APPENDIX C

DCPVSIMP PROGRAM FORTRAN CODE

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C ***** SIMPLIFIED DIRECT-COUPLED PHOTOVOLTAIC SIMULATION PROGRAM
C
C ***** TIM TOWNSEND, UNIVERSITY OF WISCONSIN-MADISON; FALL 1988 *******
C
C ***** THIS PROGRAM ESTIMATES PV OUTPUT BY HOUR USING LONG-TERM
C ***** AVERAGE CORRELATIONS TO CONSTRUCT HOURLY RADIATION PATTERNS
C ***** BASED ON MONTHLY AVERAGE CLEARNESS INDICES. EACH MONTH, THE
C ***** CUMULATIVE CLEARNESS INDEX CURVE IS SPLIT INTO "X" SEGMENTS.
C ***** CALCS ARE DONE FOR SEVERAL DIFFERENT LOADS W/NO STORAGE.
C ***** IT RELIES ON INPUT FILES GENERATED SEPARATELY AND READ BY
C ***** THIS PROGRAM. ONE IS "KTcity.INP" (6 CITIES);THE OTHER IS
C ***** "MODULEx.DAT", WHERE x GOES FROM 1 TO 11 FOR DIFFERENT MODULES.
C ***** THE PROGRAM ALSO COMPUTES THE MAXIMUM POWER POINT OUTPUT
C ***** VIA AN ANALYTICAL METHOD DEVELOPED BY TOWNSEND AND VIA A
C ***** LINEAR EQUATION AS USED IN PV-fCHART AND PVFORM.
C ***** THE CELL MODEL IS A LUMPED 4 PARAMETER VERSION WHICH INCLUDES
C ***** SERIES RESISTANCE. EACH OF THE 4 UNKNOWN UNIT PARAMETERS,
C ***** INCLUDING SERIES RESISTANCE, ARE SOLVED FOR AUTOMATICALLY.
C ***** THE SERIES RESISTANCE IS PRINTED TO THE SCREEN AND
C ***** THE USER MAY OVERRIDE THE VALUE WITH A MANUAL INPUT, AFTER
C ***** WHICH EACH OF THE OTHER 3 PARAMETERS ARE RECALCULATED, AT
C ***** A REFERENCE IRRADIANCE AND CELL TEMPERATURE. OTHER RELATIONSHIPS
C ***** ARE THEN EMPLOYED TO CALCULATE THE VARIATION IN THE CELL
C ***** PARAMETERS AS FUNCTIONS OF IRRADIANCE AND CELL TEMPERATURE.
C ***** THE RESULT IS A COMPLETE I-V EXPRESSION AT ANY IRRADIANCE
C ***** AND CELL TEMPERATURE.
C ***** THE PARAMETERS ARE THE LIGHT-GENERATED CURRENT, THE REVERSE
C ***** SATURATION CURRENT, GAMMA (A MEASURE OF CELL IMPERFECTION),
C ***** AND SERIES RESISTANCE. BOTH SERIES RESISTANCE AND GAMMA
C ***** ARE ASSUMED CONSTANT AT ALL CONDITIONS. THE REVERSE SAT.
C ***** CURRENT IS ASSUMED TO BE A FUNCTION OF TEMPERATURE, AND THE LIGHT
C ***** CURRENT IS ASSUMED TO BE A FUNCTION OF IRRADIANCE AND TEMPERA-
TURE.
C
C ***** THIS SECTION IDENTIFIES ALL VARIABLES ******************
C
      IMPLICIT NONE     ! ALLOWS ONLY DECLARED VARIABLE NAMES
      CHARACTER*6 APPROACH ! INDICATOR FOR PUMP LOADS TO FIND OPER. POINT
      CHARACTER*50 MODEL  ! NAME OF SELECTED MODULE OR ARRAY FROM DATA
      CHARACTER*3 OVERRIDE ! ALLOWS USER TO SPECIFY A MANUAL Rseries
      INTEGER H         ! HOUR OF DAY COUNTER
      INTEGER J,K,L     ! LOOP COUNTERS
      INTEGER LOADTYPE,LOC ! LOADTYPE, LOCATION
      INTEGER MAX_FLAG   ! SAVES CPU TIME BY ONLY CALC. MAX POWER ONCE
      INTEGER MO,MODULETYPE ! MONTH, MODULE/ARRAY SELECTED
      INTEGER PAIRS      !# OF I-V DATA PAIRS FOR MOTOR LOADS
      INTEGER PMTYPE,RES  ! PUMP/MOTOR TYPE, LOAD RESISTANCE IN OHMS
      INTEGER R_FINAL,R_INCR,R_INIT ! LAST,INCREMENT,&FIRST LOADS, OHMS
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      INTEGER SEG       ! # OF SEGMENTS FOR KT-CURVE, OR "TYPICAL DAYS"
      REAL A,ALTMAX_YR   ! IMPERFECTION FACTOR,YEARLY KWH TOTAL BY SIMPLE
C                 ! LINEAR MAX-POWER CALC METHOD (PV-fCHART)
      REAL ALTMAX(12),AREA !MONTHLY SIMPLE MAX-POWER KWH,UNIT AREA M2
      REAL BETA,C       ! COLLECTOR SLOPE,CONSTANT IN PUMPING CALCS
      REAL CGAM,CPR_A,CPR_B ! CONSTANTS FOR BENDT AND COLLARES-PEREIRA &
C                 ! RABL (CP&R) CORRELATIONS
      REAL CUR(20)      ! PUMP LOAD CURRENT INPUTS (20 ALLOWED)
      REAL DAVG(12),DECL(12) ! AVERAGE DAY/MONTH, AVG. DECLINATION/MONTH
      REAL DENOM,EFFREF  ! DENOMINATOR IN CP&R CORR.,REFERENCE MAX EFFIC.
      REAL E(12,31,24),EG ! DIRECT-COUPLED KWH BY HOUR,BANDGAP ENERGY VOLTS
      REAL E_MAX(12,31,24) ! MAX POWER KWH BY HOUR
      REAL E_MO(12)     ! DIRECT-COUPLED KWH BY MONTH
      REAL ETYPDAY(12,31) ! DIRECT-COUPLED KWH PER SEGMENT BY MONTH
      REAL FIXVOL,FLOW(20) !FIXED LOAD VOLTAGE,PUMP FLOWRATE INPUTS (MAX 20)
      REAL FRAC         ! FRACTION ON KT CURVE CORRESPONDING TO A SEGMENT
      REAL F1,F1P,F2,F2P,F3,F3P,F4,F4P,F5,F5P !OBJ.FUNCTIONS AND THEIR
C                 ! DERIVATIVES IN VARIOUS NEWTON'S METHOD ROUTINES
      REAL F4H,F4L,F4NEW  ! OBJ. FUNCTIONS IN BISECTION SEARCH ROUTINES
      REAL GAM,GAM2     ! UNIT LEVEL CURVE FIT FACTOR,BENDT CORR. FACTOR
      REAL HD,HD_H      ! HORIZONTAL KJ/M2 DIFFUSE/TYP.DAY,TYP.DAY DIFF.FRAC
      REAL HEXT(12)     ! AVERAGE MONTHLY DAILY EXTRATERRESTRIAL RAD.,KJ/M2
      REAL HOR,HR,HRX    ! TYP.DAY TOTAL HORIZ KJ/M2,HOUR OF DAY,HOUR(FOR
ERBS)
      REAL I,IH,IHB     ! CURRENT,HOURLY GLOBAL HORIZ.IRRAD W/M2,BEAM PORTON
      REAL IHD,IL,ILR    ! DIFFUSE HOURLY HORIZ. IRRAD,LIGHT CUR.,REF.LIGHT CUR
      REAL IHIGH,ILOW    ! TEMPORARY CURRENT BOUNDS IN BISECTION SEARCH
      REAL I_MAX,IMR     ! MAX-POWER CURRENT,REFERENCE MAX-POWER CURRENT
      REAL IMXN,IMXO     ! TEMPORARY MAX-POWER CURRENTS IN NEWTON'S SOLU-
TION
      REAL INEW,IOLD     ! TEMPORARY CURRENTS IN NEWTON'S SOLUTION(&BISECT)
      REAL IO,IOREF     ! REVERSE SATURATION CURRENT, REFERENCE REV.SAT.CUR.
      REAL ISCR,ISTAR    ! SHORT-CIRCUIT CUR.,PUMP/MOTOR-ARRAY INTERSECTION
CUR
      REAL ISTARN,ISTARO  ! TEMPORARY CURRENTS IN NEWTON'S SOLUTION FOR
PUMPS
      REAL IT_MO(12)     ! TILTED SURFACE INSOLATION IN KWH PER MONTH
      REAL ITTYPD(12,31)  ! TILTED SURFACE INSOLATION IN KWH PER TYPICAL DAY
      REAL IT(12,31,24)   ! HOURLY TILTED SURFACE IRRADIANCE, W/M2
      REAL KMAX,KMIN     ! CONSTANTS FOR BENDT CORRELATION
      REAL KT,KTBAR(12)  ! CLEARNESS INDEX, MONTHLY AVG. CLEARNESS INDEX
      REAL KTYEAR       ! YRLY AVG KT-HARDWIRED INPUT USED TO EST. OPTIMUM
C                 ! ANNUAL FIXED LOAD RESISTANCE
      REAL LAT,MAX_MO(12) ! LATITUDE,MAX-POWER KWH/MONTH
      REAL MAX_YR,MISC   ! MAX-POWER KWH/YEAR,TEMPER. COEF.:SHORT-CIRCUIT
CUR.
      REAL MPC,MULT(12)   ! TEMPER.COEF.:MAX-POWER,TYP.DAY MULTIPLIER/MONTH
      REAL NP,NS,OM      ! # PARALLEL STRINGS,# UNITS PER STRING,HOUR ANGLE
      REAL OMSET(12),PI   ! AVG.SUNSET HOUR ANGLE/MONTH,3.14159
      REAL PUMPED,PVKWH   ! YEARLY M3 WATER PUMPED,YEARLY KWH DIRECT-COU-
PLED
      REAL Q_BZ,R       ! ELECTRON CHARGE/BOLTZMANN CONSTANT,LOAD RESISTANCE
      REAL RB,RD        ! RATIO OF TILT/HORIZ BEAM RAD,RATIO OF HOURLY
C                 !    DIFFUSE ENERGY TO DAILY DIFFUSE ENERGY
      REAL RLOPT        ! PRELIM. ESTIMATE OF OPT. YRLY FIXED LOAD RESISTANCE
      REAL RHO,RS       ! GROUND REFLECTIVITY,SERIES RESISTANCE
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      REAL RT,SERCELL    ! RATIO:HOURLY/DAILY GLOBAL,SERIES CELLS/UNIT
      REAL SIMPMAX       ! HOURLY MAX POWER USING SIMPLE LINEAR METHOD
      REAL SL,SUNNOCT    ! SLOPE BETWEEN PUMP I-V PAIRS,IRRAD.:NOCT CONDITIONS
      REAL SUNREF,TANOCT ! REFERENCE IRRADIANCE W/M2,NOCT TEST AMBIENT
TEMP,K
      REAL TAU_AL,TA(12,31,24) ! TRANS.-ABSORPT. PRODUCT,ERBS AMB.TEMP,K
      REAL TAVG(12),TC   ! AVG.MONTHLY AMBIENT TEMP,K,CELL TEMPERATURE, K
      REAL TCNOCT,TCR    ! CELL TEMP AT NOCT CONDITIONS, CELL TEMP AT REFER-
ENCE
      REAL TYPMAX(12,31) ! MAX-POWER KWH PER TYPICAL DAY SEGMENT BY MONTH
      REAL V,V_MAX,VMR   ! VOLTAGE, MAX-POWER VOLTAGE,REFERENCE MAX-POWER
VOLT.
      REAL VOC,VOCR      ! OPEN CIRCUIT VOLTAGE,REFERENCE OPEN CIRCUIT VOLTAGE
      REAL VOL(20)       ! PUMP LOAD VOLTAGE INPUTS (20 ALLOWED)
      REAL WATER(12)     ! M3 WATER PUMPED BY MONTH
C **** THE FOLLOWING VARIABLES ARE USED IN THE BISECTION METHOD TO GET RS
*
      REAL MVOC          ! TEMP. COEFF. OF OPEN CIRCUIT VOLTAGE
      REAL RSUP,GAMUP,IOUP,FUP,AUP,RSLOW,GAMLOW,ALOW,IOLOW,FLW,RSNEW,
     >    GAMNEW,ANEW,IONEW,FNEW
C
C ***** THIS SECTION INTERACTIVELY ASKS FOR LOCATION AND OPENS INPUT
C ***** AND OUTPUT FILES
C
      WRITE(*,*) 'THIS SIMPLIFIED PV PERFORMANCE ESTIMATION PROGRAM'
      WRITE(*,*) 'USES MONTHLY AVG. CLEARNESS INDEX AND AMBIENT'
      WRITE(*,*) 'TEMPERATURE DATA, AND FROM IT, GENERATES HOURLY DATA'
      WRITE(*,*) 'TO MODEL MONTHLY AND YEARLY OUTPUT FOR DIRECT-'
      WRITE(*,*) 'COUPLED PHOTOVOLTAIC SYSTEMS FOR VARIOUS'
      WRITE(*,*) 'LOADS.  FOR COMPARISON, THE EXPECTED OUTPUT'
      WRITE(*,*) 'IN THE MAX-POWER MODE IS ALSO CALCULATED'
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER THE NUMBER OF THE LOCATION'
 2    WRITE(*,*) ' '
      WRITE(*,*) '1 IS FOR MADISON'
      WRITE(*,*) '2 IS FOR NASHVILLE'
      WRITE(*,*) '3 IS FOR ALBUQUERQUE'
      WRITE(*,*) '4 IS FOR MIAMI'
      WRITE(*,*) '5 IS FOR NEW YORK CITY'
      WRITE(*,*) '6 IS FOR SEATTLE'
      READ(*,*) LOC
      IF(LOC.EQ.1) THEN
      LAT=43.1 !! MADISON LATITUDE !!
      KTYEAR=0.4889 ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]SIMPMAD.OUT',STATUS='NEW') !!OUTPUT FILE!!
      WRITE(10,*)' '
      WRITE(10,*)'       THIS PERFORMANCE ESTIMATE IS FOR MADISON, WI'
      OPEN(15,FILE='KTMAD.INP',STATUS='OLD',READ ONLY)
C
      ELSE IF(LOC.EQ.2) THEN
      LAT=36.1 !! NASHVILLE LATITUDE !!
      KTYEAR=0.4750 ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]SIMPNASH.OUT',STATUS='NEW') !!OUTPUT FILE!!
      WRITE(10,*)' '
      WRITE(10,*)'       THIS PERFORMANCE ESTIMATE IS FOR NASHVILLE, TN'
      OPEN(15,FILE='KTNASH.INP',STATUS='OLD',READ ONLY)
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C
      ELSE IF(LOC.EQ.3) THEN
      LAT=35.0 !! ALBUQUERQUE LATITUDE !!
      KTYEAR=0.7005 ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]SIMPALB.OUT',STATUS='NEW') !!OUTPUT FILE!!
      WRITE(10,*)' '
      WRITE(10,*)'    THIS PERFORMANCE ESTIMATE IS FOR ALBUQUERQUE, NM'
      OPEN(15,FILE='KTALB.INP',STATUS='OLD',READ ONLY)
C
      ELSE IF(LOC.EQ.4) THEN
      LAT=25.8 !! MIAMI LATITUDE !!
      KTYEAR=0.5237 ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]SIMPMIA.OUT',STATUS='NEW') !!OUTPUT FILE!!
      WRITE(10,*)' '
      WRITE(10,*)'      THIS PERFORMANCE ESTIMATE IS FOR MIAMI, FL'
      OPEN(15,FILE='KTMIA.INP',STATUS='OLD',READ ONLY)
C
      ELSE IF(LOC.EQ.5) THEN
      LAT=40.8 !! NEW YORK CITY LATITUDE !!
      KTYEAR=0.4364 ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]SIMPNYC.OUT',STATUS='NEW') !!OUTPUT FILE!!
      WRITE(10,*)' '
      WRITE(10,*)'      THIS PERFORMANCE ESTIMATE IS FOR NEW YORK, NY'
