Sandia National Laboratories
Albuquerque, New Mexico 87185

October 15, 1986

Mr. John Peshel
Engineering Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Dear Mr. Peshel:

The enclosed monthly report summarizes the activities during the month of September for FIN A-1755.

If you have any questions, please feel free to contact me at FTS 844-8368 or L. R. Shipers at FTS 846-3051.

Sincerely,

Robert M. Cranwell

Robert M. Cranwell
Supervisor
Waste Management Systems
Division 6431

RMC:6431

Enclosure

Copy to:
Office of the Director, NMSS
Attn: Program Support Branch
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6430 N. R. Ortiz
6431 R. M. Cranwell
6431 L. R. Shipers
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PROGRAM: Coupled Thermal-Hydrological-Mechanical Assessments and Site Characterization Activities for Geologic Repositories

FIN#: A-1755

CONTRACTOR: Sandia National Laboratories

BUDGET PERIOD: 10/85 - 9/86

DRA PROGRAM MANAGER: J. Peshel

BUDGET AMOUNT: 226K

CONTRACT PROGRAM MANAGER: R. M. Cranwell

FTS PHONE: 844-8368

PRINCIPAL INVESTIGATOR: L. R. Shipers

FTS PHONE: 846-3051

PROJECT OBJECTIVES

To provide technical assistance to NRC in the assessment of coupled thermal-hydrological-mechanical phenomena and site characterization activities for high-level waste repositories.

ACTIVITIES DURING SEPTEMBER 1986

Activities and Accomplishments

Beginning October 1, 1986, L. R. Shipers will assume the duties of principal investigator for FIN A-1755. Please direct all communications concerning this project to him.

During the month of September, the investigations on numerical modelling applications to rock response around boreholes and shafts and to shaft liner response was continued. The thermomechanical stresses around emplacement holes were analyzed using several simple computer models. This analysis resulted in a modified thermal stress solution for hollow cylinders (program THCYLB1) and an improved version of a previously supplied program (EXCAV) which calculates the stress distribution around circular cavities. Also, a new program (EXCAV2) which permits the calculation of the stress field at multiple radial and angular locations in a single run was written. The results of the thermomechanical stress analysis are included as an attachment to this report. Also, a floppy disk containing the previously mentioned programs is included.

It is recommended that this investigation be continued and that the simplified analyses be supplemented by more sophisticated studies using two- and three-dimensional numerical models. An effort is currently underway to develop a two-dimensional simulation of a shaft using STEALTH 2D to assess shaft liner response. To supplement this work with a fully three-dimensional model, two codes, JAC3D and STEALTH 3D, are currently under consideration. The choice of computer codes is limited because a number of the three-dimensional codes are dynamic in nature and not suitable for quasi-static geomechanics calculations. JAC3D is currently available at SNLA and has documentation in a draft form. But a proprietary and somewhat expensive pre-processor, PATRAN, is necessary for the use of JAC3D. While PATRAN is currently available at SNLA, a fair amount of effort will be required to learn its use. As a additional note, a great many three-dimensional mechanical codes, including ABAQUS and NASTRAN, use PATRAN as a pre-processor for grid generation. STEALTH 3D was installed at SNLA approximately 3 years ago but it is not clear at this time if the three-dimensional version is still in existence either on CRAY or on tape. The current version of STEALTH 3D exists only as a dynamic code and not the quasi-static version necessary for geomechanical calculations. While it would be a rather straightforward extension of the existing updates used for the waste isolation version of STEALTH 2D, some time would be required to convert the existing version of STEALTH 3D to a quasi-static code. It should be noted that this quasi-static conversion has been successfully performed with earlier versions of STEALTH 3D. Any decisions regarding the performance of a three-dimension simulation will be made in consultation with NRC staff.

Travel

None.

Problems Encountered

On October 1, 1986 all work was stopped on FIN A-1755 pending the arrival of funding for the 1987 fiscal year since no carry-over funding existed. Upon arrival of fiscal year 1987 funding work will resume on this project.

