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Conversion and Availiblity of HEATING5 -- A Heat Conduction Program

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Introduction

The computer code HEATING5 has recently been converted to and is availible for use on the Fermilab CDC Cyber 175 Computer System. HEATING5 is the latest edition of "The HEATING Program" where HEATING is an acronym for Heat Engineering and Transfer in Nine Geometries. HEATING was originally developed by Liguori and Stephenson (Ref. 1) from Fowler and Volk's generalized heat conduction code GHT (Ref. 2). HEATING5, written by Turner, Elrod and I. Siman-Tov (Ref. 3), is a modified version of Turner and M. Siman-Tov's HEATING3 (Ref. 4).

Program Description

HEATING5 is designed to solve steady-state and/or transient heat conduction problems in one-, two-, or three-dimensional Cartesial or cylindrical coordinates or one-dimensional spherical coordinates. The thermal conductivity, density, and specific heat may be both spatially and temperature-dependent. The thermal conductivity rates may be dependent on time, temperature and position, and boundary temperatures may be time-dependent. The boundary conditions, which may be surface-to-boundary or surface-to-surface, may be fixed 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. The mesh spacing can be variable along each axis. The code is designed to allow the following maxima :

- 100 regions
- 50 materials
- 50 boundary conditions
- 100 fine lattice lines along any axis
- 50 gross lattice lines along any axis
- 20 heat generation functions
- 25 initial temperature functions
- 25 analytical functions
- 5 materials with change-of-phase capabilities
- 20 nodes in special temperature table
- 25 tabular functions
- 25 points per tabular function
- 100 printout times
- 2000 surface-to-surface connectors

The maximum number of lattice points can be easily adjusted to fit the problem and the computer storage requirements.

Dummy subroutines are included in the package for the intended user-supplied functions defining the thermal conductivity (CONDTN), density (DNSITY), specific heat (CPHEAT), initial temperature distribution (INITTP), volumetric heat generation rate (HEATGN), boundary temperature (BNDTMP), film coefficient for forced convective heat transfer (CONVTN), coefficient for radiative heat transfer (RADITN), coefficient and exponent for natural convective heat transfer (NATCON and NCONEX), and the flux across a boundary (BNFLUX).

Method of Solution

The point successive overrelaxation iterative method and a modification of the "Aitken delta**2 extrapolation process" are used by HEATING5 to solve the finite difference equations which approximate the partial differential equations for a steady-state problem.

The transient problem may be solved using any one of several finite difference schemes. These include an implicit technique which can range from Crank Nicolson to the Classical Implicit Procedure, an explicit method which is stable for a time step of any size, and the Classical Explicit Procedure which involves the first forward time difference. The solution of the system of equations arising from the implicit technique is accomplished by point successive overrelaxation iteration, and includes procedures to estimate the optimum acceleration parameter. The time step size for implicit transient calculations may be varied as a function of the maximum temperature change at a node. Transient problems involving materials with change-of-phase capabilities cannot be solved using the implicit tecnique with this version of HEATING5.

Use of HEATING5

HEATING5 resides on disk as the direct access public file HEATING in user area 93523. HEATING is an Update program library (Ref. 5 & 6) and in its present form must be compiled by the FTN5 compiler (Ref. 7). Figure 1 shows a protion of an actual job which uses HEATING. The file

```
GET,HEATCS,HEATIN.
ATTACH,HEATING/UN=93523.
ATTACH,FTN5,FTN5LIB/UN=TESTLIB.
UPDATE,P=HEATING,I=HEATCS,F.
FTN5,B=HEATB,I,DO,LO=M/A/R,OPT,PN,DB=O/PMD.
HEATB,HEATIN
```

*** Figure 1. ***

HEATCS contains the Update correction set while the file HEATIN contains the input data for HEATING. It is suggested that the user should not change the FTN5 parameter DB (debug) from the value shown for the time being as there are compiler bugs (or perhaps program bugs) that may appear with different parameter settings. This problem will be taken care of as soon as possible.

Figure 2 shows a procedure which submits a job that runs HEATING. This procedure is stored on disk as the indirect access public file HEATJ1 in user area 93523 and may be used

```
.PROC,HEATJ1,HEATCS,HEATIN,JOBSTRM=#DATA.
SUBMIT,JOBSTRM,B.
REVERT.
.DATA
HEATING.
USER,*****,*******.
CHARGE,***.
GET,HEATCS,HEATIN.
ATTACH,HEATING/UN=93523.
ATTACH,FTN5,FTN5LIB/UN=TESTLIB.
UPDATE,P=HEATING,I=HEATCS,F.
FTN5,B=HEATB,I,DO,LO=M/A/R,OPT,PN,DB=O/PMD.
HEATB,HEATIN.
DAYFILE,DAY.
REPLACE,DAY.
EXIT.
DAYFILE,DAY.
REPLACE,DAY.
```

*** Figure 2. ***

for simple runs of HEATING. The files HEATCS and HEATIN are the same as in figure 1. Notice that the user, password and charge code must be filled in by the user before use.

