APPENDIX D: HEATING 7.2 DESCRIPTION

HEATING is a multidimensional, general-purpose heat transfer code written in FORTRAN 77. The name HEATING is an acronym for Heat Engineering and Transfer In Nine Geometries (although with modifications there are now 12 geometries). Earlier versions of HEATING have been reported previously[1-9]. HEATING solves steady-state and/or transient problems in one-, two-, or three-dimensional Cartesian, cylindrical, or spherical coordinates. The mesh spacing may be variable along each axis. A model may include multiple materials, and the thermal conductivity, density, and specific heat of each material may be both time- and temperature-dependent. Thermal conductivity may be anisotropic. Materials may undergo up to five changes of phase for transient calculations involving either of the explicit procedures. The heat-generation rates may be dependent on time, temperature, and position. Boundary temperatures may be dependent on time and position. Boundary conditions include specified temperatures or any combination of prescribed heat flux, forced convection, natural convection, and radiation. The boundary condition parameters may be time-and/or temperature-dependent. In addition, one may model either one-dimensional radiative heat transfer directly across gaps embedded in the model, or multidirectional radiation within enclosures using externally calculated radiation exchange factors.

For steady-state problems there are three solution techniques available: a point-successive-overrelaxation iterative method with a modified Aitken δ^2 extrapolation

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1. T. B. Fowler and E. R. Volk, *Generalized Heat Conduction Code for the IBM-704 Computer*, ORNL-2734, Union Carbide Corp., Nuclear Div., Oak Ridge National Laboratory, October 1959.
2. R. R. Liguori and J. W. Stephenson, *The HEATING Program*, ASTRA 417-5.0, ASTRA, Inc., Raleigh, N.C., January 1961.
3. W. D. Turner and J. S. Crowell, *Notes on HEATING - An IBM 360 Heat Conduction Program*, CTC/INF-980, Union Carbide Corp., Nuclear Div., November 1969.
4. W. D. Turner and M. Siman-Tov, *HEATING3 - An IBM 360 Heat Conduction Program*, ORNL/TM-3208, Union Carbide Corp., Nuclear Div., Oak Ridge National Laboratory, February 1971.
5. W. D. Turner, D. C. Elrod, and I. I. Siman-Tov, *HEATING5 - An IBM 360 Heat Conduction Program*, ORNL/CSD/TM-15, Union Carbide Corp., Nuclear Div. Oak Ridge National Laboratory, March 1977.
6. D. C. Elrod, G. E. Giles, and W. D. Turner, *HEATING6: A Multidimensional Heat Conduction Analysis with the Finite-Difference Formulation*, ORNL/NUREG/CSD-2/V2, Union Carbide Corp., Nuclear Div., Oak Ridge National Laboratory, October 1981.
7. K. W. Childs, G. E. Giles, C. B. Bryan, and C. K. Cobb, *HEATING: A Computer Program for Multidimensional Heat Transfer Analysis (Version 6.1)*, ORNL/NUREG/CSD-2/V2/R3, Martin Marietta Energy Systems, Oak Ridge National Laboratory, to be published.
8. K. W. Childs, *HEATING 7.0 User's Manual*, K/CSD/INF/90-32, Martin Marietta Energy Systems, Inc., Oak Ridge Gaseous Diffusion Plant, July 1990.
9. K. W. Childs, *HEATING 7.1 User's Manual*, K/CSD/TM-96, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, July 1991.

process, a direct-solution method for one- and two-dimensional problems, and a conjugate gradient method. Several numerical schemes are available in HEATING to solve transient heat-conduction problems. In the implicit technique, which can range from Crank-Nicolson to the Classical Implicit Procedure, the system of equations is solved by point-successive-overrelaxation iteration. The technique includes procedures to estimate the optimum acceleration parameters for both the case where the coefficient matrix remains unchanged during the calculations and the case where it varies during the solution because of dependence on time, temperature, or time-step size. The time-step size for the implicit transient calculations may be controlled so that either the maximum temperature change or the maximum relative temperature change over a time step does not exceed specified values. The time-step size may also be controlled by specifying an initial time step, a multiplication factor to be multiplied by the time-step size after each time level, a maximum allowable time-step size, and/or the time period for which it applies. Transient problems may also be solved either by the Classical Explicit Procedure, whose time step is stability-limited, or with the Levy explicit method, which allows a larger time step for some cases.

HEATING does not have to be recompiled with each execution since computer memory allocation is handled at execution time. Any array whose size is a function of the input data is variably dimensioned. These array dimensions are determined from the model information in the input data file.

HEATING uses free-form reading subroutines[10] to interpret the input data file which is subdivided into data blocks identified by keywords. HEATING reads the input data file until a keyword specifying a steady-state or transient solution is encountered or until an end-of-case indicator is encountered. The input data are checked for errors and inconsistencies, and messages identifying any problems are written. Some data errors cause processing to be terminated immediately. However, most errors will allow the processing of input data to be completed, but will not allow the case to be executed. If no input data errors are encountered, HEATING will proceed with the specified calculations for the case.

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10. L. M. Petrie and N. F. Cross, *KENO IV - An Improved Monte Carlo Criticality Program*, ORNL-4938, Union Carbide Corp., Nuclear Div., Oak Ridge National Laboratory, November 1975.