Modified Thermal Stresses - Hollow Cylinder

Thermal stress solutions for solid and hollow cylinders and solid and hollow spheres were included in the monthly report for August, 1985 for FIN A-1755. Those analytical solutions assume zero radial stress at the boundaries. Furthermore, steady-state temperature solutions are used for each of the geometries. When the outer radius is assumed to be large, the situation of a waste package in a borehole can be simulated. However, at the time when the peak temperatures occur at the borehole surface, the farthest distance to which heat dissipates is relatively small. The physical implication of this is that the temperature gradients in the vicinity of the borehole are higher than those predicted by a steady-state distribution which assumes a large outer radius. A better approximation of the thermal stresses can be obtained by using a small outer radius for the thermal boundary and a large outer radius for the zero radial stress condition. The integral equations that represent the hollow cylinder solution are (as before)

$$\sigma_r = \frac{\alpha E}{1 - \nu} \frac{1}{r^2} \left[\frac{r^2 - a^2}{b^2 - a^2} \int_a^b Trdr - \int_a^r Trdr \right] \tag{1}$$

$$\sigma_\theta = \frac{\alpha E}{1 - \nu} \frac{1}{r^2} \left[\frac{r^2 + a^2}{b^2 - a^2} \int_a^b Trdr + \int_a^r Trdr - Tr^2 \right] \tag{2}$$

$$\sigma_z = \frac{\alpha E}{1 - \nu} \left[\frac{2\nu}{b^2 - a^2} \int_a^b Trdr - T \right] \tag{3}$$

for zero axial stress and

$$\sigma'_z = \frac{\alpha E}{1 - \nu} \left[\frac{2}{b^2 - a^2} \int_a^b Trdr - T \right] \tag{4}$$

for zero axial end force. Let b_1 be the outer radius with respect to the thermal response. Assuming that a steady-state thermal solution is valid between the radii a and b_1, the temperature distribution becomes

$$T(r) = \tau \ln(b_1/r)/\ln(b_1/a) \tag{5}$$

where $T = 0$ for $r > b_1$ and τ is the temperature at the inner radius, a. For $r < b_1$, substituting Eq. (5) into Eqs. (1) - (4) and integrating yields

$$\sigma_r = \frac{\alpha E \tau}{r^2(1 - \nu)\ln(b_1/a)} \left\{ \frac{r^2 - a^2}{b^2 - a^2} \left[-\frac{a^2}{2} \ln(b_1/a) + \frac{b_1^2}{4} - \frac{a^2}{4} \right] - \frac{r^2}{2} \ln(b_1/r) + \frac{a^2}{2} \ln(b_1/a) - \frac{r^2}{4} + \frac{a^2}{4} \right\} \tag{6}$$

$$\sigma_\theta = \frac{\alpha E \tau}{r^2(1 - \nu)\ln(b_1/a)} \left(\frac{r^2 + a^2}{b^2 - a^2}\left[-\frac{a^2}{2}\ln(b_1/a) + \frac{b_1^2}{4} - \frac{a^2}{4}\right]\right.$$

$$\left. + \frac{r^2}{2}\ln(b_1/r) - \frac{a^2}{2}\ln(b_1/a) + \frac{r^2}{4} - \frac{a^2}{4} - r^2 \ln(b_1/r)\right) \quad (7)$$

$$\sigma_z = \frac{\alpha E \tau}{(1 - \nu)\ln(b_1/a)} \left(\frac{2\nu}{b^2 - a^2}\left[-\frac{a^2}{2}\ln(b_1/a) + \frac{b_1^2}{4} - \frac{a^2}{4}\right] - \ln(b_1/r)\right) \quad (8)$$

$$\sigma'_z = \frac{\alpha E \tau}{(1 - \nu)\ln(b_1/a)} \left(\frac{2}{b^2 - a^2}\left[-\frac{a^2}{2}\ln(b_1/a) + \frac{b_1^2}{4} - \frac{a^2}{4}\right] - \ln(b_1/r)\right) \quad (9)$$

These modified expressions for thermal stresses in a hollow cylinder have been incorporated into a PC program named "THCYLB1".