      OPEN(15,FILE='KTNYC.INP',STATUS='OLD',READ ONLY)
C
      ELSE IF(LOC.EQ.6) THEN
      LAT=47.5 !! SEATTLE LATITUDE !!
      KTYEAR=0.4246 ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]SIMPSEA.OUT',STATUS='NEW') !!OUTPUT FILE!!
      WRITE(10,*)' '
      WRITE(10,*)'      THIS PERFORMANCE ESTIMATE IS FOR SEATTLE, WA'
      OPEN(15,FILE='KTSEA.INP',STATUS='OLD',READ ONLY)
C
      ELSE
      WRITE(*,*) 'TRY ENTERING THE CITY NUMBER AGAIN'
      GO TO 2
      END IF
C ***** THE NEXT LINE READS THE DATA FOR THE SELECTED CITY **********
      READ(15,*) (KTBAR(K),TAVG(K),K=1,12) !!TAVG IN DEGREES KELVIN!!
C
      WRITE(*,*) ' '
      WRITE(*,*) 'HOW MANY SEGMENTS WILL THE Kt CURVE BE SPLIT INTO ?'
      READ(*,*) SEG
      WRITE(*,*) ' '
C ***** THIS SECTION INTERACTIVELY ASKS FOR THE MODULE TYPE, NUMBER
C ***** AND ELECTRICAL ARRANGEMENT, AND ORIENTATION
C
      WRITE(*,*) ' '
      WRITE(*,*) 'THE FOLLOWING UNIT TYPES ARE AVAILABLE:'
      WRITE(*,*) '1= 44 W KYOCERA PSA 100H-361H module'
      WRITE(*,*) '2= 30 W MOBIL RA 30 module'
      WRITE(*,*) '3= 30 W SOLAREX MSX-30 module '
      WRITE(*,*) '4= 640 W BARN.MUNI,SERIES STRING OF 4 MOBIL RA 180s'
      WRITE(*,*) '5= 500 W BARN.RESID. SERIES STRING OF 13 ARCO M-53s'
      WRITE(*,*) '6= 1900 W BARN.PARK, 2 PARALLEL w/5 SERIES MOBIL 180s'
      WRITE(*,*) '7= 4500 W SWRES TRISOLAR ARRAY (AT 52 C, 992 W/M2)'
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      WRITE(*,*) '8= 4500 W SWRES TRISOLAR ARRAY (AT 39 C, 1125 W/M2)'
      WRITE(*,*) '9= 4500 W SWRES TRISOLAR ARRAY (AT 47.6 C, 1018 W/M2)'
      WRITE(*,*) '   TRISOLAR ARRAY=2 PAR X 22 SER. APPLIED SOLAR MODS.'
      WRITE(*,*) '10= 43 W PGandE ARCO M52'
      WRITE(*,*) '11= 71 W PGandE APPLIED SOLAR 60-3062'
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER THE NUMBER CORRESPONDING TO THE MODULE TYPE'
      READ(*,*) MODULETYPE
C ***** SERCELL IS THE # OF SERIES CELLS PER UNIT(for units 1 to 11)
      IF(MODULETYPE.EQ.1) THEN
      OPEN(20,FILE='MODULE1.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ELSEIF(MODULETYPE.EQ.2) THEN
      OPEN(20,FILE='MODULE2.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ELSEIF(MODULETYPE.EQ.3) THEN
      OPEN(20,FILE='MODULE3.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ELSEIF(MODULETYPE.EQ.4) THEN
      OPEN(20,FILE='MODULE4.DAT',STATUS='OLD',READ ONLY)
      SERCELL=704.
      ELSEIF(MODULETYPE.EQ.5) THEN
      OPEN(20,FILE='MODULE5.DAT',STATUS='OLD',READ ONLY)
      SERCELL=468.
      ELSEIF(MODULETYPE.EQ.6) THEN
      OPEN(20,FILE='MODULE6.DAT',STATUS='OLD',READ ONLY)
      SERCELL=660.
      ELSEIF(MODULETYPE.EQ.7) THEN
      OPEN(20,FILE='MODULE7.DAT',STATUS='OLD',READ ONLY)
      SERCELL=418.
      ELSEIF(MODULETYPE.EQ.8) THEN
      OPEN(20,FILE='MODULE8.DAT',STATUS='OLD',READ ONLY)
      SERCELL=418.
      ELSEIF(MODULETYPE.EQ.9) THEN
      OPEN(20,FILE='MODULE9.DAT',STATUS='OLD',READ ONLY)
      SERCELL=418.
      ELSEIF(MODULETYPE.EQ.10) THEN
      OPEN(20,FILE='MODULE10.DAT',STATUS='OLD',READ ONLY)
      SERCELL=12.
      ELSEIF(MODULETYPE.EQ.11) THEN
      OPEN(20,FILE='MODULE11.DAT',STATUS='OLD',READ ONLY)
      SERCELL=34.
      ENDIF
      READ(20,3) MODEL
3     FORMAT(A50)
      READ(20,*) (ISCR,VOCR,TCR,SUNREF,VMR,IMR,MISC,MVOC,TCNOCT,
     *          SUNNOCT,TANOCT,EG,AREA)
      WRITE(*,*) ' '
      WRITE(*,*) 'THE FILE NAMED "MODULE.DAT" INDICATES YOU WILL BE'
      WRITE(*,*) 'USING THE FOLLOWING TYPE OF MODULE AS THE BASIC UNIT:'
      WRITE(*,*) ' '
      WRITE(*,*) MODEL
      WRITE(*,*) ' '
      WRITE(*,*) ' '
      WRITE(*,*) 'HOW MANY PARALLEL STRINGS OF THESE DO YOU WANT?'
      READ(*,*) NP
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      WRITE(*,*) ' '
      WRITE(*,*) 'HOW MANY BASIC UNITS WILL BE WIRED IN SERIES IN EACH'
      WRITE(*,*) 'STRING?'
      READ(*,*) NS
      WRITE(*,*) ' '
      WRITE(*,*) 'WHAT IS THE COLLECTOR SLOPE IN DEGREES?'
      READ(*,*) BETA
      WRITE(*,*) ' '
C
C ***** THIS SECTION IDENTIFIES THE TYPE OF LOAD **********************
C
      WRITE(*,*) 'WHAT TYPE OF LOAD WILL BE SERVED ?'
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER 1 FOR RESISTIVE LOADS'
      WRITE(*,*) 'ENTER 2 FOR DC MOTOR/PUMP LOADS'
      WRITE(*,*) 'ENTER 3 FOR CONSTANT VOLTAGE LOADS'
      WRITE(*,*) ' '
      READ(*,*) LOADTYPE
      IF(LOADTYPE.EQ.1) THEN
      WRITE(*,*) 'WHAT RANGE OF ELECTRICAL LOAD RESISTANCES (OHMS)'
      WRITE(*,*) 'DO YOU WISH TO RUN THE SIMULATION FOR ?'
      WRITE(*,*) ' '
C
      RLOPT=VMR*NS*SUNREF/(IMR*NP*1353*KTYEAR)
C
      WRITE(*,*) 'NOTE: AN APPROXIMATE OPTIMAL LOAD RESISTANCE'
      WRITE(*,*) 'IS ABOUT',RLOPT,'OHMS'
      WRITE(*,*) ' '
      WRITE(*,*) 'THE CORRESPONDING QUADRANT ANGLE W/RESP. TO THE'
      WRITE(*,*) 'V-AXIS IS:'
      WRITE(*,*) ATAND(1./RLOPT),'DEGREES'
      WRITE(*,*) ' '
      WRITE(*,*) 'THE RESISTANCES IN OHMS WILL RANGE FROM (LOWEST):'
      WRITE(*,*) 'must use integer amounts !'
      READ(*,*) R_INIT
      WRITE(*,*) ' '
      WRITE(*,*) 'TO (HIGHEST):'
      READ(*,*) R_FINAL
      WRITE(*,*) ' '
      WRITE(*,*)'OVER AN INCREMENT OF:'
      READ(*,*) R_INCR
      WRITE(*,*)' '
      ELSE IF(LOADTYPE.EQ.2) THEN
      WRITE(*,*) 'WHAT TYPE OF PUMP/MOTOR COMBO ?'
      WRITE(*,*) ' '
      WRITE(*,*) '1 = 4000 W CENT.WATER PUMP/5000 W PERM.MAG.MOTOR'
      WRITE(*,*) '2 = 4000 W CENT.WATER PUMP/5000 W SERIES MOTOR'
      WRITE(*,*) '3 = 700 W CENT. FAN/1100 W SERIES MOTOR'
      WRITE(*,*) '4 = 700 W CENT. FAN/1100 W PERM. MAG. MOTOR'
      WRITE(*,*) '5 = 700 W CENT. FAN/1100 W SHUNT MOTOR'
      WRITE(*,*) '6 = 50 W MONO/SUNTRON POS.DISPL.PUMP/PERM. MAG.MOTOR'
      READ(*,*) PMTYPE
      IF(PMTYPE.EQ.1) THEN
      OPEN(31,FILE='CENPPM.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.2) THEN
      OPEN(31,FILE='CENPSR.DAT',STATUS='OLD',READ ONLY)
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      ELSE IF(PMTYPE.EQ.3) THEN
      OPEN(31,FILE='CENFSR.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.4) THEN
      OPEN(31,FILE='CENFPM.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.5) THEN
      OPEN(31,FILE='CENFSH.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.6) THEN
      OPEN(31,FILE='PDPUMP.DAT',STATUS='OLD',READ ONLY)
      END IF
      READ(31,4) PAIRS
 4    FORMAT(T3,I2)
      DO 6 J=1,PAIRS
      READ(31,5) CUR(J),VOL(J),FLOW(J)
 5    FORMAT(T3,F6.3,T10,F6.2,T18,F5.2)
 6    CONTINUE
      ELSE IF(LOADTYPE.EQ.3) THEN
      WRITE(*,*) ' '
      WRITE(*,*) 'WHAT CONSTANT VOLTAGE WILL BE USED ?'
      READ(*,*) FIXVOL
      END IF
      WRITE(*,*) ' '
C
C ***** THIS SECTION ASKS FOR SOME MODULE CHARACTERISTICS AND
C ***** Kt DISTRIBUITON CHOICES
C
      WRITE(*,*) 'ENTER A VALUE FOR THE TEMPERATURE COEFFICIENT OF'
      WRITE(*,*) 'THE MAX POWER POINT (TRY 0.0035 to 0.0055 ?)'
      READ(*,*) MPC
C
C ***** THIS SECTION INITIALIZES SOME VARIABLES *****
      PI=3.14159
      MO=1
      Q_BZ=11604.45 !! UNITS ARE DEGREES K/VOLT !!
      EFFREF=IMR*VMR/(SUNREF*AREA) !! REFERENCE MAX-POWER EFFICIENCY !!
      TAU_AL=0.9  !! TRANSMITTANCE-ABSORPTANCE PRODUCT !!
      RHO=0.2  !! GROUND REFLECTANCE !!
      MAX_FLAG=0 !! COUNTER TO REDUCE CPU TIME BY CALCULATING
C             !! MAX-POWER CALCULATIONS ONLY ONCE
      DO 40 L=1,12
      ALTMAX(L)=0. !! THIS IS THE MONTHLY SUM OF MAX POWER OUTPUT
C           !! USING SIEGEL et al.'s SIMPLIFIED METHOD
 40   CONTINUE
C
      DAVG(1)=17.
      DAVG(2)=47.    !! FOR EACH MONTH, AN AVERAGE DAY IS CHOSEN
      DAVG(3)=75.    !! AND THE ASSOCIATED DAY-OF-THE-YEAR IS
      DAVG(4)=105.   !! LISTED FOR EACH MONTH
      DAVG(5)=135.
      DAVG(6)=162.
      DAVG(7)=198.
      DAVG(8)=228.
      DAVG(9)=258.
      DAVG(10)=288.
      DAVG(11)=318.
      DAVG(12)=344.
      MULT(1)=31./(FLOAT(SEG))
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      MULT(2)=28./(FLOAT(SEG))
      MULT(3)=31./(FLOAT(SEG))  !! THESE ARE MULTIPLIERS USED TO
      MULT(4)=30./(FLOAT(SEG))  !! CONSTRUCT A FULL MONTH OF
      MULT(5)=31./(FLOAT(SEG))  !! OUTPUT WITH LESS THAN A FULL
      MULT(6)=30./(FLOAT(SEG))  !! MONTH WORTH OF TYPICAL DAYS
      MULT(7)=31./(FLOAT(SEG))  !! i.e., SEGMENTS
      MULT(8)=31./(FLOAT(SEG))
      MULT(9)=30./(FLOAT(SEG))
      MULT(10)=31./(FLOAT(SEG))
      MULT(11)=30./(FLOAT(SEG))
      MULT(12)=31./(FLOAT(SEG))
C
C ***** THE NEXT SECTION CALCULATES ALL FOUR UNKNOWN PARAMETERS **
C ***** IT FIRST ESTIMATES THE SERIES RESISTANCE USING A BISECTION METHOD
C
      RSUP=((SERCELL*TCR*LOG(1.-IMR/ISCR)/Q_BZ)+VOCR-VMR)/IMR
      AUP=1.
      GAMUP=SERCELL
      IOUP=ISCR*EXP(-Q_BZ*VOCR/(GAMUP*TCR))
      RSLOW=0.0
      GAMLOW=Q_BZ*(VMR-VOCR)/(TCR*LOG(1.-IMR/ISCR))
      ALOW=GAMLOW/SERCELL
      IOLOW=ISCR*EXP(-Q_BZ*VOCR/(GAMLOW*TCR))
      DO WHILE ((ABS(RSUP-RSLOW)).GT.0.0005)
      RSNEW=0.5*(RSUP+RSLOW)
      GAMNEW=Q_BZ*(VMR-VOCR+IMR*RSNEW)/(TCR*LOG(1.-IMR/ISCR))
      ANEW=GAMNEW/SERCELL
      IONEW=ISCR*EXP(-Q_BZ*VOCR/(GAMNEW*TCR))
      FUP=-MVOC+(GAMUP/Q_BZ)*(LOG(1.+ISCR/IOUP)+(TCR/(ISCR+IOUP))*
     >   (MISC-ISCR*((Q_BZ*EG/(AUP*TCR*TCR))+3./TCR)))
      FLW=-MVOC+(GAMLOW/Q_BZ)*(LOG(1.+ISCR/IOLOW)+(TCR/(ISCR+IOLOW))*
     >   (MISC-ISCR*((Q_BZ*EG/(ALOW*TCR*TCR))+3./TCR)))
      FNEW=-MVOC+(GAMNEW/Q_BZ)*(LOG(1.+ISCR/IONEW)+(TCR/(ISCR+IONEW))*
     >   (MISC-ISCR*((Q_BZ*EG/(ANEW*TCR*TCR))+3./TCR)))
      IF((FLW*FNEW).LT.0.0) RSUP=RSNEW
      IF((FLW*FNEW).GT.0.0) RSLOW=RSNEW
      GAMUP=Q_BZ*(VMR-VOCR+IMR*RSUP)/(TCR*LOG(1.-IMR/ISCR))
      AUP=GAMUP/SERCELL
      IOUP=ISCR*EXP(-Q_BZ*VOCR/(GAMUP*TCR))
      GAMLOW=Q_BZ*(VMR-VOCR+IMR*RSLOW)/(TCR*LOG(1.-IMR/ISCR))
      ALOW=GAMLOW/SERCELL
      IOLOW=ISCR*EXP(-Q_BZ*VOCR/(GAMLOW*TCR))
      END DO
      RS=RSNEW
      GAM=GAMNEW
      IO=IONEW
      ILR=ISCR/(1.-EXP(Q_BZ*(ISCR*RS-VOCR)/(GAM*TCR)))
C     GAM=(Q_BZ/TCR)*((2.*VMR)-VOCR)/((IMR/(ISCR-IMR))+LOG(1.-
C    >   IMR/ISCR))
C     ILR=ISCR/(1.-EXP(Q_BZ*(ISCR*RS-VOCR)/(GAM*TCR)))
C     IOREF=ILR/(EXP(Q_BZ*VOCR/(GAM*TCR))-1.)
C     RS=((GAM*TCR/Q_BZ)*LOG(1.-IMR/ILR)+VOCR-VMR)/IMR
      WRITE(*,*)' '
      WRITE(*,*) 'THE UNIT SERIES RESISTANCE WAS CALCULATED TO BE:'
      WRITE(*,*) RS,'OHMS'
      WRITE(*,*)' '
```

