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WM DOCKET CONTROL CENTER

ENGINEERS INTERNATIONAL, INC.

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WM-RES
WM Record File D1004
EI

WM Project 10,11,16
Docket No.
PDR ✓
LPDR ✓ (B,N,S)

Distribution:
Buckley
(Return to WM, 623-SS)

31 October 1984
Ref. No. 1148-003
Letter No. 061

U. S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Attention: Mr. John Buckley
Project Officer

Subject: Replacement Data Reviews
Task Order 003
Contract No. NRC-02-84-002

Ladies and Gentlemen:

Please find enclosed copies of the corrected data reviews referred to in our August monthly report, to replace those that were not received.

We believe we have hereby satisfied all the requirements for deliverables under this Task Order.

We appreciate the opportunity to have been of service to the Nuclear Regulatory Commission.

Sincerely,

ENGINEERS INTERNATIONAL, INC.

Robert A. Cummings
Project Engineer

RAC/bt

Enclosure

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SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Thermal property laboratory tests/ thermal conductivity

Data Documented: ORNL/TM-6809: Morgan, M.T., Thermal Conductivity Of Rock Salt from Louisiana Salt Domes; Oak Ridge National Laboratory, Oak Ridge, Tennessee, June, 1979.

Data Collection Location:

(a) Areal Location: Avery Island and Jefferson Island Salt Domes, Southern Louisiana

(b) Subsurface Location: From Floor of mine, level &/or depth not specified.

Method of Data Collection/Analyses: Cores 2 and 2 1/8 inch diameter taken from mine floors. Samples prepared, and thermal conductivities measured using a Dynatech TCFCM-20 comparative thermal conductivity instrument.

Amount of Data: Thermal conductivities given for 15 samples at 100°C & plotted against density measured at 25°C. Rock salt impurities & their specific heat also given.

Data Sources: Core specimens, laboratory testing

Data Interpreted by: M. T. Morgan, ORNL

Data Storage Location: Oak Ridge, Tennessee 37830

Data Related Uncertainties: Uncertainty in thermal conductivity, using Pyroceram 9606 as a reference material, is reported as ± 5% at room temperature and ± 10% at higher temperatures. Cummulative error estimated within 20%, and precision within 10%. Data is definitive for stated conditions and uncertainties.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Creep property laboratory tests/ triaxial compression creep experiments.

Data Documented: ONWI-104: Mansen, F.D. & K.D. Mellegard; Creep of 50-mm Diameter Specimens of Dome Salt from Avery Island, Louisiana; prepared by RE/SPEC, Inc., for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, August, 1980.

Data Collection Location:

(a) Areal Location: Avery Island, Louisiana

(b) Subsurface Location: 500' Level of Avery Island Mine

Method of Data Collection/Analysis: Samples collected from three 16 inch diameter heater holes and many smaller instrument holes. 50 mm diameter samples were recored from field samples using a vertical milling machine, a thin-walled diamond-impregnated bit, and saturated brine solution.

Laboratory experimentation includes triaxial compression and data for time, temperature, axial stress, confining pressure, axial displacement, and volumetric displacement. Specimen was subjected to some axial stress (most more than one stress, or temperature) and allowed to creep. A constitutive law for transient creep is derived. Strain data were fitted to constitutive law in form

$$\varepsilon = kt^{n}\Delta\sigma^{m}T^{p}$$

Amount of Data: 40 tests on 20 specimens with varying conditions. Numerous plots and tables showing summary of data, test parameters, results, comparisons, stress-strain plots of stress difference application, axial strain as a function of time, total transient axial strain as a function of temperature, and others. Creep law parameters and derivation included.

Data Sources: Avery Island Mine specimens and laboratory tests

Data Interpreted by: Hansen & Mellegard, RE/SPEC, Inc.

Data Storage Location: RE/SPEC, Inc.

Data Related Uncertainties: Raw data-minor, Derived-model dependent, possibly major. Possible flaws are mentioned, though no specific uncertainties are reported. The report states that "there are several weaknesses in the constitutive laws...and they should be further evaluated and perhaps modified." Raw data may be considered definitive, and modelling, preliminary.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Thermal Property field tests/ heater tests

Data Documented: ONWI 190(1): Sambeek, Leo L., Avery Island Heater Tests: Temperature Measurements for the First 300 Days; prepared by RE/SPEC, Inc., for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, October, 1980.

