```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
C
C
      CALL F04APF(PNET,IND,IW,IIW,IRNUM,IA,W,VOLTCURR,MTYPE,IFAIL)
      WRITE(2,103) IFAIL
  103 FORMAT(' FOR CALL TO F04APF,IFAIL WAS ',I2//)
      IF(IFAIL.NE.0) STOP
C
      CALL TIME(ATIME)
      WRITE(2,203) ATIME
  203 FORMAT(' NAG ROUTINE FINISHED,TIME WAS ',A8//)
C
C
C     CALCULATE EFFECTIVE THERMAL CONDUCTIVITY.
C
      CALL EFFCOND(N,MPLUS1)
C
C     CALCULATE AND OUTPUT A VOLTAGE MAP OF MATRIX.
C
      CALL WRITE(N,MPLUS1)
C
C     CALCULATE AND OUTPUT VOLTAGE CONTOUR DATA.
C
      CALL WRITEGRAPH(N,MPLUS1)
C
C     OUTPUT EFFECTIVE THERMAL CONDUCTIVITY.
C
      WRITE(2,999) CONDEFF
  999 FORMAT(///' KEFFECTIVE = ',F12.6)
C
C
C     RECORD JOB FINISH TIME.
C
      CALL TIME(ATIME)
      WRITE(2,204) ATIME
  204 FORMAT(///' JOB FINISHED AT ',A9//)
C
C
C
C
      STOP
C
C     PROGRAM ERROR EXITS.
C
    7 WRITE(2,101) ICOUNT,IRNUM
  101 FORMAT(' THE NUMBER OF EQUATIONS IS NOT THE SAME AS THE NUMBER
     C'OF UNKNOWNS.'/
     C' THE NUMBER OF EQUATIONS = ',I4/
     C' THE NUMBER OF UNKNOWNS = ',I4/
     C' PROGRAM HALTED.'///)
    9 WRITE(2,102)
  102 FORMAT(' ERROR - THE PROGRAM DOES NOT HOLD FOR THE ONE COLUMN
     C'CASE.'/
     C' PROGRAM HALTED.'///)
      STOP
      END
C
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

C
C
      SUBROUTINE MESH4I(I,J,N,M,ICOUNT)
C
C     A PROGRAM TO SET UP IN THE MATRIX RNET,RESISTOR VALUES ASSOCIATED
C     OF A 4 RESISTANCE MESH.
C
      DIMENSION RNET(11000),R(210),IND(11000)
C
C     RNET IS THE ARRAY OF RESISTANCE VALUES.
C     R IS THE ARRAY CONTAINING THE VALUES OF EACH RESISTOR.
C
      COMMON /NETWORK/RNET,IND,IL,IH,NUM
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /GENERAL/K
C
C     IPOS IS THE NUMBER OF THE RESISTOR IN THE LOWEST POSITION
C     IN THE MESH.
C
      IPOS=K+2*J-1
C
C     PUT VALUES OF RESISTORS INTO ARRAY RNET.
C
C     CHECK IF RESISTOR LIES IN THE MESH.
C
      INUMROW=IPOS-1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 1
      INUMROW=IPOS
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 1
      INUMROW=IPOS+1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      IF(I.EQ.M) GO TO 4
      INUMPOW=IPOS+(2*N-1)
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      RETURN
C
    4 INUMROW=K+(2*N-1)+J
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      RETURN
C
    1 RNET(NUM)=-R(INUMROW)
      GO TO 3
C
    2 RNET(NUM)=R(INUMROW)
    3 IND(NUM)=ICOUNT
      NUM=NUM+1
      RETURN
      END
C
C
C
      SUBROUTINE MESH3I(I,J,N,M,ICOUNT)
C
C     A PROGRAM TO SET UP IN THE MATRIX RNET,RESISTOR VALUES ASSOCIATED
C     OF A 3 RESISTOR MESH.
C
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

      DIMENSION RNET(11000),R(210),IND(11000)
C
C     RNET IS THE ARRAY OF RESISTANCE VALUES.
C     R IS THE ARRAY CONTAINING THE VALUES OF EACH RESISTOR.
C
      COMMON /NETWORK/RNET,IND,IL,IH,NUM
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /GENERAL/K
C
C     TEST TO SEE IF THIS IS THE FIRST OR LAST MESH IN THE ROW.
C
      IF(J.GT.1) GO TO 1
C
C     IPOS IS THE NUMBER OF THE RESISTOR IN THE LOWEST POSITION
C     IN THE MESH.