```
      WRITE(*,*) 'IF THIS VALUE IS NEGATIVE OR SEEMS INCORRECT, THEN'
      WRITE(*,*) 'YOU CAN OVERRIDE THIS CALCULATION AND ENTER YOUR'
      WRITE(*,*) 'OWN ESTIMATE BY TYPING "YES" BELOW.  DO YOU WANT'
      WRITE(*,*) 'TO ENTER ANOTHER VALUE FOR Rs ?'
      READ(*,10) OVERRIDE
   10  FORMAT(A1)
      IF((OVERRIDE.EQ.'Y').OR.(OVERRIDE.EQ.'y')) THEN
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER A VALUE FOR UNIT SERIES RESISTANCE, IN OHMS'
      WRITE(*,*) 'NOTE: AN APPROXIMATE UNIT VALUE SHOULD BE:'
      WRITE(*,*)  0.056*(7.183/5.389)*(VMR/IMR),'OHMS'
      READ(*,*) RS
      END IF
      GAM=Q_BZ*(VMR-VOCR+IMR*RS)/(TCR*LOG(1.-IMR/ISCR))
      ILR=ISCR/(1.-EXP(Q_BZ*(ISCR*RS-VOCR)/(GAM*TCR)))
      IOREF=ILR/(EXP(Q_BZ*VOCR/(GAM*TCR))-1.)
      WRITE(*,*)'ILR=',ILR
      WRITE(*,*)'IOREF',IOREF
      WRITE(*,*)'GAM',GAM
      WRITE(*,*) '        each value is on a unit, not array, basis'
      ILR=NP*ILR !! THIS SETS ILR FOR THE ENTIRE SYSTEM !!
      IOREF=NP*IOREF !! THIS SETS IOREF FOR THE ENTIRE SYSTEM !!
      GAM=NS*GAM !! THIS SETS GAMMA FOR THE SYSTEM !!
      RS=(NS/NP)*RS !! THIS SETS THE SYSTEM SERIES RESISTANCE !!
      A=GAM/(NS*SERCELL) !! "A" IS THE SINGLE CELL IMPERFECTION FACTOR!
      WRITE(*,*) 'A=',A
C
C ***** THIS BEGINS THE OVERALL DAILY LOOP  ****
C
      RES=R_INIT
   50  R=FLOAT(RES) !! THIS IS WHERE THE PROGRAM RETURNS TO FOR MULTIPLE
C                RESISTANCE LEVEL RUNS !!
      DO 120 MO=1,12
C
      DECL(MO)=23.45*SIND((360./365.)*(284.+DAVG(MO)))
      OMSET(MO)=ACOSD(TAND(LAT)*TAND(DECL(MO))*(-1.))
      HEXT(MO)=(24.*3600./PI)*(1.+0.033*COSD(360.*DAVG(MO)/365.))*
     *        1.353*(COSD(LAT)*COSD(DECL(MO))*SIND(OMSET(MO))+
     *        (2.*PI*OMSET(MO)/360.)*SIND(LAT)*SIND(DECL(MO)))
C
C ***** DECL=DECLINATION,OMSET=SUNSET HOUR ANGLE,HEXT=EXTRATERRESTRI-
AL**
C ***** HEXT(MO) IS IN KJ/M2.DAY BASED ON THE AVERAGE DAY OF A MONTH ***
C ***** (FROM DUFFIE&BECKMAN)
C ***** THE NEXT SECTION COMPUTES THE KT VALUE FOR EACH SEGMENT ********
C ***** AND ALSO THE DIFFUSE FRACTION FOR EACH SEGMENT         *******
C ***** ADAPTED FROM BENDT'S CORRELATION AND DUFFIE&BECKMAN  *********
C
      KMIN=0.05
      KMAX=0.6313+0.267*KTBAR(MO)-11.9*((ABS(KTBAR(MO)-0.75))**8.)
      CGAM=(KMAX-KMIN)/(KMAX-KTBAR(MO))
      GAM2=-1.498+(1.184*CGAM-27.182*EXP(CGAM*(-1.5)))/(KMAX-KMIN)
C
C ***** CPR_A AND CPR_B AND "DENOM" ARE COEFFICIENTS (FROM COLLARES-
C ***** PEREIRA AND RABL) TO BE USED IN CALCULATING AN HOURLY FRACTION
C ***** OF DAILY TOTAL RADIATION
```

```
      CPR_A=0.409+0.5016*SIND(OMSET(MO)-60.0)
      CPR_B=0.6609-0.4767*SIND(OMSET(MO)-60.0)
      DENOM=SIND(OMSET(MO))-(PI*OMSET(MO)/180.)*COSD(OMSET(MO))
C
      FRAC=-.5/(FLOAT(SEG)) !! THIS PROVIDES A STARTING POINT FOR FRAC,
C           THE FRACTION OF DAYLIGHT TIME IN A MONTH FOR
C           0<KT(FRAC)<KT, IN THE FOLLOWING LOOP
C
      DO 110 J=1,SEG
      FRAC=FRAC+1./(FLOAT(SEG))
      KT=(1./GAM2)*LOG(((1.-FRAC)*EXP(GAM2*KMIN))+(FRAC*EXP(GAM2*KMAX)))
      IF(KT.LT.0.0) KT=0.0
      IF(KT.GT.1.0) KT=1.0
      HOR=KT*HEXT(MO) !!TOTAL HORIZ. KJ/M^2 PER "TYPICAL DAY" SEGMENT!!
C ***** NEXT, CALCULATE DAILY DIFFUSE KJ/M2 *****
      IF(KT.LE.0.17) HD_H=0.99
      IF((KT.GT.0.17).AND.(KT.LT.0.75)) THEN
      HD_H=1.188-2.272*KT+9.473*(KT**2)-21.865*(KT**3)+14.648*
     >    (KT**4)  !! FROM COLLARES-PEREIRA&RABL !!
      END IF
      IF((KT.GE.0.75).AND.(KT.LT.0.80)) HD_H=0.632-0.54*KT
      IF(KT.GE.0.80) HD_H=0.2
      HD=HD_H*HOR  !! KJ/M^2 OF DIFFUSE PER "TYP. DAY" SEGMENT !!
      DO 100 H=1,24
      HR=FLOAT(H)
      OM=(HR-12.5)*15.  !! OM=HOUR ANGLE (DEG) AT MIDPOINT OF HOUR !!
      IF(ABS(OM).LE.OMSET(MO)) THEN
      RT=(PI/24.)*(CPR_A+CPR_B*COSD(OM))*(COSD(OM)-COSD(OMSET(MO)))
     >   /DENOM
      RD=(PI/24.)*(COSD(OM)-COSD(OMSET(MO)))/DENOM
      IH=RT*HOR  !! KJ/M^2 PER HOUR TOTAL HORIZONTAL !!
      IHD=RD*HD  !! KJ/M^2 PER HOUR DIFFUSE !!
      IF(IHD.GT.IH) IHD=IH  !! THIS PREVENTS AN OCCASIONAL SMALL NEG
C                   !! VALUE AT HIGH HOUR ANGLES, WHICH SHOULD
C                   !! BE IMPOSSIBLE EXCEPT FOR THE APPROXI-
C                   !! MATIONS USED IN MONTHLY AVERAGING
      IHB=IH-IHD  !! KJ/M^2 PER HOUR BEAM !!
      RB=(COSD(DECL(MO))*COSD(OM)*COSD(LAT-BETA)+SIND(LAT-BETA)*
     *   SIND(DECL(MO)))/
     *   (COSD(LAT)*COSD(DECL(MO))*COSD(OM)+SIND(LAT)*SIND(DECL(MO)))
C ***** THE FOLLOWING STATEMENT LIMITS THE TILTED SURFACE CALCULATION**
C ***** TO HOURS WITH REALISTIC VALUES OF Rb *****
      IF((RB.LT.0.0).OR.(RB.GT.10.)) THEN
      IT(MO,J,H)=0.0
      ELSE
      IT(MO,J,H)=(IHB*RB+IHD*0.5*(1.+COSD(BETA))+
     *   IH*RHO*0.5*(1.-COSD(BETA)))/(3.6)
C ***** THE FOLLOWING CODE USES ERBS' CORRELATION TO GET A DIURNAL
C ***** TEMPERATURE PROFILE
      HRX=(HR-1.0)*PI/12.0
      TA(MO,J,H)=TAVG(MO)+(25.8*KT-5.21)*(0.4632*COS(HRX-3.805)
     >       +0.0984*COS(2.*HRX-0.36)+0.0168*COS(3.*HRX-0.822)
     >       +0.0138*COS(4.*HRX-3.513))
      END IF
C  ***** IT(MO,J,H)= WATTS/M^2; (CONSTANT OVER ONE HOUR)********
      ELSE
```

```
      IT(MO,J,H)=0.0
      END IF
  100 CONTINUE
  110 CONTINUE
  120 CONTINUE
C ***** AT THIS POINT, THE TEMP. AND TILT RAD. ARE KNOWN FOR
C ***** EACH HOUR OF EACH MONTH FOR EACH SEGMENT (OR "TYPICAL DAY")
C
C ***** THIS BEGINS THE PV POWER CALCULATIONS ************************
C
      DO 410 MO=1,12
      DO 405 J=1,SEG
      DO 400 H=1,24
  130 IF(IT(MO,J,H).GT.0.0) THEN
C ***** THIS PART CALCULATES THE CELL TEMPERATURE  *****
      TC=TA(MO,J,H)+IT(MO,J,H)*((TCNOCT-TANOCT)/SUNNOCT)*(1.0-
     *                    (EFFREF/TAU_AL))
C ***** THIS PART CALCULATES THE LIGHT CURRENT, IL ********
      IL=(IT(MO,J,H)/SUNREF)*(ILR+MISC*NP*(TC-TCR))
      IF (IL.LT.0.0) IL=0.0 !!SAFEGUARD AGAINST NEGATIVE CURRENT!!
C ***** THIS PART CALCULATES THE REVERSE SATURATION CURRENT, IO ****
      IO=IOREF*((TC/TCR)**3.)*EXP((Q_BZ*EG/A)*((1/TCR)-(1/TC)))
C ***** THIS PART CALCULATES THE OPEN-CIRCUIT VOLTAGE, VOC *********
      VOC=GAM*TC*LOG((IL/IO)+1.0)/Q_BZ
C ***** THIS PART CALCULATES THE MAX-POWER CURRENT & VOLTAGE
C ***** USING NEWTON'S METHOD TO SOLVE FOR THE MAX-POWER VOLTAGE *
      IF(MAX_FLAG.EQ.0.0) THEN
      IMXO=0.0
      IMXN=(IT(MO,J,H)/SUNREF)*NP*(IMR+MISC*(TC-TCR)) !!A FIRST GUESS!!
      DO WHILE (ABS(IMXN-IMXO).GT.0.00005)
      IMXO=IMXN
      F1=IMXO+(IMXO-IL-IO)*(LOG((IL-IMXO+IO)/IO)-IMXO*Q_BZ*RS/(GAM*TC
     >  ))/(1.+(IL-IMXO+IO)*(Q_BZ*RS/(GAM*TC)))
      F1P=2.+(LOG((IL-IMXO+IO)/IO)-(Q_BZ*RS*IMXO/(GAM*TC)))/
     >   ((1.+(IL-IMXO+IO)*(Q_BZ*RS/(GAM*TC)))**2.)
      IMXN=IMXO-(F1/F1P)
      END DO
      I_MAX=IMXN
      V_MAX=LOG(1.+(IL-I_MAX)/IO)*(TC*GAM/Q_BZ)-I_MAX*RS
C ***** THIS PART CALCULATES THE ARRAY OUTPUT FOR MAX-POWER MODE **
      E_MAX(MO,J,H)=I_MAX*V_MAX*0.001  !! KWH PER HOUR !!
C
C ***** THIS SECTION CALCULATES THE MAX POWER OUTPUT VIA SIEGEL,
C ***** KLEIN, AND BECKMAN'S SIMPLIFIED METHOD AS USED IN PVFCHART
C * * * ALTMAX IS IN KILOWATT-HRS AND IS SUMMED CONTINUOUSLY TO GET A
C * * * YEARLY TOTAL
C
      SIMPMAX=IT(MO,J,H)*NS*NP*IMR*VMR*(1.-MPC*(TC-TCR))*0.001/SUNREF
      ALTMAX(MO)=ALTMAX(MO)+SIMPMAX
      END IF !!THIS IF BLOCK BEGAN WITH THE IF MAX_FLAG=0.0 STATEMENT!!
C ***** THIS PART USES NEWTON'S METHOD TO SOLVE FOR THE CURRENT *****
C ***** FOR THE DIFFERENT DIRECT-COUPLED LOAD TYPES ****************
C
      IF(LOADTYPE.EQ.1) THEN
      IOLD=0
C ***** THE FOLLOWING CALC. PREPARES AN INITIAL GUESS FOR THE OPERATING
```