Data Collection Location:

(a) Areal Location: Avery Island Salt Dome, Louisiana

(b) Subsurface Location: 550 ft. below mean sea level

Method of Data Collection/Analyses:

- a heated borehole was surrounded by monitoring holes.
- measurement of temperature and moisture were made in each hole.

Amount of Data: Several plots of temperature vs. days of heating, and temperature vs. radial distance. Several tables showing heater temperatures for initial 32 hours, and tables and plots of temperatures at specific periods of heating for 3 heater tests. Considerable data contained in appendices.

Data Sources: ONWI, RE/SPEC

Data Storage Location: RE/SPEC, Inc., Rapid City, SD
ONWI, Columbus, OH

Data Related Uncertainties: Attached Table gives source & magnitude of potential errors in temperature measurement. Data is definitive.

TABLE 2

SOURCE AND MAGNITUDE OF POTENTIAL ERRORS
IN TEMPERATURE MEASUREMENT

	RTD's on Site A Sleeve	Thermocouples in Heater Assemblies	Thermocouples in the Salt
Source of Error	**Magnitude of Error**		
Sensor Accuracy	±0.9°F 0°<T<212°F ±1.8°F 212°<T<392°F ±3.6°F 392°<T<752°F --- ±(0.3° + 0.6%)	± 0.4% T>530°F	±2°F T<530°F
Lead Wire Compensation/ Signal Conversion-Interpolation	±1.2°F @ 200°F ±3.8°F @ 750°F --- ±(0.3° + 0.5%)	±2.1°F @ 200°F ±2.9°F @ 750°F --- ±(1.8°F + 0.2%)	
Installation Technique	±5%	±5%	±(0.015%(T-100°F)T)
Assigning Radial Location	included in installation technique error	included in installation technique error	±(0.02 + 0.5%Z) ΔT/ΔR

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Geomechanical Property field tests/ displacement and stress measured during heater tests.

Data Documented: ONWI-190(2); Sambeek, Leo L., Randall G. Stickney & Keith B. DeJong: Avery Island Heater Tests: Displacement and Stress Data for the First 300 Days; prepared by RE/SPEC, Inc., for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, June, 1981.

Data Collection Location:

(a) Areal Location: Avery Island Salt Dome - Louisiana

(b) Subsurface Location: 550 ft. below mean sea level

Method of Data Collection/Analyses:

- Vertical and inclined extensometers for displacement/strain.
- Anchored bolts referenced to series of permanent bench marks beyond expected zone of influence for floor heave.

Amount of Data: Numerous plots and tables present data including displacements at 6 depth intervals per extensometer, 13 extensometers, and 17 time intervals over 300 days for 3 sites; days of heating vs. strain; floor heave data for 13 array pins at 3 sites, at various temperatures and time intervals. Detailed temperature data reported elsewhere (ONWI-190(1)). Also Roof to floor & Pillar Expansion measurements & borehole closure measurements.

Data Sources: ONWI/RE/SPEC

Data Storage Location: RE/SPEC, Inc., Rapid City, SD
ONWI, Columbus, OH

Data Related Uncertainties: "Extensometer propable error ± 0.002 inches. Floor heave measurements - random error of ± 0.05 inches." Data is definitive for specific conditions.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Thermal Property/Field Test variations in hydraulic conductivity with temp.

Data Documented: ONWI-190(3) Nitrogen Gas Permeability at Avery Island Blankenship, PA and Stickney, Randall G., RE/SPEC Inc., Battelle Memorial Institute, Columbus, OH, 1983.

Data Collection Location:

(a) Areal Location: Gulf Coast Salt Domes, Avery Island

(b) Subsurface Location: Heater Site C

Method of Collection/Analyses: Mechanical Packer with constant pressure and falling head measurements 1½" ϕ hole, 6 ft. section, nitrogen as the permeant.

Amount of Data: 10 Falling head tests
8 constant pressure tests

Data Sources: ONWI, RE/SPEC

Data Storage Location: RE/SPEC Rapid City, SD or
ONWI, Columbus, OH

Data Related Uncertainties: Probable errors for hydraulic conductivities were calculated. Probable errors are a function of:

- tested length
- effective radius
- borehole radius
- time
- pressure difference
- well pressure

Due to the small values of k the errors approach the calculated values of k.

Data is definitive for conditions stated.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Thermal Property/Field Tests

Data Documented: ONWI-190(4) Avery Island Brine Migration Tests: Installation, Operation, Data Collection, and Analysis, Krause, W.B. RE/SPEC, Battelle Memorial Institue, Columbus, OH, 1984.

