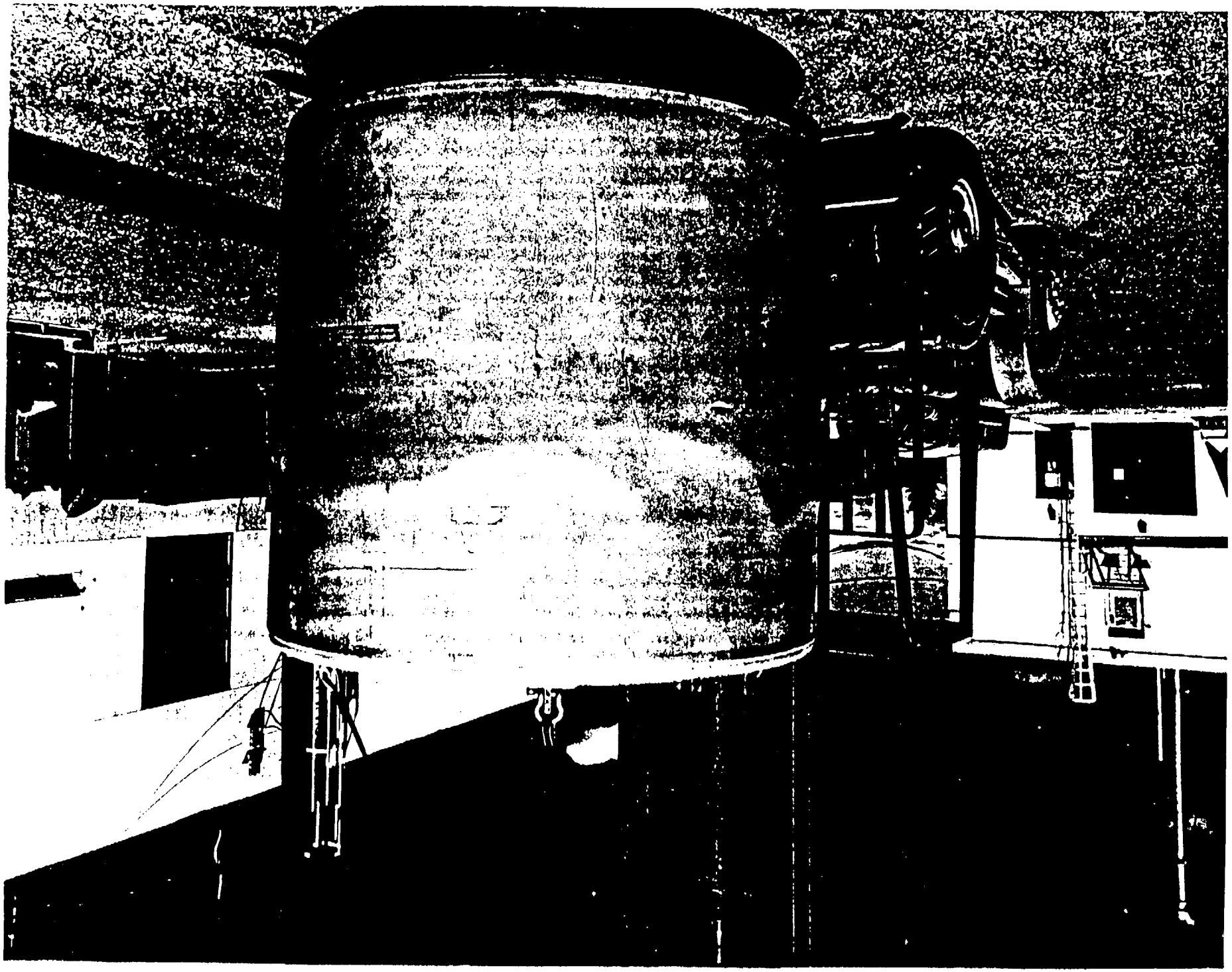


REGULATORY OBJECTIVES

- CLASSIFY LOW-LEVEL RADIOACTIVE WASTE
- CHARACTERIZE LOW-LEVEL RADIOACTIVE WASTE FOR RADIONUCLIDE AND CHEMICAL CONTENT
- STABILIZE SOLIDIFIED LOW-LEVEL RADWASTE
- PROTECT PUBLIC HEALTH AND SAFETY FROM RADIONUCLIDE RELEASES DUE TO INTRUSION & WATER INFILTRATION AT LLW DISPOSAL SITES

REGULATORY NEEDS

- TO UNDERSTAND RADIONUCLIDE AND CHEMICAL COMPOSITION AND DISTRIBUTION IN LLW
- ASSESS UNSUCCESSFUL CEMENT SOLIDIFICATIONS
- UNDERSTAND MECHANISMS AFFECTING STABILIZATION OF CEMENT WASTE FORMS
- SOLIDIFIED WASTE FORM STABILITY TESTS:
  1. ASSESS EFFECTIVENESS ON REAL SOLIDIFIED LLW
  2. DEVELOP TO ASSESS LONG-TERM PERFORMANCE
  3. DEVELOP FOR INSPECTION OF LLW AT BURIAL SITE
  4. IDENTIFY PCP PARAMETERS FOR SOLIDIFICATIONS
- LN-TERM PERFORMANCE FROM ST-TERM TESTS; LG-SCALE PERFORMANCE FROM SM-SCALE TESTS

REGULATORY NEEDS (CONT.)

- TO DETERMINE RADIONUCLIDE RELEASES FROM SOLIDIFIED WASTE FORMS AND ACTIVATED METALS
- ASSESS EFFECTS OF CHELATES ON RADIONUCLIDE RELEASE AND TRANSPORT FR DECONTAMINATION LLW
- ASSESS RADIATION DECOMPOSITION EFFECTS OF LLW
- DETERMINE BIODEGRADATION EFFECTS ON LLW
- EVALUATE LABORATORY LEACHING AND WASTE FORM STABILITY STUDIES WITH PERFORMANCE TO FIELD STUDIES IN NATURAL ENVIRONMENTS
- DEVELOP UNDERSTANDING OF ENVIRONMENTAL PATHWAYS FOR RADIONUCLIDES (e.g. C-14, I-129)

RESEARCH STRATEGY

- USE ACTUAL LLW FROM NUCLEAR STATIONS
- COLLECT SOLIDIFIED DECONTAMINATION, BORIC ACID, ETC. SOLIDIFIED LLW & ACTIVATED METALS
- CHARACTERIZE LLW FOR RADIONUCLIDE AND CHEMICAL (e.g. ORGANICS) CONTENT
- APPLY NRC TECHNICAL POSITION TESTS ON WASTE FORMS TO DETERMINE STABILITY
- LEACH SOLIDIFIED LLW AND ACTIVATED METALS
- EVALUATE UNSUCCESSFUL SOLIDIFICATIONS; BULGED MILLSTONE LINER; CRACKED TMI LINER
- CLIFTON-POMERSHEIM MODEL:LONG-TERM STABILITY

RESEARCH STRATEGY (CONT.)

- STUDY CHEMISTRY OF LLW SOLIDIFICATION
- STUDY CHELATING AGENTS EFFECTS ON RADIONUCLIDE RELEASE AND TRANSPORT
- USE FIELD LYSIMETERS: SOLIDIFIED WF; ACT METAL
- STUDY BIODEGRADATION OF SOLIDIFIED LLW
- STUDY C-14 PATHWAY/UPTAKE IN PLANTS
- DETERMINE LONG-LIVED RADIONUCLIDES
- DEVELOP SCREENING, QUALIFYING, INSPECTION AND PROCESS CONTROL TESTS FOR WASTE STABILITY

RESEARCH STRATEGY (CONT.)