Thermomechanical Stresses Around Emplacement Holes

In order to expedite the solution procedure for stress distributions around circular cavities, the EXCAV program was modified to provide multiple solutions in a single execution. When the in-situ state of stress is biaxial, the stresses vary as a function of the angular orientation of a radius vector. A new program, EXCAV2, permits the calculation of the stress field at multiple radial and angular locations in a single run.

Following the procedures summarized in the August 1986 monthly report, excavation stresses were estimated for a rectangular opening in basalt using the computer code BDYELM. The following data were utilized in BDYELM:

Opening dimension = 6.7 m × 3.23 m

Depth from Surface = 826 m (implied by overburden)

In-situ Stresses: σ_v = 23 MPa, $\sigma_{h_{max}}$ = 57.5 MPa

Stress Ratio = 2.5

Young's Modulus = 7.56×10^{10} Pa

Poisson's Ratio = 0.27

Strength Parameters (Hoek-Brown Criterion):

σ_c = 290 MPa

m = 18.44

s = 0.0375

The BDYELM output was monitored to select σ'_v as the maximum stress at pillar mid-height for horizontal emplacement. Likewise, σ'_h was selected as the maximum stress below the floor centerline for vertical emplacement. The other principal stress component for either emplacement geometry is $\sigma_{h_{min}}$, which is known beforehand.

Using the stress values stated above, separate calculations were made for horizontal and vertical emplacement. The "in-situ" stresses for a borehole of radius 0.813 were prescribed as

Horizontal Case: σ'_v = 25 MPa and $\sigma_{h_{min}}$ = 33 MPa

Vertical Case: σ'_h = 70 MPa and $\sigma_{h_{min}}$ = 33 MPa

The EXCAV2 program was then used to compute the excavation stresses around a horizontal and a vertical borehole. The maximum stress in each case occurs at the borehole wall (i.e., the tangential component of stress). The maximum stress for the horizontal case was 74 MPa and for the vertical case was 177 MPa.

Next, a temperature distribution was assumed and the thermal stresses were calculated using THCYLB1 and/or THERST. Recall that in THCYLB1 the outer boundary for temperature and for radial stress prescriptions may be at different locations. A comparison calculation was performed to quantify the differences in stress estimates using THERST (which uses the same radius for thermal and mechanical boundaries) and THCYLB1. Three cases, as shown by the table below, were examined.

	Case 1	Case 2	Case 3
Program	THERST	THCYLB1	THCYLB1
Inner Radius (r_{in})	0.813 m	0.813 m	0.813 m
Outer Radius for Stress Boundary (r_{out})	500 m	500 m	500 m
Outer Radius for Temperature Boundary (r_{cut})	500 m	500 m	25 m
Temperature at Inner Boundary (T_i)	200°C	200°C	200°C

The comparison of interest is between Cases 1 and 3. This comparison will provide an assessment of the effect of two different temperature distributions for a given borehole wall temperature. The two temperature distributions used for this comparison are shown in Figure 1. For Case 1, the normalized temperature becomes zero at a radial distance of 500 m. Case 2 was run to verify that THCYLB1 gives the same results as THERST when the thermal and mechanical boundaries are specified at the same radius. As may be seen from the results presented in Tables 1 and 2, Case 1 and Case 2 give identical results. Tables 1 and 3 show results of principal stress distribution near the borehole as a function of radial distance. At the borehole wall the tangential component of thermal stress is 76.4 MPa for Case 1 as compared to 82.8 MPa for Case 3. The Case 3 calculation should be regarded as being more realistic and conservative when compared to Case 1. At larger radii, the stresses and stress distributions differ substantially. The data in Tables 4 and 5 show principal stress values at increments of 2 m upto a radius of 25 m. In general, the radial stress beyond 3 m has a lower value for Case 3 (after a peak value of 29 MPa at about 2.3 m) than Case 1. The tangential stress for Case 3 becomes tensile at a radius of about 15.5 m whereas the Case 1 value at that radius is still compressive and relatively large.

