A review of PV, solar thermal, and PV/thermal collector models in TRNSYS

A Report of IEA SHC - Task 35
PV/Thermal Solar Systems
Report DB1
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Mike Collins
A review of PV, solar thermal, and PV/thermal collector models in TRNSYS

by

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A technical report of Subtask B
Report DB1

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The International Energy Agency (IEA) is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) based in Paris. Established in 1974 after the first “oil shock,” the IEA is committed to carrying out a comprehensive program of energy cooperation among its members and the Commission of the European Communities.

The IEA provides a legal framework, through IEA Implementing Agreements such as the Solar Heating and Cooling Agreement, for international collaboration in energy technology research and development (R&D) and deployment. This IEA experience has proved that such collaboration contributes significantly to faster technological progress, while reducing costs; to eliminating technological risks and duplication of efforts; and to creating numerous other benefits, such as swifter expansion of the knowledge base and easier harmonization of standards.

The Solar Heating and Cooling Programme was one of the first IEA Implementing Agreements to be established. Since 1977, its members have been collaborating to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. Current members are:

- Australia
- Austria
- Belgium
- Canada
- Denmark
- European Commission
- Germany
- Finland
- France
- Italy
- Mexico
- Netherlands
- New Zealand
- Portugal
- Spain
- Sweden
- Switzerland
- United States
- Norway

A total of 44 Tasks have been initiated, 33 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition to the Task work, a number of special activities—Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops—have been undertaken.

To find Solar Heating and Cooling Programme publications and learn more about the Programme visit [www.iea-shc.org](http://www.iea-shc.org) or contact the SHC Executive Secretary, Pamela Murphy, e-mail: pmurphy@kmgrp.net.
The Tasks of the IEA Solar Heating and Cooling Programme, both underway and completed are as follows:

Current Tasks & Working Group:
Task 35  PV/Thermal Solar Systems
Task 36  Solar Resource Knowledge Management
Task 37  Advanced Housing Renovation with Solar & Conservation
Task 38  Solar Thermal Cooling and Air Conditioning
Task 39  Polymeric Materials for Solar Thermal Applications
Task 40  Net Zero Energy Solar Buildings
Task 42  Compact Solar Thermal Energy Storage
Working Group  Daylight Research Group

Completed Tasks:
Task 1  Investigation of the Performance of Solar Heating and Cooling Systems
Task 2  Coordination of Solar Heating and Cooling R&D
Task 3  Performance Testing of Solar Collectors
Task 4  Development of an Insolation Handbook and Instrument Package
Task 5  Use of Existing Meteorological Information for Solar Energy Application
Task 6  Performance of Solar Systems Using Evacuated Collectors
Task 7  Central Solar Heating Plants with Seasonal Storage
Task 8  Passive and Hybrid Solar Low Energy Buildings
Task 9  Solar Radiation and Pyranometry Studies
Task 10 Solar Materials R&D
Task 11 Passive and Hybrid Solar Commercial Buildings
Task 12 Building Energy Analysis and Design Tools for Solar Applications
Task 13 Advance Solar Low Energy Buildings
Task 14 Advance Active Solar Energy Systems
Task 16 Photovoltaics in Buildings
Task 17 Measuring and Modeling Spectral Radiation
Task 18 Advanced Glazing and Associated Materials for Solar and Building Applications
Task 19 Solar Air Systems
Task 20 Solar Energy in Building Renovation
Task 21 Daylight in Buildings
Task 23 Optimization of Solar Energy Use in Large Buildings
Task 22 Building Energy Analysis Tools
Task 24 Solar Procurement
Task 25 Solar Assisted Air Conditioning of Buildings
Task 26 Solar Combsystems
Task 28 Solar Sustainable Housing
Task 27 Performance of Solar Facade Components
Task 29 Solar Crop Drying
Task 31 Daylighting Buildings in the 21st Century
Task 32 Advanced Storage Concepts for Solar and Low Energy Buildings
Task 33 Solar Heat for Industrial Processes
Task 34 Testing and Validation of Building Energy Simulation Tools

Completed Working Groups:
CSHPSS, ISOLDE, Materials in Solar Thermal Collectors, and the Evaluation of Task 13 Houses

Nov 2009
IEA SHC Task 35 PV/Thermal Solar Systems

Objective
The objectives of the Task are to catalyze the development and market introduction of high quality and commercial competitive PV/Thermal Solar Systems and to increase general understanding and contribute to internationally accepted standards on performance, testing, monitoring and commercial characteristics of PV/Thermal Solar Systems in the building sector.