- SURVEY WASTE STREAMS AND ACTIVATED METALS:

  1. DETERMINE RADIONUCLIDES NOT LISTED IN 10 CFR PART 61.56 (e.g. Cl-36, Mo-93, Ag108m)

  2. EVALUATE EXISTING MEASUREMENT TECHNIQUES AND DETERMINE LONG-LIVED RADIONUCLIDES (e.g. Tc-99, Ni-63, C-14, Nb-94)

  3. DETERMINE SCALING FACTORS FOR USE WHEN RADIONUCLIDES ARE AT OR BELOW LLD

  4. LEACH ACTIVATED METALS FOR RADIONUCLIDES

  5. PERFORM FIELD LYSIMETER STUDIES USING ACTIVATED METALS

REGULATORY APPLICATIONS

- SUPPORTS DEVELOPMENT OF REGULATORY CRITERIA FOR CLASSIFICATION AND STABILITY OF LOW-LEVEL RADWASTE
- PROVIDES ASSURANCE OF TEST METHODS FOR DETERMINING STABILITY AND CLASSIFICATION OF LOW-LEVEL RADWASTE
- PROVIDES DATA FOR DETERMINING RELEASES OF RADIONUCLIDES AND CHEMICALS (CHELATES) FROM LOW-LEVEL RADWASTE AND BURIAL SITES
- SUPPORT REVIEWS OF LICENSEE PROCESS CONTROL PROGRAMS AND TOPICAL REPORTS

18WRSM8.CHT 10-90

RESEARCH PROGRAMS
CLASSIFICATION AND WASTE FORM STABILITY

IDAHO NATIONAL ENGINEERING LABORATORY

I. <u>CHARACTERISTICS OF LOW-LEVEL RADWASTE</u>

1. SOLIDIFIED LLW FROM NUCLEAR STATIONS
2. DECONTAMINATION RADWASTE (CHELATES)
3. EVALUATING WASTE FORM STABILITY TESTS
4. ASSESSING UNSUCCESSFUL SOLIDIFICATIONS

II. <u>FIELD LYSIMETER STUDIES IN SOILS</u>

1. TWO LOCATIONS IN U.S. (ANL AND ORNL)
2. RADWASTE ION-EXCHANGE RESINS
3. CEMENT AND VINYL-ESTER STYRENE
4. RADIONUCLIDE RELEASE AND TRANSPORT
5. RADIATION DEGRADATION EFFECTS

RESEARCH PROGRAMS STATUS

I. CHARACTERISTICS OF LOW-LEVEL RADWASTE

1. COLLECTED SOLIDIFIED DECONTAMINATION RADWASTE FROM PEACH BOTTOM NUCLEAR STATION.
2. COMPLETED LEACHING OF CEMENT WASTE FORMS. COLLECTED FROM BRUNSWICK AND FITZPATRICK NS.
3. DETERMINED RADIONUCLIDES, CHELATES, AND STABLE METAL INDEXES AND RELEASE RATES IN LEACHATES.
4. EVALUATING CEMENT COMPRESSION STRENGTH DATA.
5. CONTINUED EVALUATING UNSUCCESSFUL CEM. SOLID.
6. PREPARED PROGRAM PLAN: BULGED MILLSTONE LINER
7. PREPARED PROGRAM PLAN: CHEMICAL ANALYSIS LLW.
8. PREPARED DRAFT REPORT: NH3 FR. PEACH BOTTOM.
9. PREPARING DRAFT REPORT ON LEACHING AND COMPRESSION STRENGTH OF CEMENT WASTE FORMS COLLECTED FROM OPERATING NUCLEAR STATIONS.

RESEARCH PROGRAMS STATUS (CONTINUED)

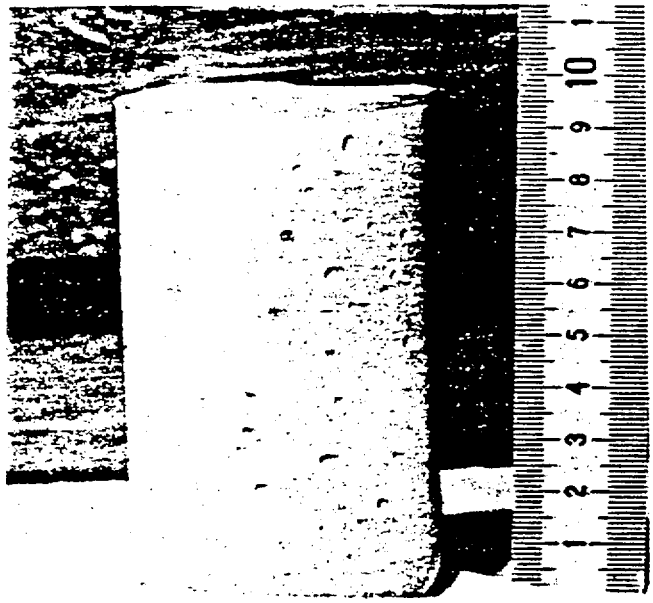
II. FIELD LYSIMETER STUDIES

1. CONTINUED MONITORING FIELD LYSIMETERS AT ANL AND INEL FOR RADIONUCLIDE RELEASES.
2. DETERMINING RADIONUCLIDE TRANSPORT IN SOILS UNDER NATURAL ENVIRONMENTAL CONDITIONS.
3. CONTINUED COMPRESSION TESTING OF CEMENT & VES WASTE FORMS AS A FUNCTION OF TIME.
4. COMPLETED AND PREPARED NUREG/CR REPORT ON RADIATION DEGRADATION OF ION-EXCHANGE RESINS.
5. PREPARING PROGRAM PLAN FOR LYSIMETER STUDY WITH DECONTAMINATION & ACTIVATED METALS LLW.

RESEARCH RESULTS

18WRSM12.CHT 11-90

Brunswick Plant Unit 1 cation resin waste-form specimans prior to leaching.



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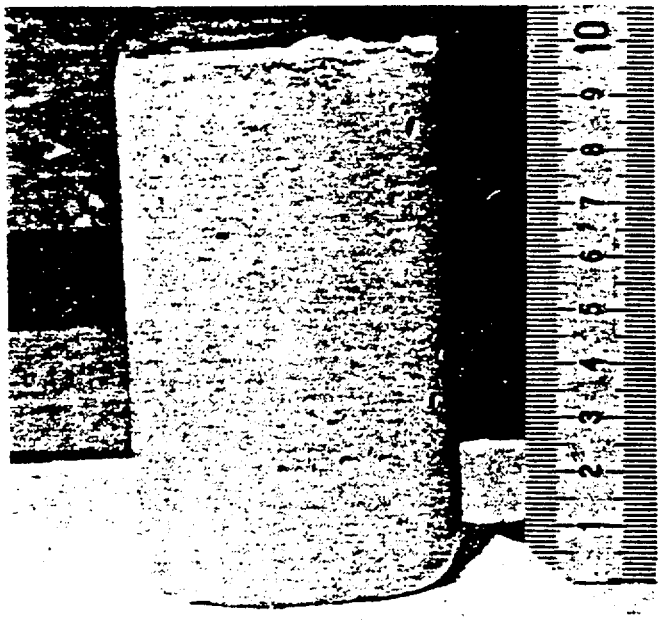