Figure 3 shows another procedure which runs HEATING. This procedure is more general in nature and demostrates the proper order for file names when executing HEATING with auxiliary files. It too is stored on disk as an indirect access file in user area 93523 but with the file name HEATJ2. The files HEATCS and HEATIN are the same as in figure 1 and have the default names HEATCS and HEATIN respectively. HEATOUT is the output file for HEATING and has the default name OUTPUT. The files PLOTIN and PLOTOUT have default names DUMMY1 and DUMMY2 respectively and contain old and new graphical data sets if this option is selected in the HEATING input file (see the description of input card 4 in the HEATING5 operating instructions). The files TEMPIN and TEMPOUT (default names DUMMY3 and DUMMY4 respectively) contain the initial and final temperatures respectively (see card 4 again). Finally, the file STATUS with default name HEATSTA is the special problem status file for remote users (see card 4). If STATUS is set to DUMMY5 it will not be saved on disk. This file is of special aid since the output of this job is, by default, sent to the microfiche output queue.

If the user wishes to change the maximum number of lattice points to a different number (the version on disk will allow a maximum of 100) he/she must make changes to four (4) lines in subroutine HEATN5. If MAXPTS is the maximum number of lattice points then the variable N must be

HEATING5

```
.PROC,HEATJ2,HEATCS =HEATCS ,HEATIN =HEATIN ,
             HEATOUT=HEATOUT,PLOTIN =DUMMY1 ,
             PLOTOUT=DUMMY2 ,TEMPIN =DUMMY3 ,
             TEMPOUT=DUMMY4 ,STATUS =HEATSTA,
             DAY    =HEATDAY,LP     =NO/YES ,
             JOBSTRM=#DATA.
SUBMIT,JOBSTRM,B.
REVERT.
.DATA
HEATING.
USER,*****,*******.
CHARGE,***.
IFE,$_LP_$.EQ.$NO$,FICHE.
ROUTE,OUTPUT,DC=PR,FC=AF,TID=C,DEF.
ENDIF,FICHE.
GET,HEATCS,HEATIN.
IFE,$_PLOTIN_$.NE.$DUMMY1$,ASSIGN1.
GET,PLOTIN.
ENDIF,ASSIGN1.
IFE,$_TEMPIN_$.NE.$DUMMY3$,ASSIGN2.
GET,TEMPIN.
ENDIF,ASSIGN2.
ATTACH,HEATING/UN=93523.
ATTACH,FTN5,FTN5LIB/UN=TESTLIB.
UPDATE,P=HEATING,I=HEATCS,F.
FTN5,B=HEATB,I,DO,LO=M/A/R,OPT,PN,DB=0/PMD.
NOEXIT.
HEATB,HEATIN,HEATOUT,PLOTIN,PLOTOUT,TEMPIN,TEMPOUT,STATUS.
IFE,$_HEATOUT_$.NE.$OUTPUT$,SAVE1.
REPLACE,HEATOUT.
ENDIF,SAVE1.
IFE,$_PLOTOUT_$.NE.$DUMMY2$,SAVE2.
REPLACE,PLOTOUT.
ENDIF,SAVE2.
IFE,$_TEMPOUT_$.NE.$DUMMY4$,SAVE3.
REPLACE,TEMPOUT.
ENDIF,SAVE3.
IFE,$_STATUS_$.NE.$DUMMY5$,SAVE4.
REPLACE,STATUS.
ENDIF,SAVE4.
DAYFILE,DAY.
REPLACE,DAY.
EXIT.
DAYFILE,DAY.
REPLACE,DAY.
```

*** Figure 3. ***

initialized to equal MAXPTS. Also, the dimensions of arrays CORE, ICORE, LCORE must be 56*MAXPTS.

As few changes have been made in the input specifications as possible. The maximum CPU time specified on input card number two (2) is the time in the CYBER CPU the program is running in. No allowance is made for which CYBER the program is running in. (Remember, main frame D is about 15% faster than main frames E and F.) Only the absolute value of the input/output unit numbers input on card four (4) are important. The actual unit numbers are transparent to the user.

Future of HEATING5

In addition to HEATING5, three other programs have been recieved from the National Energy Software Center. The first of these programs, REGPLOT (Ref. 8), is a graphics program which generates maps of the regions with labels for materials, the heat generation function numbers, the initial condition function numbers, and the boundary condition function numbers specified by the input data to permit the user to visually check the HEATING5 input data. The second and third programs are two versions of the same concept, HEATPLOT (Ref. 9). They are both temperature distribution plotting programs which may be used with a plotting data set produced by HEATING5 to plot temperature contours (isotherms), temperature-time profiles, and temperature-distance profiles from a temperature distribution or from temperature changes relative to an initial temperature distribution. These programs are in the proccess of being converted for use on the Cybers.

As changes or additions are made to HEATING5 and/or related programs entries will be made in the indirect access public file HEATNWS in user area 93523. If problems or questions arise the Cyber mail facility (Ref. 10) may be used to submit these. Mail should be sent to user 93523. Copies of references 3, 8, and 9 and example runs are availible from the author on request.

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