C
      IPOS=K+1
C
      PUT VALUES OF RESISTORS INTO ARRAY RNET IF IN THE MESH.
C
      INUMROW=IPOS
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      INUMROW=IPOS+1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      INUMROW=IPOS+(2*N-1)
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      RETURN
C
    2 RNET(NUM)=-R(INUMROW)
      GO TO 4
C
    3 RNET(NUM)=R(INUMROW)
    4 IND(NUM)=ICOUNT
      NUM=NUM+1
      RETURN
C
C     THIS IS THE PROCESS FOR THE MESHES AT THE OTHER END
C     OF THE NETWORK.
C
    1 IPOS=K+2*J-1
      INUMROW=IPOS-1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      INUMROW=IPOS
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      IF(I.EQ.M) GO TO 5
      INUMROW=IPOS+(2*N-1)
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      RETURN
    5 INUMROW=IPOS+N
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      RETURN
      END
C
C
C
      SUBROUTINE POINT3I(I,J,N,ICOUNT)
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

C
C     A PROGRAM TO SET UP IN THE MATRIX RNET,RESISTOR VALUES ASSOCIATED
C     OF A 3 RESISTOR POINT LOCATION.
C
      DIMENSION RNET(11000),IND(11000)
C
C     RNET IS THE ARRAY OF RESISTANCE VALUES.
C
      COMMON /NETWORK/RNET,IND,IL,IH,NUM
      COMMON /GENERAL/K
C
C     TEST TO SEE IF THIS IS THE FIRST OR LAST ROW OF POINTS.
C
      IF(I.GT.1) GO TO 1
C
C     IPOS IS THE POSITION OF THE LOWEST AND MOST LEFTWARD
C     OF THE 3 RESISTORS USED AT EACH POINT.
C
      IPOS=2*J-1
C
C     SET APPROPRIATE ELEMENTS OF ARRAY TO 1.0
C
      INUMROW=IPOS
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      INUMROW=IPOS+1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      INUMROW=IPOS+2
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      RETURN
C
    2 RNET(NUM)=1.0
      GO TO 4
C
    3 RNET(NUM)=-1.0
    4 IND(NUM)=ICOUNT
       NUM=NUM+1
      RETURN
C
C     THIS IS THE PROCESS FOR THE POINTS ON THE TOP ROW OF THE MESH.
C
    1 IPOS=K+J
      IN=K-(2*N-1)
      INUMROW=IPOS
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      INUMROW=IPOS+1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      INUMROW=IN+2*J
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 3
      RETURN
      END
C
C
C
      SUBROUTINE POINT4I(J,N,ICOUNT)
C
C     A PROGRAM TO SET UP IN THE ARRAY RNET,PARAMETERS ASSOCIATED
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
C     WITH A 4 RESISTOR POINT LOCATION.
C
      DIMENSION RNET(11000),IND(11000)
C
C     RNET IS THE ARRAY OF RESISTANCE VALUES.
C
      COMMON /NETWORK/RNET,IND,IL,IH,NUM
      COMMON /GENERAL/K
C
C     IPOS IS THE POSITION OF THE LOWEST AND LEFTMOST OF THE
C     4 RESISTORS USED AT EACH POINT.
C
      IPOS=K+(2*J-1)
C
C     SET APPROPRIATE COEFFICIENTS OF ARRAY TO 1.0
C
      INUMROW=IPOS
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 1
      INUMROW=IPOS+1
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 1
      INUMROW=IPOS+2
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      INUMROW=IPOS-(2*N-2)
      IF(INUMROW.GT.IL.AND.INUMROW.LT.IH) GO TO 2
      RETURN
C
    1 RNET(NUM)=1.0
      GO TO 3
C
    2 RNET(NUM)=-1.0
    3 IND(NUM)=ICOUNT
      NUM=NUM+1
      RETURN
      END
C
C
C
      SUBROUTINE OVERALLI(N,ICOUNT)
C
C     THIS ROUTINE SETS UP ONE EQUATION USING ALL THE RESISTORS
C     ON THE BOTTOM (M=1) ROW.
C
      DIMENSION RNET(11000),R(210),IND(11000)
C
C     RNET IS THE ARRAY OF RESISTANCE VALUES.
C     R IS THE ARRAY CONTAINING THE VALUE OF EACH RESISTOR.
C
      COMMON /NETWORK/RNET,IND,IL,IH,NUM
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
C
C     CALCULATE THE NUMBER OF RESISTORS IN THE LINE AND
C     PUT VALUES OF RESISTORS INTO RNET.