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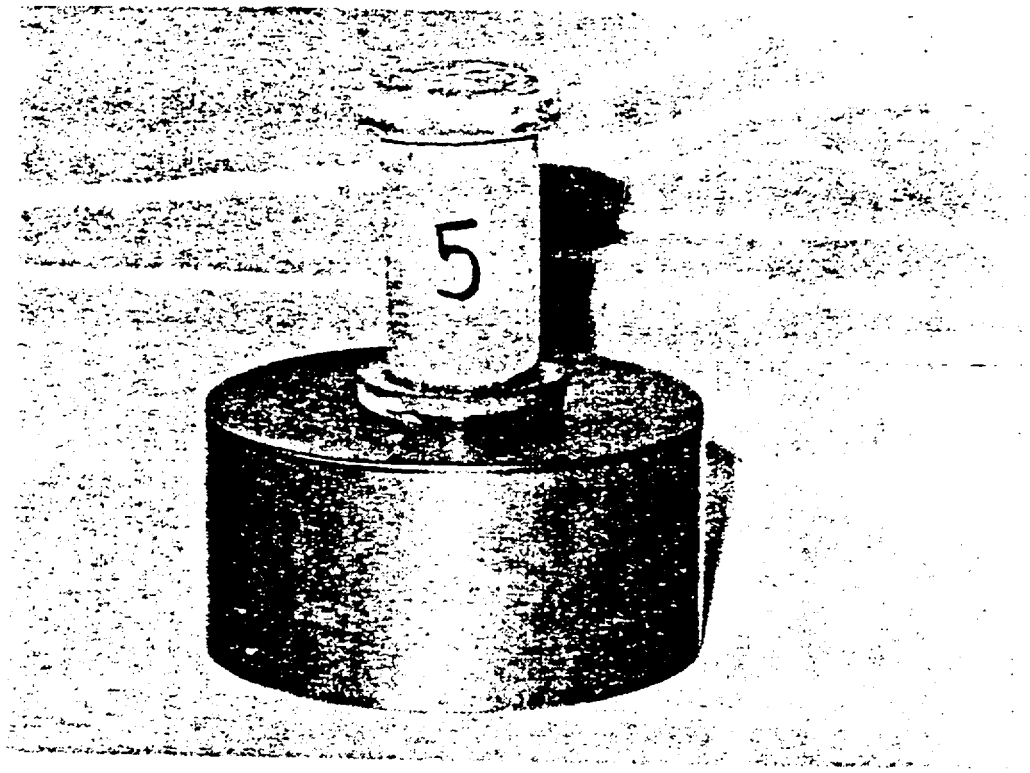
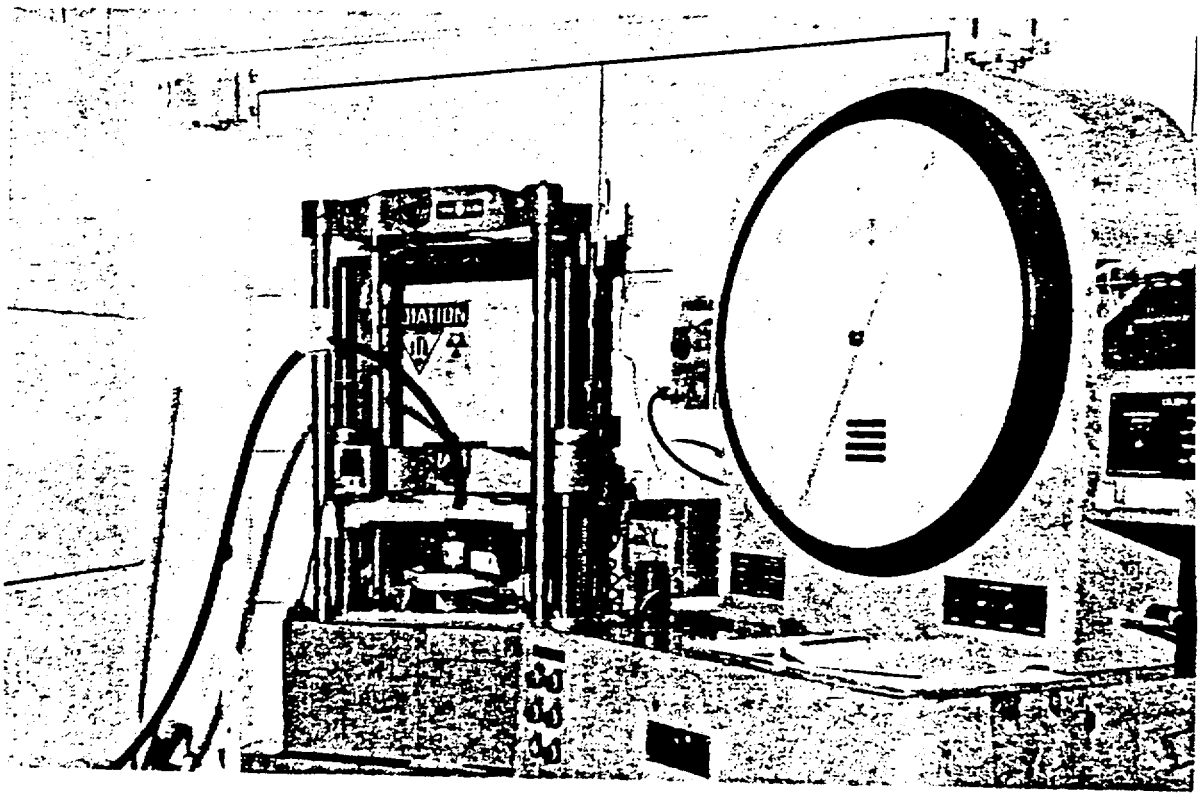


Waste-form specimen with epoxy end-caps prior to testing for compressive strength.

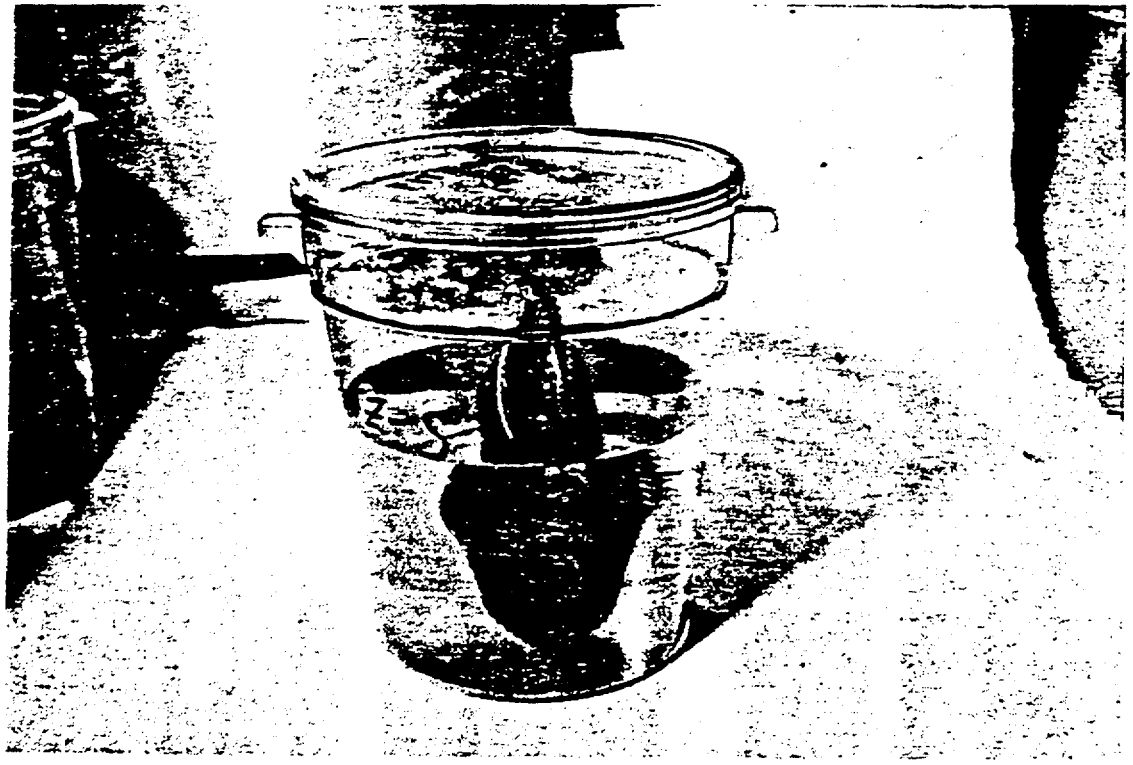


Compressive strength testing system.