```
C ***** POINT CURRENT BASED ON A COMPARISON OF THE LOAD RESISTANCE TO
C ***** A MORE OPTIMAL LOAD RESISTANCE AT THIS IRRADIANCE
C
    IF(R.GE.(V_MAX/I_MAX)) THEN
    INEW=V_MAX/R  !! GUESS FOR OPERATING POINT CURRENT !!
    ELSE
    INEW=I_MAX+(IL-I_MAX)*((R-(V_MAX/I_MAX))/(-(V_MAX/I_MAX)))
    END IF
    DO WHILE ((ABS(INEW-IOLD)).GT.0.00005)
    IOLD=INEW
    F2=IL+IO-IOLD-IO*EXP(Q_BZ*(R+RS)*IOLD/(GAM*TC))
    F2P=-1.-IO*(Q_BZ*(R+RS)/(GAM*TC))*EXP(Q_BZ*(R+RS)*IOLD
   >    /(GAM*TC))
    INEW=IOLD-(F2/F2P)
    END DO
    I=INEW
C ***** THIS PART CALCULATES THE MODULE VOLTAGE FOR RESISTIVE LOADS **
    V=I*R
C
    ELSE IF(LOADTYPE.EQ.2) THEN
C
    IF((VOL(1).GT.VOC).OR.(CUR(1).GT.IL)) THEN
    E(MO,J,H)=0.0
    GO TO 380
    END IF
C
    ISTARO=0.0
    IF(VOL(1).LE.V_MAX) THEN
    ISTARN=(IL+I_MAX)/2. !! GUESS BETWEEN IL AND I_MAX !!
    ELSE
    ISTARN=I_MAX*(1.-(VOL(1)-V_MAX)/(VOC-V_MAX))
    END IF
    DO WHILE ((ABS(ISTARN-ISTARO)).GT.0.00005)
    ISTARO=ISTARN
    F3=IL-ISTARO+IO-IO*EXP(Q_BZ*(VOL(1)+ISTARO*RS)/(GAM*TC))
    F3P=-1.-IO*(Q_BZ*RS/(GAM*TC))*EXP(Q_BZ*(VOL(1)+ISTARO*RS)
   >    /(GAM*TC))
    ISTARN=ISTARO-(F3/F3P)
    END DO
    ISTAR=ISTARN
    IF(ISTAR.LT.CUR(1)) THEN
    E(MO,J,H)=0.0
    GO TO 380
    END IF
    DO 350 K=1,(PAIRS-1) !! OR ELSE JUMP OUT WHEN SOLUTION IS FOUND !!
    SL=(CUR(K+1)-CUR(K))/(VOL(K+1)-VOL(K))
    C=VOL(K)-(CUR(K)/SL)
    IF((SL.LE.0.0).AND.
   >  (C.GE.VOC)) THEN
    APPROACH='BISECT' !USE BISECTION SEARCH METHOD!
    ELSE IF((SL.LE.0.0).AND.((-SL*C).GE.(IL*0.999)).AND.
   >  (C.LT.VOC)) THEN
    GO TO 350
    ELSE
    APPROACH='NEWTON'
    END IF
```

```
      IF(APPROACH.EQ.'BISECT') THEN
      IHIGH=CUR(K)
      ILOW=SL*(VOC-C)
      INEW=0.0
      DO WHILE ((ABS(IHIGH-ILOW)).GT.0.0005)
      INEW=0.5*(IHIGH+ILOW)
      F4H=IL+IO-IHIGH-IO*EXP((Q_BZ/(GAM*TC))*(C+IHIGH*(RS+1./SL)))
      F4L=IL+IO-ILOW-IO*EXP((Q_BZ/(GAM*TC))*(C+ILOW*(RS+1./SL)))
      F4NEW=IL+IO-INEW-IO*EXP((Q_BZ/(GAM*TC))*(C+INEW*(RS+1./SL)))
      IF((F4L*F4NEW).LT.0.0) IHIGH=INEW
      IF((F4L*F4NEW).GT.0.0) ILOW=INEW
      IF((F4L*F4NEW).EQ.0.0) THEN
      I=INEW
      GO TO 250
      END IF
      END DO
      I=0.5*(ILOW+IHIGH)
  250 V=C+(I/SL)
      END IF
      IF(APPROACH.EQ.'NEWTON') THEN
      IOLD=0.0
C ***** GUESSES FOR CURRENT, BASED ON SLOPES&INTERCEPTS, ARE CALC'TD NEXT
**
      IF((SL.LT.(I_MAX/V_MAX)).AND.((-C*SL).GT.0.0)) THEN
      IF((SL*(V_MAX-C)).GT.I_MAX) THEN
      INEW=SL*(V_MAX-C)  ! GUESS FOR CURRENT WHEN INTERSECT IS ABOVE I_MAX!
      IF(INEW.GT.IL) INEW=IL*0.999 !LIMITS THE GUESS TO APPROX. Isc !!
      ELSE
      INEW=SL*(V_MAX+(VOC-V_MAX)*(-C/(VOC-C))-C)
C ***** THIS PROVIDES A LEVERAGED GUESS BASED ON THE X-INTERCEPT MAGNI-
TUDE
C ***** RELATIVE TO THE OPEN-CIRCUIT VOLTAGE
      END IF
      ELSE IF((SL.LT.(I_MAX/V_MAX)).AND.((-C*SL).LE.0.0)) THEN
      INEW=SL*(V_MAX-C)
      ELSE IF((SL.GE.(I_MAX/V_MAX)).AND.((-C*SL).GT.0.0)) THEN
      INEW=(IL+I_MAX)/2.
      ELSE IF((SL.GE.(I_MAX/V_MAX)).AND.((-C*SL).LE.0.0)) THEN
      IF((SL*(V_MAX-C)).GT.I_MAX) THEN
      INEW=(IL+I_MAX)/2.
      ELSE
      INEW=SL*(V_MAX-C)
      END IF
      END IF
      DO WHILE ((ABS(INEW-IOLD)).GT.0.0005)
      IOLD=INEW
      F4=IL+IO-IOLD-IO*EXP((Q_BZ/(GAM*TC))*(C+IOLD*(RS+1./SL)))
      F4P=-1.-IO*EXP((Q_BZ/(GAM*TC))*(IOLD*(RS+1./SL)+C))*
     >    (RS+1./SL)*(Q_BZ/(GAM*TC))
      INEW=IOLD-(F4/F4P)
      END DO
      I=INEW
      V=C+(I/SL)
      END IF
      IF((V.GE.VOL(K)).AND.(V.LE.VOL(K+1))) THEN
C ***** UNITS OF FLOW(K) ARE M3/HOUR
```

```
      WATER(MO)=WATER(MO)+(FLOW(K)+(FLOW(K+1)-FLOW(K))*(I-CUR(K))/
     >    (CUR(K+1)-CUR(K))) !!INTERPOLATION TO FIND FLOW RATE!!
      GO TO 370
      END IF
  350 CONTINUE
      E(MO,J,H)=0.0
      GO TO 380
      ELSE IF(LOADTYPE.EQ.3) THEN
      V=FIXVOL
      IF(V.GT.VOC) THEN
      E(MO,J,H)=0.0
      GO TO 380
      END IF
      IOLD=0.0
      INEW=IL-IO*(EXP(Q_BZ*V/(GAM*TC))-1.0) !! GUESS !!
      DO WHILE((ABS(INEW-IOLD)).GT.0.00005)
      IOLD=INEW
      F5=IL-IOLD+IO-IO*EXP(Q_BZ*(V+IOLD*RS)/(GAM*TC))
      F5P=-1.-IO*(Q_BZ*RS/(GAM*TC))*EXP(Q_BZ*(V+IOLD*RS)/(GAM*TC))
      INEW=IOLD-(F5/F5P)
      END DO
      I=INEW
      IF(I.LT.0.0) I=0.0
      END IF
C ***** THIS PART CALCULATES THE ARRAY WORK (KWH) OUTPUT *********
C ***** FOR THE DIRECT-COUPLED MODE **********
  370 E(MO,J,H)=I*V*0.001
      END IF !! THIS IF BLOCK BEGAN AT STATEMENT #130 !!
  380 CONTINUE
  400 CONTINUE
  405 CONTINUE
  410 CONTINUE
C
C ***** AT THIS POINT,THE AVG. OUTPUT FOR EACH HOUR OF EACH TYPICAL DAY,
C ***** FOR EACH MONTH, IS KNOWN, ALONG WITH THE CORRESPONDING MAX-
C ***** POWER OUTPUT. ALSO, THE SIMPLIFIED MAX-POWER AMOUNTS
C ***** AND THE WATER PUMPED ARE KNOWN OVER THE REDUCED MONTH
C ***** EACH OF THE SUMMED TYP. DAY OUTPUTS NEEDS TO BE
C ***** MULTIPLIED BY THE MULTIPLIER FOR THAT MONTH.
C ***** THIS SECTION SUMMARIZES AND PRINTS OUT THE RESULTS *******
      DO 500 J=1,12
      DO 475 L=1,SEG
      DO 450 K=1,24
      ETYPDAY(J,L)=ETYPDAY(J,L)+E(J,L,K) !!UNITS ARE KWH/TYPDAY
      IF(MAX_FLAG.EQ.0.0) TYPMAX(J,L)=TYPMAX(J,L)+E_MAX(J,L,K)
C     !! UNITS=KWH/TYPDAY
      ITTYPD(J,L)=ITTYPD(J,L)+IT(J,L,K)*0.001 !! KWH/M2*TYPDAY
C ***** ITTYPD IS IN kWH/M2."TYP DAY SEGMENT"  *********
  450 CONTINUE
  475 CONTINUE
  500 CONTINUE
      DO 550 J=1,12
      DO 525 L=1,SEG
      E_MO(J)=E_MO(J)+ETYPDAY(J,L)*MULT(J) !! KWH/MONTH
      IT_MO(J)=IT_MO(J)+ITTYPD(J,L)*MULT(J) !! KWH/M2*MONTH
      IF(MAX_FLAG.EQ.0.0) MAX_MO(J)=MAX_MO(J)+TYPMAX(J,L)*MULT(J)
```

```
C     !! KWH/MONTH
 525  CONTINUE
      IF(MAX_FLAG.EQ.0.0) ALTMAX(J)=ALTMAX(J)*MULT(J)
      WATER(J)=WATER(J)*MULT(J)
 550  CONTINUE
      DO 560 J=1,12
      PVKWH=PVKWH+E_MO(J) !! KWH/YEAR
      IF(MAX_FLAG.EQ.0.0) MAX_YR=MAX_YR+MAX_MO(J) !! KWH/YEAR
      PUMPED=PUMPED+WATER(J)
      IF(MAX_FLAG.EQ.0.0) ALTMAX_YR=ALTMAX_YR+ALTMAX(J)
 560  CONTINUE
      WRITE(10,571)MODEL,NP,'IN PARALLEL',NS,'IN SERIES'
 571  FORMAT(2X,A30,2X,F4.0,A12,2X,F4.0,A10)
      IF(LOADTYPE.EQ.3) THEN
      WRITE(10,572) 'LOAD VOLTAGE=',FIXVOL,'  SLOPE=',BETA,' DEGREES'
 572  FORMAT(3X,A13,F6.1,4X,A9,F4.1,A9)
      ELSE IF(LOADTYPE.EQ.1) THEN
      WRITE(10,573)'RESISTANCE=',R,' OHMS ',' SLOPE=',BETA,' DEGREES'
 573  FORMAT(3X,A11,F5.1,A6,A8,F4.1,A9)
      ELSE IF(LOADTYPE.EQ.2) THEN
      WRITE(10,574)'PUMP/MOTOR TYPE:',PMTYPE,'   SLOPE=',BETA,' DEGREES'
 574  FORMAT(3X,A16,I1,A9,F4.1,A8)
      END IF
      WRITE(10,575)'MAX POWER TEMP. COEFFICIENT =',MPC,
     *          'TYPICAL DAY SEGMENTS =',SEG
 575  FORMAT(3X,A29,F6.4,3X,A22,I2)
      WRITE(10,*)' '
      WRITE(10,576)'MO','PV KWH',
     *     'MAX KWH','POA KWH','T AVG(C)','Kt-bar',
     *      'WATER m3'
 576  FORMAT(5X,A2,7X,A6,5X,A7,5X,A7,1X,A8,1X,A6,4X,A8)
      DO 580 J=1,12
      WRITE(10,577) J,E_MO(J),MAX_MO(J),IT_MO(J)*AREA*NS*NP,
     *          TAVG(J)-273.15,KTBAR(J),
     *          WATER(J)
 577  FORMAT(5X,I2,3X,F9.2,3X,F9.2,3X,F9.2,3X,F5.1,3X,F5.3,
     *    3X,F9.0)
 580  CONTINUE
      WRITE(10,*)'YEARLY TOTAL PV KWH OUTPUTS FOR DIRECT-COUPLED,
     > ANALYTICAL MAX-POWER, AND'
      WRITE(10,*)'SIMPLIFIED MAX POWER CALC. MODES ARE:'
      WRITE(10,585) PVKWH,MAX_YR,ALTMAX_YR
 585  FORMAT(5X,F10.1,5X,F10.1,5X,F10.1)
      WRITE(10,586) 'THE EFFECTIVENESS IS =',
     >         PVKWH/MAX_YR
 586  FORMAT(1X,A22,3X,F5.3)
      WRITE(10,*) 'YEARLY CU.METERS OF WATER PUMPED =',PUMPED
      MAX_FLAG=1.
      PUMPED=0.
      PVKWH=0.0
      DO 588 J=1,12
      WATER(J)=0.0
      E_MO(J)=0.0
      MAX_MO(J)=0.0
      IT_MO(J)=0.0
      DO 587 L=1,31
```

```
      ETYPDAY(J,L)=0.0
      ITTYPD(J,L)=0.0
  587 CONTINUE
  588 CONTINUE
      IF((LOADTYPE.EQ.1).AND.(RES.LT.R_FINAL)) THEN
      RES=RES+R_INCR
      GO TO 50
      END IF
  590 CONTINUE
C
      IF(LOC.EQ.1) THEN
      WRITE(*,*)'THIS SIMULATION IS FOR MADISON, WI'
      ELSEIF(LOC.EQ.2) THEN
      WRITE(*,*)'THIS SIMULATION IS FOR NASHVILLE, TN'
      ELSEIF(LOC.EQ.3) THEN
      WRITE(*,*)'THIS SIMULATION IS FOR ALBUQUERQUE, NM'
      ELSEIF(LOC.EQ.4) THEN
      WRITE(*,*)'THIS SIMULATION IS FOR MIAMI, FL'
      ELSEIF(LOC.EQ.5) THEN
      WRITE(*,*)'THIS SIMULATION IS FOR NEW YORK, NY'
      ELSEIF(LOC.EQ.6) THEN
      WRITE(*,*)'THIS SIMULATION IS FOR SEATTLE, WA'
      END IF
      WRITE(*,*) 'THE RESULTS CAN BE SEEN BY TYPING THE FOLLOWING:'
      WRITE(*,*) 'TYPE [TIM.RESULTS]SIMP____.OUT,
     > (WHERE THE ____ IS EITHER'
      WRITE(*,*) 'MAD,NASH,ALB,MIA,NYC, or SEA)'
  600 CONTINUE
      END
```

DCPVDET PROGRAM FORTRAN CODE

