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AGENCE POUR L'ÉNERGIE NUCLÉAIRE
NUCLEAR ENERGY AGENCY

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EN/S/2577

Paris, 22nd December 1987

RE: ISAG Status Report, "Geological Disposal of Radioactive Waste: In-Situ Research and Investigations in OECD Member countries

Dear Mr. Nataraja,

Please find enclosed copies of parts of the ISAG Status Report relevant to your country or organisation:

(1) Chapter 6 - individual country in-situ programme overviews.

(2) Chapter 7.2 - selected references for in-situ programmes in Member countries (for Chapter 6 and Annex II).

(3) Annex II - individual country summaries of in-situ tests.

To assist in completing the document for early publication in 1988, I would be very grateful if you could review the enclosures for correction of factual errors, completion of references, etc. To facilitate our schedule for publication, I would also appreciate receiving your review comments by 18th January 1988, if at all possible.

Best wishes for the Holiday Season.

Sincerely,

pp. L. Chamney
Division of Radiation Protection
and Waste Management

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6.11 UNITED STATES

INSTITUTIONAL FRAMEWORK

The Nuclear Waste Policy Act of 1982 (NWPA) assigns the U.S. Department of Energy (DOE) the responsibility of locating, constructing, operating, closing and decommissioning a high-level nuclear waste repository. The U.S. Nuclear Regulatory Commission (NRC) has the statutory responsibility for reviewing DOE's license application and site investigation programmes. NRC regulations regarding the disposal of high level nuclear waste are contained in Part 10 of the Code of Federal Regulations (10 CFR).

NUCLEAR REGULATORY COMMISSION

DISPOSAL CONCEPTS AND APPROACH - REGULATION OF CIVILIAN PROGRAMME WASTES

Before submitting a license application for a civilian programme radioactive waste repository, the DOE is required by the Nuclear Waste Policy Act of 1982 and by 10 CFR Part 60 to conduct a programme of site characterisation [1]. In-situ testing is viewed as an important element of site characterisation, and such tests are to be performed from the exploratory shaft(s) and underground openings on surrounding rock and on other materials and components such as the waste package, engineered backfill, linings and seals. The conditions under which these in-situ tests are to be conducted should represent, as closely as possible, the realistic repository environment (for example, temperature and stresses). The tests performed under such conditions would provide data to assess the suitability of a particular site and a particular geologic medium to host high-level nuclear waste, and also realistic input parameters for the design of a geologic repository.

In-situ tests can only be conducted for a limited duration compared with the long time span during which the repository must function to isolate the waste. Analytical, experimental and numerical models must be used to make predictions far into the future. However, models have their own limitations on applicability and are sensitive to the quality of data used as input. Some of the uncertainties in the prediction process can be reduced by conducting appropriate in-situ tests on a representative volume of rock, and by using appropriate models to account for possible inherent spatial variations of physical, hydraulic and chemical properties within the rock formation. By comparing in-situ test data with modeling results, models can be validated, thereby reducing some uncertainties in the prediction process.

NRC Technical Positions on In-Situ Testing

The NRC staff technical positions on in-situ testing during site characterisation are:

(a) Before submitting a license application, DOE should perform a necessary and sufficient variety and amount of in-situ testing to support, if the facts so warrant, a staff position that the requirements for issuance of a construction authorisation (10 CFR Part 60.31) have been met.

(b) The in situ testing programme should be developed with two major objectives: (i) characterisation of host rock and in-situ measurement of its properties prior to construction and waste emplacement; and (ii) determination of response characteristics of the host rock and engineered components to construction and waste emplacement.

(c) DOE should present its site-specific and design-specific in-situ test plans in the Site Characterisation Plan (SCP).

(d) Before developing the in-situ test plan, DOE should develop a rationale for in situ testing and present this rationale with the test plan in the SCP. The overall goal of the rationale should be to ensure that all important parameters are identified and ranked according to their relative importance in supporting 10 CFR Part 60 licensing findings.