. COMPRESSIVE STRENGTHS OF WASTE-FORM SPECIMENS

Waste Form	Cross-Sectional Area		Maximum Load		Compressive Strength	
	(cm^2)	(in^2)	(kg)	(lb)	(kPa)	(psig)
Brunswick-1						
cation	26.19	4.06	721	1590	2.70×10^3	392
mixed-bed	25.41	3.94	903	1990	3.48×10^3	505
FitzPatrick						
baked	17.54	2.72	2291	5050	1.28×10^4	1857
unbaked	17.42	2.70	2331	5140	1.31×10^4	1906
Pilgrim						
unleached	17.22	2.67	1120	2470	6.37×10^3	924
leached	17.54	2.72	2522	5560	1.41×10^4	2044
Indian Point-3						
unleached	17.35	2.69	1075	2370	6.09×10^3	883
leached	18.00	2.79	295	650	1.61×10^3	233

. FitzPatrick waste-form specimen after leaching in deionized water for 99 days.

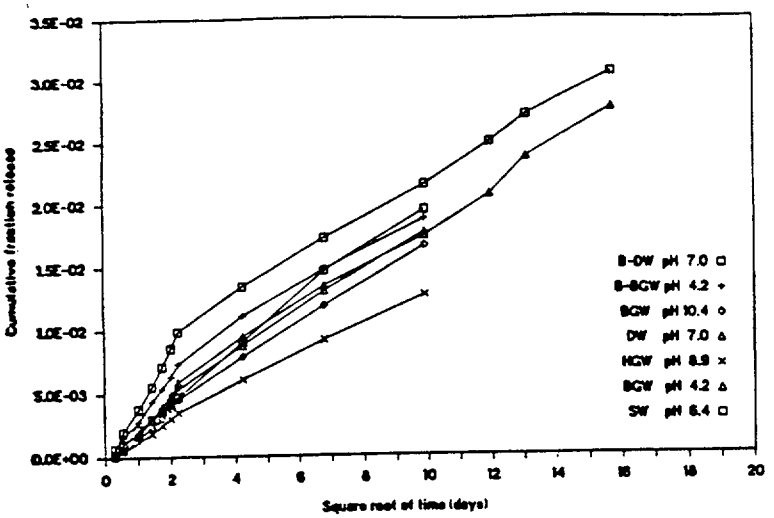


FitzPatrick waste-form specimen after leaching in synthetic seawater for 99 days.

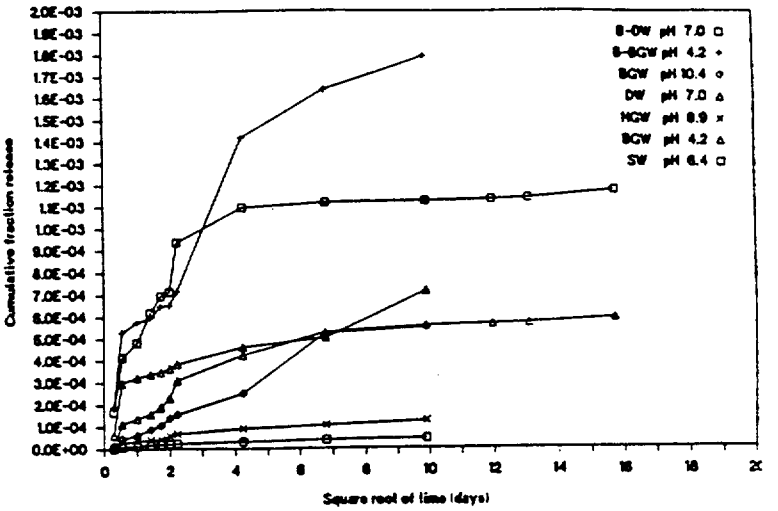
Brunswick-1 cation resin waste-form specimen leaching in synthetic seawater.

Brunswick-1 cation resin waste-form specimen after leaching in deionized water.

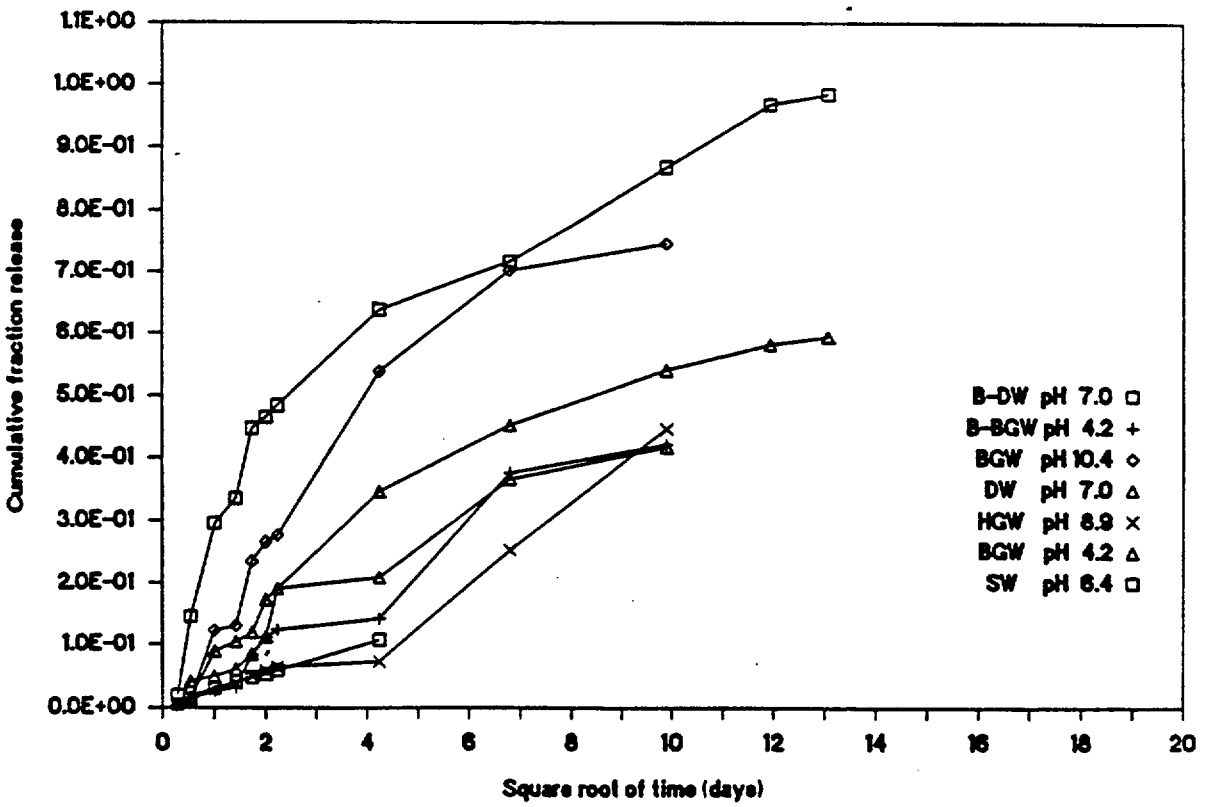
FITZ CO-60



FITZ MN-54



FITZ PICOLINIC



LEACHING RESULTS
MILLSTONE-1 NUCLEAR POWER STATION

COMPONENTS	L	RELEASE RATE (uCi/cm²/s)	FRACTION RELEASE RATE (CFR/cm²/s)
RADIONUCLIDES			
^{54}Mn	14.7	3.09E-10	1.93E-12
^{55}Fe	14.9	4.43E-09	3.30E-12
^{60}Co	13.2	3.10E-09	5.85E-12
^{63}Ni	11.1	4.73E-09	8.07E-11
^{90}Sr	8.0	1.04E-10	2.62E-09
^{125}Sb	11.8	5.09E-10	4.72E-11
^{137}Cs	6.1	3.09E-09	2.14E-08
^{241}Pu	14.3	1.52E-10	6.64E-12
CHELATING AGENTS			
EDTA	8.3	6.98E-04[1]	1.68E-09
OXALIC ACID	9.4	2.44E-04	4.90E-10
CITRIC ACID	10.4	6.19E-05	1.45E-10
STABLE METALS			
CHROMIUM	10.0	2.50E-06[1]	1.02E-10
IRON	14.0	2.54E-06	6.50E-12
COBALT	7.5	1.27E-05	1.18E-08
NICKEL	10.7	2.37E-05	1.73E-10