Data Collection Location:

(a) Areal Location: Gulf Coast Salt Domes - Avery Island

(b) Subsurface Location: Upper level of Avery Island Salt Mine 500 ft. deep (169 m).

Method of Collection/Analyses:

- a heated borehole was surrounded by monitoring holes.
- measurement of temperature and moisuture were made in each hole.

Amount of Data: Two complete sets of data for natural and synthetic brine movement and temperature with time & a control test at ambient temperature conditions.

Data Sources: ONWI, RE/SPEC

Data Storage Location: ONWI, Columbus, OH
RE/SPEC, Rapid City, SD

Data Related Uncertainties: Large inclusions lead to highly increased migration and permeability rates.

Problems were reported for:

- long term operation of pneumatic packers.
- maintaining pressurization and fluid level indication in brine (monitoring) borehold.
- attachment of floor sealing ring.
- thermocouples attachment for long term monitoring.
- emplacement of glass beads to provide a collecting medium.

Due to redundancy or correction these problems did not significantly affect data quality.

Data is definitive for conditions and uncertainties as given.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Thermal Property/Field Tests

Data Documented: ONWI 190(5) Avery Island Heater Tests, Measured Data for 1,000 Days of Heating, Van Sambeck, L.L., Stickney, R.G., DeJong, K.B., RE/SPEC, Inc. Battelle Memorial Institute, Columbus, OH, 1984.

Data Collection Location:

(a) Areal Location: Gulf Coast Salt Domes - Avery Island

(b) Subsurface Location: ∿ 500 feet deep (169 m) upper level of Avery Island Salt Mine.

Method of Collection/Analyses:

- thermocouples in boreholes ((EX), 1½ ϕ), salt back filled at various distances.

Amount of Data: Considerable in Appendices A-F and text plots with distance from heater and time.

Data Sources: ONWI, RE/SPEC

Data Storage Location: ONWI, Columbus, OH
RE/SPEC, Rapid City, SD

Data Related Uncertainties: Report uncertainties include the following:

The uncertainties are minimized by the internal consistency and smooth and uniform plots with time.

Occasionally temperature measurements at the heater were inconsistent due to recrystallized salt in the annulus around the sleeve.

The data are only as certain as the thermocouple location due to high gradients.

Data is definitive for the stated conditions and uncertainties.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Geomechanical Property/Field Tests

Data Documented: ONWI190(5) Avery Island Heater Tests: Measured data for 1,000 days of heating, Van Sambeek, L. L., Stickney, R. G., and DeJong, K. B., RE/SPEC, Inc., Battelle Memorial Institute, Columbus, OH, 1983.

Data Collection Location:

(a) Areal Location: Gulf Coast Salt Domes - Avery Island

(b) Subsurface Location: approx. 500 ft deep (169 m) upper level of Avery Island Salt Mine

Method of Collection/Analysis: Extensometers in the pillars and floor and ceiling. Stressmeters in borehole around heated hole.

Amount of Date: Considerable in Appendices G-L. Plots with distance from heater and time.

Data Sources: ONWI Re/SPEC

Data Storage Location: ONWI, Columbus, OH; RE/SPEC, Rapid City, SD.

Date Related Uncertainties: Uncertainties were reported as follows: No complications of the stress measurement or displacement measurement were noted. The anchor depths for floor extensometers may not have been deep enough to measure all the displacement. The anchor depth for horizontal pillars was ½ the pillar width but this assumes the pillar is expanding the same in all directions which is unlikely due to the thermal gradient. Data is definitive for the reported conditions and uncertainties.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics/Creep Property/Laboratory Tests

Data Documented: ONWI-250, Quasi Static Strength and Creep Characteristics of 100-mm-Diameter Specimens of Salt from Avery Island, Louisiana, Mellegard, K.D., Senseny, P.E., Hansen, F.D., RE/SPEC, Inc., Battelle Memorial Institute, 1983.

Data Collection Location:

(a) Areal Location: Avery Island

(b) Subsurface Location: 500 ft. deep, (169 m) upper level Avery Island Salt mine.

Method of Collection/Analyses: Volumetric changes during heated triaxial testing of 100 mm ϕ samples.

Amount of Data: 1) 30 creep tests at $\sigma_1-\sigma_2$ from 5.4-20.7 MPa
$\sigma_2=\sigma_3$ from 0.7-30.7 MPa
T=24°-200°C
100 mm and samples

2) Quasi Static Strengths @ $\dot{\varepsilon}^{\circ} = 0.002$ σ = 0-20.7 MPa

Data Sources: ONWI, RE/SPEC

Data Storage Location: ONWI, Columbus, OH
RE/SPEC, Rapid City, SD

Data Related Uncertainties: Uncertainties were reported as follows:

The interaction of activation energy and temperature may lead to uncertain results. The calculations assumed activation energy was independent of temperature.