(e) For successful site characterisation, DOE should integrate the data from surface borehole testing and laboratory testing on small-scale samples with the in-situ test results.

This technical position is general and covers in-situ testing for all potential repository sites and designs. It was developed and presented to the Department of Energy in an effort to provide on-going pre-licensing guidance.

DEPARTMENT OF ENERGY

DISPOSAL CONCEPTS AND APPROACH - DISPOSAL OF CIVILIAN PROGRAMME WASTES

In accordance with the requirements specified in the Nuclear Waste Policy Act of 1982, the Department of Energy (DOE) is developing site characterisation plans for the three potential sites for the first repository [2]. Those sites are the Hanford site in the state of Washington, the Yucca Mountain site in Nevada and the Deaf Smith County site in Texas. As part of the site characterisation plans, the DOE will describe the methodology used to identify the information needed from the characterisation studies and the tests necessary to obtain that information.

The methodology used in developing the site characterisation plans was to first identify a common set of issues that must be resolved to demonstrate compliance with applicable Federal regulations and to support site selection and licensing. The next phase was to develop "issue resolution strategies" for each of the issues. Since the issues are derived from applicable Federal regulations, the information needed to resolve them will be the basis for planning of the work that needs to be done to demonstrate compliance with the regulatory requirements. The issue resolution strategy provides a step-wise procedure for identifying and planning the work needed to support resolution of the issues. Because the rock types and conditions at each of the candidate sites are different, the issue resolution strategies and the related site characterisation plans will differ from site to site.

As part of the issue resolution strategy, DOE utilises a process called "performance allocation". Performance allocation entails deciding which items within a geologic repository will be relied upon in resolving a particular issue. The function an item must perform and the processes that affect the performance are identified for each item. Using performance allocation, a testing programme can be developed which obtains the information necessary to demonstrate that an item will perform its particular function as expected. Once the appropriate information needs are identified, DOE can identify what underground tests should be conducted.

IN-SITU RESEARCH AND INVESTIGATIONS

The in-situ tests currently being considered for site characterisation at each of the three candidate sites are grouped under three broad categories: (a) basic geologic characterisation tests; (b) hydrologic characterisation tests; and (c) near field and thermally perturbed tests. The objective and/or rationale for performing a test is based on the performance allocation process.

Of the 44 tests currently defined, more than half of the tests will be conducted at all three sites. The differences in the test plan reflects differences in the characteristics of the site (i.e., rock type, in-situ conditions, etc.) or differences in the design of the test facility. For example, the perched water test for the Nevada Nuclear Waste Investigations project (NNWSI) and the brine migration test for the Salt Repository Project Office (SRPO) are not planned at the other sites due to the site-specific nature of the phenomenon being investigated. The design of the shafts to the exploratory shaft facility at the Basalt Waste Isolation Project (BWIP) prevents the mapping of the shaft walls. The shaft will be blind-drilled, and the shaft liner installed while the drilling mud is still in the shaft, thus preventing direct access to the shaft wall.

As part of the site characterisation plan, detailed test plans and procedures are being written for the test at each site. In addition, quality assurance procedures are required to insure the test data is accurate, reliable and traceable. Consultative drafts of test plans will be reviewed by the NRC and representatives of the States and Indian tribes in the first quarter of 1988. The test plans may change based on review recommendations or to reflect modifications in the information needs and strategies chosen to resolve the various issues.

DEFENCE WASTE DISPOSAL PROGRAMME

DISPOSAL CONCEPTS AND APPROACH - DEFENCE WASTES

The Experimental Program for the Waste Isolation Pilot Plant (WIPP) has been developed by the Department of Energy (DOE) to address those technical issues that concern the safe disposal of Defence Transuranic (TRU) Wastes and Defence High-Level Wastes (DHLW) in underground storage rooms [3]. This programme involves technology development through laboratory and theoretical studies and in-situ testing conducted in representative waste storage room configurations for both the ambient (for TRU) and heated (for DHLW) conditions.