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[1]RELEASE RATES FOR CHELATING AGENTS AND STABLE METALS ARE ug/cm²/s

LEACH TEST RESULTS FOR BAKED JAMES A. FITZPATRICK MIXED-BED RESIN WASTE-FORM SPECIMEN LEACHED IN DEIONIZED WATER

Nuclide	CFR	Release Rate (μCi/cm^2/s)	Release Rate (cm^{-2}s^{-1})	Effective Diffusivity (cm^2/s)	Leach Index
^{54}Mn	1.1(-3)	4 ± 2 (- 9)	2 ± 1 (-11)	2 ± 1 (-12)	12.9 ± 0.5
^{55}Fe	---[a]	---[a]	---[a]	---[a]	---[a]
^{58}Co	1.5(-2)	1.9 ± 0.7(- 8)	1.1 ± 0.4(-10)	7 ± 2 (-11)	10.4 ± 0.2
^{60}Co	2.2(-2)	1.0 ± 0.4(- 7)	1.5 ± 0.5(-10)	1.3 ± 0.3(-10)	10.1 ± 0.2
^{63}Ni	---[a]	---[a]	---[a]	---[a]	---[a]
^{65}Zn	4.0(-3)	1.5 ± 0.6(- 9)	4 ± 2 (-11)	6 ± 2 (-12)	11.5 ± 0.2
^{90}Sr	---[a]	---[a]	---[a]	---[a]	---[a]
^{125}Sb	< 7.8(-3)	< 1.8 (-10)	< 1.2 (-10)	< 3.6 (-11)	> 10.9
^{134}Cs	7.2(-1)	1.4 ± 0.6(- 8)	1.0 ± 0.5(- 8)	6 ± 1 (- 7)	6.3 ± 0.1
^{137}Cs	6.3(-1)	3 ± 1 (- 8)	9 ± 4 (- 9)	5 ± 1 (-7)	6.4 ± 0.1
Acid or Metal		**(μg/cm^2/s)**			
Picolinic acid	8.7(-1)	2 ± 1 (- 2)	8 ± 4 (- 9)	5 ± 2 (- 7)	6.5 ± 0.2
Chromium	< 6.7(-3)[b]	< 1.6 (- 6)	< 5.6 (-11)	< 2.5 (-11)	> 11.2
Iron	< 2.6(-3)[b]	< 9.7 (- 6)	< 2.9 (-11)	< 4.9 (-12)	> 12.1
Cobalt	< 2.5(-2)[b]	< 7.8 (- 6)	< 2.1 (-10)	< 3.6 (-10)	> 10.0
Nickel	5.8(-2)[b]	8 ± 5 (- 6)	5 ± 3 (-10)	2.0 ± 0.8(- 9)	9.3 ± 0.5

a. Concentrations in leachate samples were not determined.

b. Not all leachate samples were analyzed for this metal. CFR value was estimated by interpolating measured release rates.

Lysimeters

- Two sites- cold humid and warm humid
- Five lysimeters per site
- One-liter waste forms
- Five moisture cups per lysimeter
- Three moisture/temperature probes per lysimeter
- Bottom leachate collector in each lysimeter
- Dedicated weather station/data acquisition system

C8 5199

Waste Forms

- Solidification agents
  - Dow Vinyl Ester-Styrene (VES)
  - Portland Type I-II cement
- Size and shape
  - 5-cm (2-in.) diameter x 7.5-cm (3-in.) high
- Formulations by weight percent
  - Dow - 60 resin, 40 VES
  - Cement - 24 resin, 63 cement, 13 water

