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GENGTC, A ONE-DIMENSIONAL CEIR COMPUTER PROGRAM FOR CAPSULE
TEMPERATURE CALCULATIONS IN CYLINDRICAL GEOMETRY

Hall C. Roland

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Contract No. W-7405-eng-26

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TEMPERATURE CALCULATIONS IN CYLINDRICAL GEOMETRY

Hall C. Roland

DECEMBER 1967

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
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U.S. ATOMIC ENERGY COMMISSION

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GENGTC, A ONE-DIMENSIONAL CEIR COMPUTER PROGRAM FOR CAPSULE
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ABSTRACT

An analysis has been made and a generalized computer program in BASIC language is presented for one dimensional radial heat transfer calculations in cylindrical geometry. Provision is made for fission heat, gamma heat, multiple solid radiation shields, liquid filled annuli and gas filled annuli. Radiation heat transfer across gas filled annuli is included. Correction is made for variation of thermal conductivities with temperature and for changes in dimensions due to thermal expansion.

INTRODUCTION

In the design of capsule fuel element irradiation experiments it is necessary to perform many heat transfer calculations. The configuration is usually that of a solid or hollow fuel cylinder surrounded by cladding, radiation shields, and secondary and primary containments. The annuli between concentric solid cylinders contain either liquids or gases. The problem is considerably complicated by the fact that gamma heat in the solid elements, variation of thermal conductivity with temperature, radiation heat transfer, and change of dimensions due to thermal expansion must be considered. The solution thus becomes one of trial and error or of repeated iteration and is ideally handled by high speed computers.

Direct access to such a computer is now available at ORNL through the CEIR service. Accordingly a generalized analysis of such problems was made and the result programmed for execution using the CEIR service. The program, written in BASIC language and entitled GENGTC (for Generalized Gap Temperature Calculator), is saved at the computer for ready use.

ANALYSIS

The general configuration for which the analysis is made is shown in Fig. 1. The points for temperature evaluation (henceforth referred to as nodes) are numbered along with their corresponding subscripted radii. Due to the handling of thermal expansion the configuration required is alternating solid and liquid or gas annuli starting with the fuel as a solid. Further comment on this is made in connection with the treatment of thermal expansion and in the section "Suggestions for Specific Program Adaptations", page 10. The program provides for a minimum node range of 0 (single solid or hollow element) and a maximum node range of 20 (a central solid element surrounded by 10 solid annuli).

The required input information for the program includes:

1. The maximum node for the given problem.
2. Outside surface heat transfer coefficient for the capsule.
3. Linear fission heat rate for the innermost solid element.
4. Ambient coolant temperature (or saturation temperature for water if there is boiling at the surface).
5. A number to specify the type of heat transfer calculation at the capsule surface.
6. Inside radius of fuel cylinder.
7. Radii of the nodes.
8. Radiation emissivities at each surface.
9. A number for each node to designate whether the material just inside that node is solid, liquid or gas.
10. Gamma heat rate for material immediately inside each node.
11. A number for each node to select material properties from available table. Number applies to material just inside the node.
12. Material properties for materials used which are not in the available table.

The outside surface temperature (maximum nodal point) is calculated following the calculation of the total heat load passing through the area at each nodal point for a capsule of 1 ft length. The general equation for the surface temperature is:*

*Notation is given in Nomenclature.

Fig. 1. General Configuration for Gap Temperature Calculation Analysis.

$$T_s = T_\infty + \frac{Q}{hA} \quad (1)$$

The surface coefficient h is either input or calculated for natural convection or boiling in water. (See "Data Input" for details.)

The general conduction heat transfer equation in cylindrical coordinates, with uniform internal heat generation and known inside surface heat load, was solved to get the following equation for the inside surface temperature of solid or liquid annuli:

$$T_i = T_o + \frac{G(r_o^2 - r_i^2)}{4k} + \frac{Qr_i}{A_i k} - \frac{Gr_i^2}{2k} \log_e \frac{r_o}{r_i} \quad (2)$$

The thermal conductivity k is calculated based on the arithmetic mean temperature of the annulus. The following polynomial form is used:

$$k = C_0 + C_1 \bar{T} + C_2 \bar{T}^2 + C_3 \bar{T}^3 + C_4 \bar{T}^4 \quad (3)$$

Conductivity is based on the temperature T_o for the first estimate of T_i , correction of k is made and then T_i is recalculated. This iteration is repeated 5 times.