```
C ***** DETAILED HOURLY DIRECT-COUPLED PHOTOVOLTAIC SIMULATION PROGRAM
C
C ***** TIM TOWNSEND, UNIVERSITY OF WISCONSIN-MADISON; FALL 1988
C
C ***** THIS PROGRAM SIMULATES THE OUTPUT FOR EACH HOUR OF
C ***** A "TMY", BASED ON DIFFERENT LOADS W/NO STORAGE.
C ***** IT RELIES ON INPUT FILES GENERATED SEPARATELY AND
C ***** READ BY THIS PROGRAM.  THE INPUT FILES ARE OF THE FORM
C ***** "MODULEx.DAT" FOR x FROM 1 TO 11.
C ***** THE PROGRAM WILL ALSO GENERATE A MONTHLY Kt DISTRIBUTION.
C ***** THE PROGRAM ALSO COMPUTES THE MAXIMUM POWER POINT OUTPUT
C ***** VIA AN ANALYTICAL METHOD DEVELOPED BY TOWNSEND AND VIA A
C ***** SIMPLIFIED LINEAR METHOD AS USED IN PV-fCHART AND PVFORM.
C ***** THE CELL MODEL IS A LUMPED 4 PARAMETER VERSION WHICH INCLUDES
C ***** SERIES RESISTANCE.  EACH OF THE 4 UNKNOWN UNIT PARAMETERS,
C ***** INCLUDING SERIES RESISTANCE, ARE SOLVED FOR AUTOMATICALLY.
C ***** THE SERIES RESISTANCE IS PRINTED TO THE SCREEN AND
C ***** THE USER MAY OVERRIDE THE VALUE WITH A MANUAL INPUT, AFTER
C ***** WHICH EACH OF THE OTHER 3 PARAMETERS ARE RECALCULATED AT
C ***** A REFERENCE IRRADIANCE AND CELL TEMPERATURE.  OTHER RELATIONSHIPS
C ***** ARE THEN EMPLOYED TO CALCULATE THE VARIATION IN THE CELL
C ***** PARAMETERS AS FUNCTIONS OF IRRADIANCE AND CELL TEMPERATURE.
C ***** THE RESULT IS A COMPLETE I-V EXPRESSION AT ANY IRRADIANCE
C ***** AND CELL TEMPERATURE.
C ***** THE PARAMETERS ARE THE LIGHT-GENERATED CURRENT, THE REVERSE
C ***** SATURATION CURRENT, GAMMA (A MEASURE OF CELL IMPERFECTION),
C ***** AND SERIES RESISTANCE.  BOTH SERIES RESISTANCE AND GAMMA
C ***** ARE ASSUMED CONSTANT AT ALL CONDITIONS.  THE REVERSE SAT.
C ***** CURRENT IS ASSUMED TO BE A FUNCTION OF TEMPERATURE, AND THE LIGHT
C ***** CURRENT IS ASSUMED TO BE A FUNCTION OF IRRADIANCE AND TEMPERA-
TURE.
C
C
C ***** THIS SECTION IDENTIFIES ALL VARIABLES *****************
      IMPLICIT NONE      ! ALLOWS ONLY DECLARED VARIABLE NAMES
      CHARACTER*6 APPROACH ! INDICATOR FOR PUMP LOADS TO FIND OPER. POINT
      CHARACTER*50 MODEL  ! NAME OF SELECTED MODULE OR ARRAY FROM DATA
      CHARACTER*3 KT_FLAG ! KT DISTRIBUTION ON/OFF SELECTOR
      CHARACTER*3 OVERRIDE ! ALLOWS USER TO SPECIFY A MANUAL Rseries
      INTEGER DM,DY,H    ! DAY OF MONTH, DAY OF YEAR, HOUR OF DAY
      INTEGER HRM        ! HOUR OF MONTH COUNTER
      INTEGER J,K,L,M    ! LOOP COUNTERS
      INTEGER LOADTYPE,LOC ! LOADTYPE, LOCATION
      INTEGER MAX_FLAG   ! SAVES CPU TIME BY ONLY CALC. MAX POWER ONCE
      INTEGER MO,MODULETYPE ! MONTH, MODULE/ARRAY SELECTED
      INTEGER PAIRS      ! # OF I-V DATA PAIRS FOR MOTOR LOADS
      INTEGER PMTYPE,RES  ! PUMP/MOTOR TYPE, LOAD RESISTANCE IN OHMS
      INTEGER R_FINAL,R_INCR,R_INIT ! LAST,INCREMENT,&FIRST LOADS, OHMS
C **** FOLLOWING VARIABLES ARE USED IN THE BISECTION METHOD TO GET RS *****
      REAL MVOC          ! TEMP. COEFF. OF OPEN CIRCUIT VOLTAGE
      REAL RSUP,GAMUP,IOUP,FUP,AUP,RSLOW,GAMLOW,ALOW,IOLOW,FLW,RSNEW,
     >    GAMNEW,ANEW,IONEW,FNEW
C *******
```

```
      REAL A,ALTMAX     ! IMPERFECTION FACTOR,YEARLY KWH TOTAL BY SIMPLE
C                 ! LINEAR MAX-POWER CALC METHOD (PV-fCHART)
      REAL AREA         ! UNIT AREA, M2
      REAL AVMTEMP(12)  ! AVG. MONTHLY AMBIENT KELVIN TEMPERATURE
      REAL BETA,C       ! COLLECTOR SLOPE,CONSTANT IN PUMPING CALCS
      REAL CUR(20)      ! PUMP LOAD CURRENT INPUTS (20 ALLOWED)
      REAL DAY          ! DAY OF YEAR
      REAL DECL,DF      ! DECLINATION,HOURLY DIFFUSE FRACTION
      REAL EAVG(12,24)  ! AVG. DIRECT COUPLED KWH FOR EACH HOUR OF A MONTH
      REAL EFFREF       ! REFERENCE MAX-POWER EFFICIENCY
      REAL E(12,31,24),EG ! DIRECT-COUPLED KWH BY HOUR,BANDGAP ENERGY VOLTS
      REAL E_MAX(12,31,24) ! MAX POWER KWH BY HOUR
      REAL E_MAXAV(12,24) ! AVG. MAX-POWER KWH BY HOUR OF DAY BY MONTH
      REAL E_MAXSUM(12,24) ! TOTAL MAX-POWER KWH BY HOUR OF DAY BY MONTH
      REAL ESUM(12,24)  ! TOTAL DIRECT COUPLED KWH BY HOUR OF DAY BY MONTH
      REAL EXTRA        ! HOURLY EXTRATERRESTRIAL INSOLATION KJ/M2.HR
      REAL FIXVOL,FLOW(20) !FIXED LOAD VOLTAGE,PUMP FLOWRATE INPUTS (MAX 20)
      REAL FRAC         ! ONE DAY'S FRACTION OF TOTAL MONTHLY HOURS
      REAL F1,F1P,F2,F2P,F3,F3P,F4,F4P,F5,F5P !OBJ.FUNCTIONS AND THEIR
C                 ! DERIVATIVES IN VARIOUS NEWTON'S METHOD ROUTINES
      REAL F4H,F4L,F4NEW  ! OBJ. FUNCTIONS IN BISECTION SEARCH ROUTINES
      REAL GAM          ! UNIT LEVEL CURVE FIT FACTOR
      REAL HEXT(12)     ! MONTHLY TOTAL EXTRATERRESTRIAL RAD.,KJ/M2
      REAL HORZ,HR      ! DAILY TOTAL HORIZ KJ/M2,HOUR OF DAY
      REAL IEXT         ! HOURLY EXTRATERRESTRIAL INSOL KJ/M2.HR
      REAL I,IH(12,31,24) ! CURRENT,HOURLY GLOBAL HORIZ.INSOL KJ/M2.HR
      REAL IHAVG(12,24)  ! AVG. HORIZ KJ/M2 FOR EACH HOUR OF DAY BY MONTH
      REAL IHIGH,ILOW    ! TEMPORARY CURRENT BOUNDS IN BISECTION SEARCH
      REAL IHSUM(12,24)  ! TOTAL HORIZ KJ/M2 FOR EACH HOUR OF DAY BY MONTH
      REAL IHTEMP       ! TEMPORARY VALUE:HOURLY HORIZ KJ/M2 FROM TMY FILE
      REAL IL,ILR       ! LIGHT CURRENT,REFERENCE LIGHT CURRENT
      REAL I_MAX,IMR    ! MAX-POWER CURRENT,REFERENCE MAX-POWER CURRENT
      REAL IMXN,IMXO    ! TEMPORARY MAX-POWER CURRENTS IN NEWTON'S SOLU-
TION
      REAL INEW,IOLD    ! TEMPORARY CURRENTS IN NEWTON'S SOLUTION (& FALSI)
      REAL IO,IOREF     ! REVERSE SATURATION CURRENT, REFERENCE REV.SAT.CUR.
      REAL ISCR,ISTAR   ! SHORT-CIRCUIT CUR.,PUMP/MOTOR-ARRAY INTERSECTION
CUR
      REAL ISTARN,ISTARO  ! TEMPORARY CURRENTS IN NEWTON'S SOLUTION FOR
PUMPS
      REAL KT,KTDAY(12,31) ! HOURLY CLEARNESS INDEX, DAILY CLEARNESS INDEX
      REAL KTYEAR       ! YRLY AVG. KT-HARDWIRED INPUT USED TO EST. OPTIMUM
C                 ! ANNUAL FIXED LOAD RESISTANCE
      REAL LAT,MAXKWH(12) ! LATITUDE,MAX-POWER KWH/MONTH
      REAL MAX_TOTAL,MISC ! MAX-POWER KWH/YEAR,TEMPER. COEF.:SHORT-CIRCUIT
CUR.
      REAL MPC          ! TEMPER.COEF.:MAX-POWER
      REAL NP,NS,OM     ! # PARALLEL STRINGS,# UNITS PER STRING,HOUR ANGLE
      REAL PVKWH(12)    ! DIRECT-COUPLED KWH BY MONTH
      REAL PV_TOTAL     ! YEARLY SUM DIRECT-COUPLED KWH
      REAL PUMPED       ! YEARLY M3 WATER PUMPED
      REAL Q_BZ,R       ! ELECTRON CHARGE/BOLTZMANN CONSTANT,LOAD RESISTANCE
      REAL RB           ! RATIO OF TILT/HORIZ BEAM RAD
      REAL RHO,RS       ! GROUND REFLECTIVITY,SERIES RESISTANCE
      REAL RLOPT        ! PRELIM. EST. OF OPT. YRLY FIXED LOAD RESISTANCE
      REAL SERCELL      ! # SERIES CELLS/UNIT
```

```
      REAL SIMPMAX      ! HOURLY MAX POWER USING SIMPLE LINEAR METHOD
      REAL SL,SUNNOCT    ! SLOPE BETWEEN PUMP I-V PAIRS,IRRAD.:NOCT CONDITIONS
      REAL SUN(12,31,24) ! HOURLY TILTED SURFACE IRRADIANCE, W/M2
      REAL SUNAVG(12,24) ! AVG. TILT INSOL KJ/M2.HR BY HOUR OF DAY BY MONTH
      REAL SUNB,SUND     ! HORIZ BEAM INSOL. KJ/M2.HR,HORIZ DIFFUSE KJ/M2.HR
      REAL SUNSUM(12,24) ! TOTAL TILT KJ/M2 INSOL FOR EACH HOUR OVER EACH
MONTH
      REAL SUNREF,TANOCT ! REFERENCE IRRADIANCE W/M2,NOCT TEST AMBIENT
TEMP,K
      REAL TAU_AL       ! TRANSMITTANCE-ABSORPTANCE PRODUCT
      REAL TA(12,31,24),TC ! HOURLY AMBIENT TEMP,K,CELL TEMPERATURE,K
      REAL TAAVG(12,24)  ! AVG. AMBIENT KELVIN TEMP. BY HOUR OF DAY BY MONTH
      REAL TATEMP       ! TEMPORARY AMBIENT TEMP. FROM TMY FILE,DEGREES C X 10
      REAL TCNOCT,TCR    ! CELL TEMP AT NOCT CONDITIONS, CELL TEMP AT REFER-
ENCE
      REAL THORIZ(12)    ! TOTAL MONTHLY HORIZONTAL INSOLATION IN KJ/M2
      REAL TTILT(12)     ! TOTAL MONTHLY TILTED INSOLATION IN KJ/M2
      REAL TMAXKT,T2MAXKT ! TEMPORARY VALUES OF KT USED IN KT DISTRIBUTION
LOGIC
      REAL V,V_MAX,VMR   ! VOLTAGE, MAX-POWER VOLTAGE,REFERENCE MAX-POWER
VOLT.
      REAL VOC,VOCR      ! OPEN CIRCUIT VOLTAGE,REFERENCE OPEN CIRCUIT VOLTAGE
      REAL VOL(20)       ! PUMP LOAD VOLTAGE INPUTS (20 ALLOWED)
      REAL WATER(12)     ! M3 WATER PUMPED BY MONTH
C
C ***** THIS SECTION INTERACTIVELY ASKS FOR LOCATION AND OPENS INPUT
C ***** AND OUTPUT FILES
C
      WRITE(*,*) 'THIS HOURLY PV SIMULATION PROGRAM USES TMY DATA'
      WRITE(*,*) 'TO MODEL MONTHLY AND YEARLY OUTPUT FOR DIRECT-'
      WRITE(*,*) 'COUPLED PHOTOVOLTAIC SYSTEMS FOR VARIOUS'
      WRITE(*,*) 'LOADS.  FOR COMPARISON, THE EXPECTED OUTPUT'
      WRITE(*,*) 'IN THE MAX-POWER MODE IS ALSO CALCULATED'
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER THE NUMBER OF THE SIMULATION LOCATION'
2     WRITE(*,*) ' '
      WRITE(*,*) '1 IS FOR MADISON'
      WRITE(*,*) '2 IS FOR NASHVILLE'
      WRITE(*,*) '3 IS FOR ALBUQUERQUE'
      WRITE(*,*) '4 IS FOR MIAMI'
      WRITE(*,*) '5 IS FOR NEW YORK CITY'
      WRITE(*,*) '6 IS FOR SEATTLE'
      READ(*,*) LOC
      OPEN(11,FILE='[TIM.RESULTS]KWHMONTH.OUT',STATUS='NEW')
C       ! THIS WRITES ACTUAL,MAX KWH/MO. !
      WRITE(11,*) LOC
      IF(LOC.EQ.1) THEN
      LAT=43.1 !! MADISON LATITUDE !!
      KTYEAR=0.4889  ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]DETMAD.OUT',STATUS='NEW') !! OUTPUT FILE !!
      WRITE(10,*)' '
      WRITE(10,*)'THIS SIMULATION IS FOR MADISON, WI'
      OPEN(15,FILE='USER$DISK2:[TRNSYS.WEATHER]MADISON.ALL',
     >    STATUS='OLD',READ ONLY)
      OPEN(30,FILE='KTMAD.OUT',STATUS='NEW')
C
```

```
      ELSE IF(LOC.EQ.2) THEN
      LAT=36.1 !! NASHVILLE LATITUDE !!
      KTYEAR=0.4750  ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]DETNASH.OUT',STATUS='NEW') !!OUTPUT FILE !!
      WRITE(10,*)' '
      WRITE(10,*)'THIS SIMULATION IS FOR NASHVILLE, TN'
      OPEN(15,FILE='USER$DISK2:[TRNSYS.WEATHER]NASH.ALL',
     >    STATUS='OLD',READ ONLY)
      OPEN(30,FILE='KTNASH.OUT',STATUS='NEW')
C
      ELSE IF(LOC.EQ.3) THEN
      LAT=35.0 !! ALBUQUERQUE LATITUDE !!
      KTYEAR=0.7005  ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]DETALB.OUT',STATUS='NEW') !!OUTPUT FILE !!
      WRITE(10,*)' '
      WRITE(10,*)'THIS SIMULATION IS FOR ALBUQUERQUE, NM'
      OPEN(15,FILE='USER$DISK2:[TRNSYS.WEATHER]ALBUQ.ALL',
     >    STATUS='OLD',READ ONLY)
      OPEN(30,FILE='KTALB.OUT',STATUS='NEW')
C
      ELSE IF(LOC.EQ.4) THEN
      LAT=25.8 !! MIAMI LATITUDE !!
      KTYEAR=0.5237  ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]DETMIA.OUT',STATUS='NEW') !!OUTPUT FILE !!
      WRITE(10,*)' '
      WRITE(10,*)'THIS SIMULATION IS FOR MIAMI, FL'
      OPEN(15,FILE='USER$DISK2:[TRNSYS.WEATHER]MIA.ALL',
     >    STATUS='OLD',READ ONLY)
      OPEN(30,FILE='KTMIA.OUT',STATUS='NEW')
C
      ELSE IF(LOC.EQ.5) THEN
      LAT=40.8 !! NEW YORK CITY LATITUDE !!
      KTYEAR=0.4364  ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]DETNYC.OUT',STATUS='NEW') !!OUTPUT FILE !!
      WRITE(10,*)' '
      WRITE(10,*)'THIS SIMULATION IS FOR NEW YORK, NY'
      OPEN(15,FILE='USER$DISK2:[TRNSYS.WEATHER]NYNY.ALL',
     >    STATUS='OLD',READ ONLY)
      OPEN(30,FILE='KTNYC.OUT',STATUS='NEW')
C
      ELSE IF(LOC.EQ.6) THEN
      LAT=47.5 !! SEATTLE LATITUDE !!
      KTYEAR=0.4246  ! YEARLY KTBAR USED TO ESTIMATE OPTIMUM RESISTIVE LOAD
      OPEN(10,FILE='[TIM.RESULTS]DETSEA.OUT',STATUS='NEW') !!OUTPUT FILE !!
      WRITE(10,*)' '
      WRITE(10,*)'THIS SIMULATION IS FOR SEATTLE, WA'
      OPEN(15,FILE='USER$DISK2:[TRNSYS.WEATHER]SEATLE.ALL',
     >    STATUS='OLD',READ ONLY)
      OPEN(30,FILE='KTSEA.OUT',STATUS='NEW')
C
      ELSE
      WRITE(*,*) 'TRY ENTERING THE CITY NUMBER AGAIN'
      GO TO 2
      END IF
C
C ***** THIS SECTION INTERACTIVELY ASKS FOR THE MODULE TYPE, NUMBER
```