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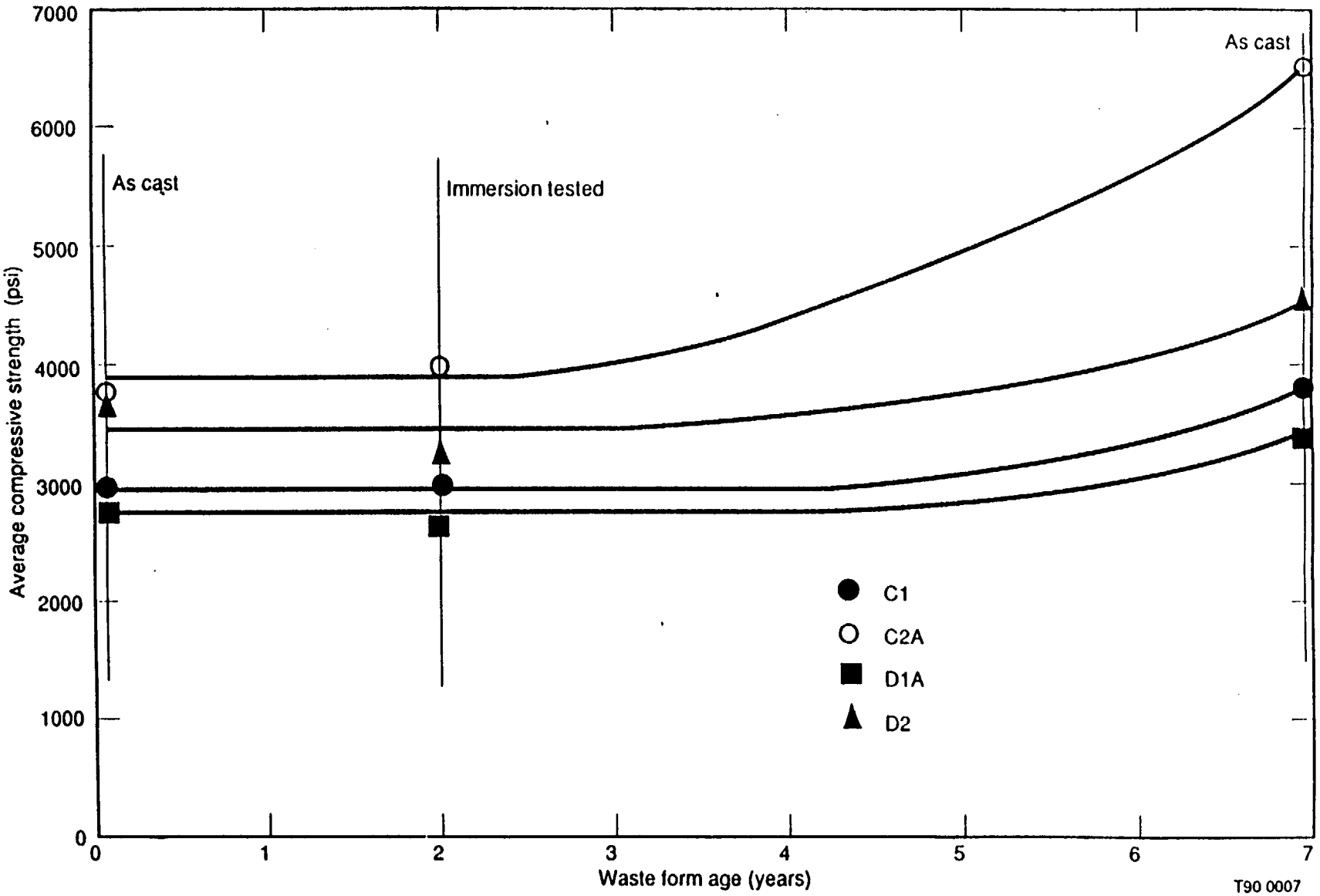
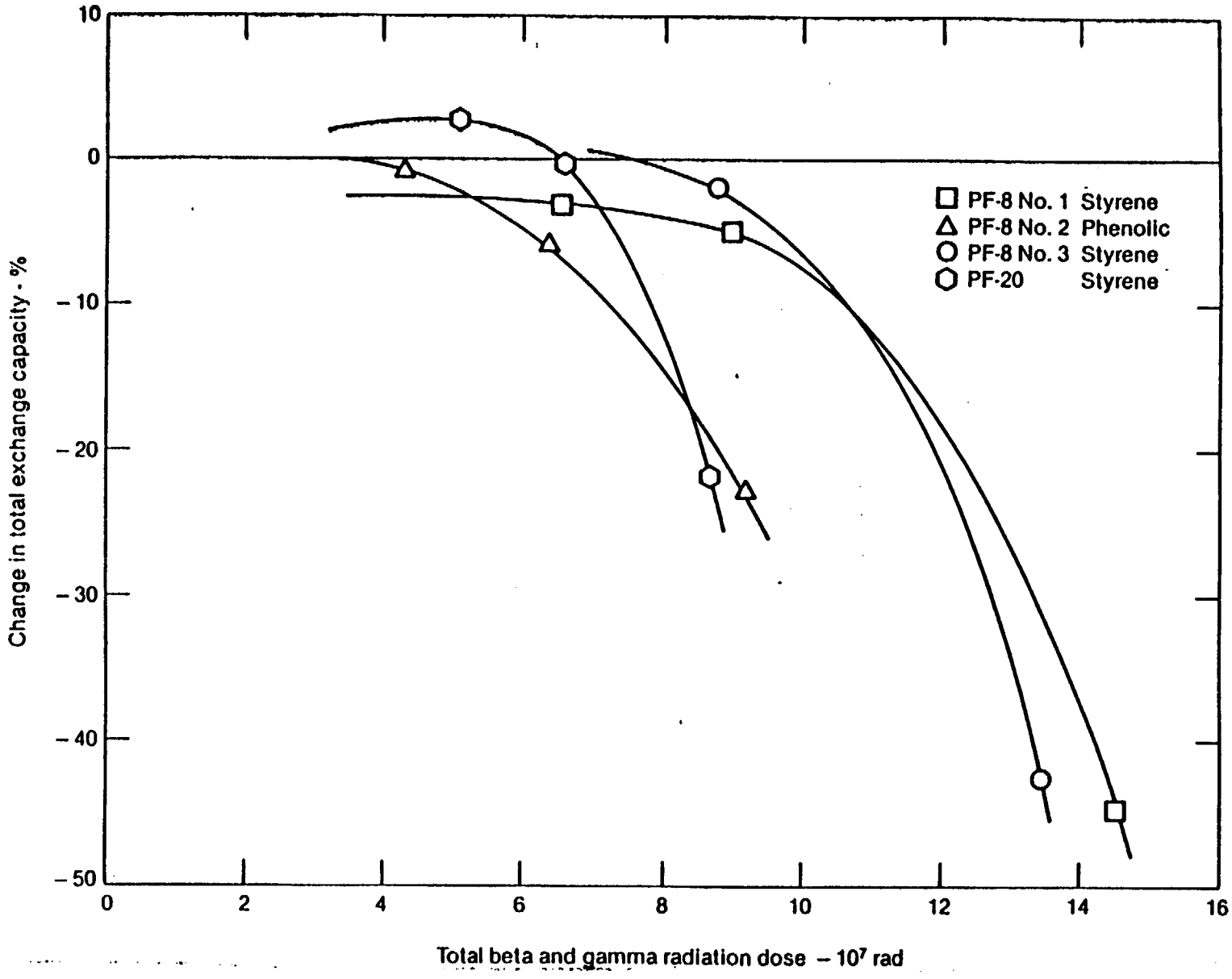
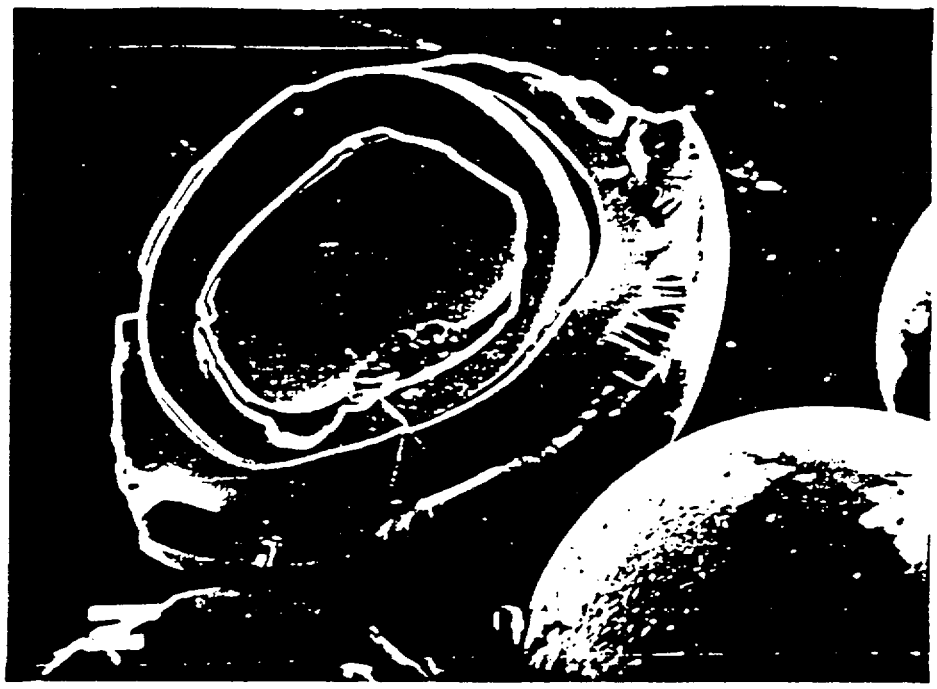
CHANGE IN COMPRESSION STRENGTH WITH TIME