For gas filled annuli both radiation and conduction modes of heat transfer are included. The calculation is performed using the following procedure:

1. Set inside temperature equal to the outside temperature.
2. Evaluate the radiation shape factor.
3. Set temperature increment at $+35^\circ\text{F}$.
4. Increment the inside temperature and evaluate conductivity based on mean temperature.
5. Calculate the conductive heat transfer rate.
6. Calculate the radiative heat transfer rate.
7. If conduction rate plus radiation is less than the actual heat load and the increment was $+35^\circ\text{F}$ return to Step 4. If conduction rate plus

radiation rate is greater than the actual heat load and increment was +35° change increment to -5° and return to Step 4. If conduction rate plus radiation rate is greater than the actual heat load and the increment was -5° return to Step 4. If conduction rate plus radiation rate is less than the actual heat load and the increment was -5° the solution is considered complete and the next annulus is considered.

In Step 2 the shape factor is evaluated from:

$$F_{i/o} = \frac{1}{1/e_i + (r_i/r_o) [(1/e_o) - 1]} \quad (4)$$

In Step 5 the conductive heat transfer rate is evaluated from:

$$Q_k = \frac{kA_i(T_i - T_o)}{r_i \log_e(r_o/r_i)} \quad (5)$$

In Step 6 the radiative heat transfer rate is evaluated from:

$$Q_r = 0.174 F_{i/o} A_i [(T_i/100)^4 - (T_o/100)^4] \quad (6)$$

The calculation thus proceeds from the outside surface inward until all node temperatures are evaluated.

After the node temperatures are calculated using the input radii these radii are corrected for thermal expansion and the temperatures recalculated. The thermal expansion coefficient of each material is first calculated from:

$$\alpha = \beta_1 + \beta_2 T_m \quad (7)$$

Note that α is the average expansion coefficient from 70°F to T_m .

The temperature used is the arithmetic mean temperature. The new radii for the solid annuli are then calculated from:

$$r' = r + \frac{1}{3} \{r_{70}[1+\alpha(T_m-70)] - r\} \quad (8)$$

This method of allowing only 1/3 the indicated expansion at each iteration was found to be necessary to prevent an unstable oscillation or very slow convergence in the solution in some cases. The iterative correction for thermal expansion is repeated 8 times, test cases having indicated that this number of iterations is sufficient. In cases where Eq. 8 produces radii with less than .0005" clearance the expansion limit of the inner radius is arbitrarily set as .0005" less than the next outer radius as this has been found a reasonable approximation to account for contact resistance.

SPECIFIC FORM FOR DATA INPUT

After the program has been recalled from memory in the CEIR system new data are input by typing (or preferably reading from prepared tape) new DATA statements. These DATA statements are numbered 100 through 125 and then start again at 600. Normally the user will make changes starting at 600 as numbers 100 through 125 are the density, conductivity coefficient and thermal expansion coefficient table for stored materials. The user may, however, after checking the listing of this table, enter values for new materials into the table or change existing values. Do not change the 100 DATA statement. It must remain as is for dummy values. Any other statement in the table which contains dummy zero values may be replaced by working values as the user desires. As an example statement 120 DATA might then contain in order, and separated by commas:

120 DATA

1. Density, g/cc.
2. First thermal conductivity coefficient.
3. Second thermal conductivity coefficient.
- |
- |
6. Fifth thermal conductivity coefficient.
7. First thermal expansion coefficient.
8. Second thermal expansion coefficient.

Data statements starting with number 600 DATA contain the following data:

600 DATA

1. Maximum node number of present configuration. (Must be ≤ 20).
2. Surface heat transfer coefficient, $B/hr.ft^2.^{\circ}F$.
3. Linear fission heat rate, kw/ft .
4. Ambient coolant temperature (or water saturation temperature for boiling), $^{\circ}F$.
5. Designator number for surface heat transfer coefficient.

Note: If designator number is 0 the computer will use the value input in 2. If designator number is 1 the computer will calculate a coefficient based on pool boiling. In the latter place put in saturation temperature in 4.

6. Inside hole radius for hollow center element, in.

Note: For solid center element use 0.

601 DATA

1. Radius of node 0, in.
2. Radius of node 1, in.
- |
- |
- n. Radius of node n-1 (surface), in.

602 DATA

Continuation of 601 DATA if necessary. In the interest of standardized data numbering this statement number is to be supplied even if all radii are given in 601 DATA.