```
C ***** AND ELECTRICAL ARRANGEMENT, AND ORIENTATION
C
      WRITE(*,*) ' '
      WRITE(*,*) 'THE FOLLOWING UNIT TYPES ARE AVAILABLE:'
      WRITE(*,*) '1= 44 W KYOCERA PSA 100H-361H module'
      WRITE(*,*) '2= 30 W MOBIL RA 30 module'
      WRITE(*,*) '3= 30 W SOLAREX MSX-30 module '
      WRITE(*,*) '4= 640 W BARN.MUNI,SERIES STRING OF 4 MOBIL RA 180s'
      WRITE(*,*) '5= 500 W BARN.RESID. SERIES STRING OF 13 ARCO M-53s'
      WRITE(*,*) '6= 1900 W BARN.PARK, 2 PARALLEL w/5 SERIES MOBIL 180s'
      WRITE(*,*) '7= 4500 W SWRES TRISOLAR ARRAY (AT 52 C, 992 W/M2)'
      WRITE(*,*) '8= 4500 W SWRES TRISOLAR ARRAY (AT 39 C, 1125 W/M2)'
      WRITE(*,*) '9= 4500 W SWRES TRISOLAR ARRAY (AT 47.6 C, 1018 W/M2)'
      WRITE(*,*) '   TRISOLAR ARRAY=2 PAR X 22 SER. APPLIED SOLAR MODS.'
      WRITE(*,*) '10= 43 W PGandE ARCO M52'
      WRITE(*,*) '11= 71 W PGandE APPLIED SOLAR 60-3062'
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER THE NUMBER CORRESPONDING TO THE MODULE TYPE'
      READ(*,*) MODULETYPE
C ***** SERCELL IS THE # OF SERIES CELLS PER UNIT(for units 1 to 11)
      IF(MODULETYPE.EQ.1) THEN
      OPEN(20,FILE='MODULE1.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ELSEIF(MODULETYPE.EQ.2) THEN
      OPEN(20,FILE='MODULE2.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ELSEIF(MODULETYPE.EQ.3) THEN
      OPEN(20,FILE='MODULE3.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ELSEIF(MODULETYPE.EQ.4) THEN
      OPEN(20,FILE='MODULE4.DAT',STATUS='OLD',READ ONLY)
      SERCELL=576.
      ELSEIF(MODULETYPE.EQ.5) THEN
      OPEN(20,FILE='MODULE5.DAT',STATUS='OLD',READ ONLY)
      SERCELL=468.
      ELSEIF(MODULETYPE.EQ.6) THEN
      OPEN(20,FILE='MODULE6.DAT',STATUS='OLD',READ ONLY)
      SERCELL=540.
      ELSEIF(MODULETYPE.EQ.7) THEN
      OPEN(20,FILE='MODULE7.DAT',STATUS='OLD',READ ONLY)
      SERCELL=418.
      ELSEIF(MODULETYPE.EQ.8) THEN
      OPEN(20,FILE='MODULE8.DAT',STATUS='OLD',READ ONLY)
      SERCELL=418.
      ELSEIF(MODULETYPE.EQ.9) THEN
      OPEN(20,FILE='MODULE9.DAT',STATUS='OLD',READ ONLY)
      SERCELL=418.
      ELSEIF(MODULETYPE.EQ.10) THEN
      OPEN(20,FILE='MODULE10.DAT',STATUS='OLD',READ ONLY)
      SERCELL=12.
      ELSEIF(MODULETYPE.EQ.11) THEN
      OPEN(20,FILE='MODULE11.DAT',STATUS='OLD',READ ONLY)
      SERCELL=36.
      ENDIF
      READ(20,3) MODEL
3     FORMAT(A50)
```

```
      READ(20,*) (ISCR,VOCR,TCR,SUNREF,VMR,IMR,MISC,MVOC,TCNOCT,
     *          SUNNOCT,TANOCT,EG,AREA)
      WRITE(*,*) ' '
      WRITE(*,*) 'THE FILE NAMED "MODULE.DAT" INDICATES YOU WILL BE'
      WRITE(*,*) 'USING THE FOLLOWING TYPE OF MODULE AS THE BASIC UNIT:'
      WRITE(*,*) ' '
      WRITE(*,*) MODEL
      WRITE(*,*) ' '
      WRITE(*,*) ' '
      WRITE(*,*) 'HOW MANY PARALLEL STRINGS OF THESE DO YOU WANT?'
      READ(*,*) NP
      WRITE(*,*) ' '
      WRITE(*,*) 'HOW MANY BASIC UNITS WILL BE WIRED IN SERIES IN EACH'
      WRITE(*,*) 'STRING?'
      READ(*,*) NS
      WRITE(*,*) ' '
      WRITE(*,*) 'WHAT IS THE COLLECTOR SLOPE IN DEGREES?'
      READ(*,*) BETA
      WRITE(*,*) ' '
C
C
C ***** THIS SECTION IDENTIFIES THE TYPE OF LOAD **********************
C
      WRITE(*,*) 'WHAT TYPE OF LOAD WILL BE SERVED ?'
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER 1 FOR RESISTIVE LOADS'
      WRITE(*,*) 'ENTER 2 FOR DC MOTOR/PUMP LOADS'
      WRITE(*,*) 'ENTER 3 FOR CONSTANT VOLTAGE LOADS'
      WRITE(*,*) ' '
      READ(*,*) LOADTYPE
      IF(LOADTYPE.EQ.1) THEN
      WRITE(*,*) 'WHAT RANGE OF ELECTRICAL LOAD RESISTANCES (OHMS)'
      WRITE(*,*) 'DO YOU WISH TO RUN THE SIMULATION FOR ?'
      WRITE(*,*) ' '
C
      RLOPT=VMR*NS*SUNREF/(IMR*NP*1353*KTYEAR)
C
      WRITE(*,*) 'NOTE: AN APPROXIMATE OPTIMAL MODULE RESISTANCE'
      WRITE(*,*) 'IS ABOUT',RLOPT,'OHMS'
      WRITE(*,*) ' '
      WRITE(*,*) 'THE CORRESPONDING QUADRANT ANGLE W/RESP. TO THE'
      WRITE(*,*) 'V-AXIS IS:'
      WRITE(*,*) ATAND(1./RLOPT),'DEGREES'
      WRITE(*,*) ' '
      WRITE(*,*) 'THE RESISTANCES IN OHMS WILL RANGE FROM (LOWEST):'
      WRITE(*,*) 'must use integer amounts !'
      READ(*,*) R_INIT
      WRITE(*,*) ' '
      WRITE(*,*) 'TO (HIGHEST):'
      READ(*,*) R_FINAL
      WRITE(*,*) ' '
      WRITE(*,*)'OVER AN INCREMENT OF:'
      READ(*,*) R_INCR
      WRITE(*,*)' '
C
      ELSE IF(LOADTYPE.EQ.2) THEN
```

```
      WRITE(*,*) 'WHAT TYPE OF PUMP/MOTOR COMBO ?'
      WRITE(*,*) ' '
      WRITE(*,*) '1 = 4000 W CENT.WATER PUMP/5000 W PERM.MAG.MOTOR'
      WRITE(*,*) '2 = 4000 W CENT.WATER PUMP/5000 W SERIES MOTOR'
      WRITE(*,*) '3 = 700 W CENT. FAN/1100 W SERIES MOTOR'
      WRITE(*,*) '4 = 700 W CENT. FAN/1100 W PERM. MAG. MOTOR'
      WRITE(*,*) '5 = 700 W CENT. FAN/1100 W SHUNT MOTOR'
      WRITE(*,*) '6 = 50 W MONO/SUNTRON POS.DISPL.PUMP/PERM. MAG.MOTOR'
      READ(*,*) PMTYPE
      IF(PMTYPE.EQ.1) THEN
      OPEN(31,FILE='CENPPM.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.2) THEN
      OPEN(31,FILE='CENPSR.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.3) THEN
      OPEN(31,FILE='CENFSR.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.4) THEN
      OPEN(31,FILE='CENFPM.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.5) THEN
      OPEN(31,FILE='CENFSH.DAT',STATUS='OLD',READ ONLY)
      ELSE IF(PMTYPE.EQ.6) THEN
      OPEN(31,FILE='PDPUMP.DAT',STATUS='OLD',READ ONLY)
      END IF
      READ(31,4) PAIRS
 4    FORMAT(T3,I2)
      DO 6 J=1,PAIRS
      READ(31,5) CUR(J),VOL(J),FLOW(J)
 5    FORMAT(T3,F6.3,T10,F6.2,T18,F5.2)
 6    CONTINUE
C
      ELSE IF(LOADTYPE.EQ.3) THEN
      WRITE(*,*) ' '
      WRITE(*,*) 'WHAT CONSTANT VOLTAGE WILL BE USED ?'
      READ(*,*) FIXVOL
      END IF
      WRITE(*,*) ' '
C
C ***** THIS SECTION ASKS FOR SOME MODULE CHARACTERISTICS AND
C ***** Kt DISTRIBUITON CHOICES
C
      WRITE(*,*) 'ENTER A VALUE FOR THE TEMPERATURE COEFFICIENT OF'
      WRITE(*,*) 'THE MAX POWER POINT (TRY 0.002 to 0.005 ?)'
      READ(*,*) MPC
      WRITE(*,*) ' '
      WRITE(*,*)'DO YOU ALSO WISH TO GENERATE A CUMULATIVE Kt
     > DISTRIBUTION ?'
      WRITE(*,*)'CURVE (ON A SEPARATE OUTPUT FILE) ? [YES or NO]'
      READ(*,9) KT_FLAG
 9    FORMAT(A1)
C
C ***** THIS SECTION IDENTIFIES THE RUN FOR THE MONTHLY OUTPUT FILE
      WRITE(11,*) MODULETYPE
      WRITE(11,*) NP
      WRITE(11,*) NS
      WRITE(11,*) BETA
      WRITE(11,*) LOADTYPE
      IF(LOADTYPE.EQ.1) THEN
```

```
      WRITE(11,*) R_INIT
      WRITE(11,*) R_FINAL
      WRITE(11,*) R_INCR
      ELSE IF(LOADTYPE.EQ.2) THEN
      WRITE(11,*) PMTYPE
      ELSE IF(LOADTYPE.EQ.3) THEN
      WRITE(11,*) FIXVOL
      END IF
C
C ***** THIS SECTION INITIALIZES SOME VARIABLES *****
      DM=1
      MO=1
      Q_BZ=11604.45
      EFFREF=IMR*VMR/(SUNREF*AREA)
      TAU_AL=0.9  !! TRANSMITTANCE-ABSORPTANCE PRODUCT !!
      RHO=0.2  !! GROUND REFLECTANCE !!
      MAX_FLAG=0 !! COUNTER TO REDUCE CPU TIME BY CALCULATING
C             !! MAX-POWER CALCULATIONS ONLY ONCE
      ALTMAX=0. !! THIS IS THE CONTINUOUS SUM OF MAX POWER OUTPUT
C           !! USING SIEGEL et al.'s SIMPLIFIED METHOD
C
C ***** THE NEXT SECTION CALCULATES ALL FOUR UNKNOWN PARAMETERS **
C ***** IT FIRST ESTIMATES THE SERIES RESISTANCE USING A BISECTION METHOD
C
      RSUP=((SERCELL*TCR*LOG(1.-IMR/ISCR)/Q_BZ)+VOCR-VMR)/IMR
      AUP=1.
      GAMUP=SERCELL
      IOUP=ISCR*EXP(-Q_BZ*VOCR/(GAMUP*TCR))
      RSLOW=0.0
      GAMLOW=Q_BZ*(VMR-VOCR)/(TCR*LOG(1.-IMR/ISCR))
      ALOW=GAMLOW/SERCELL
      IOLOW=ISCR*EXP(-Q_BZ*VOCR/(GAMLOW*TCR))
      DO WHILE ((ABS(RSUP-RSLOW)).GT.0.0005)
      RSNEW=0.5*(RSUP+RSLOW)
      GAMNEW=Q_BZ*(VMR-VOCR+IMR*RSNEW)/(TCR*LOG(1.-IMR/ISCR))
      ANEW=GAMNEW/SERCELL
      IONEW=ISCR*EXP(-Q_BZ*VOCR/(GAMNEW*TCR))
      FUP=-MVOC+(GAMUP/Q_BZ)*(LOG(1.+ISCR/IOUP)+(TCR/(ISCR+IOUP))*
     >   (MISC-ISCR*((Q_BZ*EG/(AUP*TCR*TCR))+3./TCR)))
      FLW=-MVOC+(GAMLOW/Q_BZ)*(LOG(1.+ISCR/IOLOW)+(TCR/(ISCR+IOLOW))*
     >   (MISC-ISCR*((Q_BZ*EG/(ALOW*TCR*TCR))+3./TCR)))
      FNEW=-MVOC+(GAMNEW/Q_BZ)*(LOG(1.+ISCR/IONEW)+(TCR/(ISCR+IONEW))*
     >   (MISC-ISCR*((Q_BZ*EG/(ANEW*TCR*TCR))+3./TCR)))
      IF((FLW*FNEW).LT.0.0) RSUP=RSNEW
      IF((FLW*FNEW).GT.0.0) RSLOW=RSNEW
      GAMUP=Q_BZ*(VMR-VOCR+IMR*RSUP)/(TCR*LOG(1.-IMR/ISCR))
      AUP=GAMUP/SERCELL
      IOUP=ISCR*EXP(-Q_BZ*VOCR/(GAMUP*TCR))
      GAMLOW=Q_BZ*(VMR-VOCR+IMR*RSLOW)/(TCR*LOG(1.-IMR/ISCR))
      ALOW=GAMLOW/SERCELL
      IOLOW=ISCR*EXP(-Q_BZ*VOCR/(GAMLOW*TCR))
      END DO
      RS=RSNEW
      GAM=GAMNEW
      IO=IONEW
      ILR=ISCR/(1.-EXP(Q_BZ*(ISCR*RS-VOCR)/(GAM*TCR)))
```