C
      INUM=2*N-1
      DO 1 I=1,INUM,2
      IF(I.GT.IL.AND.I.LT.IH) GO TO 2
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
    1 CONTINUE
      RETURN
    2 RNET(NUM)=R(I)
      IND(NUM)=ICOUNT
      NUM=NUM+1
      RETURN
      END
C
C
C
      SUBROUTINE ARRAYZERO(IRNUM)
C
C     A ROUTINE TO SET TO ZERO THE RESISTANCE ARRAY.
C
      DIMENSION R(210)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
C
C     IRNUM IS THE NUMBER OF RESISTORS AND CURRENTS.
C
      DO 1 I=1,IRNUM
      R(I)=0.0
    1 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE CALCRESNUM(N,M,IRNUM)
C
C     A ROUTINE TO CALCULATE THE NUMBER OF RESISTORS/CURRENTS,.
C     FROM INPUT VALUES OF M AND N.
C
      IRNUM=((M+1)*N)+((N-1)*M)
      RETURN
      END
C
C
C
      SUBROUTINE ARRAYSIZE(N,M)
C
C     A ROUTINE TO READ IN THE NUMBER OF HORIZONTAL AND VERTICAL MESHES
C     AND THE OVERALL DIMENSIONS IN MILLIMETRES.
C
      DIMENSION CONDINC(20)
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
      WRITE(2,101)
  101 FORMAT(' ENTER N AND M >')
      READ(1,100) N,M
  100 FORMAT(2I0)
      WRITE(2,102) N,M
  102 FORMAT(' N WAS ',I2,'   M WAS ',I2//)
      WRITE(2,103)
  103 FORMAT(' ENTER XSIZE(N-DIR) AND YSIZE(M-DIR) IN MM')
      READ(1,104) XSIZE,YSIZE
  104 FORMAT(2F0.0)
      WRITE(2,105) XSIZE,YSIZE
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

  105 FORMAT(' XSIZE(N-DIR) WAS ',F9.4,' MM   YSIZE(M-DIR) WAS ',
     CF9.4,' MM'//)
      RETURN
      END
C
C
C
      SUBROUTINE ARRAYRES(IRNUM,JJJ,N,M)
C
C     A ROUTINE TO SET UP THE VALUES OF WHOLE RESISTORS,
C     IN X AND Y DIRECTIONS,
C     FOR THE MATRIX AND EACH INCLUSION.
C
      DIMENSION R(210),CONDINC(20)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
C
      IF(JJJ.GT.1) GO TO 1
      WRITE(2,100)
  100 FORMAT(' ENTER THERMAL CONDUCTIVITY OF THE MESH >')
      READ(1,101) CONDMAT
  101 FORMAT(F0.0)
      WRITE(2,103) CONDMAT
  103 FORMAT(/' THE THERMAL CONDUCTIVITY OF THE MESH WAS ',F9.4//)
      CALL LINE
C
C
C
    1 WRITE(2,105) JJJ
  105 FORMAT(//' *** INFORMATION ABOUT INSERT NUMBER ',I2,' ***'//)
      WRITE(2,102)
  102 FORMAT(' ENTER THERMAL CONDUCTIVITY OF THE INCLUSION(S) >')
      READ(1,101) CONDINC(JJJ)
      WRITE(2,104) CONDINC(JJJ)
  104 FORMAT(/' THE THERMAL CONDUCTIVITY OF THE INCLUSION(S) WAS ',
     CF9.4//)
C
      IF(JJJ.GT.1) GO TO 3
      RXM=XSIZE/YSIZE/CONDMAT*M/N
      RYM=YSIZE/XSIZE/CONDMAT*N/M
    3 RXI=XSIZE/YSIZE/CONDINC(JJJ)*M/N
      RYI=YSIZE/XSIZE/CONDINC(JJJ)*N/M
      RETURN
      END
C
C
C
      SUBROUTINE EFFCOND(N,MPLUS1)
C
C     A ROUTINE TO CALCULATE THE EFFECTIVE CONDUCTIVITY,
C     BY SUMMING THE CURRENT VALUES ACROSS A PLANE
C     PERPENDICULAR TO THE APPLIED TEMPERATURE.