IN-SITU RESEARCH AND INVESTIGATIONS

Technology development studies since 1975 have been investigating phenomena associated with radioactive waste emplacement in a rock salt environment, and have produced response models and predictive techniques using available laboratory and theoretical data. The in-situ testing programme at WIPP has been developed to evaluate these models and predictive techniques through full-size experiments in the actual host rock. The first portion of the in-situ tests (underway since 1984) are without radioactive materials and use electric heaters to simulate heat-generating waste where applicable. The second portion of the in situ testing programme, scheduled for the early 1990s, will include the use of actual radioactive wastes and other radioactive sources.

The in-situ testing programme includes analyses and evaluations of data obtained from in situ measurements that provide an understanding of the actual behaviour of salt surrounding full-size storage rooms while undergoing creep closure due to overburden stresses and thermal loadings from waste containers. Data analyses and evaluations also pertain to tests that are designed to measure TRU and DHLW container performance, materials interface interactions, and engineered barriers and seals performance in an actual salt environment. These tests are expected to provide a better understanding of the phenomena, provide in-situ data to validate models and theoretical studies, and demonstrate the behaviour of the salt, waste packages, and engineered barriers and seals in an actual underground salt environment. An underground layout of the in situ tests at WIPP is illustrated in Figure 22.

Figure 22. In-Situ Tests, WIPP

Management, Vol. 1, 1981, p. 365.

UNITED STATES

[1] Nataraja, M.S., Generic technical position on in-situ testing during site characterisation for high-level nuclear waste repositories. Presented at the First Meeting of the NEA Advisory Group on In-Situ Research and Investigations for Geologic Disposal (ISAG), Paris, 28-29 October 1986.

[2] Voss, C.F., Nelson, J.W. and Rhoderick, J.E., Selection of site-characterisation tests in the exploratory - shaft facility at three candidate repository sites. PNL Report (1987).

[3] Matalucci, R.V., Summary report: the integrated in-situ testing program for the Waste Isolation Pilot Plant (WIPP). Sandia Report Sand86--2716, Sandia National laboratories (SNL), Albuquerque (1987).

.ST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
?) continued	Salt	SRPO	Direct observation/testing of rock in areas not reached by exploratory drifts.	Cores approx. 30 m in length.	
3) Borehole ondition/ onvergence onitoring	Tuff	NNWSI	Monitoring of borehole stability convergence and related rock mechanics/engineering properties.	Monitored in selected instrumentation boreholes, and demonstration tests of large diameter horizontal boring machine.	[2]
	Basalt	BWIP	Obtain information on stability of canister boreholes under ambient conditions. Results useful for waste package design, emplacement functions, need for canister borehole liner.	Prototype canister borehole to be drilled.	
	Salt	SRPO	Observation of boreholes for any mechanical effects not necessarily predictable by numerical analysis. Observe time-dependent behaviour of rock mass, especially at interfaces of discontinuities.		
I) Overcore .ress Tests	Tuff	NNWSI	Determine in-situ stresses, in order to optimise repository design, evaluate excavation stability, and obtain input and boundary condition data for geomechanical models.		[2]