603 DATA

1. Radiant emissivity at node 0.
2. Radiant emissivity at node 1.
- |
- |
- n. Radiant emissivity at node n-1 (surface).

Note: Even though radiation heat transfer does not occur from some nodes an emissivity must be supplied for every node. It is suggested that a dummy value of 0 be used at surfaces where no radiation heat transfer occurs.

604 DATA

1. Designator number for material type immediately inside node 0.
2. Designator number for material type immediately inside node 1.

|
|
|

- n. Designator number for material type immediately inside node n-1 (surface). Note: For gases the designator number is 0. For liquids and solids the designator number is 1.

605 DATA

1. Gamma heat rate for material immediately inside node 0, watts/gram.
2. Gamma heat rate for material immediately inside node 1, watts/gram.

|
|
|

- n. Gamma heat rate for material immediately inside node n-1 (surface), watts/gram.

606 DATA

1. Selector number for material immediately inside node 0.
2. Selector number for material immediately inside node 1.

|
|
|

- n. Selector number for material immediately inside node n-1 (surface).

Note: A selector number of 0 indicates the material is not in the stored table and data will be supplied in 607 DATA --, 608 DATA --, etc., in order as such unlisted materials occur in going from node 0 outward.

Materials in the stored table as given in the program (Appendix A) are:

Selector No.	Material	Temperature Range (°F)
1	Cb-1% Zr	0-3000
2	Hastelloy-X	900-1800
3	Helium	0-5000
4	NaK-44	0-2500
5	Neon	0-3000
6	SS-304	0-1500

Selector No.	Material	Temperature Range (°F)
7	SS-316	0-1500
8	T-111	0-3000
9	UN	1500-2900
10	UO ₂	0-2500
11	U-26% Re	0-3000
12	Zr-2	0-1400
13	Argon	0-2000
14	Graphite	0-2200
15	Lithium	0-2400
16	Molybdenum	0-2200
17	Tungsten	0-2200
18	Sol-Gel	1650-3800
19	SiC	0-5000
20	Aluminum	32-932

Selector numbers 21-25 are at present available for new material data, and correspond to DATA statements 121 through 125 respectively. Data follow order given in 607 DATA statement below.

607 DATA

1. Density of first material not in stored table, g/cm³.
2. First thermal conductivity calculation coefficient for first material not in stored table.
- 3.
- 4.
- 5.
6. Fifth thermal conductivity calculation coefficient for first material not in stored table.
7. First thermal expansion calculation coefficient for first material not in stored table.
8. Second thermal expansion calculation coefficient for first material not in stored table.

608 DATA, 609 DATA, etc. follow same order for the remaining materials not in the stored table. See again Note for 606 DATA statement.

OUTPUT FORMAT

There are three columns of output in the first section headed NODE, COLD RADIUS, and MATERIAL NO.. NODE is self explanatory. COLD RADIUS is the input radius. MATERIAL NO. is the materials selector number for the material just inside the corresponding node.

There are three columns in the second section headed NODE, CALC. RADIUS, and ACT. RADIUS. CALC. RADIUS is the radius calculated from the calculated temperatures with no restraint due to surrounding cylinders. The radii under ACT. RADIUS have been adjusted for a .0005 inch clearance in cases of interference. All output radii are in inches.

There are three columns in the third section headed NODE, TEMPERATURE, F., and TEMPERATURE, C. which are self-explanatory.

There are four columns in section four headed NODE, POWER [F,G], Q/A, and CONDUCTIVITY. POWER [F,G] is the total B./hr., including fission and gamma, developed within the corresponding nodal radius, for a one foot capsule. Q/A is the surface heat load in B./hr·ft² crossing the cylindrical surface at the corresponding nodal radius. CONDUCTIVITY is the conductivity in B./hr ft. °F. of the material just inside the corresponding node as finally calculated.

Following section four the central element inside (center for a solid) temperature is output in °F. and °C.

A listing of the program, with sample output is given in Appendix B.

SUGGESTIONS FOR SPECIFIC PROGRAM ADAPTATIONS

Careful examination of the above analysis and the program itself will no doubt allow the user to adapt it to his (or her) own problem in many particulars. The following adaptations are given as examples.

1. In some cases the fuel to clad thermal resistance may be negligible. Use a very high (say $1. \times 10^8$) thermal conductivity.
2. The outside surface nodal temperature may be specified rather than the ambient temperature of the surrounding fluid. Set the ambient temperature equal to the specified surface temperature and use a very high (say $1. \times 10^8$) surface coefficient.
3. The radii are to be input at operating temperature and no thermal expansion change is desired. Set all thermal expansion coefficients equal to 0.