C
      DIMENSION CONDINC(20),VOLTCURR(210),R(210)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
      COMMON /CURRVOLT/VOLTCURR
C
      INTEGER SUMLOW
      SUMLOW=2*N-1
      SUM=0.0
      DO 1 I=1,MPLUS1
      LOC=1+(I-1)*SUMLOW
      SUM=SUM+VOLTCURR(LOC)
    1 CONTINUE
      CONDEFF=SUM/YSIZE*XSIZE
      WRITE(6,100) CONDEFF
      WRITE(3,100) CONDEFF
  100 FORMAT(1X,F10.4)
      RETURN
      END
C
C
C
      SUBROUTINE WRITE(N,MPLUS1)
C
C     A ROUTINE TO CALCULATE AND OUTPUT THE VOLTAGE MAP,.
C     OF THE MATRIX.
C
C     VOLT IS AN ARRAY TO HOLD A LINE OF OUTPUT.
C
      DIMENSION VOLTCURR(210),VOLT(11),R(210)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /CURRVOLT/VOLTCURR
C
C     ZERO-ISE ARRAY VOLT.
C
      DO 5 I=1,11
      VOLT(I)=0.0
    5 CONTINUE
C
C     WRITE OUT FIRST LINE OF RESULTS,IE ALL ZERO'S.
C
      WRITE(3,100) (VOLT(I),I=1,MPLUS1)
C
C     GO THROUGH RESULTS ONE VERTICAL LINE AT A TIME.
C
      DO 1 J=1,N
      DO 2 I=1,MPLUS1
      K=(I-1)*(2*N-1)
      IF(I.EQ.MPLUS1) GO TO 3
      LOC=K+2*J-1
      GO TO 4
    3 LOC=K+J
    4 VOLT(I)=VOLT(I)+VOLTCURR(LOC)*R(LOC)
    2 CONTINUE
      WRITE(3,100) (VOLT(IM),IM=1,MPLUS1)
    1 CONTINUE
  100 FORMAT(1X,11(F7.4,4X))
C
      RETURN
      END
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
C
C
C
      SUBROUTINE SETVOLTARRAY(IRNUM)
C
C     A ROUTINE TO SET UP THE ARRAY OF VOLTAGES,.
C     FORMING THE RHS OF THE EQUATION.
C
      DIMENSION VOLTCURR(210)
C
      COMMON /CURRVOLT/VOLTCURR
C
      IEND=IPNUM-1
      DO 1 I=1,IEND
      VOLTCURR(I)=0.0
    1 CONTINUE
C
      VOLTCURR(IRNUM)=1.0
C
      RETURN
      END
C
C
C
      SUBROUTINE EXITPARAM
C
C     A ROUTINE TO WRITE OUT THE VARIOUS OUTPUT PARAMETERS OF THE NAG
C     IT IS CALLED IN ERROR CONDITION.
C
C     ROUTINES ON EXIT.
C
      DIMENSION IW(210,13)
C
      COMMON /NETWORK/RNET,IND,IL,IH,NUM
      COMMON /ANSCHECK/G,D1,ID2,IW
C
      NRELM=IW(IRNUM+1,1)-1
      WRITE(2,207) NRELM
  207 FORMAT(1H1,' THE NUMBER OF ELEMENTS IN L/U = ',I5//)
      WRITE(2,200) G
  200 FORMAT(' G = ',E15.8//)
      WRITE(2,201) D1,ID2
  201 FORMAT(' D1 = ',E15.8,'   ID2 = ',I5//)
C
C
      WRITE(2,205)
  205 FORMAT(' COLUMN PIV',18X,'COL SP',19X,'ROW SP',
     C16X,'ORDER PIV ROW'//)
      DO 203 I=1,NUM
      WRITE(2,204) IW(I,2),IW(I,3),IW(I,4),IW(I,5)
  203 CONTINUE
  204 FORMAT(1X,4(I10,15X))
      WRITE(2,206)
  206 FORMAT(//////)
C
      RETURN
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
      END
C
C
C
      SUBROUTINE WRITEGRAPH(N,MPLUS1)
C
C     A ROUTINE TO WRITE OUT DATA TO A FILE FOR USE WITH THE
C     GINO-F PROGRAM.
C     IT CALCULATES THE POSITIONS OF THE 0.1 VOLT INCREMENTS
C     ACROSS THE SAMPLE, ALONG THE ROWS OF THE MESH.