```
C     GAM=(Q_BZ/TCR)*((2.*VMR)-VOCR)/((IMR/(ISCR-IMR))+LOG(1.-
C    >   IMR/ISCR))
C     ILR=ISCR/(1.-EXP(Q_BZ*(ISCR*RS-VOCR)/(GAM*TCR)))
C     IOREF=ILR/(EXP(Q_BZ*VOCR/(GAM*TCR))-1.)
C     RS=((GAM*TCR/Q_BZ)*LOG(1.-IMR/ILR)+VOCR-VMR)/IMR
      WRITE(*,*)' '
      WRITE(*,*) 'THE UNIT SERIES RESISTANCE WAS CALCULATED TO BE:'
      WRITE(*,*) RS,'OHMS'
      WRITE(*,*)' '
      WRITE(*,*) 'IF THIS VALUE IS NEGATIVE OR SEEMS INCORRECT, THEN'
      WRITE(*,*) 'YOU CAN OVERRIDE THIS CALCULATION AND ENTER YOUR'
      WRITE(*,*) 'OWN ESTIMATE BY TYPING "YES" BELOW.  DO YOU WANT'
      WRITE(*,*) 'TO ENTER ANOTHER VALUE FOR Rs ?'
      READ(*,10) OVERRIDE
 10   FORMAT(A1)
      IF((OVERRIDE.EQ.'Y').OR.(OVERRIDE.EQ.'y')) THEN
      WRITE(*,*) ' '
      WRITE(*,*) 'ENTER A VALUE FOR UNIT SERIES RESISTANCE, IN OHMS'
      WRITE(*,*) 'NOTE: AN APPROXIMATE UNIT VALUE SHOULD BE:'
      WRITE(*,*)  0.056*(7.183/5.389)*(VMR/IMR),'OHMS'
      READ(*,*) RS
      END IF
      GAM=Q_BZ*(VMR-VOCR+IMR*RS)/(TCR*LOG(1.-IMR/ISCR))
      ILR=ISCR/(1.-EXP(Q_BZ*(ISCR*RS-VOCR)/(GAM*TCR)))
      IOREF=ILR/(EXP(Q_BZ*VOCR/(GAM*TCR))-1.)
      WRITE(*,*)'ILR=',ILR
      WRITE(*,*)'IOREF',IOREF
      WRITE(*,*)'GAM',GAM
      WRITE(*,*) '        each value is on a unit, not array, basis'
      ILR=NP*ILR !! THIS SETS ILR FOR THE ENTIRE SYSTEM !!
      IOREF=NP*IOREF !! THIS SETS IOREF FOR THE ENTIRE SYSTEM !!
      GAM=NS*GAM !! THIS SETS GAMMA FOR THE SYSTEM !!
      RS=(NS/NP)*RS !! THIS SETS THE SYSTEM SERIES RESISTANCE !!
      A=GAM/(NS*SERCELL) !! "A" IS THE SINGLE CELL IMPERFECTION FACTOR!
      WRITE(*,*) 'A=',A
C
C ***** THIS BEGINS THE OVERALL DAILY LOOP  ****
C
      RES=R_INIT
 50   R=FLOAT(RES) !! THIS IS WHERE THE PROGRAM RETURNS TO FOR MULTIPLE
C               RESISTANCE LEVEL RUNS !!
      DO 410 DY=1,365
      DAY=FLOAT(DY)
      DECL=23.45*SIND(360.*(284.+DAY)/365.)
      DO 400 H=1,24
      READ(15,30) MO,HRM,IHTEMP,TATEMP
 30   FORMAT (T2,I2,T5,I3,T15,F4.0,T20,F4.0)
      HR=FLOAT(H)
      DM=1+INT((HRM-1.)/24.)
      TA(MO,DM,H)=(TATEMP/10.0)+273.15
      IH(MO,DM,H)=IHTEMP !! KJ/M2-HR
      OM=(HR-12.5)*15.
      IF(IH(MO,DM,H).GT.0.0) THEN
      IEXT=3.6*1353.*(1.+0.033*COSD(360.*DAY/365.))*(COSD(LAT)*
     *    COSD(DECL)*COSD(OM)+SIND(LAT)*SIND(DECL)) !!KJ/M2-HR
      IF(IEXT.LE.0.0) THEN
```

```
      SUN(MO,DM,H)=0.0
      KT=0.0
      E(MO,DM,H)=0.0
      E_MAX(MO,DM,H)=0.0
      SIMPMAX=0.0
      TC=TA(MO,DM,H)
      GO TO 380
      END IF
C **** EXTRA AND HORZ ARE DAILY TOTALS
      EXTRA=EXTRA+IEXT
      HORZ=HORZ+IH(MO,DM,H)
      HEXT(MO)=HEXT(MO)+IEXT
      KT=IH(MO,DM,H)/IEXT
      ELSE
      SUN(MO,DM,H)=0.0
      KT=0.0
      E(MO,DM,H)=0.0
      E_MAX(MO,DM,H)=0.0
      SIMPMAX=0.0
      TC=TA(MO,DM,H)
      GO TO 380
      END IF
C ****  DIFFUSE FRACTION CALC'S BELOW ARE FROM ORGILL&HOLLANDS *******
      IF (KT.GT.0.75) DF=0.177
      IF ((KT.GE.0.35).AND.(KT.LE.0.75)) DF=1.557-1.84*KT
      IF (KT.LT.0.35) DF=1.0-0.249*KT
C
      SUND=IH(MO,DM,H)*DF
      SUNB=IH(MO,DM,H)*(1.0-DF)
      RB=(COSD(DECL)*COSD(OM)*COSD(LAT-BETA)+SIND(LAT-BETA)*SIND(DECL))
     *   /(COSD(LAT)*COSD(DECL)*COSD(OM)+SIND(LAT)*SIND(DECL))
C ***** THE FOLLOWING STATEMENT LIMITS THE TILTED SURFACE CALCULATION
C ***** TO HOURS WITH REALISTIC VALUES OF Rb ************************
      IF((RB.LT.0.0).OR.(RB.GT.10.0)) THEN
      SUN(MO,DM,H)=0.0
      E(MO,DM,H)=0.0
      E_MAX(MO,DM,H)=0.0
      SIMPMAX=0.0
      TC=TA(MO,DM,H)
      GOTO 380
      END IF
C
C ***** THIS PART CALCULATES THE HOURLY TILTED SURFACE RADIATION *****
C *****              IN WATTS/M^2                    *****
      SUN(MO,DM,H)=(SUNB*RB+SUND*(1.+COSD(BETA))*0.5+IH(MO,DM,H)*RHO*
     >          (1.-COSD(BETA))*0.5)/3.6
C
C ***** THIS BEGINS THE PV POWER CALCULATIONS ***********************
C
      TC=TA(MO,DM,H)+(SUN(MO,DM,H)*(TCNOCT-TANOCT)/SUNNOCT)*(1.-
     >  (EFFREF/TAU_AL))
C
C ***** THIS PART CALCULATES THE LIGHT CURRENT, IL ********
      IL=(SUN(MO,DM,H)/SUNREF)*(ILR+MISC*NP*(TC-TCR))
      IF (IL.LT.0.0) IL=0.0 !! SAFEGUARD AGAINST NEGATIVE CURRENT !!
C ***** THIS PART CALCULATES THE REVERSE SATURATION CURRENT, IO ****
```

```
      IO=IOREF*((TC/TCR)**3)*EXP((Q_BZ*EG/(A))*((1./TCR)-(1./TC)))
C ***** THIS PART CALCULATES THE OPEN-CIRCUIT VOLTAGE, VOC *********
      VOC=TC*GAM*LOG((IL/IO)+1.0)/Q_BZ
C ***** THIS PART CALCULATES THE MAX-POWER CURRENT & VOLTAGE
C ***** USING NEWTON'S METHOD TO SOLVE FOR THE MAX-POWER VOLTAGE *
      IF(MAX_FLAG.EQ.0.0) THEN
      IMXO=0.0
      IMXN=(SUN(MO,DM,H)/SUNREF)*NP*(IMR+MISC*(TC-TCR)) !A FIRST GUESS!
      DO WHILE (ABS(IMXN-IMXO).GT.0.0005)
      IMXO=IMXN
      F1=IMXO+(IMXO-IL-IO)*(LOG((IL-IMXO+IO)/IO)-IMXO*Q_BZ*RS/(GAM*TC
     >  ))/(1.+(IL-IMXO+IO)*(Q_BZ*RS/(GAM*TC)))
      F1P=2.+(LOG((IL-IMXO+IO)/IO)-(Q_BZ*RS*IMXO/(GAM*TC)))/
     >   ((1.+(IL-IMXO+IO)*(Q_BZ*RS/(GAM*TC)))**2.)
      IMXN=IMXO-(F1/F1P)
      END DO
      I_MAX=IMXN
      V_MAX=LOG(1.+(IL-I_MAX)/IO)*(TC*GAM/Q_BZ)-I_MAX*RS
C ***** THIS PART CALCULATES THE ARRAY OUTPUT FOR MAX-POWER MODE **
      E_MAX(MO,DM,H)=I_MAX*V_MAX*0.001  !! KWH PER HOUR !!
C
C ***** THIS SECTION CALCULATES THE MAX POWER OUTPUT VIA SIEGEL,
C ***** KLEIN, AND BECKMAN'S SIMPLIFIED METHOD AS USED IN PVFCHART
C * * * ALTMAX IS IN KILOWATT-HRS AND IS SUMMED CONTINUOUSLY TO GET A
C * * * YEARLY TOTAL
C
      SIMPMAX=SUN(MO,DM,H)*NS*NP*IMR*VMR*(1.-MPC*(TC-TCR))*0.001/SUNREF
      ALTMAX=ALTMAX+SIMPMAX
C
      END IF !!THIS IF BLOCK BEGAN WITH THE IF MAX_FLAG=0.0 STATEMENT!!
C ***** THIS PART USES NEWTON'S METHOD TO SOLVE FOR THE CURRENT *****
C ***** FOR THE DIFFERENT DIRECT-COUPLED LOAD TYPES *****************
C
      IF(LOADTYPE.EQ.1) THEN
      IOLD=0
C ***** THE FOLLOWING CALC. PREPARES AN INITIAL GUESS FOR THE OPERATING
C ***** POINT CURRENT BASED ON A COMPARISON OF THE LOAD RESISTANCE TO
C ***** A MORE OPTIMAL LOAD RESISTANCE AT THIS IRRADIANCE
C
      IF(R.GE.(V_MAX/I_MAX)) THEN
      INEW=V_MAX/R  !! GUESS FOR OPERATING POINT CURRENT !!
      ELSE
      INEW=I_MAX+(IL-I_MAX)*((R-(V_MAX/I_MAX))/(-(V_MAX/I_MAX)))
      END IF
      DO WHILE ((ABS(INEW-IOLD)).GT.0.0005)
      IOLD=INEW
      F2=IL+IO-IOLD-IO*EXP(Q_BZ*(R+RS)*IOLD/(GAM*TC))
      F2P=-1.-IO*(Q_BZ*(R+RS)/(GAM*TC))*EXP(Q_BZ*(R+RS)*IOLD
     >    /(GAM*TC))
      INEW=IOLD-(F2/F2P)
      END DO
      I=INEW
C ***** THIS PART CALCULATES THE MODULE VOLTAGE FOR RESISTIVE LOADS **
      V=I*R
C
C ***** THIS PART CALCULATES THE MODULE CURRENT FOR MOTOR/PUMP LOADS **
```

```
      ELSE IF(LOADTYPE.EQ.2) THEN
C
      IF((VOL(1).GT.VOC).OR.(CUR(1).GT.IL)) THEN
      E(MO,DM,H)=0.0
      GO TO 380
      END IF
C
      ISTARO=0.0
      IF(VOL(1).LE.V_MAX) THEN
      ISTARN=(IL+I_MAX)/2. !! GUESS BETWEEN IL AND I_MAX !!
      ELSE
      ISTARN=I_MAX*(1.-(VOL(1)-V_MAX)/(VOC-V_MAX))
      END IF
      DO WHILE ((ABS(ISTARN-ISTARO)).GT.0.0005)
      ISTARO=ISTARN
      F3=IL-ISTARO+IO-IO*EXP(Q_BZ*(VOL(1)+ISTARO*RS)/(GAM*TC))
      F3P=-1.-IO*(Q_BZ*RS/(GAM*TC))*EXP(Q_BZ*(VOL(1)+ISTARO*RS)
     >    /(GAM*TC))
      ISTARN=ISTARO-(F3/F3P)
      END DO
      ISTAR=ISTARN
      IF(ISTAR.LT.CUR(1)) THEN
      E(MO,DM,H)=0.0
      GO TO 380
      END IF
      DO 350 J=1,(PAIRS-1) !! OR ELSE JUMP OUT WHEN SOLUTION IS FOUND !!
      SL=(CUR(J+1)-CUR(J))/(VOL(J+1)-VOL(J))
      C=VOL(J)-(CUR(J)/SL)
      IF((SL.LE.0.0).AND.
     > (C.GE.VOC)) THEN
      APPROACH='BISECT' !USE BISECTION SEARCH METHOD!
      ELSE IF((SL.LE.0.0).AND.((-SL*C).GE.(IL*0.999)).AND.
     > (C.LT.VOC)) THEN
      GO TO 350
      ELSE
      APPROACH='NEWTON'
      END IF
      IF(APPROACH.EQ.'BISECT') THEN
      IHIGH=CUR(J)
      ILOW=SL*(VOC-C)
      INEW=0.0
      DO WHILE ((ABS(IHIGH-ILOW)).GT.0.0005)
      INEW=0.5*(IHIGH+ILOW)
      F4H=IL+IO-IHIGH-IO*EXP((Q_BZ/(GAM*TC))*(C+IHIGH*(RS+1./SL)))
      F4L=IL+IO-ILOW-IO*EXP((Q_BZ/(GAM*TC))*(C+ILOW*(RS+1./SL)))
      F4NEW=IL+IO-INEW-IO*EXP((Q_BZ/(GAM*TC))*(C+INEW*(RS+1./SL)))
      IF((F4L*F4NEW).LT.0.0) IHIGH=INEW
      IF((F4L*F4NEW).GT.0.0) ILOW=INEW
      IF((F4L*F4NEW).EQ.0.0) THEN
      I=INEW
      GO TO 250
      END IF
      END DO
      I=0.5*(ILOW+IHIGH)
250   V=C+(I/SL)
      END IF
```

```
      IF(APPROACH.EQ.'NEWTON') THEN
      IOLD=0.0
C ***** GUESSES FOR CURRENT, BASED ON SLOPES&INTERCEPTS, ARE CALC'TD NEXT
**
      IF((SL.LT.(I_MAX/V_MAX)).AND.((-C*SL).GT.0.0)) THEN
      IF((SL*(V_MAX-C)).GT.I_MAX) THEN
      INEW=SL*(V_MAX-C)  ! GUESS FOR CURRENT WHEN INTERSECT IS ABOVE I_MAX!
      IF(INEW.GT.IL) INEW=IL*0.999 !LIMITS THE GUESS TO APPROX. Isc !!
      ELSE
      INEW=SL*(V_MAX+(VOC-V_MAX)*(-C/(VOC-C))-C)
C ***** THIS PROVIDES A LEVERAGED GUESS BASED ON THE X-INTERCEPT MAGNI-
TUDE
C ***** RELATIVE TO THE OPEN-CIRCUIT VOLTAGE
      END IF
      ELSE IF((SL.LT.(I_MAX/V_MAX)).AND.((-C*SL).LE.0.0)) THEN
      INEW=SL*(V_MAX-C)
      ELSE IF((SL.GE.(I_MAX/V_MAX)).AND.((-C*SL).GT.0.0)) THEN
      INEW=(IL+I_MAX)/2.
      ELSE IF((SL.GE.(I_MAX/V_MAX)).AND.((-C*SL).LE.0.0)) THEN
      IF((SL*(V_MAX-C)).GT.I_MAX) THEN
      INEW=(IL+I_MAX)/2.
      ELSE
      INEW=SL*(V_MAX-C)
      END IF
      END IF
      DO WHILE ((ABS(INEW-IOLD)).GT.0.0005)
      IOLD=INEW
      F4=IL+IO-IOLD-IO*EXP((Q_BZ/(GAM*TC))*(C+IOLD*(RS+1./SL)))
      F4P=-1.-IO*EXP((Q_BZ/(GAM*TC))*(IOLD*(RS+1./SL)+C))*
     >    (RS+1./SL)*(Q_BZ/(GAM*TC))
      INEW=IOLD-(F4/F4P)
      END DO
      I=INEW
      V=C+(I/SL)
      END IF
      IF((V.GE.VOL(J)).AND.(V.LE.VOL(J+1))) THEN
      WATER(MO)=WATER(MO)+(FLOW(J)+(FLOW(J+1)-FLOW(J))*(V-VOL(J))/
     >    (VOL(J+1)-VOL(J)))
      GO TO 370
      END IF
 350  CONTINUE
      E(MO,DM,H)=0.0
C ***** THIS PART CALCULATES THE MODULE CURRENT FOR FIXED VOLTAGE LOADS
      GO TO 380
      ELSE IF(LOADTYPE.EQ.3) THEN
      V=FIXVOL
      IF(V.GT.VOC) THEN
      E(MO,DM,H)=0.0
      GO TO 380
      END IF
      IOLD=0.0
      INEW=IL-IO*(EXP(Q_BZ*V/(GAM*TC))-1.0) !! GUESS !!
      DO WHILE((ABS(INEW-IOLD)).GT.0.0005)
      IOLD=INEW
      F5=IL-IOLD+IO-IO*EXP(Q_BZ*(V+IOLD*RS)/(GAM*TC))
      F5P=-1.-IO*(Q_BZ*RS/(GAM*TC))*EXP(Q_BZ*(V+IOLD*RS)/(GAM*TC))
```