The Task is organized in 5 subtasks:
• Subtask A: Market and Commercialization of PV/T
• Subtask B: Energy Analysis and Modeling
• Subtask C: Product and System Development, Tests and Evaluation
• Subtask D: Demonstration Projects
• Subtask E: Dissemination

Organisation
IEA SHC Task 35 "PV/Thermal Solar Systems" is a three year Task initiated by the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programme in January 2005. The Danish Energy Authority, acting through Mr. Henrik Sørensen, Esbensen Consulting Engineers A/S, Denmark, is designated as Operating Agent for the Task.

Task 35 is a so-called "minimum-level" collaboration task with IEA PVPS (Photovoltaic Power Systems Programme). At this level, experts selected by the PVPS Executive Committee participate in experts meetings of the Task managed by the SHC Executive Committee. The Task is fully defined and managed by the SHC Executive Committee with appropriate input from the PVPS Executive Committee. In this project Israel participated as a PVPS country member.

The official participants in the Task are listed in the table below:

<table>
<thead>
<tr>
<th>Country</th>
<th>Organization</th>
<th>Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Dept. of Mechanical Engineering, University of Waterloo, Waterloo, Ontario, Canada</td>
<td>Mike Collins</td>
</tr>
<tr>
<td>Denmark</td>
<td>Esbensen Consulting Engineers A/S</td>
<td>Henrik Sørensen</td>
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<tr>
<td></td>
<td>Solar Energy Center, Danish Technological Institute</td>
<td>Ivan Katic</td>
</tr>
<tr>
<td>Israel</td>
<td>Millemium Electric</td>
<td>Ami Elazar</td>
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<tr>
<td>Sweden</td>
<td>Lund Technical University</td>
<td>Björn Karlsson</td>
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<td>Johan Nilsson</td>
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<td>Bengt Perers</td>
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<tr>
<td>The Netherlands</td>
<td>ECN (Energy Research Centre of the Netherlands)</td>
<td>Wim van Helden</td>
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<td></td>
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<td>Herbert Zondag</td>
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<td></td>
<td></td>
<td>Marco Bakker</td>
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</tbody>
</table>

Apart from the above mentioned a number of manufacturers, universities, and research institutes from the countries Germany, Greece, Hong Kong, Italy, South Korea, Thailand, and Spain have been involved in the work.

Visit the Task 35 website: http://www.iea-shc.org/task35 for more details on activities and results.
INTRODUCTION

This document has been prepared in support of IEA Task 35: PV/Thermal Solar Systems – Subtask B: Energy Analysis and Modelling. Specifically, it reports on the availability of Photovoltaic and Solar Thermal system models. Special attention is paid to models of collectors that include both PV and Solar Thermal in the same absorber.

This report is intended as a reference to those who intend to develop new models.

EXISTING SYSTEM MODELS

An extensive search was undertaken to identify relevant solar thermal, solar electric, and PV/T system models. TRNSYS [1] was found to be the predominant source of models, and as such, it was decided by the Subtask to focus exclusively on that platform. The results have been laid out in the following sections.

The underlying theory behind each of these models can be complex. In most cases, each is the result of an individual Graduate research project, and is only fully described in the associated Thesis. The TRNSYS user manual [1] provides significant detail regarding the theory and capabilities of most of the models, and input and output parameters. Those not available with the TRNSYS package can likely found on the TRNSYS users web site: Thermal Energy System Specialists (TESS). Alternatively, Duffie and Beckman [2] provide theoretical detail of most of the solar thermal components. The capabilities of each model is described in point form.

Models programmed via other means were found. They have been included for reference, but will not be considered in detail.