The Case 3 results have been chosen in the present analysis as representative thermal stresses to estimate the total stress field around the emplacement boreholes.

By appropriate summation of excavation and thermal stresses, the peak stress at the borehole wall can be estimated. Using the EXCAV2 stress predictions and the Case 3 thermal stresses, the largest thermomechanical stresses are found to be 157 MPa for horizontal emplacement and 259 MPa for vertical emplacement. Since the radial stresses are zero at the borehole wall, the tangential stress level (i.e., the peak thermomechanical stresses given above) can be compared to the compressive strength for assessing rock failure at the borehole wall. Upon setting $\sigma_3 = 0$, the Hoek-Brown Criterion becomes:

$$\sigma_1 = \sqrt{s}\,\sigma_c$$

As in the BDYELM analysis, let $\sigma_c = 290$ MPa and $s = 0.0375$. This results in the right-hand side value of 56.2 MPa. The σ_1 values of 157 MPa and 259 MPa then yield "factor-of-safety" values of 0.36 for horizontal emplacement and 0.22 for vertical emplacement. In either case, the rock is predicted to fail indicating severe borehole stability problems. Without the thermal load, the excavation stress of 74 MPa for the more stable horizontal case is still well in excess of the 56.2 MPa value of critical stress.

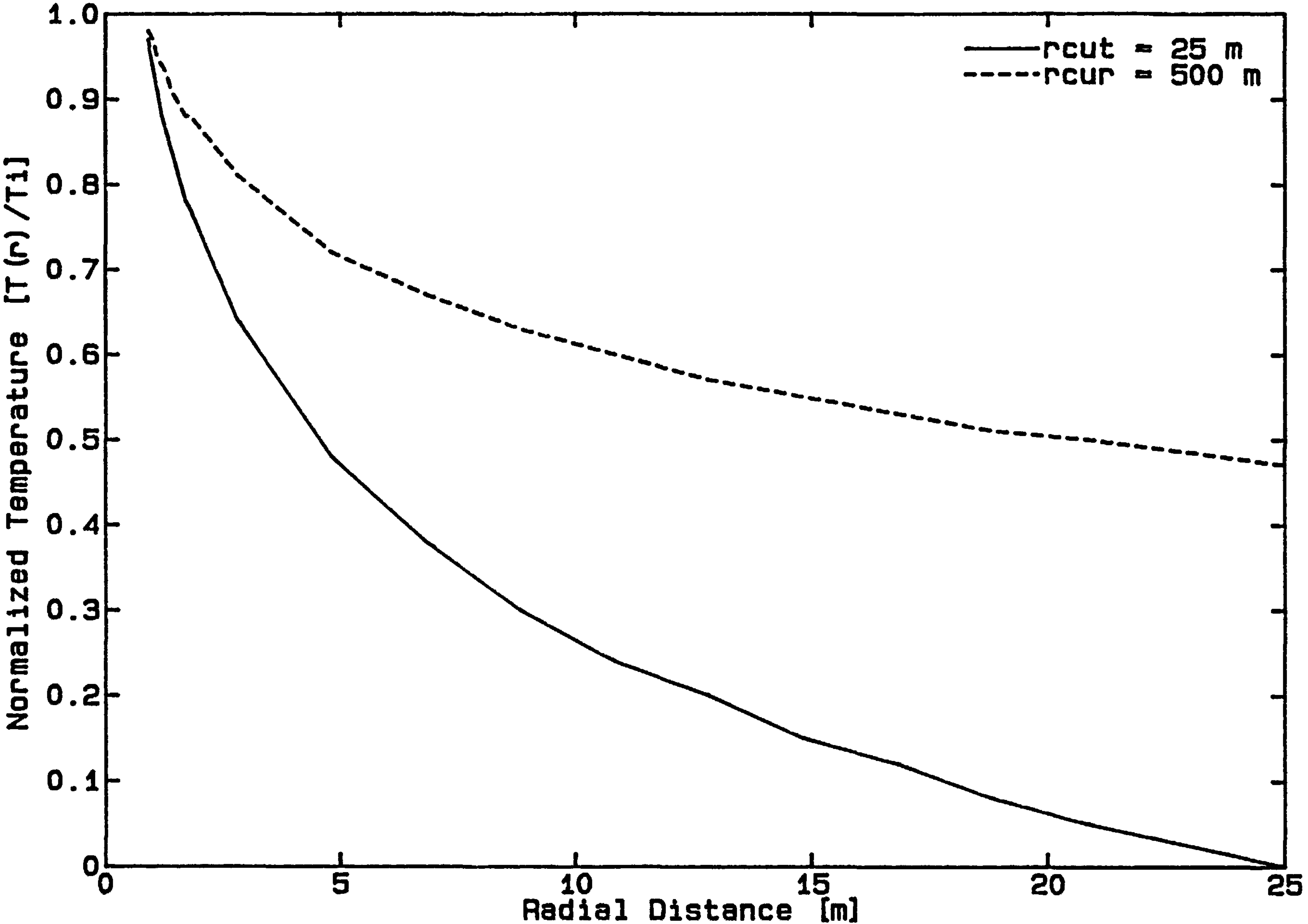

Figure 1. Temperature Profile in a Hollow Cylinder

Table 1

Thermal Stress Calc. with THERST, rdin = 0.813

```
          alpha        young      theta     anu      rdin      rdout
        4.000E-06    7.560E+10   200.00    .270     .8130   500.0000