C
      DIMENSION VOLTGRAPH(9),VOLTCURR(210),R(210),CONDINC(20)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /CURRVOLT/VOLTCURR
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
C
C
      WRITE(2,200)
  200 FORMAT(//' POSITIONS OF 0.1 V INCPEMENTS ACROSS THE SAMPLE.'/)
C
      SUMLOW=2*N-1
      XINC=XSIZE/FLOAT(N)
      DO 1 I=1,MPLUS1
      V1=0.0
      V2=0.0
      REMAIN=0.0
      TEMP=0.1
      IJ=1
      DO 2 J=1,N
      K=(I-1)*SUMLOW
      LOC=K+2*J-1
      IF(I.EQ.MPLUS1) LOC=K+J
      V2=V1+VOLTCURR(LOC)*R(LOC)
      IF(V2.LT.TEMP.AND.ABS(TEMP-V2).GT.1.0E-6) GO TO 4
      VDIFF=V2-V1
    3 VOLTGRAPH(IJ)=(TEMP-V1)/VDIFF*XINC+REMAIN
      IJ=IJ+1
      IF(IJ.EQ.10) GO TO 5
      TEMP=TEMP+0.1
      IF(TEMP.LE.V2) GO TO 3
    4 V1=V2
      REMAIN=FLOAT(J)*XINC
    2 CONTINUE
    5 WRITE(6,100) (VOLTGRAPH(IK),IK=1,9)
      WRITE(2,100) (VOLTGRAPH(IK),IK=1,9)
  100 FORMAT(1X,9F8.4)
    1 CONTINUE
C
C     PRINT END LABEL FOR GRAPHICS PROGRAM.
C
      IC=-1
      WRITE(6,600) IC
  600 FORMAT(1X,I4)
C
      RETURN
      END
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

C
C
C
      SUBROUTINE INCLUSION(N,M,JJJ,INCNUM)
      DIMENSION CONDINC(20)
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
C
C     READ IN INCLUSION DATA AND
C     OUTPUT DATA TO THE GRAPHICS DATA FILE.
C
C
      ICON=1
      IF(JJJ.EQ.1) WRITE(6,605) ICON
      IF(JJJ.EQ.1) WRITE(3,605) ICON
  605 FORMAT(1X,I5)
C
      IF(JJJ.EQ.1) WRITE(6,601) M,N,INCNUM
      IF(JJJ.EQ.1) WRITE(3,601) M,N,INCNUM
  601 FORMAT(1X,3(I3,4X))
      IF(JJJ.EQ.1) WRITE(6,606)XSIZE,YSIZE,CONDMAT
      IF(JJJ.EQ.1) WRITE(3,606)XSIZE,YSIZE,CONDMAT
  606 FORMAT(1X,3(F10.4,2X))
      WRITE(6,604) CONDINC(JJJ)
      WRITE(3,604) CONDINC(JJJ)
  604 FORMAT(1X,F10.4)
      WPITE(2,100)
  100 FORMAT(' ENTER SHAPE CODE:1=SQUARE OR RECTANGLE,2=CIRCLE')
      READ(1,101) ISC
  101 FORMAT(I0)
C
C
      WRITE(2,104) ISC
  104 FORMAT(' SHAPE CODE WAS ',I2//)
      WRITE(6,600) ISC
      WRITE(3,600) ISC
  600 FORMAT(1X,I4)
C
      WRITE(2,102)
  102 FORMAT(' ENTER CENTRE POSITION (N/X,M/Y) ')
      READ(1,103) XC,YC
  103 FORMAT(2F0.0)
      WRITE(2,110) XC,YC
  110 FORMAT(/' CENTRE POSITION IN "N/X" DIRECTION WAS ',F12.6/
     C' CENTRE POSITION IN "M/Y" DIRECTION WAS ',F12.6//)
      WRITE(2,107)
  107 FORMAT(//' ++++++ALL SIZES MUST BE REAL.++++++'//)
      GO TO (1,2) ,ISC
    1  WRITE(2,114)
  114 FORMAT(' ENTER XL & YL IN MM.'/
     C' (SIDE SIZES IN N/X & M/Y DIR.RESP.) >')
      READ(1,106) XL,YL
  106 FORMAT(2F0.0)
      WRITE(2,105) XL,YL
  105 FORMAT(' XL (N-DIR.) WAS ',F12.6,'   YL (M-DIR) WAS ',F12.6//)
      HXL=XL/2.0
      HYL=YL/2.0
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
      WRITE(6,602) XC,YC,HXL,HYL
      WRITE(3,602) XC,YC,HXL,HYL
  602 FORMAT(1X,4(F10.4,2X))
C
C     CALCULATE RESISTOR VALUES FOR RECTANGULAR INSERTS.