The transient strain equation is empirical derived from a "best fit" for lab size samples. Comparison between 50-mm and 100-mm samples indicate they are statistically different in their behavior.

Raw data is definite. Modelling for laboratory creep is considered preliminary.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Thermal Property Field Tests/ Bottom hole temperature, geothermal analysis

Data Documented: ONWI-289: Law Engineering Testing Company; Geothermal Studies of Seven Interior Salt Domes; prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, June, 1983.

Data Collection Location:

(a) Areal Location: Eight selected Gulf Coast salt domes in the Gulf Interior Region of Mississippi, Louisiana and Texas.

(b) Subsurface Location: Various, ranging from 500 to 20,000 feet.

Method of Collection/Analysis: Bottom hole temperatures, and electrical logging runs which occurred within six hours of circulation, from oil and gas exploration wells, were plotted and corrected to estimate actual geothermal environment.

Law Engineering - analysis, modelling, and interpretation of data.

Amount of Data: More than 700 temperature readings from 317 well logs. One well log for Cypress Creek; 45 for Richton, and 79 for Vacherie.

Data Sources: Oil and gas well logs from petroleum industry.

Data Interpreted by: Law Engineering Testing Company

Data Storage Location: Law Engineering Testing Company, Marietta, GA.

Data Related Uncertainties: Temperature estimates, after data correction reported as "probably accurate within 10°F for depths down to 5,000 feet." Data is definitive for stated conditions and uncertainties.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Creep property field tests/short term borehole creep

Data Documented: ONWI-400: Nelson, R.A., J.G. Kocherhaus, M.R. Schnapp; In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah; prepared by Woodward-Clyde Consultants for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, November, 1982.

Data Collection Location:

(a) Areal Location: GD-1 Borehole, Gibson Dome, San Juan County, Utah

(b) Subsurface Location: Five depth intervals-160 ft @ 4785-4945 ft; 160 ft @ 3160-3320 ft; 100 ft @ 3928-4028 ft; 100 ft @ 3575-3675 ft; and 70 ft @ 4245-4315 ft

Method of Data Collection/Analysis: Evaluated during minimum unloading pressure when nitrogen pressure was zero in Geotechnical Drill Stem Tests (GDST). Measured by downhole triple quartz-crystal pressure transducers (TQCT). Volumetric strain values obtained from direct measurements of fluid level & from precise measurements of test zone pressure.

Slopes of pressure versus time plots for 3 tests (GDST-1, 2 & 4) were converted to volumetric & radial logarithmic strain rates. Slope calculated as $\varepsilon r = \frac{1}{2}\varepsilon v = (\Delta p/\Delta t) \times (TC/FG) \times Vo$.

Woodward-Clyde Consultants-analysis and interpretation of data

Amount of Data: Plots for creep versus time. Three tests reported, only one with adequate fluid level change (GDST-1). Radial strain creep rate given for GDST-1, 2 & 4.

Data Sources: GD-1 Borehole, Geotechnical Drill Stem Tests

Data Interpreted by: Woodward-Clyde Consultants

Data Storage Location: Woodward-Clyde Consultants, San Francisco, CA

Data Related Uncertainties: Raw data - "TQCT pressure sensor with drift of ± 1kPa (0.2 psi) was able to record fluid level changes as small as ± 0.09 m (0.3 foot)." Converting maximum pressure change into fluid level change gives...a value close to the directly measured value." Data considered definitive for stated conditions and uncertainties.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Geomechanical property field test/ unloading stress-strain

Data Documented: ONWI-400: Nelson, R.A., J.G. Kocherhaus, M.R. Schnapp; In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah; prepared by Woodward Clyde Consultants for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, November, 1982.

Data Collection Location:

(a) Areal Location: GD-1 Borehole, Gibson Dome, San Juan County, Utah

(b) Subsurface Location: Five depth intervals - 160 ft @ 4785-4945 ft; 160 ft @ 3160-3320 ft; 100 ft @ 3928-4028 ft; 100 ft @ 3575-3675 ft; and 70 ft @ 4245-4315 ft.

Method of Data Collection/Analysis: Primary data-downhole pressures recorded above drilling fluid pressure, within and below test zone at one- to five-minute intervals per test, during each unloading geotechnical drill-stem test (GDST). Fluid level data measured by dunking pressure transducer or shorting-type electrical sensor on electric cable wireline.