Full code listing has been provided for the PV/T models as Appendix A.
A) PV/T Models

TRNSYS Models

TYPE 50: PV-Thermal Collector [3]
- A theoretical model of a generic collector (air or water) with integrated PV.
- Can be glazed/unglazed with non-transpired absorber.
- User choice of 8 operational modes based on known information
  1. Collector loss and cover transmission required
  2. Cover transmission required
  3. Collector loss and angular dependent cover transmission required
  4. Collector loss and cover transmission calculated internally
  5. Concentrating collector. Collector loss and cover transmission required. PV output is free-floating
  6. Concentrating collector. Detailed collector loss and cover transmission required. PV output is free-floating
  7. Concentrating collector. Collector loss and cover transmission required. PV output is set
  8. Concentrating collector. Detailed collector loss and cover transmission required. PV output is set

- A theoretical model of an unglazed air collector with integrated PV.

TYPE 56(Mode): PV-Thermal Collector [4]
- A theoretical model of a generic collector (air or water) with integrated PV.
- Can be glazed/unglazed with non-transpired absorber.
- User choice of 6 operational modes based on known information
  1. Mode 0: Unglazed water. General heat transfer model
  2. Mode 3: Unglazed water. Detailed heat transfer model
  3. Mode 6: Glazed air. General heat transfer model
  4. Mode 7: Glazed air. Detailed heat transfer model
  5. Mode 8: Unglazed air. General heat transfer model

Many of the TYPE50 models contain serious errors which limit their usability. In particular, a ‘floating point (division by zero) error’ is often encountered which prevents completion of a simulation.

The TYPE555 and 56(Mode) models are updated (and more reliable) versions of the TYPE50 models. Unfortunately, they are more specific in their applicability in that they have been adapted for building integrated systems.

Given that the TYPE50 models are not reliable, and that the TYPE555 and TYPE56(Mode) models are more specific than required. Subtask B of IEA SHC Task 35 has produced reliable generic PV/Thermal collector models for use in TRNSYS. The models (called the TYPE 201, 250, and 251 models) are available from the Task website as part of a downloadable package. The installation and use of these models, is given in a report included with that package [5].
It is further noted that these new models were used to help develop procedures for characterizing and monitoring PV/Thermal systems. Details of these procedures can be found in IEA SHC Task 35, Report DB-2 [6].

**Other Models**


Raghuraman [9] – Two separate one-dimensional analyses have been developed for the prediction of the thermal and electrical performance of both liquid and air flat-plate, photovoltaic/thermal (PV/T) collectors. The results of the analyses are compared with test measurements, and therefrom design recommendations are made to maximize the total energy extracted from the collectors.


**B) Photovoltaic Component Models**

**TRNSYS Models**

TYPE 94: Photovoltaic Array
- A theoretical model of a generic PV cell.
- Cell characteristics are required.

**Other Electrical Elements**
1. TYPE 47: Battery
2. TYPE 48: Inverter/Regulator
3. PV Array, Maximum Power Point Tracker, Charge Controllers, Battery [11]
C) Solar Thermal Component Models

TRNSYS Models

TYPE 1: Flat Plate Solar Collector
- A theoretical model of a generic flat plate collector (air or water).
- The results from a standard efficiency versus $\Delta T/G$ test is required as input (modeled as quadratic equation).
- Inlet, average, or outlet fluid temperatures can be used.
- User choice of 5 optical models
  1. normal incidence only
  2. 1 axis incidence angle modifier
  3. 1 axis incidence angle modifier
  4. properties based on cover materials
  5. bi-axial incidence angle modifier
- Modified versions found in literature include non-linear solar collector characterization [3], and a second order incidence angle modifier [4]
- User choice of 5 optical models

TYPE 71: Unglazed Transpired Collector System [12]
- A theoretical model of a transpired air collector.