TEST NAME	ROCK TYPE	SITE / PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(4) continued	Basalt	BWIP	As above	Further evaluate preliminary estimates of high horizontal stresses obtained from hydrofrac tests.	
	Salt	SRPO	Measure absolute stress of elastic strata	Conducted in ESF; technique not suitable for stress measurement in the salt strata, which exhibits a complex inelastic time- and temperature-dependent behaviour.	
(5) Demonstration Breakout Room Test	Tuff	NNWSI	Evaluate rock-mass responses to mining effects.		
	Basalt	BWIP	As above; to confirm ability to develop stable excavated openings in columnar basalt.		[2]
	Salt	SRPO	Validate models for stress-deformation/time behaviour of excavations. Optimise engineering design.		
(6) Sequential Drift-Mining Test	Tuff	NNWSI	Validate geomechanical models. Define limits for the relaxed zone. Improve mining evaluations. Correlate air and water permeability measurements for reference in hydrological calculations.		[2]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(6) continued	Basalt	BWIP	Optimise excavation techniques and support requirements, and to examine methods for minimising the disturbed rock zone. Validation of numerical models.	Room-scale enlargement/mine-by test, to monitor rock displacements, stress changes and hydraulic conductivity changes.	
	Salt	SRPO	Validate rock-stress response models under ambient temperature conditions. Obtain information related to structural stability, waste emplacement and retrieval. Obtain data to predict mechanical environment surrounding waste containers.		
(7) Cross hole Seismic Test	Tuff	NNWSI	Obtain calibration data for gross rock characteristics and fracture variabiltiy in order to assist extrapolation of structural and stratigraphic conditions.		
	Basalt	BWIP	Determine extent of disturbed rock zone and excavation-induced stress distribution.	Results to be compared with other tests to verify use of the method for optimal investigation of spatial variation of rock mass deformability.	[2]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(7) continued	Salt	SRPO	Investigate extent of disturbed zone, as input to decisions on backfill/seal material characteristics.		
(8) Seismic Surveys	Tuff	NNWSI	Obtain geologic data.	Seismic refraction/ reflection studies.	
	Basalt	BWIP	Characterise test site and damaged rock zone (cross-hole seismics).	Seismic refraction/ reflection studies also to be conducted.	[2]
	Salt	SRPO	Obtain information in basic geological/geomechanical site conditions, and mechanical conditions of repository rock mass.		
(9) Caliper Log	Tuff	NNWSI	Evaluate formation damage and monitor changes in borehole diameter.		[2]
	Basalt	BWIP	As above		
	Salt	SRPO	As above; information used to estimate deformation modulus.		
(10) Gamma-density Log	Tuff	NNWSI	Identify differences in lithology, stratigraphy and mineralogy.	Measurements of apparent bulk density.	[2]
	Basalt	BWIP	As above		
	Salt	SRPO	As above		

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(11) Sonic Log	Tuff	NNWSI	Detect changes in lithology and stratigraphy, porosity and dynamic modulus.		[2]
	Basalt	BWIP	As above		
	Salt	SRPO	As above; as well as location of fractured zones and presence of gas.		
(12) Neutron-epithermal Neutron Log	Tuff	NNWSI	Determine moisture content and bulk porosity.		[2]
	Basalt	BWIP	As above		
	Salt	SRPO	As above		
(13) Fluid Temperature Log	Tuff	NNWSI	Detect occurrence of perched water zones.		[2]
	Basalt	BWIP	Determine source/direction of groundwater inflow to boreholes.		
	Salt	SRPO	As above, as well as estimating temperature gradients with depth.		
14) Electric urvey	Tuff	NNWSI	Identify anomalies/ discontinuities.		[2]
	Basalt	BWIP	As above		
	Salt	SRPO	As above (brine pockets).		

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(15) Seismic Monitoring	Basalt	BWIP	Monitor dynamic response of various geologic units.		[2]
	Salt	SRPO	Obtain information on potential seismic hazards.		
(16) Shaft Convergence Test	Tuff	NNWSI	Determine horizontal stresses. Evaluate relaxation phenomena as they apply to material characterisation/shaft design.		[2]
	Salt	SRPO	Validate models, or refine engineering design.		
(17) Hydraulic Fracturing Stress Test	Basalt	BWIP	Confirm earlier surface test results.		[2]
	Salt	SRPO	Assess stress changes resulting from excavation of ESF and heat loads applied during certain tests. Model validation and design evaluations.		
(18) Plate-loading Test	Tuff	NNWSI	Assemble data base of deformation modulus measurements. Determine large-scale deformation modulus.	Used for performance assessment sensitivity analyses, and for extrapolation to adjacent rock masses.	[2]
	Basalt	BWIP	As above	Used to quantify anisotrophy/fracturing effects on rock mass deformation properties.	