Data translated into unloading pressure versus volumetric strain values, by Volumetric Strain = $\Delta V/Vo$, and radial strain $\Delta r/ro = 0.5\ \Delta V/Vo$.

Woodward-Clyde Consultants-analysis and interpretation of data.

Amount of Data: 70 fluid level measurements for GDST-1, 8 for GDST-2; 21 for GDST-4. Pressure graphs for GDST 1, 2 & 4 showing pressures in and below test zone, and drilling fluid pressures. Five tests-two successful, one partially successful, and two unsuccessful, are reported.

Data Sources: GD-1 Borehole, Geotechnical Drill Stem Tests

Data Interpreted by: Woodward-Clyde Consultants

Data Storage Location: Woodward-Clyde Consultants, San Francisco, CA

Data Related Uncertainties: Possibly major. "Refinements of equipment will improve accuracy of unloading fluid level data...," "Equipment malfunctions during this test (GDST-2) could have yielded anomalous measurements..." No uncertainties reported. Uncertainty in raw data minor. Data definitive for stated conditions; preliminary considering possible large uncertainties.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Creep Property Laboratory Tests/ creep at various temperatures.

Data Documented: ONWI-400: Nelson, R.A., J.G. Kocherhaus, M.R. Schnapp; In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah; prepared by Woodward-Clyde Consultants for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, November, 1982.

Data Collection Location:

(a) Areal Location: GD-1 Borehole, Gibson Dome, San Juan County, Utah.

(b) Subsurface Location: Salt Cycle 6, 6 samples: between 998 and 1,017 m (3,275 & 3,335 ft.) below drill rig datum.

Method of Data Collection/Analysis: Tests conducted on right circular cylinders of salt from salt cycle 6. Seven parameters monitored: axial stress, confining pressure, total axial displacement, axial strain, radial strain, temperature, and time. On samples with elevated temperatures, T was increased at 0.5°C (1°F) per minute to desired temperature. Samples isotropically compressed to desired pressure & allowed to equilibrate 24 hours, then quickly unloaded at rates between 7KPa/sec (1 psi/sec) and 140 KPa/sec (20 psi/sec), and data recorded every 30 sec.

Exponential-time creep law formed as $\Sigma = e_a\ (1-\exp\ (-\xi t))\ t\Sigma^{\circ}_{ss}t$ and total axial strain values as calculated from LVDT measurements vs. elapsed time were fit to creep law.

Woodward-Clyde Consultants - analysis and interpretation of data.

Amount of Data: 18 strain vs. time plots, at various unloading stages for six samples tested. Tables and plots of creep law parameters. 15 tests on 6 samples at given temperatures and confining pressures.

Data Sources: GD-1 Borehole samples

Data Interpreted by: Woodward-Clyde Consultants

Data Storage Location: Woodward-Clyde Consultants, San Francisco, CA.

Data Related Uncertainties: It is reported that the "model sometimes overestimates the steady-state strain rate by about 10 percent." Various parameters reported and compared to work by others show considerable differences. Uncertainties probably major. Raw data definitive for specific conditions, modelling is preliminary.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Geomechanical property laboratory tests/ strength

Data Documented: ONWI-400: Nelson, R.A., J.G. Kocherhaus, M.R. Schnapp; In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah; prepared by Woodward-Clyde Consultants for Office of Nuclear Waste Isolation, Batelle Memorial Institute, Columbus, OH, November, 1982.

Data Collection Location:

(a) Areal Location: GD-1 Borehole, Gibson Dome, San Juan County, Utah.

(b) Subsurface Location: Salt cycle 6 between 998 and 1,017m (3,275 and 3,335 feet) below drill rig datum.

Method of Data Collection/Analysis: .9 m (3-foot) core lengths cut w/ diamond saw in 19 cm (7-5 inch) sample lengths. 4-inch diameter core, undercored to 3 inch diameter. Electrical resistance, foil-type strain gages affixed to sample. Testing was done using uniaxial compression, extension unload, compression load, compression unload, and extension load, using both uniaxial and triaxial testing.

Strain values from axial and circumferential gages calculated as $\varepsilon=0.5_{abs}(S_\tau-S_o)$; total strain measured by linear-variable-displacement-transducer (LVDT) calculated as $\varepsilon_\tau=(LVDT_\tau-LVDT_o)/H_o$; and axial stress computed as $\sigma_{ax}=L-(A_p-A_\tau)P/A_\tau$.