TYPE 72: Performance Map Solar Collector
- A theoretical model of a generic flat plate collector (air or water).
- The results from an efficiency versus $\Delta T/G$, wind speed, and radiation are required (modeled as quadratic equation).
- Inlet, average, or outlet fluid temperatures can be used.
- User choice of 5 optical models
  1. normal incidence only
  2. 1 axis incidence angle modifier
  3. 1 axis incidence angle modifier
  4. properties based on cover materials
  5. bi-axial incidence angle modifier

TYPE 73: Theoretical Flat Plate Solar Collector
- A theoretical model of a generic flat plate collector (air or water).
- No measured performance input is required.
- Inlet, average, or outlet fluid temperatures can be used.

TYPE 74: Compound Parabolic Concentrating Collector
- A theoretical model of a generic CPC collector (air or water).
- No measured performance input is required.

TYPE 132: Unglazed Collector [13]
- A theoretical model of a generic flat plate collector (air or water).

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1 This is not the Model 71 that is supplied with TRNSYS. It is a model that must be downloaded from the TRNSYS website.
TYPE 186: Serpentine Collector [14]
- A theoretical model of a generic flat plate collector (air or water).

Other Collector Models
1. TYPE 45: Thermosiphon Collector with Integral Storage
2. TYPE 71: Evacuated Tube Solar Collector

Solar Storage Elements
1. TYPE 4: Stratified Fluid Storage Tank
2. TYPE 10: Rock Bed Thermal Storage
3. TYPE 38: Algebraic Tank (Stratified)
4. TYPE 39: Variable Volume Tank
5. TYPE 60: Detailed Fluid Storage with Heaters
6. TYPE 74\(^2\): Stratified Fluid Storage with Internal Heat Exchanger [8]

Solar Controllers
1. TYPE 2: ON/Off Differential
2. TYPE 40: Microprocessor

Other Models

ESP-r - [16] – Supposedly has capability, but I was unable to find anything definitive.

RetScreen – Separate Excel based tools for PV and Solar Thermal [17].

MODEL INPUTS
A list of parameters, inputs, and outputs is provided via the TRNSYS software for each of the models it contains. For each of the models noted in the previous section, that list has been provided (Appendix B). If existing TRNSYS models are to be adapted as the norm, than these variables will be the ones of interest.

Attempting to compile all of the possible variables into a comprehensive list is difficult. The number of system components, for both PV and Solar Thermal systems, is large and varied in nature. Therefore, to facilitate model / experiment comparison, testing groups should refer to Appendix B and instrument accordingly. It is noted that as future tasks demand the development of new models or refinement of existing models, new parameters may be introduced that need to be monitored.

\(^2\) TYPE 74 has already been used. I'm uncertain why the repeat has occurred at this point.
REFERENCES


[16] http://www.esru.strath.ac.uk/

Appendix A
Code Listing for PV/T TRNSYS Models
Type 50

Type 50a: PV/T Flat Plate Collector (Constant losses)

Type 50b: PV/T Flat Plate Collector (Losses=f(temperature, wind, geometry))

Type 50c: PV/T Flat Plate Collector (Angular dependence of transmittance)

Type 50d: PV/T Flat Plate Collector (Losses=f(temperature, wind, geometry) and t=angle)

Type 50e: PV/T Concentrating collectors (Constant losses - No cell operating voltage)

Type 50f: PV/T Concentrating collectors (Top Loss=f(wind, T) No cell operating voltage)

Type 50g: PV/T Concentrating collectors (Constant Losses - Cell operating V is input)

Type 50h: PV/T Concentrating collectors (Top Loss=f(wind, T) Cell operating voltage is input)

SUBROUTINE TYPE50 (TIME, XIN, OUT, T, DTDT, PAR, INFO, ICN)