                     k      n       ra        rb        rc
                     2      20     .7130     .1000     .0000

k    i      r        sigr          sigth          sigz           sigzl
2    1     .81     1.092E+00    -7.640E+07    -8.111E+07    -7.640E+07
2    2     .91    -7.829E+06    -6.707E+07    -7.961E+07    -7.490E+07
2    3    1.01    -1.332E+07    -6.024E+07    -7.827E+07    -7.356E+07
2    4    1.11    -1.730E+07    -5.505E+07    -7.706E+07    -7.235E+07
2    5    1.21    -2.023E+07    -5.100E+07    -7.595E+07    -7.124E+07
2    6    1.31    -2.245E+07    -4.776E+07    -7.492E+07    -7.021E+07
2    7    1.41    -2.415E+07    -4.512E+07    -7.398E+07    -6.927E+07
2    8    1.51    -2.546E+07    -4.293E+07    -7.309E+07    -6.839E+07
2    9    1.61    -2.648E+07    -4.108E+07    -7.227E+07    -6.756E+07
2   10    1.71    -2.729E+07    -3.950E+07    -7.149E+07    -6.678E+07
2   11    1.81    -2.792E+07    -3.813E+07    -7.076E+07    -6.605E+07
2   12    1.91    -2.842E+07    -3.694E+07    -7.007E+07    -6.536E+07
2   13    2.01    -2.882E+07    -3.588E+07    -6.941E+07    -6.470E+07
2   14    2.11    -2.913E+07    -3.495E+07    -6.878E+07    -6.408E+07
2   15    2.21    -2.937E+07    -3.411E+07    -6.819E+07    -6.348E+07
2   16    2.31    -2.956E+07    -3.335E+07    -6.762E+07    -6.291E+07
2   17    2.41    -2.970E+07    -3.266E+07    -6.707E+07    -6.236E+07
2   18    2.51    -2.981E+07    -3.203E+07    -6.655E+07    -6.184E+07
2   19    2.61    -2.988E+07    -3.145E+07    -6.604E+07    -6.134E+07
2   20    2.71    -2.993E+07    -3.092E+07    -6.556E+07    -6.085E+07
```