C
      CALL INCSC1(N,M,XL,YL,XC,YC)
      CALL LINE
      RETURN
C
    2 WRITE(2,108)
  108 FORMAT(' ENTER RADIUS IN MM >')
      READ(1,106) RAD
      WRITE(2,109) RAD
  109 FORMAT(' RADIUS WAS ',F12.6//)
      WRITE(6,603) XC,YC,RAD
      WRITE(3,603) XC,YC,RAD
  603 FORMAT(1X,3(F10.4,2X))
C
C
C     CALCULATE RESISTOR VALUES FOR CIRCULAR INSERTS.
C
      CALL INCSC2(N,M,RAD,XC,YC,
C
      CALL LINE
C
      RETURN
      END
C
C
C
      SUBROUTINE LINE
C
C     A ROUTINE TO DRAW A SEPARATING LINE.
C
      WRITE(2,100)
  100 FORMAT(///' ++++++++++++++++++++++++++++++++++++++++++++'///)
C
      RETURN
      END
C
C
C
      SUBROUTINE EDGERESCOMP(N,M,IRNUM)
C
C     A ROUTINE TO DOUBLE THE VALUE OF ALL THE EDGE RESISTORS,
C     AS THESE ARE SHARED WITH THE ADJACENT ROW OF THE MESH.
C
      DIMENSION R(210)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      INTEGER SUMLOW
      SUMLOW=2*N-1
      DO 1 I=1,SUMLOW,2
      R(I)=2.0*R(I)
    1 CONTINUE
      ILOW=M*SUMLOW+1
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

      DO 2 I=ILOW,IRNUM
      P(I)=2.0*R(I)
    2 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE NUMOFINC(INCNUM)
C
C     A ROUTINE TO READ IN THE NUMBER OF INCLUSIONS.
C
      WRITE(2,100)
  100 FORMAT(' ENTER NUMBER OF INCLUSIONS')
      READ(1,101) INCNUM
  101 FORMAT(I0)
      WRITE(2,102) INCNUM
  102 FORMAT(' THE NUMBER OF INCLUSIONS WAS ',I2//)
      RETURN
      END
C
C
C
      SUBROUTINE INCSC1(N,M,XL,YL,XC,YC)
C
C     A ROUTINE TO CALCULATE THE RESISTOR VALUES FOR A
C     SQUARE/RECTANGULAR INSERT.
C
      DIMENSION R(210),CONDINC(20)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
      INTEGER SUMLOW
C
C
      HXL=XL/2.0
      HYL=YL/2.0
      XINC=XSIZE/N
      YINC=YSIZE/M
      SUMLOW=2*N-1
C
C     ICROSS1/2=1 IF MESH POINT IS IN INSERT ELSE =0.
C
C
C     WORK ALONG HORIXONTAL MESH LINES.
C
      RMV=RXM
      RIV=RXI
C
      DO 2 J=1,M+1
      DO 1 I=1,N+1
C
C     CALCULATE PARTICULAR RESISTOP NUMBER.
C
      NUM=(J-1)*SUMLOW+(I-1)*2-1
C
C     SPECIAL CASE FOR TOP ROW OF RESISTORS.
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
C
      IF(J.EQ.M+1) NUM=(J-1)*SUMLOW+(I-1)
C     CALCULATE OFFSETS FROM INSERT CENTRE TO RESISTOR.
C
      XPOS=FLOAT(I-1)*XINC
      YPOS=FLOAT(J-1)*YINC
      DX=ABS(XC-XPOS)
      DY=ABS(YC-YPOS)
C
C     CHECK IF RESISTOR IS INSIDE INSERT.
C     GO TO 9 = INSIDE.
C     GO TO 3 = OUTSIDE.
C
      IF((ABS(DX-HXL).LT.1.0E-6.AND.DY.LE.HYL).OR.
     C(ABS(DY-HYL).LT.1.0E-6.AND.DX.LE.HXL).OR.
     C(ABS(DX-HXL).LT.1.0E-6.AND.ABS(DY-HYL).LT.1.0E-6)) GO TO 9
       IF(DX.GT.HXL.OR.DY.GT.HYL) GO TO 3
C
C     CHECK FOR FIRST COLUMN OF MESH POINTS.
C
    9 IF(I.EQ.1) GO TO 5
C
C     INSIDE INSERT.
C
      ICROSS2=1
C
C     IF ALL RESISTOR LENGTH IS IN INSERT, GO TO 8.
C
      IF(ICROSS1.EQ.1) GO TO 8
C
C     CALCULATE WHAT PART OF RESISTOR LIES INSIDE INSERT.
C
      DIST=DX+XINC
      RPART=DIST-HXL
C
C     CALCULATE VALUE OF THAT RESISTOR.