***************************************************************************

C***************************************************************************

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INFO7=INFO(7)
IF (INFO(7).GE.0) GO TO 1
C REMOVED BECAUSE OF POSSIBLE TOLERANCE PROBLEMS
C INFO(9)=0
C TEMPORARILY ADD ANOTHER OUTPUT,FR
FR=0.
INFO6=20
C INFO(6) =12
C **************D*C**********
MODE=PAR(1)
NP=INFO(4)
IF (MODE.EQ.1) CALL TYPECK (1,INFO,5,NP,0)
IF (MODE.EQ.2) CALL TYPECK (1,INFO,6,NP,0)
IF (MODE.EQ.3) CALL TYPECK (1,INFO,7,NP,0)
IF (MODE.EQ.4) CALL TYPECK (1,INFO,8,NP,0)
IF (MODE.EQ.5) CALL TYPECK (1,INFO,4,NP,0)
IF (MODE.EQ.6) CALL TYPECK (1,INFO,6,NP,0)
IF (MODE.EQ.7) CALL TYPECK (1,INFO,5,NP,0)
IF (MODE.EQ.8) CALL TYPECK (1,INFO,7,NP,0)
IF (MODE.GE.1.AND.MODE.LE.8) GO TO 1
CALL TYPECK (4,INFO,0,0,0)
RETURN
1 CONTINUE
ITER=0
IF (INFO(1).EQ.IUNIT) GO TO 10
IUNIT=INFO(1)
MODE=PAR(1)
A=PAR(2)
FP=PAR(3)
CPF=PAR(4)
ALF=PAR(5)
GO TO (2,3,4,5,6,6,6,6), MODE
2 UL=PAR(6)
TAU=PAR(7)
BR=PAR(8)
CELLPF=PAR(10)
TAU=PAR(11)
TAU=PAR(12)
CELLPF=PAR(13)
GO TO 10
3 XNG=PAR(6)
EP=PAR(7)
UBE=PAR(8)
ANGLE=PAR(9)
TAU=PAR(10)
BR=PAR(11)
TR=PAR(12)
CELLPF=PAR(13)
NG=XNG
TAU=PAR(14)
TAU=PAR(15)
GO TO 10
4 XNG=PAR(6)
UL=PAR(7)
XKL=PAR(8)
BR=PAR(9)
TR=PAR(10)
CELLPF=PAR(11)
NG=XNG
GO TO 9
5 XNG=PAR(6)
EP=PAR(7)
UBE=PAR(8)
ANGLE=PAR(9)
XKL=PAR(10)
BR=PAR(11)
TR=PAR(12)
CELLPF=PAR(13)
UL=0.
NG=XNG
GO TO 9
6 AR=PAR(3)
IF (MODE.GE.7) NPP=1
FE=PAR(6)
CB=PAR(8)
UB=PAR(9)
IF (MODE.GE.7) NPP=1
IF (CB.LT.1.E-5) CALL TYPECK (4,INFO,0,0,0)
TAU=PAR(10)
TAU=PAR(11)
TAU=PAR(12)
TAU=PAR(13)
UL=0.
NG=XNG
GO TO 9
7 UT=PAR(11)
LUIN=1
IF (MODE.GE.7) NPP=1
IF (INFO(4).EQ.12) LUIN=PAR(12)
GO TO 10
8 XNG=PAR(11)
EP=PAR(12)
UB=PAR(13)
IF (MODE.GE.7) NPP=1
IF (INFO(4).EQ.13) LUIN=PAR(13)
GO TO 10
9 CONTINUE
TAU60=EXP(-1.21453*XNG*NL)*(1.-EXP((ATR(NG)+(BTR(NG)+CTR(NG)*0.5)*0.5)*0.5))
C TAU60 IS THE TRANSMITTANCE OF THE GLASS COVER SYSTEM AT AN
C INCIDENCE ANGLE OF 60 DEGREES, AS ASSUMED FOR DIFFUSE RADIATION
C SEE HOTTEL AND WOERTZ
10 CONTINUE
TIN=XIN(1)
FLWRT=XIN(2)
TA=XIN(3)
IF (MODE.GE.5) GO TO 11
TC=TR+1./BR
$BA = 1.0/(TC - TA)$