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(19) Borehole-jacking Test	Basalt	BWIP	As above		[2]
	Salt	SRPO	As above		
(20) Slot-strength/Flat Jack Test	Tuff	NNWSI	Determine field-scale compressive bearing strengths, for comparison to laboratory measurements.		[2]
	Basalt	BWIP	As above		
(21) Underground Gravity Survey	Salt	SRPO	Identify possible brine inclusion and fracture zones.	Based on density variations.	[2]
(22) Room Backfill Test	Salt	SRPO	Obtain field data for assessment of long-term behaviour of backfill material. Validate predictive thermo-mechanical models		[2]
(23) Boring Machine Test	Tuff	NNWSI	Demonstrate boring-machine technology to bore long horizontal waste-canister emplacement holes.		[2]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
B. HYDROLOGIC CHARACTERISATION TESTS:					
(1) Matrix Property Test	Tuff	NNWSI	Determine magnitudes/ variations of rock matrix hydrologic properties. Determine functional relations between moisture content, permeability and matrix potential.		[2]
	Basalt	BWIP	Reduce uncertainty in measuring hydrologic properties (large-scale hydraulic conductivity, storativity).		
(2) Intact-fracture Test	Tuff	NNWSI	Evaluate fluid flow/ chemical transport properties of single, undisturbed fractures. Calibrate, test and validate fracture flow models.		[2]
	Basalt	BWIP	Determine hydraulic properties of rock zones.		
	Salt	SRPO	As for NNWSI and BWIP.		
(3) Infiltration Test	Tuff	NNWSI	Determine the hydrologic conditions under which fracture and matrix flow occurs.		[2]
	Basalt	BWIP	As above		

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(3) continued	Salt	SRPO	Evaluate short term aspects of borehole and room seal design/ emplacement. Validate hydrological models.		
(4) Bulk Permeability Test	Tuff	NNWSI	Determine validity of continuum hypothesis for fluid flow. Evaluate excavation effects.		[2]
	Basalt	BWIP	As for Infiltration Test		
(5) Radial Borehole Test	Tuff	NNWSI	Detect vertical movement of water in the unsaturated zone. Evaluate potential for lateral movement of water. Evaluate excavation effects on hydrologic properties.	Test will provide data on tortuosity, effective porosity and the unsaturated zone.	[2]
(5) continued:	Basalt	BWIP	Evaluate hydraulic properties of disturbed/ undisturbed rock mass. Estimate directional hydrologic properties of surrounding rock.		
	Salt	SRPO	Determine hydraulic conductivity profiles and ranges in values.		
(6) Excavation Effect Test	Tuff	NNWSI	Estimate effects of shaft excavation and lining on modification of hydrologic properties.	Topopah Spring welded unit.	
					[2]

(6) continued	Basalt	BWIP	Quantify expected groundwater flow into large underground openings.	Use of a chamber test	
	Salt	SRPO	Establish/confirm boundary conditions for geohydrological model. Assess hydraulic perturbations.		
(7) Hydrochemistry Test	Tuff	NNWSI	Estimate resistance time of water. Evaluate chemical reactions operative in unsaturated zone. Evaluate recharge characteristics.	Data on chemical composition/physical properties of water in pores, fractures and perched zones within the unsatur-zone.	[2]
	Basalt	BWIP	Assess redox conditions, and chemical/particulate characteristics of groundwater.		
	Salt	SRPO	As above.		
(8) Tracer Test	Tuff	NNWSI	Determine vertical flow rates through unsaturated zone to water table. Determine extent to which nonsorbing tracers diffuse into water-filled pores of tuff.		[2]
	Basalt	BWIP	Quantify effective porosity, dispersivity and solute retardation.		
	Salt	SRPO	Estimate hydraulic conductivity/specific storage for materials within discontinuity or permeable interbed. Assess applicability of the equivalent porous media approach to hydrologic characterisation		