Table 2

Thermal Stress Calc. with THCYLB1, rdin = 0.813, rcut = 500.

```
       alpha        young       theta      anu       rdin    rdout
     4.000E-06    7.560E+10    200.00     .270      .8130  500.0000

                   n        ra        rb        rc      rcut
                  20      .7130     .1000     .0000  500.0000

  i      r         sigr          sigth          sigz          sigzl
  1     .81      .000E+00     -7.640E+07    -8.111E+07    -7.640E+07
  2     .91    -7.829E+06     -6.707E+07    -7.961E+07    -7.490E+07
  3    1.01    -1.332E+07     -6.024E+07    -7.827E+07    -7.356E+07
  4    1.11    -1.730E+07     -5.505E+07    -7.706E+07    -7.235E+07
  5    1.21    -2.023E+07     -5.100E+07    -7.595E+07    -7.124E+07
  6    1.31    -2.245E+07     -4.776E+07    -7.492E+07    -7.021E+07
  7    1.41    -2.415E+07     -4.512E+07    -7.398E+07    -6.927E+07
  8    1.51    -2.546E+07     -4.293E+07    -7.309E+07    -6.839E+07
  9    1.61    -2.648E+07     -4.108E+07    -7.227E+07    -6.756E+07
 10    1.71    -2.729E+07     -3.950E+07    -7.149E+07    -6.678E+07
 11    1.81    -2.792E+07     -3.813E+07    -7.076E+07    -6.605E+07
 12    1.91    -2.842E+07     -3.694E+07    -7.007E+07    -6.536E+07
 13    2.01    -2.882E+07     -3.588E+07    -6.941E+07    -6.470E+07
 14    2.11    -2.913E+07     -3.495E+07    -6.878E+07    -6.408E+07
 15    2.21    -2.937E+07     -3.411E+07    -6.819E+07    -6.348E+07
 16    2.31    -2.956E+07     -3.335E+07    -6.762E+07    -6.291E+07
 17    2.41    -2.970E+07     -3.266E+07    -6.707E+07    -6.236E+07
 18    2.51    -2.981E+07     -3.203E+07    -6.655E+07    -6.184E+07
 19    2.61    -2.988E+07     -3.145E+07    -6.604E+07    -6.134E+07
 20    2.71    -2.993E+07     -3.092E+07    -6.556E+07    -6.085E+07
```

Table 3

Thermal Stress Calc. with THCYLB1, rdin = 0.813, rcut = 25.

alpha	young	theta	anu	rdin	rdout
4.000E-06	7.560E+10	200.00	.270	.8130	500.0000

n	ra	rb	rc	rcut
20	.7130	.1000	.0000	25.0000

i	r	sigr	sigth	sigz	sigzl
1	.81	.000E+00	-8.282E+07	-8.284E+07	-8.282E+07
2	.91	-8.424E+06	-7.159E+07	-8.004E+07	-8.001E+07
3	1.01	-1.423E+07	-6.327E+07	-7.752E+07	-7.750E+07
4	1.11	-1.834E+07	-5.689E+07	-7.525E+07	-7.522E+07
5	1.21	-2.130E+07	-5.184E+07	-7.317E+07	-7.314E+07
6	1.31	-2.347E+07	-4.776E+07	-7.125E+07	-7.123E+07
7	1.41	-2.506E+07	-4.439E+07	-6.947E+07	-6.945E+07
8	1.51	-2.624E+07	-4.156E+07	-6.782E+07	-6.780E+07
9	1.61	-2.712E+07	-3.914E+07	-6.627E+07	-6.625E+07
10	1.71	-2.775E+07	-3.704E+07	-6.482E+07	-6.480E+07
11	1.81	-2.822E+07	-3.521E+07	-6.345E+07	-6.342E+07
12	1.91	-2.854E+07	-3.359E+07	-6.215E+07	-6.213E+07
13	2.01	-2.875E+07	-3.214E+07	-6.092E+07	-6.089E+07
14	2.11	-2.888E+07	-3.084E+07	-5.974E+07	-5.972E+07
15	2.21	-2.894E+07	-2.966E+07	-5.862E+07	-5.860E+07
16	2.31	-2.895E+07	-2.858E+07	-5.756E+07	-5.753E+07
17	2.41	-2.891E+07	-2.760E+07	-5.653E+07	-5.651E+07
18	2.51	-2.884E+07	-2.669E+07	-5.555E+07	-5.553E+07
19	2.61	-2.874E+07	-2.584E+07	-5.461E+07	-5.458E+07
20	2.71	-2.862E+07	-2.505E+07	-5.370E+07	-5.368E+07