Woodward Clyde Consultants-analysis and interpretation of data.

Amount of Data: 42 plots of Stress Difference vs. Strain; 32 results at maximum stress difference, showing values for bulk density, effective porosity, confining stress, axial stress, stress difference, and total strain.

Data Sources: GD-1 Borehole samples

Data Interpreted by: Woodward-Clyde Consultants

Data Storage Location: Woodward-Clyde Consultants, San Francisco, CA.

Data Related Uncertainties: Typical accuracy of strains is reported as ± 0.5 percent of recorded value for temperatures from 22° to 50°C (72° to 122°F) and ± 1 percent for 50° to 150°C (122° to 302°F), with a resolution to 40 microstrain. Accuracy of loading press LVDT is ± 0.5% of 2.5 cm (1.0 inch) full scale; resolution to .0025 mm (0.0001 inches); of loading press force transducer-.25% of 445KN (100,000 lb) full scale, resolution to 44N (10 lb); of confining pressure transducer-±0.3% of 69 MPa (10,000 psi) full scale, resolution to 7KPa (1 psi). Data is definitive.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Geomechanical property field tests/ loading/hydraulic fracture geotechnical drill stem tests (GDST)-in situ stress measurements.

Data Documented: ONWI-400: Nelson, R.A., J.G. Kocherhaus, M.R. Schnapp; In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah; prepared by Woodward-Clyde Consulants for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, November, 1982.

Data Collection Location:

(a) Areal Location: GD-1 Borehole, Gibson Dome, San Juan County, Utah.

(b) Subsurface Location: GDST-9(3137 ft); GDST-4a(3630 ft); GDST-8(4177 ft); GDST-7(4577 ft); GDST-6A(4847 ft); and GDST-6(4887 ft).

Method of Data Collection/Analysis: Technique involves raising fluid pressure in inflated-packer-sealed segment of borehole until tensile fracture is induced. Continued pumping opens fracture & extends it away from hole. Whem pumping ceases, pressure in hole comes to equilibrium level as horizontal stress closes fracture. Subsequent analyses of pressure time history yields magnitudes of in situ principal stresses.

Stresses evaluated using breakdown pressure (P_B)= 3Sh-SH-P_p + T and fracture opening pressure (P_f)= 3Sh-SH-P_p

Woodward-Clyde Consultants-analysis and interpretation of data.

Amount of Data: Plots of pressure vs. volume, surface pressure vs. time, and parameters for the six tests, including depth, test zone length; test zone temperature; P_B (breakdown pressure); P_F (fracture opening pressure); P_o (pore pressure); SH (maximum horizontal stress); ISIP (instantaneous shut in pressure); Sh (minimum horizontal stress); S_v (vertical stress); T_o (tensile strength); and S_u (maximum shear stress).

Data Sources: GD-1 Borehole, Geotechnical Drill Stem Tests

Data Interpreted by: Woodward-Clyde Consultants

Data Storage Location: Woodward-Clyde Consultants, San Francisco, CA.

Data Related Uncertainties: Major-"several potential sources of error...(1) uncertainty in determination of pore pressure (2) uncertainty of magnitude of tensile strength of salt, and (3) possibility that assumption of elastic response may not be strictly valid for salt in GD-1." Additionally at least 5 assumptions are made which may not all be valid.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Creep Property Laboratory tests/ triaxial compression creep tests

Data Documented: ONWI-450: Pfeifle, T.W., K.D. Mellegard, P.E. Senseny; Preliminary Constitutive Properties for Salt and Nonsalt Rocks from Four Potential Repository Sites; prepared by RE/SPEC, Inc. for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, July, 1983.

Data Collection Location:

(a) Areal Location: Richton Dome - DOE Masonite MRIG-9
Vacherie Dome - LSU #1 (DOE-Smith #1 or DOE-V)
Permian Basin - Mansfield #1, Oldham County
#1 Rexwhite, Randall County
#1 Grabbe, Swisher County
Paradox Basin, Gibson Dome, GD-1

(b) Subsurface Location: Richton (MRIG-9) 35.9-386.7m (1177.4-1268.5 ft.)
Vacherie (LSU #1) 605.4-613.8m (1986.3-2013.8 ft.)
Permian (Mansfield #1) 446.1-451.6m (1463.7-1481.6 ft.)
Cycle 5
(#1 Rexwhite) 572.0-572.8m (1876-7-1879.3 ft.)
Cycle 4
(#1 Grabbe) 770.1-801.7 (2526.5-2630.2 ft.)
Cycle 4)
Paradox (GD-1) Carnallite - 971.7-974.8m (3187.9-3198.2 ft.
Salt Cycle 6 - 1010.8-1022.9m (3316.3-3356.0 ft.
Salt Cycle 7 - 1038.9-1042.8 (3408.4-3421.1 ft.