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(8) continued			of discontinuous salt. Determine bulk effective porosity values for performance modelling at room-scale.		
(9) Hydraulic Conductivity of Shaft Seal Interval	Basalt	BWIP	Determine apparent permeability of cement grout, and the success of shaft liner system. Determine bulk density and bonding characteristics at interfaces.	Groundwater flow measured in radial boreholes at incremental distances from shaft liner. Ultrasonic geophysical probes.	[2]
(10) Room Seal Test	Basalt	BWIP	Evaluate design and installation performance		[2]
	Salt	SRPO	Evaluate design and short-term construction aspects of seal performance. Validate hydrologic models.		
(11) Borehole Seal Test	Basalt	BWIP	As above, for boreholes.		[2]
	Salt	SRPO	As above, for boreholes.		
(12) Brine Migration Test	Salt	SRPO	Evaluate brine migration in vicinity of waste canister emplacement holes. Validate associated predictive models used for performance assessment.		[2]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(13) Perched Water Test	Tuff	NNWSI	Evaluate hydrogeology of Calico Hills non welded unit. Determine realistic hypotheses for mechanisms of flow, flow paths and travel times.		[2]
C. <u>NEAR-FIELD AND THERMALLY PERTURBED-ZONE TESTS:</u>					
(1) Waste Package Environment Test	Tuff	NNWSI	Assess expected performance of waste package subsystem.	Obtain information on near-field hydrological, thermal and mechanical conditions	[2]
	Basalt	BWIP	Determine canister hole stability under elevated temperature conditions. Correlate laboratory-scale and rock mass-scale thermal conductivity/thermal expansion coefficients.		
	Salt	SRPO	Evaluate thermo-mechanical reponse of rock salt in near-field, and interactions between salt and canister. Validate predictive thermomechanical models. Provide canister corrosion data.		

