

SCIENTIFIC NOTEBOOK

By

Andrew J. Grohmann

Southwest Research Institute
Center for Nuclear Waste Regulatory Analyses
San Antonio, TX

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Scientific Notebook No. 472E: Heat
Conduction in the Waste Package
(06/14/2001 through 08/16/2001)

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INITIAL ENTRIES

Scientific Notebook: #472E

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This computerized electronic notebook is intended to address the criteria of CNWRA QAP-001.

Heat Conduction in the Waste Package

Account Number: 20.01402.671
Description: RDTME
Collaborators: Worked under Dr. Doug Gute

Objective:

Determine the temperature distribution in the waste package.

6.13.01 Performed calculations to determine the effective thermal conductivity of the waste package inside the inner barrier. These calculations can be found in the Microsoft Word document *Conductivity.doc* found on the CD of this electronic scientific notebook. I also calculated the heat generated per unit volume in the waste package based on the DOE values for thermal output of the waste package.

WASTE PACKAGE THERMAL OUTPUT

Maximum thermal output of 11.8 kW per waste package (Yucca Mountain Science and Engineering Report DOE/RW-0539, p 2-6, 2-21, 2-24)

2 m (6.6 ft) spacing between waste packages = 1 kW/m drift thermal load at emplacement (Example Scenario 1: Increased Waste Package Spacing and Extended Ventilation, *Yucca Mountain Science and Engineering Report DOE/RW-0539*, p 2-25)

$$Q = 7.165 \text{ kW per waste package}$$

All waste packages would be placed approximately end-to-end within the drift to create a 1 kW/m linear thermal load at emplacement. (Example Scenario 2: De-Rated or Smaller Waste Packages, *Yucca Mountain Science and Engineering Report DOE/RW-0539*, p 2-25)

$$Q = 5.165 \text{ kW per waste package}$$

6 m (20 ft) average spacing between waste packages = 0.7 kW/m drift thermal load at emplacement (Example Scenario 3: Increased Spacing and Duration of Forced Ventilation, *Yucca Mountain Science and Engineering Report DOE/RW-0539*, p 2-27)

$$Q = 7.8155 \text{ kW per waste package}$$

2 m (6.6 ft) spacing between waste packages = 0.5 kW/m drift thermal load at emplacement (Example Scenario 4: Extended Surface Aging with Forced Ventilation, *Yucca Mountain Science and Engineering Report DOE/RW-0539*, p 2-27)

$$Q = 3.5825 \text{ kW per waste package}$$

6.14.01 Dr. Doug Gute asked me to help derive the temperature profile of the waste package. Using *Principles of Heat Transfer* by Kreith and Bohn, Harper & Row Publishers, New York, the governing differential equation for the temperature distribution in a cylindrical object was adapted for this problem. Assuming conduction only (i.e. no convection), the temperature distribution in the waste package was derived. This derivation can be found in the Mathcad 2000 file *Heat Conduction.mcd* on the CD of this electronic scientific notebook. An interesting note is that assuming steady state conditions, the temperature inside the waste package will always be higher than the temperature at its exterior surface.

6.15.01 Proved that the temperature distribution equation in Timoshenko and Goodier was not the same as the temperature distribution equation in Kreith and Bohn. It was decided by Doug and myself to use the equation from Kreith and Bohn after further discussion. For more information see the Mathcad 2000 file *Proof of Incorrect Temperature Distribution.mcd* found on the CD of this electronic scientific notebook.

6.25.01 Researched the von Mises failure criterion to determine the proper equation to use for approximating the amount of distortion energy needed to reach the equivalent yield energy in uniaxial tension. See the Microsoft Word document *von Mises.doc* found on the CD of this electronic scientific notebook. Also researched all the values for various properties of the materials in the waste package. These values can be found in the Microsoft Word document *Reference Documentation.doc* found on the CD of this electronic scientific notebook.

7.15.01 Doug has been asking me to do some differential thermal expansion calculations for the waste package while I have been running backups off of Manitou. These preliminary calculations turned into a summer project that involved creating a program that would approximate the stresses due to differential thermal expansion in the waste package. After doing preliminary calculations assuming plane stress and plane strain, Doug and I decided the best way to set up our problem was to model the waste package expansion as a constant axial stress problem. This stress would be created when the inner barrier expands into the outer barrier in the axial direction. The complete derivation of the problem can be found in the Mathcad 2000 file *Dtherm Documentation.mcd* on the CD of this electronic scientific notebook.

8.4.01

DTHERM v. 1.0

Account number: 20-1402-671

Description: Dtherm v. 1.0

Collaborators: Worked under Dr. Doug Gute

Objective:

Derive a closed-form method for approximating the stresses in the waste package due to differential thermal expansion. After deriving this solution, a program was written in Mathcad 2000 that will calculate the stresses in the waste package.

8.05.01 Decided the best way to set up the program would be 3 different Mathcad 2000 worksheets. One worksheet will calculate the stresses for a given radial and axial gap between the inner and outer barrier of the waste package. The second worksheet will calculate the maximum von Mises stresses for a range of axial and radial gaps and then output these values to a file that can be read into Mathcad for 3-D plots of the Maximum von Mises stress as functions of radial and axial gap. The third Mathcad 2000 worksheet will take this data file and create the 3-D plots.

8.12.01 I will now explain the subscripts that are in the Dtherm program. The first subscript of a variable signifies what the variable is. (i.e. In σ_r the r denotes radial stress.) The second subscript denotes on which barrier it applies. (i.e. In σ_i the i denotes inner barrier.) The third subscript denotes which case the variable is for. (i.e. In $\sigma_{\theta o4}$ the θ denotes hoop stress, the o denotes outer barrier and the 4 denotes case 4.) Note: In some cases the first subscript will denote inner or outer barrier, this is because some variables are descriptive enough already. (i.e. ν_i denotes Poisson's ratio for the inner barrier.)

8.16.01 The final program is a Mathcad 2000 workbook that can be found in the *Dtherm* folder on the CD of this electronic scientific notebook. The documentation for the program is also included in the files *Dtherm Documentation.doc* and *Dtherm Documentation.mcd*. Both files can be found on the CD of this electronic scientific notebook. The software is called Dtherm v. 1.0 and is under SCR 352.