NOMENCLATURE

A	area, ft^2
$C_o - C_4$	coefficients for calculating thermal conductivity
e	radiant emissivity
F	shape factor for radiant heat transfer
G	volumetric heat source, $\text{B./hr}\cdot\text{ft}^3$.
h	convective heat transfer coefficient, $\text{B./hr}\cdot\text{ft}^2\cdot^\circ\text{F}$.
k	thermal conductivity, $\text{B./hr}\cdot\text{ft}\cdot^\circ\text{F}$.
T	temperature, $^\circ\text{F}$ or $^\circ\text{R}$ as required
Q	heat transfer rate, B/hr .
r	radius, ft
r'	radius corrected for thermal expansion, ft
α	thermal expansion coefficient, $\text{in./in.}/^\circ\text{F}$.
β_1, β_2	coefficients for calculating thermal expansion coefficient

Subscripts

i	inside
o	outside
m	arithmetic mean
s	surface
∞	ambient
70	evaluated at 70°F

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Appendix A

GENGTC PROGRAM

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1 REM PROGRAM NAME - GENGTC , HALL C. ROLAND , 3-7501
2 REM 08/11/67
3 REM FIRST SAVED 8/7/67
4 REM THIS PROGRAM IS UNDER WEEKLY USE.
20 LET L = 12
30 DIM R(20),T(20),V(20),D(20),P(20),M(20),G(20),C(20,4)
40 DIM E(20),A(20),U(20),S(20,1),L(20),O(20),W(20),Z(25,7)
50 DIM Q(20),Y(20),H(20)
60 MAT READ Z(25,7)
100 DATA 0,0,0,0,0,0,0,0
101 DATA 8.66,26,.005,0,0,0,4.1,2.12E-4
102 DATA 8.23,5.4,.00583,0,0,0,6.85,.00133
103 DATA 0,.083,9.1E-5,0,0,0,0,0
104 DATA .5,14.7,7.9E-5,5.25E-6,-4.62E-9,8.94E-13,0,0
105 DATA 0,.026,3.27E-5,-4.84E-9,7.82E-13,-5.36E-17,0,0
106 DATA 7.98,8.5,.00417,0,0,0,8.9,.0013
107 DATA 7.98,8.5,.00417,0,0,0,8.9,.0013
108 DATA 16.73,23.6,.00727,0,0,0,3.33,3.35E-4
109 DATA 14.3,5.581,6.515E-3,-1.389E-6,9.388E-11,0,4.1,6.E-4
110 DATA 10.96,6.1,-6.99E-3,5.173E-6,-2.E-9,3.E-13,6.46,0
111 DATA 19.7,81,-.035,1.8E-5,-3.25E-9,7.4E-14,2.83,7.1E-5
112 DATA 6.47,6.16,5.57E-3,-1.06E-5,1.63E-8,-6.64E-12,3.65,2.41E-4
113 DATA 0,7.985E-3,1.924E-5,-3.6067E-9,-2.7924E-12,1.288E-15,0,0
114 DATA 1.8,82.17,-.0422,9.26E-6,-2.49E-10,-1.37E-13,0,0
115 DATA .473,18.9,-3.247E-3,2.246E-5,-1.68E-8,3.048E-12,0,0
116 DATA 10.2,75.2,-2.027E-2,8.99E-6,-2.4E-9,2.78E-13,2.85,.000232
117 DATA 19.3,93.9,-2.998E-2,1.144E-5,-2.15E-9,1.96E-13,2.45,.000232
118 DATA 9.27028,1.1556,0,0,0,0,0,0
119 DATA 3.21,35.3,-1.72E-2,2.51E-6,3.83E-11,-2.19E-14,18.4,3.58E-3
120 DATA 2.7,116.9,3.09E-3,1.63E-5,8.13E-8,-5.96E-11,12.58,3.02E-3
121 DATA 0,0,0,0,0,0,0,0
122 DATA 0,0,0,0,0,0,0,0
123 DATA 0,0,0,0,0,0,0,0
124 DATA 0,0,0,0,0,0,0,0
125 DATA 0,0,0,0,0,0,0,0
126 READ D9,H9,F9,T9,N9,R9
127 MAT READ R(D9)
128 LET T9=T9+460
129 MAT READ E(D9)
130 MAT READ M(D9)
131 MAT READ H(D9)
132 MAT READ W(D9)
133 FOR I=0 TO D9
134 LET U(I)=R(I)
135 IF W(I)>.5 THEN 138
136 READ D(I),C(I,0),C(I,1),C(I,2),C(I,3),C(I,4),S(I,0),S(I,1)
137 GO TO 147
138 LET Z9=W(I)
139 LET D(I)=Z(Z9,0)
140 LET C(I,0)=Z(Z9,1)
141 LET C(I,1)=Z(Z9,2)
142 LET C(I,2)=Z(Z9,3)

```