Method of Data Collection/Analysis: Specimens aquired by coring. Experiments on salt include triaxial compression creep tests, used to derive a creep law. Three creep experiments were performed at axial stress differences and temperatures of (5 MPa, 100°C), (10 MPa, 100°C), and (5 MPa, 200°C), and all at a confining pressure of 15 MPa. A total of 19 tests was performed. Three tests for specimens at each depth investigated, except carnallite where only one was performed. All test durations were nominally 2.4×10^6 seconds, except for three which were terminated at shorter times.

Creep tests were fit to exponential-time creep law
$\varepsilon c = \varepsilon sst + ea(1-\exp(-\xi t))$

Amount of Data: Axial strain vs. time plots at 3 temperature/pressures. Axial strain vs. time as measured & as predicted, for each site. Creep law parameters for each site.

Data Sources: Corehole samples & laboratory tests

Data Interpreted by: Pfeile, Melgard, Senseny-RE/SPEC, Inc.

Data Storage Location: RE/SPEC, Inc.

Data Related Uncertainties: "Predictive capability of creep law measured by its ability to reproduce data when appropriate fitting parameters were used. Steady-state strains are predicted very well. Transient portions of curves appear to account for most of deviations between measured and predicted response. Generally, the combinations of fitting parameters result in good fits to the data." No specific uncertainties reported. Raw data definitive, modeling preliminary.

SALT REPOSITORY PROJECT
SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Geomechanical property laboratory tests/elastic moduli and failure envelope at 20°C (salt) and elastic moduli, unconfined compressive strength & tensile strength at 24°C (nonsalt).

Data Documented: ONWI-450: Pfeifle, T.W., K.D. Mellegard, P.E. Senseny; Preliminary Constitutive Properties for Salt and Nonsalt Rocks from Four Potential Repository Sites; prepared by RE/SPEC, Inc., for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, July, 1983.

Date Collection Location:

(a) Areal Location: Richton Dome - DOE Masonite MR16-9
Vacherie Dome - LSU #1 (DOE - Smith #1 or DOE - V)
Pennian Basin - Mansfield #1, Oldham County
#1 Rexwhite, Randall County
#1 Grabbe, Swisher County
Paradox Basin, Gibson Dome, GD-1

(b) Subsurface Location: Richton (MR16-9) 359-386.7 m (1177.4-1268.5 ft.)
Vacherie (LSU #1) 605.4-613.8 m (1986.3-2013.8 ft.)
Permian (Manisfield #1) 446.1-451.6 m (1463.7-1481.6 ft.) Cycle 5
(#1 Rexwhite) 572.0-572.8 m (1876.7-1879.3 ft.) Cycle 4
(#1 Grabbe) 770.1-801.7 m (2526.5-2630.2 ft.) Cycle 4
Paradox (GD-1) Carnallite - 971.7-974.8 m (3187.9-3198.2 ft.)
Salt Cycle 6 - 1010.8-1022.9 m (3316.3-3356.0 ft.)
Salt Cycle 7 - 1038.9-1042.8 m (3408.4-3421.1 ft.)

Method of Data Collection/Analysis: Specimens acquired by coring. Experiments on salt include quasi-static triaxial compression tests and Brazilian (indirect tension) tests. Four of six tests performed at 24°C and confining pressures of 0, 5, 10, and 15 MPa & remaining two at 10 MPa and temperatures of 100°C and 200°C. Three Brazilian tests were performed at 24°C. All nonsalt experiments at 24°C.

Amount of Data: 6 failure envelopes in salt, one in carnallite
strength vs. temperature for 7 cases
7 failure criteria parameters
Axial strain vs. time under varied conditions
Youngs modulus & Poisson's Ratio
31 samples-Elastic parameters & strength-nonsalt
42 Axial stress difference vs. strain plots
148 stress vs. lateral & axial strain for nonsalt

Data Sources: Corehole samples & laboratory tests.

Data Interpreted by: Pfeifle, Melegard, Senseny - RE/SPEC, Inc.

Data Storage Location: RE/SPEC, Inc.

Data Related Uncertainties: Not reported; probably minor to moderate. Definitive for conditions noted, preliminary with regard to possible application.