```
      INEW=IOLD-(F5/F5P)
      END DO
      I=INEW
      IF(I.LT.0.0) I=0.0
      END IF
C ***** THIS PART CALCULATES THE ARRAY WORK (KWH) OUTPUT *********
C ***** FOR THE DIRECT-COUPLED MODE **********
 370  E(MO,DM,H)=I*V*0.001
 380  CONTINUE
 400  CONTINUE
      KTDAY(MO,DM)=HORZ/EXTRA
      EXTRA=0.0
      HORZ=0.0
 410  CONTINUE
C ***** THIS SECTION SUMMARIZES AND PRINTS OUT THE RESULTS *******
      DO 450 J=1,12
      DO 440 K=1,24
      IF((J.EQ.1).OR.(J.EQ.3).OR.(J.EQ.5).OR.(J.EQ.7).OR.(J.EQ.8)
     > .OR.(J.EQ.10).OR.(J.EQ.12)) THEN
      DO 425 L=1,31
      EAVG(J,K)=EAVG(J,K)+E(J,L,K)/31.
      IF(MAX_FLAG.EQ.0.) E_MAXAV(J,K)=E_MAXAV(J,K)+E_MAX(J,L,K)/31.
      IHAVG(J,K)=IHAVG(J,K)+IH(J,L,K)/31.
      TAAVG(J,K)=TAAVG(J,K)+TA(J,L,K)/31.
      SUNAVG(J,K)=SUNAVG(J,K)+SUN(J,L,K)*3.6/31.
 425  CONTINUE
      ESUM(J,K)=EAVG(J,K)*31.
      IF(MAX_FLAG.EQ.0.) E_MAXSUM(J,K)=E_MAXAV(J,K)*31.
      IHSUM(J,K)=IHAVG(J,K)*31.
      SUNSUM(J,K)=SUNAVG(J,K)*31.
      END IF
      IF((J.EQ.4).OR.(J.EQ.6).OR.(J.EQ.9).OR.(J.EQ.11)) THEN
      DO 430 L=1,30
      EAVG(J,K)=EAVG(J,K)+E(J,L,K)/30.
      IF(MAX_FLAG.EQ.0.) E_MAXAV(J,K)=E_MAXAV(J,K)+E_MAX(J,L,K)/30.
      IHAVG(J,K)=IHAVG(J,K)+IH(J,L,K)/30.
      TAAVG(J,K)=TAAVG(J,K)+TA(J,L,K)/30.
      SUNAVG(J,K)=SUNAVG(J,K)+SUN(J,L,K)*3.6/30.
 430  CONTINUE
      ESUM(J,K)=EAVG(J,K)*30.
      IF(MAX_FLAG.EQ.0.) E_MAXSUM(J,K)=E_MAXAV(J,K)*30.
      IHSUM(J,K)=IHAVG(J,K)*30.
      SUNSUM(J,K)=SUNAVG(J,K)*30.
      END IF
      IF(J.EQ.2) THEN
      DO 435 L=1,28
      EAVG(J,K)=EAVG(J,K)+E(J,L,K)/28.
      IF(MAX_FLAG.EQ.0.) E_MAXAV(J,K)=E_MAXAV(J,K)+E_MAX(J,L,K)/28.
      IHAVG(J,K)=IHAVG(J,K)+IH(J,L,K)/28.
      TAAVG(J,K)=TAAVG(J,K)+TA(J,L,K)/28.
      SUNAVG(J,K)=SUNAVG(J,K)+SUN(J,L,K)*3.6/28.
 435  CONTINUE
      ESUM(J,K)=EAVG(J,K)*28.
      IF(MAX_FLAG.EQ.0.) E_MAXSUM(J,K)=E_MAXAV(J,K)*28.
      IHSUM(J,K)=IHAVG(J,K)*28.
      SUNSUM(J,K)=SUNAVG(J,K)*28.
```

```
      END IF
  440 CONTINUE
  450 CONTINUE
      DO 470 J=1,12
      DO 460 K=1,24
      PVKWH(J)=PVKWH(J)+ESUM(J,K)
      IF(MAX_FLAG.EQ.0.) MAXKWH(J)=MAXKWH(J)+E_MAXSUM(J,K)
      THORIZ(J)=THORIZ(J)+IHSUM(J,K)
      TTILT(J)=TTILT(J)+SUNSUM(J,K)
      AVMTEMP(J)=AVMTEMP(J)+(TAAVG(J,K)/24.)
  460 CONTINUE
  470 CONTINUE
      WRITE(10,471)MODEL,NP,'IN PARALLEL',NS,'IN SERIES'
  471 FORMAT(1X,A35,2X,F4.0,A11,2X,F4.0,A9)
      IF(LOADTYPE.EQ.3) THEN
      WRITE(10,472) 'LOAD VOLTAGE=',FIXVOL,'  SLOPE=',BETA,' DEGREES'
  472 FORMAT(5X,A14,F6.1,4X,A9,F4.1,A9)
      ELSE IF(LOADTYPE.EQ.1) THEN
      WRITE(10,473)'RESISTANCE=',R,' OHMS ',' SLOPE=',BETA,' DEGREES'
  473 FORMAT(5X,A12,F5.1,A6,A8,F4.1,A9)
      ELSE IF(LOADTYPE.EQ.2) THEN
      WRITE(10,474)'PUMP/MOTOR TYPE:',PMTYPE,'   SLOPE=',BETA,' DEGREES'
  474 FORMAT(5X,A16,I1,A9,F4.1,A8)
      END IF
      WRITE(10,*)'    MAX-POWER TEMP. COEFF.=',MPC
      WRITE(10,*)' '
      WRITE(10,*)'MO','   PV KWH ', '  MAX KWH','  IH MJ/M2',
     *        'POA MJ/M2','T AVG(C)','Hext MJ/M2','Kt-bar',
     *        ' WATER m3'
      DO 480 J=1,12
      PUMPED=PUMPED+WATER(J)
      PV_TOTAL=PV_TOTAL + PVKWH(J)
      IF(MAX_FLAG.EQ.0.) MAX_TOTAL=MAX_TOTAL+MAXKWH(J)
      WRITE(11,*) PVKWH(J),MAXKWH(J)
      WRITE(10,475) J,PVKWH(J),MAXKWH(J),THORIZ(J)/1000.,TTILT(J)/1000.,
     *          AVMTEMP(J)-273.15,HEXT(J)/1000.,THORIZ(J)/
     *          HEXT(J),WATER(J)
  475 FORMAT(1X,I2,2X,F8.2,2X,F8.2,2X,F7.2,2X,F7.2,2X,F5.1,2X
     *,F7.2,2X,F6.4,2X,F6.0)
  480 CONTINUE
      WRITE(11,*) PV_TOTAL,MAX_TOTAL
      WRITE(10,*)'YEARLY TOTAL PV KWH OUTPUTS FOR DIRECT-COUPLED,
     > ANALYTICAL MAX-POWER, AND SIMPLIFIED MAX POWER MODES ARE:'
      WRITE(10,485) PV_TOTAL,MAX_TOTAL,ALTMAX
  485 FORMAT(5X,F10.1,5X,F10.1,5X,F10.1)
      WRITE(10,486) ' RATIO:DIRECT-COUPLED/MAX-POWER KWH=',
     > PV_TOTAL/MAX_TOTAL,' YEARLY M3 OF WATER=',PUMPED
  486 FORMAT(A36,F5.3,2X,A20,F9.0)
      MAX_FLAG=1.
      PUMPED=0.
      PV_TOTAL=0.0
      EXTRA=0.0
      HORZ=0.0
      DO 488 J=1,12
      WATER(J)=0.0
      PVKWH(J)=0.0
```

```
      THORIZ(J)=0.0
      TTILT(J)=0.0
      AVMTEMP(J)=0.0
      HEXT(J)=0.0
      DO 487 K=1,24
      EAVG(J,K)=0.0
      IHAVG(J,K)=0.0
      TAAVG(J,K)=0.0
      SUNAVG(J,K)=0.0
      ESUM(J,K)=0.0
      IHSUM(J,K)=0.0
      SUNSUM(J,K)=0.0
  487 CONTINUE
  488 CONTINUE
      REWIND 15
      REWIND 16
      IF((LOADTYPE.EQ.1).AND.(RES.LT.R_FINAL)) THEN
      RES=RES+R_INCR
      GO TO 50
      END IF
  490 CONTINUE
C
C ***** THIS NEXT SECTION SORTS EACH DAY OF EACH MONTH TO GET A
C ***** CUMULATIVE KT DISTRIBUTION CURVE
C
      IF((KT_FLAG.EQ.'N').OR.(KT_FLAG.EQ.'n')) GOTO 801
      DO 800 M=1,12
      TMAXKT=0.0
      T2MAXKT=0.0
      IF((M.EQ.1).OR.(M.EQ.3).OR.(M.EQ.5).OR.(M.EQ.7).OR.(M.EQ.8)
     * .OR.(M.EQ.10).OR.(M.EQ.12)) THEN
      FRAC=1.016129
  500 CONTINUE
      DO 560 DM=1,31
      DO 550 J=1,31
      IF(DM.EQ.J) GOTO 549
      IF(KTDAY(M,DM).GE.KTDAY(M,J)) THEN
       TMAXKT=KTDAY(M,DM)
      ELSE IF(KTDAY(M,J).GE.T2MAXKT) THEN
       T2MAXKT=KTDAY(M,J)
      END IF
      IF(TMAXKT.GE.T2MAXKT) T2MAXKT=TMAXKT
  549 CONTINUE
  550 CONTINUE
      IF(T2MAXKT.EQ.0.0) GOTO 570
      IF(KTDAY(M,DM).EQ.T2MAXKT) THEN
      FRAC=FRAC-0.032258
      WRITE(30,551) M,DM,KTDAY(M,DM),FRAC
  551 FORMAT(3X,I2,3X,I2,3X,F5.3,3X,F7.5)
      KTDAY(M,DM)=0.0
      TMAXKT=0.0
      T2MAXKT=0.0
      END IF
  560 CONTINUE
      GOTO 500
  570 CONTINUE
```

```
      END IF
      IF((M.EQ.4).OR.(M.EQ.6).OR.(M.EQ.9).OR.(M.EQ.11)) THEN
      FRAC=1.016667
  600 CONTINUE
      DO 660 DM=1,30
      DO 650 J=1,30
      IF(DM.EQ.J) GOTO 649
      IF(KTDAY(M,DM).GE.KTDAY(M,J)) THEN
       TMAXKT=KTDAY(M,DM)
      ELSE IF(KTDAY(M,J).GE.T2MAXKT) THEN
       T2MAXKT=KTDAY(M,J)
      END IF
      IF(TMAXKT.GE.T2MAXKT) T2MAXKT=TMAXKT
  649 CONTINUE
  650 CONTINUE
      IF(T2MAXKT.EQ.0.0) GOTO 670
      IF(KTDAY(M,DM).EQ.T2MAXKT) THEN
      FRAC=FRAC-0.033333
      WRITE(30,651) M,DM,KTDAY(M,DM),FRAC
  651 FORMAT(3X,I2,3X,I2,3X,F5.3,3X,F7.5)
      KTDAY(M,DM)=0.0
      TMAXKT=0.0
      T2MAXKT=0.0
      END IF
  660 CONTINUE
      GOTO 600
  670 CONTINUE
      END IF
      IF(M.EQ.2) THEN
      FRAC=1.017857
  700 CONTINUE
      DO 760 DM=1,28
      DO 750 J=1,28
      IF(DM.EQ.J) GOTO 749
      IF(KTDAY(M,DM).GE.KTDAY(M,J)) THEN
       TMAXKT=KTDAY(M,DM)
      ELSE IF(KTDAY(M,J).GE.T2MAXKT) THEN
       T2MAXKT=KTDAY(M,J)
      END IF
      IF(TMAXKT.GE.T2MAXKT) T2MAXKT=TMAXKT
  749 CONTINUE
  750 CONTINUE
      IF(T2MAXKT.EQ.0.0) GOTO 770
      IF(KTDAY(M,DM).EQ.T2MAXKT) THEN
      FRAC=FRAC-0.035714
      WRITE(30,751) M,DM,KTDAY(M,DM),FRAC
  751 FORMAT(3X,I2,3X,I2,3X,F5.3,3X,F7.5)
      KTDAY(M,DM)=0.0
      TMAXKT=0.0
      T2MAXKT=0.0
      END IF
  760 CONTINUE
      GOTO 700
  770 CONTINUE
      END IF
  800 CONTINUE
```

```
801  CONTINUE
     IF(LOC.EQ.1) THEN
     WRITE(*,*)'THIS SIMULATION IS FOR MADISON, WI'
     ELSEIF(LOC.EQ.2) THEN
     WRITE(*,*)'THIS SIMULATION IS FOR NASHVILLE, TN'
     ELSEIF(LOC.EQ.3) THEN
     WRITE(*,*)'THIS SIMULATION IS FOR ALBUQUERQUE, NM'
     ELSEIF(LOC.EQ.4) THEN
     WRITE(*,*)'THIS SIMULATION IS FOR MIAMI, FL'
     ELSEIF(LOC.EQ.5) THEN
     WRITE(*,*)'THIS SIMULATION IS FOR NEW YORK, NY'
     ELSEIF(LOC.EQ.6) THEN
     WRITE(*,*)'THIS SIMULATION IS FOR SEATTLE, WA'
     END IF
     WRITE(*,*) 'THE RESULTS CAN BE SEEN BY TYPING THE FOLLOWING:'
     WRITE(*,*) '"TYPE [TIM.RESULTS]DET____.OUT",
    > (WHERE THE ____ IS EITHER'
     WRITE(*,*) 'MAD,NASH,ALB,MIA,NYC, or SEA)'
     IF(KT_FLAG.EQ.'N') GOTO 810
     WRITE(*,*) ' '
     WRITE(*,*) 'THE CUMULATIVE Kt CURVE RESULTS CAN BE SEEN BY'
     WRITE(*,*) 'TYPING THE FOLLOWING:'
     WRITE(*,*) '"TYPE KT____.OUT", (WHERE THE ____ IS EITHER'
     WRITE(*,*) 'MAD,NASH,ALB,MIA,NYC, or SEA)'
810  CONTINUE
     END
```