```

143 LET C(I,3)=Z(Z9,4)
144 LET C(I,4)=Z(Z9,5)
145 LET S(I,0)=Z(Z9,6)
146 LET S(I,1)=Z(Z9,7)
147 NEXT I
149 LET C9 = 0
160 LET V(0)=(R(0)+2-R9+2)*L*.0018181
165 LET G(0)=H(0)*D(0)*96646
170 LET P(0) = V(0)*G(0)+F9*3413.
175 LET A(0)=.0436333*R(0)*L
177 LET Q(0)=P(0)/A(0)
178 IF D9=0 THEN 226
180 FOR I=1 TO D9
190 LET I1 = I-1
200 LET A(I)=.0436333*R(I)*L
205 IF C9>.5 THEN 225
210 LET V(I)=.0018181*(R(I)+2-R(I1)+2)*L
215 LET G(I)=H(I)*D(I)*96646
220 LET P(I)=V(I)*G(I)
222 LET P(I)=P(I)+P(I1)
223 LET Q(I)=P(I)/A(I)
225 NEXT I
226 LET Q9 = P(D9)/A(D9)
227 IF N9<.5 THEN 235
228 IF Q9 < 45000 THEN 231
229 LET T5 = (Q9/3300)+.77
230 GO TO 240
231 LET T5 = (Q9/41500)+25
232 GO TO 240
235 LET T5=P(D9)/(H9*A(D9))
240 LET T(D9)=T9+T5
248 IF D9=0 THEN 417
250 FOR I=D9 TO 1 STEP -1
260 LET I1 = I-1
265 LET T(I1)=T(I)
270 IF M(I)<.5 THEN 390
277 FOR J=1 TO 5
280 LET B = (T(I1)+T(I))/2 - 460
290 LET K=C(I,0)+C(I,1)*B+C(I,2)*B+2+C(I,3)*B+3+C(I,4)*B+4
295 LET T(I1)=T(I)+G(I)*(R(I)+2-R(I1)+2)/(576.*K)
300 LET T(I1)=T(I1)+(P(I1)*R(I1)/(12*A(I1)*K))*LOG(R(I)/R(I1))
305 LET T(I1)=T(I1)-(G(I)*R(I1)+2/(288*K))*LOG(R(I)/R(I1))
310 NEXT J
312 LET Y(I)=K
315 GO TO 416
390 LET N=1
395 LET X=35
400 LET F=1/(1/(E(I1)+1.E-8)+(R(I1)/R(I))*(1/(E(I)+1.E-8)-1))
401 LET T(I1)=T(I1)+X
402 LET Q1=.1714*F*A(I1)*((T(I1)/100)+4-(T(I)/100)+4)
403 LET B=(T(I1)+T(I))/2-460
404 LET K=C(I,0)+C(I,1)*B+C(I,2)*B+2+C(I,3)*B+3+C(I,4)*B+4
405 LET Y(I)=K
406 LET Q2=A(I1)*K*12*(T(I1)-T(I))/(R(I1)*LOG(R(I)/R(I1)))
407 LET Q=Q1+Q2

```