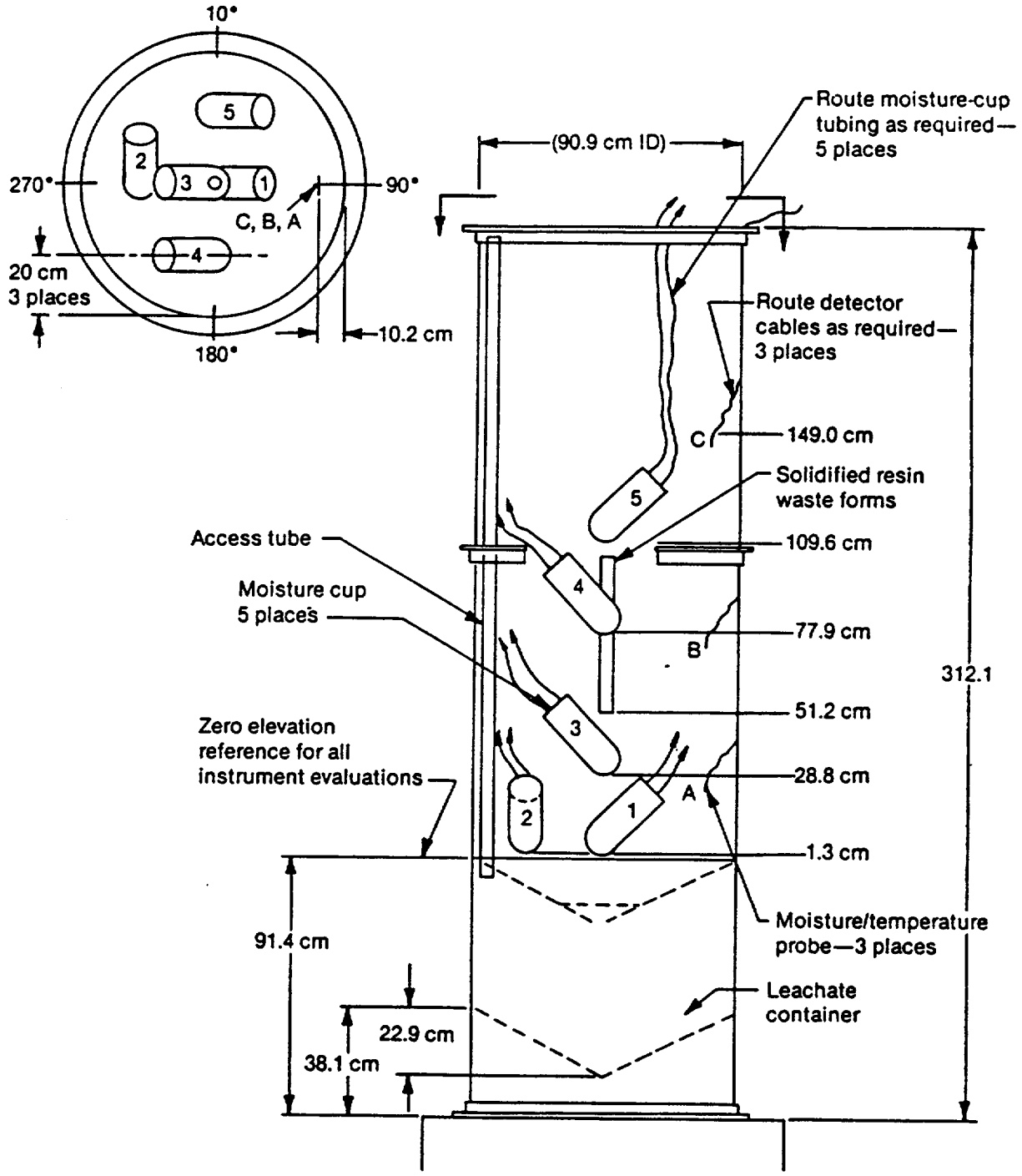
CHANGE IN TOTAL EXCHANGE CAPACITY WITH INCREASING RADIATION



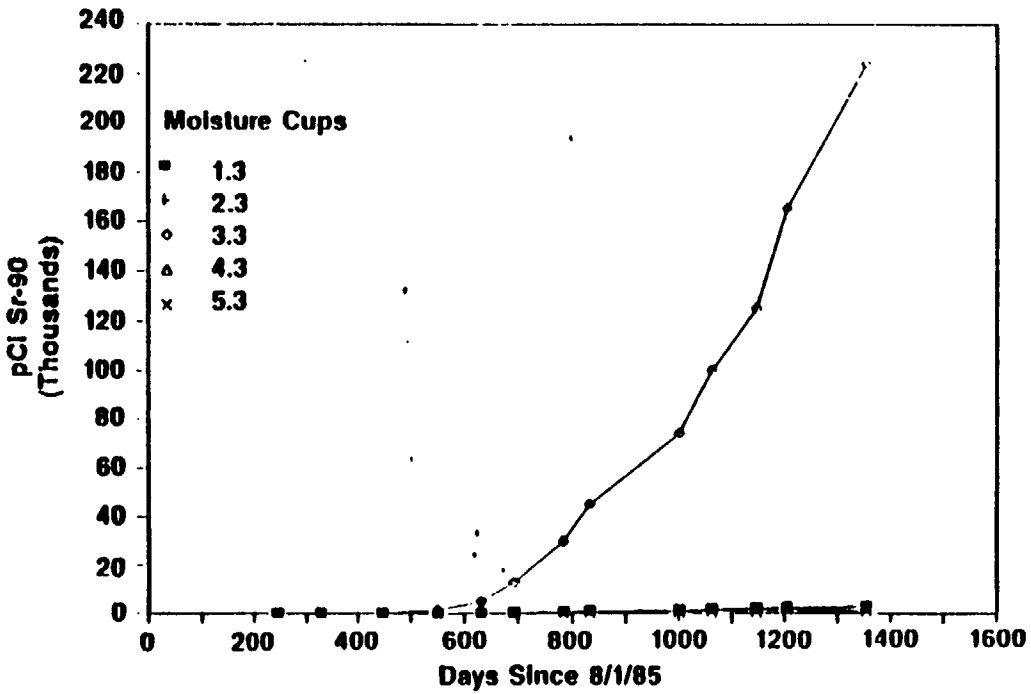
SEM photomicrograph of an EPICOR-II strong acid cation resin sample from PF-8#1, showing a close up of one unusally damaged bead, at 100 magnification.

SEM photomicrograph of an EPICOR-II strong acid cation resin sample PF-8#3, showing only one resic bead which appears to have softened and dimpled, at 100 magnification.