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(2) Canister-scale Heater Test	Tuff	NNWSI	As above for NNWSI	Will include monitoring radon/radon daughter concentration accumulation as a function of heat load.	[2]
	Basalt	BWIP	As above for BWIP.		
	Salt	SRPO	As above for SRPO.		
(3) Small-scale Heater Test	Tuff	NNWSI	Evaluate thermal behaviour of welded tuff. Monitor possible migration patterns around heater. Verify laboratory-field scaling assumptions by evaluating thermomechanical expansion parallel to the heater.		[2]
	Basalt	BWIP	Obtain data for heat transfer analyses to predict temporal temperature distribution in repository.		
	Salt	SRPO	As above for BWIP		
(4) Heated Block Test	Tuff	NNWSI	Validate 3-D deformational and temperature models. Determine dependency of fracture permeability on stress and temperature. Monitor changes in moisture content distribution as a function of temperature and position for performance assessments. Evaluate potential of cross-borehole measure-		[2]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(4) continued			ments for monitoring mechanical and hydro-logical changes		
	Basalt	BWIP	Determine effect of temperature on host rock deformability. Study thermal/thermo-mechanical properties of host rock.		
(5) Room-scale Heater Test	Salt	SRPO	Evaluate thermomechan-ical response of full-scale repository room, and room stability effects. Validate predictive thermomechanical models used for design and performance assessment.		[2]
D. THERMAL/ STRUCTURAL INTERACTIONS:			Address technical issues of underground stability and rock deformation.		
(1) Room Thermal Loading Test	Salt (Bedded)	S.E. New Mexico; Waste Isolation Pilot Plant (WIPP)	Understanding/demonstra-tion of behaviour of a full-sized Defence High-Level Waste (DHLW) stor-age room (structural stability; extent of heat transfer to host rock and effects on room deformations). Validate predictive models and techniques.	Rooms (5.5 x 5.5 m) represent a refer-ence storage room with waste canisters vertically emplaced in the floor. US DOE; Sandia National Laboratories (SNL).	[3]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/	REFERENCES
(2) DHLW Overtest of Thermal Effects	Salt (Bedded)	WIPP	Evaluate effects of high heat on storage rooms, and on the structural stability and waste encapsulation potential of storage rooms. Validate predictive techniques for accelerated thermal conditions. Evaluate long-term effects of heat and room closure on crushed-salt backfill.	US DOE; SNL. OPERATOR	[3]
(3) Heated Pillar Test	Salt (Bedded)	WIPP	Evaluate response of a large rock mass, and validate predictive models for response under stress and thermal loadings: - Behaviour of room and pillar as a result of salt creep - Mechanical properties/ failure modes. Compare data to laboratory-model pillar test data, and to data from other salt mines.	11 m diameter salt pillar surrounded by heater blanket. Geometry permits evaluation of structural finite-element codes by using an axisymmetric 2-D model. US DOE; SNL.	[3]
(4) Geomechanical Evaluation	Salt (Bedded)	WIPP	Evaluate behaviour of different drift cross-sections and geometries, and validate models/ codes to predict responses: - Effects of room geometry on creep deformation of 2-D drifts - Response of 3-D drift intersection and the validity of using 2-D models.	Phased mining of a long 2-D drift, a 3-D drift intersection and a wedge-shaped salt pillar. Wedge pillar designed to fail in order to study/define failure mode from observations of acoustic emissions and deformation measurements.	[3]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(4) continued			Verify techniques for developing drift designs	US DOE; SNL.	
(5) In-Situ Stress Test	Salt (Bedded)	WIPP	Verify hydrostatic stress states assumed to exist at site, and compare in-situ stress data with laboratory data.	Series of long bore-holes drilled hori-zontally along the axes of drifts to be excavated later. Hydrofrac tests conducted. Fluorescent dye add-ed to hydraulic fluid to facilitate measurement. US DOE; SNL.	[3]
(6) Clay-Seam Shear Test	Salt (Bedded)	WIPP	Evaluate relevant res-ponse and stability characteristics of the test rooms: - Determine the effect-ive friction coeffic-ient of clay seams - Compare laboratory and in-situ data - Evaluate calculated displacements along clay seams.	US DOE; SNL.	[3]
(7) Acoustic Emissions Monitoring	Salt (Bedded)	WIPP	Evaluate salt fracturing and development of pro-gressive failure of a salt pillar: - Timing of yielding and fracturing - Failure mode - Ultrasonic velocity of salt.	US DOE; SNL.	[3]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
E. PLUGGING AND SEALING:			Measurements of 1) characteristics of formation fluid flow, and 2) material performance for restricting fluid flow through manmade openings.		
(1) Permeability Measurements	Salt (Bedded)	WIPP	Evaluate fluid flow characteristics, potential accumulation and dissipation of waste-generated gas, and influence of the disturbed zone.	Will examine permeability/porosity, permeability variations with distance from the mined face, and influence of interspersed clay and anhydrite seams. US DOE; SNL.	[3]
(2) Plug Test Matrix	Salt (Bedded)	WIPP	Evaluate long-term durability of plug material in host-rock environment: - Interactions and geochemical stability of candidate plug materials - Emplacement techniques - Post-test laboratory investigations of samples.	Plug materials (grouts, concretes, salt mixtures) placed in boreholes and subjected to ambient, wet and thermally elevated conditions. US DOE; SNL.	[3]
(3) Borehole Plug Test	Salt (Bedded)	WIPP	Assessment of material type and emplacement technique appropriate for plugging and monitoring plug performance in deep boreholes: - Sealing performance - Interaction of plugs with host-rock - Emplacement techniques/ procedures - Stability/durability of recovered plug materials.	US DOE; SNL.	[3]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(4) Gas Testing	Salt (Bedded)	WIPP	Characterisation of naturally occurring gas (nitrogen) entrapped in the host-rock. Evaluate impact of discovered gas on operational safety. Determine gas pressure, void volume and geometry and gas composition.	US DOE; SNL.	[3]
(5) Small-scale Seal Performance Tests	Salt (Bedded)	WIPP	Evaluate emplacement techniques and in-situ performance of candidate seal materials. Evaluate structural behaviour and geochemical interactions of the seal materials/host-rock. Evaluate time-dependent and sealing effects of the seal/host-rock interactions. Develop and validate predictive techniques and models.	US DOE; SNL.	[3]
(6) Large-Scale Seal Performance Test (Bulkhead Test)	Salt (Bedded)	WIPP	Evaluate and demonstrate performance of a full-sized seal emplaced in a drift-like configuration. Address emplacement techniques, structural integrity and fluid flow restriction capability. Validate flow and structural models.	Current seal design concept consist of 1) a bentonite centre core, 2) a salt-brick and mortar support structure and 3) cementitious material on both ends. US DOE; SNL.	[3]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(7) Backfill Emplacement	Salt (Bedded)	WIPP	Evaluate and demonstrate full-scale backfill emplacement techniques/ equipment. Determine achievable emplacement consolidation of candidate backfill materials for use in modelling and structural analyses. Determine structural interactions/fluid flow performance of a back-filled storage room.	Crushed-salt-based backfill in storage rooms. US DOE; SNL.	[3]
(8) Moisture Transport and Release Tests	Salt (Bedded)	WIPP	Develop predictive models for moisture transport, release and accumulation: - Characterise/model movement of naturally occurring moisture in the host-rock. - Evaluate quantity, rates and characteristics of moisture release to openings as a function of temperature and time.	Measuring moisture release to both heated and unheated boreholes drilled in test rooms. US DOE; SNL.	[3]
F. WASTE PACKAGE PERFORMANCE:			Measurements of near-field effects adjacent to waste container to evaluate durability and containment integrity of the waste package.		