```

408 IF Q>P(I) THEN 411
409 IF N=1 THEN 401
410 GO TO 416
411 IF N=1 THEN 413
412 GO TO 401
413 LET N=2
414 LET X=-5
415 GO TO 401
416 NEXT I
417 IF D9=0 THEN 437
418 FOR I=D9 TO 2 STEP -2
419 LET I1=I-1
420 LET I2=I+1
421 LET B=(T(I)+T(I1))/2-460
422 LET T8=B-70
423 LET A7=(S(I,0)+S(I,1)*B)*1.E-06
424 LET R(I)=R(I)+(U(I)*(1+A7*T8)-R(I))/3
425 LET R(I1)=R(I1)+(U(I1)*(1+A7*T8)-R(I1))/3
426 LET L(I)=R(I)
427 LET L(I1)=R(I1)
428 IF I=D9 THEN 436
429 LET K=R(I2)-.0005
430 IF R(I)>K THEN 432
431 GO TO 436
432 LET K5=R(I)-R(I1)
433 LET R(I)=K
434 LET R(I1)=R(I)-K5
436 NEXT I
437 LET A7=(S(0,0)+S(0,1)*(T(0)-460))*1.E-06
438 LET T8=T(0)-530
439 LET R(0)=U(0)*(1+A7*T8)
440 LET L(0)=R(0)
441 IF D9=0 THEN 446
442 LET K=R(1)-.0005
443 IF R(0)<K THEN 446
444 LET R(0)=K
446 LET C9 = C9 + 1
447 IF C9<8 THEN 175
448 LET T3=T(0)
449 FOR I=0 TO 5
450 LET B=(T(0)+T3)/2-460
451 LET K=C(0,0)+C(0,1)*B+C(0,2)*B2+C(0,3)*B3+C(0,4)*B4
452 LET T3=T(0)+P(0)*(R(0)+2-R9+2)/(576*V(0)*K)
453 LET T3=T3+P(0)*R9+2*LOG((R9+1.E-8)/R(0))/(288*V(0)*K)
454 NEXT I
455 LET Y(0)=K
456 LET T3=T3-460
518 PRINT "NODE          COLD RADIUS  MATERIAL NO."
520 FOR N1 = 0 TO D9
525 PRINT N1,U(N1),W(N1)
527 NEXT N1
528 PRINT
530 PRINT "NODE          CALC. RADIUS  ACT. RADIUS"
531 FOR N1 = 0 TO D9
533 PRINT N1,L(N1),R(N1)
534 NEXT N1

```

```

535 PRINT
536 PRINT "NODE          TEMPERATURE, F.  TEMPERATURE, C."
537 FOR N1 = 0 TO D9
538 LET T(N1) = T(N1)-460
539 LET O(N1) = 5*(T(N1)-32)/9
540 PRINT N1, T(N1), O(N1)
541 NEXT N1
542 PRINT
543 PRINT "NODE          POWER(F, G)      Q/A          CONDUCTIVITY"
544 FOR N1=0 TO D9
545 PRINT N1, P(N1), Q(N1), Y(N1)
546 NEXT N1
547 PRINT
548 PRINT "TC(F.) = "T3
549 LET T3 =5*(T3-32)/9
550 PRINT
551 PRINT "TC(C.) = "T3
600 DATA 8, 1.5E3, 0, 250, 1, 0
601 DATA .031, .0315, .194, .1945, .195, .205, .245, .250, .327
603 DATA .9, .9, .9, .9, .9, .5, .5, .04, 0
604 DATA 1, 0, 1, 0, 1, 0, 1, 0, 1
605 DATA 32, 0, 32, 0, 32, 0, 32, 0, 32
606 DATA 19, 5, 14, 5, 14, 5, 7, 13, 20
5000 END

```

GENGTC OUTPUT

NODE	COLD RADIUS	MATERIAL NO.
0	.031	19
1	.0315	5
2	.194	14
3	.1945	5
4	.195	14
5	.205	5
6	.245	7
7	.25	13
8	.327	20

NODE	CALC. RADIUS	ACT. RADIUS
0	3.23944 E-2	.031
1	.0315	.0315
2	.194	.194
3	.1945	.1945
4	.195	.195
5	.207753	.207753
6	.24829	.24829
7	.250644	.250644
8	.327843	.327843

NODE	TEMPERATURE, F.	TEMPERATURE, C.
0	1863.99	1017.77
1	1858.99	1014.99
2	1847.34	1008.52
3	1827.34	997.41
4	1827.28	997.377
5	1352.28	733.488
6	1333.44	723.022
7	273.44	134.133
8	267.013	130.563

NODE	POWER [F, G]	Q/A	CONDUCTIVITY
0	208.143	12823.3	11.9384
1	208.143	12619.8	.0745
2	4658.61	45862.2	32.5669
3	4658.61	45744.3	7.39815 E-2
4	4682.26	45858.7	32.9305
5	4682.26	43621.7	6.85529 E-2
6	14374.1	112051.	14.0997
7	14374.1	109810.	2.02035 E-2
8	22468.1	131226.	120.212

TC[F.] = 1865.38

TC[C.] = 1018.54

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