C
      RVAR=RPART/XINC*RMV+(XINC-RPART)/XINC*RIV
C
C     CHECK IF RESISTOR HAS BEEN ASSIGNED A VALUE ALREADY.
C
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
C
C     SET VALUE OF RESISTOR.
C
      R(NUM)=RVAR
      GO TO 7
C
C     CHECK IF RESISTOR HAS BEEN ASSIGNED A VALUE ALREADY.
C
    8 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
C
C     SET RESISTOR TO VALUE OF RINSERT.
C
      R(NUM)=RIV
      GO TO 7
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

C
C     SHOW MESH POINT IS IN INSERT.
C
    5 ICROSS1=1
      GO TO 1
C
C     CHECK FOR FIRST COLUMN OF MESH POINTS.
C
    3 IF(I.EQ.1) GO TO 4
C
C     SHOW POINT IS IN MATRIX.
C
      ICROSS2=0
C
C     IF ALL RESISTOR LENGTH IS IN MATRIX, GO TO 6.
C
      IF(ICPOSS1.EQ.0) GO TO 6
C
C     CALCULATE WHAT PART OF RESISTOR LIES IN THE MATPIX.
C
      RPART=DX-HXL
      RVAR=RPART/XINC*RMV+(XINC-RPART)/XINC*RIV
C
C     CHECK IF RESISTOR HAS BEEN ASSIGNED A VALUE ALREADY.
C
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
C
C     NO, SO SET VALUE TO THAT CALCULATED.
C
      R(NUM)=RVAR
      GO TO 7
C
C     SHOW MESH POINT IS IN THE MATRIX.
C
    4 ICROSS1=0
      GO TO 1
C
C     IF RESISTOR VALUE ALREADY SET, THEN SKIP.
C
    6 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
C
C     SET RESISTOR TO VALUE OF RMATRIX.
C
      R(NUM)=RMV
C
C     MAKE LATEST MESH POINT "PREVIOUS MESH POINT".
C
    7 ICROSS1=ICROSS2
    1 CONTINUE
    2 CONTINUE
C
C     REPEAT AND WORK ALONG VERTICAL MESH LINES.
C
      PMV=RYM
      RIV=RYI
C
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES
      DO 12 I=1,N-1
      DO 11 J=1,M+1
      NUM=2*I+(J-2)*SUMLOW
      XPOS=FLOAT(I)*XINC
      YPOS=FLOAT(J-1)*YINC
      DX=ABS(XC-XPOS)
      DY=ABS(YC-YPOS)
      IF((ABS(DX-HXL).LT.1.0E-6.AND.DY.LE.HYL).OR.
     C(ABS(DY-HYL).LT.1.0E-6.AND.DX.LE.HXL).OR.
     C(ABS(DX-HXL).LT.1.0E-6.AND.ABS(DY-HYL).LT.1.0E-6)) GO TO 19
      IF(DX.GT.HXL.OR.DY.GT.HYL) GO TO 13
   19 IF(J.EQ.1) GO TO 15
      ICROSS2=1
      IF(ICROSS1.EQ.1) GO TO 18
      DIST=DY+YINC
      RPART=DIST-HYL
      RVAR=RPART/YINC*RMU+(YINC-RPART)/YINC*RIU
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMU).GT.1.0E-6) GO TO 17
      R(NUM)=RVAR
      GO TO 17
   18 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMU).GT.1.0E-6) GO TO 17
      R(NUM)=RIU
      GO TO 17
   15 ICROSS1=1
      GO TO 11
   13 IF(J.EQ.1) GO TO 14
      ICROSS2=0
      IF(ICROSS1.EQ.0) GO TO 16
      RPART=DY-HYL
      RVAR=RPART/YINC*RMU+(YINC-RPART)/YINC*RIU
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMU).GT.1.0E-6) GO TO 17
      R(NUM)=RVAR
      GO TO 17
   14 ICROSS1=0
      GO TO 11
   16 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMU).GT.1.0E-6) GO TO 17
      R(NUM)=RMU
   17 ICROSS1=ICROSS2
   11 CONTINUE
   12 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE INCSC2(N,M,RAD,XC,YC)
C
C     A ROUTINE TO CALCULATE THE RESISTOR VALUES FOR A
C     CIRCULAR INSERT.