SALT REPOSITORY PROJECT

SUMMARY DATA INVENTORY SHEET

Type of Data: Rock Mechanics Data/Creep property laboratory tests/ triaxial creep experiments

Data Documented: SAND 79-0115: Wawersik, W.R. and D.W. Hannum; Interim Summary of Sandia Creep Experiments on Rock Salt from the WIPP Study Area, Southeastern New Mexico, Sandia laboratories, 1979.

Data Collection Location:

(a) Areal Location: WIPP study area near Carlsbad, New Mexico

(b) Subsurface Location: ERDA #9 Corehole
Upper Level 625-650 m (2000-2100 ft.)
Lower Level 810-875 m (2600-2800 ft.)

Method of Data Collection/Analysis: Specimens were collected from the ERDA #9 Corehole, and subjected to triaxial loading. 23 tests were subjected to principal stress differences between 930 psi (6.4 MPa) and 4800 psi (33.2 MPa), and confining pressures between zero (unconfined) and 3000 psi (20.7 MPa). Test temperatures were 22, 100 and 200°C.

Cross plots of data were prepared to explore effects of principal stress difference, temperature and confining pressure. For primary (transient) creep, axial strain-time data were fitted to $\Sigma p' = A \log (t)$ and $\Sigma p'' = ct^n$. Secondary creep was estimated from straight line portions of plots and that the slope r of plots in the space log (e total), log (t) increased with time from the value r = n during primary creep towards r = 1 when secondary creep becomes overriding. Tertiary creep measured in four experiments at 500 psi (3.5 UPa) confining pressure and T = 22°C and at T = 100°C with confining pressures of 0, 500 and 3000 psi (0, 35, 20.7 UPa).

Wawersik, Hannum - analysis and interpretation of data.

Amount of Data: 23 experiments - various tables giving max. principal stress difference, strain at maximum stress, minimum stress, temperature, direction of strain, and estimated secondary creep. 1 sample - 2 variations of principal stress difference with time (plot). 1 sample - plot of principal stress difference and confining pressure vs. time. 1 sample, axial creep vs. time plots, log/log plot, semi log plot, 3 secondary creep plots. 23 data tables showing principal stress difference over several time intervals.

Data Sources: WIPP core specimens, laboratory testing

Data Interpreted by: Wawersik, & Hannum - SNL

Data Storage Location: Sandia Laboratories, Albuquerque, NM.

Data Related Uncertainties: Major uncertainties in parameter n in primary creep power law. Raw data, minor, directly measure. Secondary creep estimated, possibly major uncertainties. Tertiary creep measured - moderate uncertainties. Uncertainties not specifically reported. Raw data should be definitive, however creep data can only be preliminary, based on laboratory data and creep laws.

SALT REPOSITORY PROJECT

SUMMARY DATA INVENTORY SHEET

Type of Data: Creep property laboratory tests/triaxial creep experiments

Data Documented: SAND 79-7030: Hansen, F.D. and K.D. Mellegard; Creep Behavior of Bedded Salt from Southeastern New Mexico at Elevated Temperature; by RE/SPEC, Inc., for Sandia Laboratories, Albuquerque, New Mexico, November, 1979.

Data Collection Location:

(a) Areal Location: WIPP Study Area, Southeastern New Mexico, ERDA No. 9 corehole.

(b) Subsurface Location: Depth interval of 2605 to 2679 feet.

Method of Data Collection/Analysis: Samples from corehole subjected to triaxial loading and data, including axial and lateral strain, axial and confining pressures, time and temperature were collected. Creep response was measured for temperatures of 24, 70 and 100°C under confinement pressures of 0, 1500, 2000, 2500, and 3000 psi, and differential axial stress levels of 1500, 3000, 4500 and 6000 psi. Test durations ranged from 15 minutes to over 500 hours. 14 specimens were tested.

Axial and Lateral Strain were plotted as a function of time and compared to previous results.

Hansen & Mellegard - analysis and interpretation of data.

Amount of Data: 14 specimens, 17 experiments, with numerous plots and tables showing test parameters and results, and resulting equation fitting axial creep data to a function of time, differential stress, and temperature. ($e_1 = 1.1\ (10\text{-}35)\ t^{0.4656}\ \sigma^{2.475}\ T^{8.969}$)

Data Sources: Core speciments, laboratory tests

Data Interpreted by: Hansen & Mellegard

Data Related Uncertainties: None reported. Raw measured data minor uncertainties. Modelling - major uncertainties. Raw data should be definitive, modelling, preliminary.