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(1) Simulated DHLW Technology Experiments	Salt (Bedded)	WIPP	Evaluate performance and containment integrity of DHLW packages in a non-radioactive environment. Evaluate interactions of waste containers, back-fill materials and host rock.	Emplacement of 18 full-size simulated DHLW package in boreholes. Some containers intentionally defected. US DOE; SNL.	[3]
(2) Materials Interface Interactions Tests	Salt (Bedded)	WIPP	Evaluate various waste forms and package materials as they interact in a relevant brine and thermal environment: - Performance of non-radioactive DHLW glass (DWPF) - Compare DWPF performance to other waste glasses. Develop technical data base.	US DOE; SNL.	[3]
(3) Simulated CH and RH TRU Technology Experiments	Salt (Bedded)	WIPP	Evaluate durability, corrosion behaviour and crushing resistance of waste containers. Evaluate interactions of the waste containers with several backfill materials, and the migration and sorption of non-radioactive chemical tracer migration by these backfill materials.	CH: Contact-handled. RH: Remote-handled. US DOE; SNL.	[3]

TEST NAME	ROCK TYPE	SITE/ PROJECT	PURPOSE OF TEST	DESCRIPTION/ PRESENT STATUS/ OPERATOR	REFERENCES
(4) WIPP Radioactive Tests	Salt (Bedded)	WIPP	Evaluate near-field radionuclide migration (waste-form leaching release). Conduct/evaluate the safe handling and retrieval of radioactive materials. Evaluate moisture-release phenomena and effects of radiolysis on waste package materials and backfills. Verify phenomenological and predictive models. Evaluate cost effectiveness of waste package and backfill designs.	To be conducted in early 1990s. US DOE; SNL.	[3]

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