C
      DIMENSION R(210),CONDINC(20)
      COMMON /RESDATA/R,RXI,RYI,RXM,RYM
      COMMON /CONDDATA/CONDMAT,CONDINC,CONDEFF,XSIZE,YSIZE
      INTEGER SUMLOW
C
C
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

      XINC=XSIZE/N
      YINC=YSIZE/M
      SUMLOW=2*N-1
C
C     ICROSS1/2=1 IF MESH POINT IS IN INSERT ELSE =0.
C
C
C     WORK ALONG HORIZONTAL MESH LINES.
C
      RMV=RXM
      RIV=RXI
C
      DO 2 J=1,M+1
      DO 1 I=1,N+1
      NUM=(J-1)*SUMLOW+(I-1)*2-1
      IF(J.EQ.M+1) NUM=(J-1)*SUMLOW+(I-1)
      XPOS=FLOAT(I-1)*XINC
      YPOS=FLOAT(J-1)*YINC
      DIAG=SQRT(ABS((XC-XPOS)**2)+ABS((YC-YPOS)**2))
      IF(ABS(DIAG-RAD).LT.1.0E-6) GO TO 9
      IF(DIAG.GT.RAD) GO TO 3
    9 IF(I.EQ.1) GO TO 5
      ICROSS2=1
      IF(ICROSS1.EQ.1) GO TO 8
      DIST1=XC-XPOS+XINC
      DIST2=SQRT(RAD**2-ABS((YC-YPOS)**2))
      RPART=DIST1-DIST2
      RVAR=RPART/XINC*RMV+(XINC-RPART)/XINC*RIV
      IF(P(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
      R(NUM)=RVAR
      GO TO 7
    8 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
      R(NUM)=RIV
      GO TO 7
    5 ICROSS1=1
      GO TO 1
    3 IF(I.EQ.1) GO TO 4
      ICROSS2=0
      IF(ICROSS1.EQ.0) GO TO 6
      DIST1=XPOS-XC
      DIST2=SQRT(RAD**2-ABS((YC-YPOS)**2))
      RPART=DIST1-DIST2
      RVAR=RPART/XINC*RMV+(XINC-RPART)/XINC*RIV
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
      R(NUM)=RVAR
      GO TO 7
    4 ICROSS1=0
      GO TO 1
    6 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 7
      R(NUM)=RMV
    7 ICROSS1=ICROSS2
    1 CONTINUE
    2 CONTINUE
C
C     WORK ALONG VERTICAL MESH LINES.
C
```

```
A PROGRAM TO CALCULATE THE THERMAL CONDUCTIVITY OF COMPOSITES

      RMV=RYM
       RIV=RYI
C
      DO 12 I=1,N-1
      DO 11 J=1,M+1
      NUM=2*I+(J-2)*SUMLOW
      XPOS=FLOAT(I)*XINC
      YPOS=FLOAT(J-1)*YINC
      DIAG=SQRT(ABS((XC-XPOS)**2)+ABS((YC-YPOS)**2))
      IF(ABS(DIAG-RAD).LT.1.0E-6) GO  TO 19
      IF(DIAG.GT.RAD) GO TO 13
   19 IF(J.EQ.1) GO TO 15
      ICROSS2=1
      IF(ICROSS1.EQ.1) GO TO 18
       DIST1=YC-YPOS+YINC
      DIST2=SQRT(RAD**2-ABS((XC-XPOS)**2))
      RPART=DIST1-DIST2
      RVAR=RPART/YINC*RMV+(YINC-RPART)/YINC*RIV
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 17
      R(NUM)=RVAR
      GO TO 17
   18 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 17
      R(NUM)=RIV
      GO TO 17
   15 ICROSS1=1
      GO TO 11
   13 IF(J.EQ.1) GO TO 14
      ICROSS2=0
      IF(ICROSS1.EQ.0) GO TO 16
      DIST1=YPOS-YC
      DIST2=SQRT(RAD**2-ABS((XC-XPOS)**2))
      RPART=DIST1-DIST2
      RVAR=RPART/YINC*RMV+(YINC-RPART)/YINC*RIV
      IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 17
      R(NUM)=RVAR
      GO TO 17
   14 ICROSS1=0
      GO TO 11
   16 IF(R(NUM).GT.1.0E-6.AND.ABS(R(NUM)-RMV).GT.1.0E-6) GO TO 17
      R(NUM)=RMV
   17 ICROSS1=ICROSS2
   11 CONTINUE
   12 CONTINUE
      RETURN
      END
C
C
C
      FINISH
C
C
C
```

MAIN CALCULATION PROGRAM INPUT FILE

```
3 3
3.0 3.0
1
0.1
1.0
2
3.0 0.0
2.5
```