Table 4

Thermal Stress Calc. with THERST, rdin = 0.813

alpha	young	theta	anu	rdin	rdout
4.000E-06	7.560E+10	200.00	.270	.8130	500.0000

k	n	ra	rb	rc
2	12	1.0000	2.0000	.0000

k	i	r	sigr	sigth	sigz	sigzl
2	1	3.00	-2.996E+07	-2.959E+07	-6.426E+07	-5.955E+07
2	2	5.00	-2.861E+07	-2.435E+07	-5.767E+07	-5.296E+07
2	3	7.00	-2.698E+07	-2.164E+07	-5.333E+07	-4.862E+07
2	4	9.00	-2.558E+07	-1.980E+07	-5.009E+07	-4.538E+07
2	5	11.00	-2.439E+07	-1.840E+07	-4.750E+07	-4.279E+07
2	6	13.00	-2.338E+07	-1.725E+07	-4.534E+07	-4.064E+07
2	7	15.00	-2.250E+07	-1.629E+07	-4.350E+07	-3.879E+07
2	8	17.00	-2.172E+07	-1.546E+07	-4.188E+07	-3.717E+07
2	9	19.00	-2.102E+07	-1.472E+07	-4.045E+07	-3.574E+07
2	10	21.00	-2.039E+07	-1.406E+07	-3.916E+07	-3.445E+07
2	11	23.00	-1.981E+07	-1.346E+07	-3.798E+07	-3.327E+07
2	12	25.00	-1.928E+07	-1.292E+07	-3.691E+07	-3.220E+07

Table 5

Thermal Stress Calc. with THCYLB1, rdin = 0.813, rcut = 25.

alpha	young	theta	anu	rdin	rdout
4.000E-06	7.560E+10	200.00	.270	.8130	500.0000

n	ra	rb	rc	rcut
12	1.0000	2.0000	.0000	25.0000

i	r	sigr	sigth	sigz	sigzl
1	3.00	-2.818E+07	-2.306E+07	-5.127E+07	-5.124E+07
2	5.00	-2.424E+07	-1.465E+07	-3.891E+07	-3.889E+07
3	7.00	-2.078E+07	-9.972E+06	-3.078E+07	-3.075E+07
4	9.00	-1.800E+07	-6.680E+06	-2.470E+07	-2.468E+07
5	11.00	-1.570E+07	-4.125E+06	-1.985E+07	-1.982E+07
6	13.00	-1.375E+07	-2.032E+06	-1.581E+07	-1.578E+07
7	15.00	-1.207E+07	-2.553E+05	-1.235E+07	-1.232E+07
8	17.00	-1.059E+07	1.289E+06	-9.318E+06	-9.297E+06
9	19.00	-9.262E+06	2.656E+06	-6.629E+06	-6.607E+06
10	21.00	-8.068E+06	3.881E+06	-4.208E+06	-4.186E+06
11	23.00	-6.980E+06	4.993E+06	-2.008E+06	-1.986E+06
12	25.00	-5.981E+06	6.011E+06	8.094E+03	2.998E+04

A-1755
1628.010
SEPTEMBER 1986

THIS IS AN ESTIMATE ONLY AND MAY NOT MATCH THE INVOICES SENT TO NRC BY SANDIA'S ACCOUNTING DEPARTMENT.