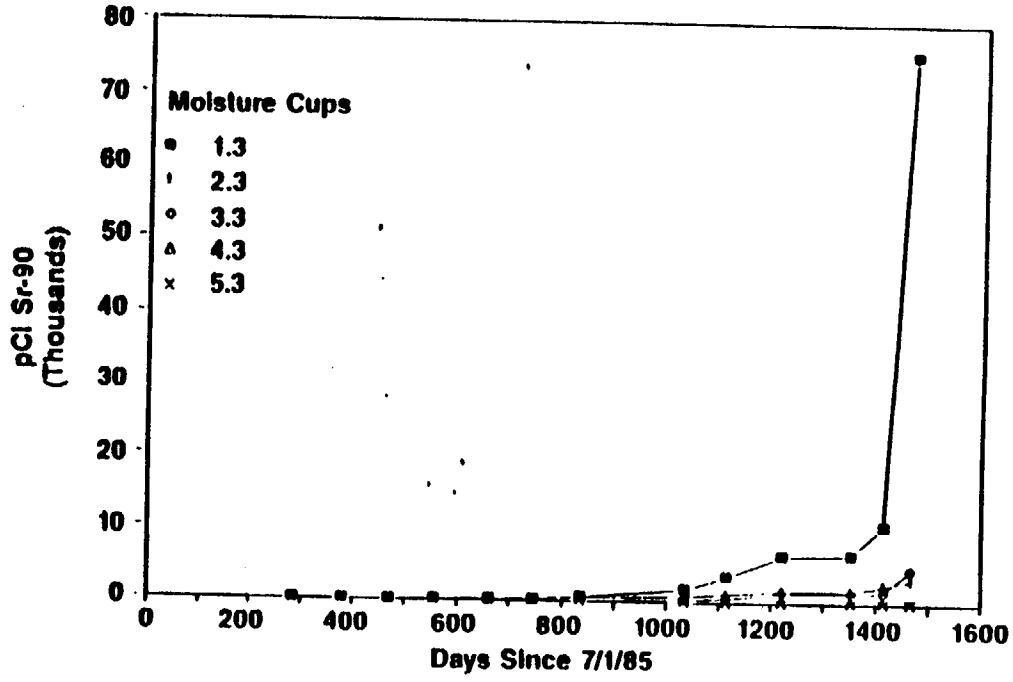
FIELD LYSIMETER VESSEL COMPONENT LOCATIONS



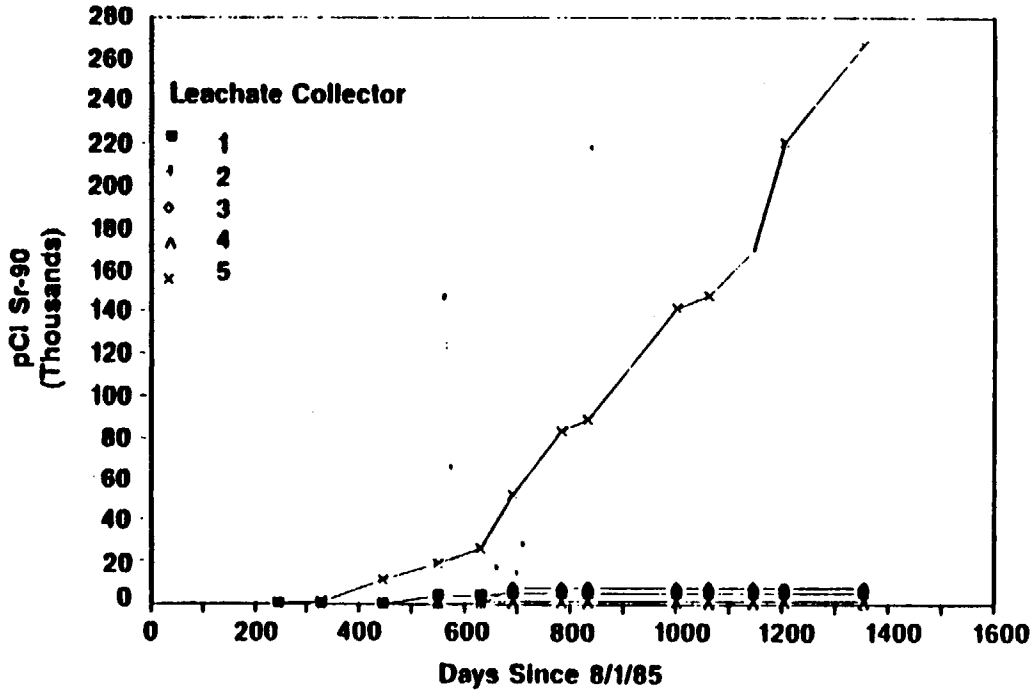
ANL-E Cumulative Sr-90 Collected in Moisture Cup Number 3



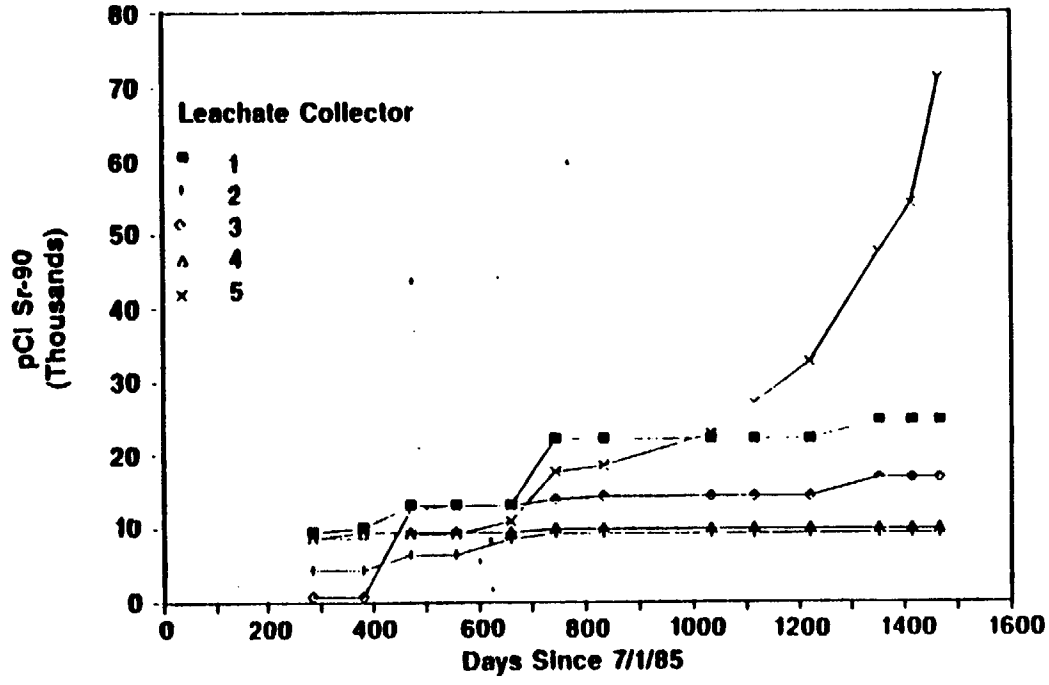
ORNL Cumulative Sr-90 Collected in Moisture Cup Number 3



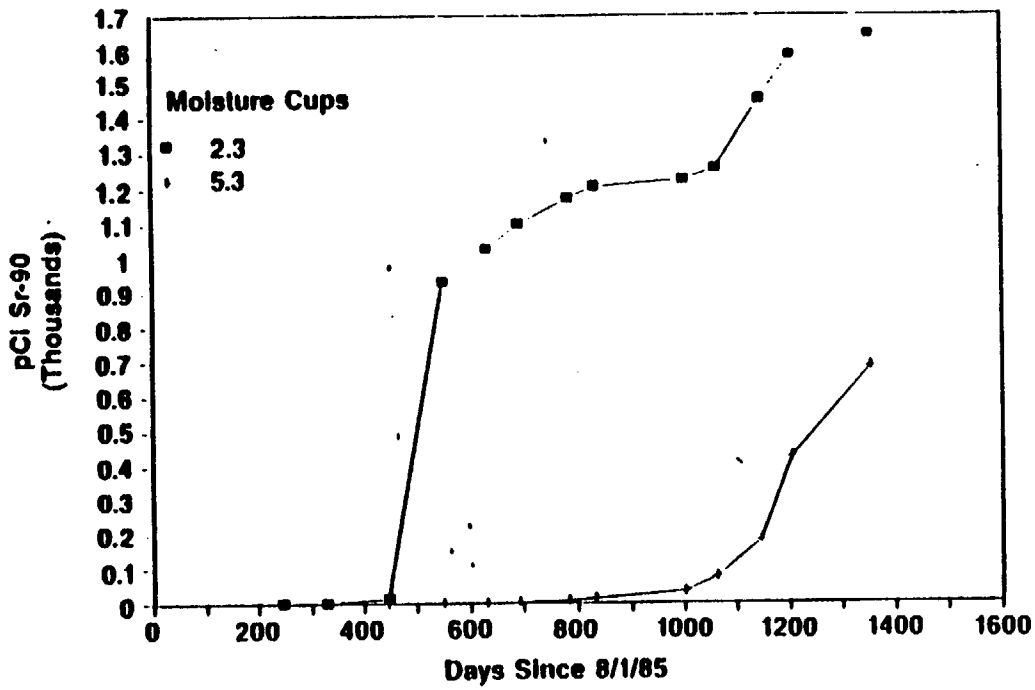
ANL-E Cumulative Sr-90 Collected in Lysimeter Leachate Collectors



ORNL Cumulative Sr-90 Collected in Lysimeter Leachate Collectors



ANL-E Cumulative Cs-137 Collected in Moisture Cup 3



Conclusions

- Successful operation through nearly 5 years
- Strontium-90 is most prevalent radionuclide detected
- Movement of strontium-90 appears to be controlled by soil type
- VES and cement are exhibiting similar release rates for strontium-90

FY91 NEW STARTS

- CHARACTERIZE LOW-LEVEL RADWASTE FOR RADIONUCLIDE AND CHEMICAL CONTENT
- PERFORM TECHNICAL POSITION TESTS FOR WASTE FORM STABILITY ON SOLIDIFIED LLW
- ACTIVATED METALS STUDIES
- BIODEGRADATION TESTING OF SOLIDIFIED LLW
- EVALUATE CHELATING EFFECTS ON STABILITY, RADIONUCLIDE RELEASES AND TRANSPORT
- LYSIMETER STUDIES: DECON LLW; ACTIV. METAL

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