		Current Month	Year -to- Date
I.	Direct Manpower (man-months of charged effort)	0.2	7.9
II.	Direct Loaded Labor Costs	1.0	80.0
	Materials and Services	0.0	0.0
	ADP Support (computer)	0.0	7.0
	Subcontracts	3.0	137.0
	Travel	0.0	1.0
	Other (computer roundoff)	0.0	1.0
	TOTAL COSTS	4.0	226.0

III. Funding Status

Prior FY Carryover	FY 86 Projected Funding Level	FY 86 Funds Received to Date	FY 86 Funding Balance Needed
31K	226K	195K	None

M. Still

A1755

NRC FORM 173
(1-84)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD ORDER FOR DOE WORK

ORDER NUMBER 50-87-004

DATE OCT 15 [illegible]

ISSUED TO: (DOE Office)
Albuquerque Operations Office

ISSUED BY: (NRC Office)
Office of Nuclear Material Safety and Safeguards (NMSS)

ACCOUNTING CITATION

APPROPRIATION SYMBOL 31X0200.507

B&R NUMBER 50-19-03-01

FIN NUMBER A1755-7

PERFORMING ORGANIZATION AND LOCATION
Sandia National Laboratories
Albuquerque, New Mexico 87115

[illegible]LE Coupled Thermal-Hydrological-Mechanical Assessments and Site Characterization Activities

WORK PERIOD - THIS ORDER

FIXED ☒	ESTIMATED ☐
FROM: 10/01/86	TO: 10/31/87

OBLIGATION AVAILABILITY PROVIDED BY:

A. THIS ORDER	$ 40,000
B. TOTAL OF ORDERS PLACED PRIOR TO THIS DATE WITH THE PERFORMING ORGANIZATION UNDER THE SAME "APPROPRIATION SYMBOL" AND THE FIRST FOUR DIGITS OF THE "B&R NUMBER" CITED ABOVE	$ 70,000
C. TOTAL ORDERS TO DATE (TOTAL A & B)	$ 110,000
D. AMOUNT INCLUDED IN "C" APPLICABLE TO THE "FIN NUMBER" CITED IN THIS ORDER.	$ 40,000

FINANCIAL FLEXIBILITY:

XX FUNDS WILL NOT BE REPROGRAMMED BETWEEN FINS. LINE D CONSTITUTES A LIMITATION ON OBLIGATIONS AUTHORIZED
☐ FUNDS MAY BE REPROGRAMMED NOT TO EXCEED ±10% OF FIN LEVEL UP TO $50K. LINE C CONSTITUTES A LIMITATION ON OBLIGATIONS AUTHORIZED.

ST[illegible]RD TERMS AND CONDITIONS (see NRC Manual Chapter 1102, Appendix Part 4) ARE PART OF THIS ORDER UNLESS OTHERWISE NOTED

ATTACHMENTS:
THE FOLLOWING ATTACHMENTS ARE HEREBY MADE A PART OF THIS ORDER:
☐ STATEMENT OF WORK
☐ ADDITIONAL TERMS AND CONDITIONS
☐ OTHER

☐ FEE RECOVERABLE WORK
☒ NON-FEE RECOVERABLE WORK

SECURITY:
☐ WORK ON THIS ORDER INVOLVES CLASSIFIED INFORMATION. NRC FORM 187 IS ATTACHED
☐ WORK ON THIS ORDER INVOLVES UNCLASSIFIED SAFEGUARDS, PROPRIETARY, OR OTHER SENSITIVE INFORMATION
☒ WORK ON THIS ORDER IS UNCLASSIFIED AND NOT SENSITIVE

REMARKS *(Reference the proposal by number and date, and indicate if the attached statement of work modifies the DOE proposal)*

Reference SOEW 50-86-142 dated 9/30/86.

This order provides partial FY87 for continuation of this project for work as delineated in the current Statement of Work and NRC Form 189 dated 2/11/86. Additional funding will be provided upon receipt of our full FY87 appropriation.

CERTIFICATION OF AVAILABILITY OF FUNDS
(10)
40 10 01-05 $40,000.00
A1755
#003
10/17/86 John J. Johnson

ISSUING AUTHORITY

SIGNATURE
John D. Evans, Director

TITLE
Planning and Program Analysis Staff, NMSS

ACCEPTING ORGANIZATION

SIGNATURE

TITLE
Director,
Energy Technologies Division

DATE OCT 22 1986

NRC FORM 173 (1-84)