11 GO TO (12, 14, 15, 20, 16, 17, 18, 19), MODE

12 CONTINUE

UL=PAR(6)
HR=XIN(4)
ETAR=XIN(5)*CELLPF
ETAA=ETAR*(1.0-0.1*(TA-TR))
UL=UL-ETAA*BA
GO TO 29

14 HR=XIN(4)
WIND=XIN(5)
ETAR=XIN(6)*CELLPF
ETAA=ETAR*(1.0-0.1*(TA-TR))
GO TO 24

15 HBT=XIN(4)
HDT=XIN(5)
THETA1=XIN(6)
ETAR=XIN(7)*CELLPF
ETAA=ETAR*(1.0-0.1*(TA-TR))
GO TO 21

16 HR=XIN(4)
ICT=1
GO TO 26

17 HR=XIN(4)
WIND=XIN(5)
TILT=XIN(6)
GO TO 24

18 HR=XIN(4)
V=XIN(5)
ICT=1
GO TO 26

19 HR=XIN(4)
WIND=XIN(5)
V=XIN(6)
TILT=XIN(7)
GO TO 24

20 HBT=XIN(4)
HDT=XIN(5)
THETA1=XIN(6)
WIND=XIN(7)
ETAR=XIN(8)*CELLPF
ETAA=ETAR*(1.0-0.1*(TA-TR))
21 CONTINUE

C.

HR=HBT+HDT
TAC=1.0E+0.0
IF (THETA1.GT.85.0) GO TO 23
IF (HR.LE.1.0E-10) GO TO 23
THETA1=THETA1+2.0*PI/360.0

COSTH1=COS(THETA1)
THETA2=ASIN(SIN(THETA1)/REFIND)
COSTH2=COS(THETA2)
TAU=TAU040(NG)
IF (COSTH1.GE.0.766) GO TO 22
TAU=1.0-EXP((ATR(NG)+(BTR(NG)+CTR(NG)*COSTH1)*COSTH1))
22 CONTINUE

C.

 GO TO (29, 24, 29, 24, 26, 24, 26, 24), MODE

24 CONTINUE

ICT=0
HWIND=5.7+3.8*WIND
TM=TIN
25 CONTINUE

IF (ITER.EQ.0) ICT=ICT+1
IF (ICT.GT.2) GO TO 45

TMC=TM+273.15
TMC=TMC+273.15
IF (TMC.LE.TAC) TMC=TAC+1.0

F=(1.0-0.04*HWIND+5.0E-04*HWIND*HWIND)*(1.0+0.091*XNG)

C=365.9*(1.0-0.00883*ANGLE+0.0001298*ANGLE*ANGLE)

STF1=C/TMC*((TMC-TAC)/(XNG+F))**0.33
STF1=XNG/STF1+1.0/HWIND
STF1=1.0/STF1
STF2=1.0+0.05*XNG*(1.0-0.05*EG-XNG)
STF2=STF2*(TMC+TAC)*TAC*(TMC+TAC)*STF2

UL=(STF1+STF2)*3.6+UBE
IF (MODE.GE.5) GO TO 26
UL=UL-TAU*HR*ETAA*BA

C. UT WILL BE SET EQUAL TO UL FOR MODES 6 & 8

C.

IF (FLWR.TE.6) ICT=ICT+1
IF (ICT.GT.2) GO TO 45

TMC=TM+273.15
TMC=TMC+273.15
IF (TMC.LE.TAC) TMC=TAC+1.0

F=(1.0-0.04*HWIND+5.0E-04*HWIND*HWIND)*(1.0+0.091*XNG)

C=365.9*(1.0-0.00883*ANGLE+0.0001298*ANGLE*ANGLE)

STF1=C/TMC*((TMC-TAC)/(XNG+F))**0.33
STF1=XNG/STF1+1.0/HWIND
STF1=1.0/STF1
STF2=1.0+0.05*XNG*(1.0-0.05*EG-XNG)
STF2=STF2*(TMC+TAC)*TAC*(TMC+TAC)*STF2

UL=(STF1+STF2)*3.6+UBE
IF (MODE.GE.5) GO TO 26
UL=UL-TAU*HR*ETAA*BA

C. UT WILL BE SET EQUAL TO UL FOR MODES 6 & 8

C.

UL IS CALCULATED USING THE RELATION OF KLEIN

GO TO 29

26 S=HR*TAU*AR
SINC=S/ALF
IF (MODE.EQ.6.OR.MODE.EQ.8) UT=UL
DENOM=UT*CB*UF+CB*UF
K1=CB/DENOM
IF (ICT.NE.1) GO TO 27
TP=K1*UT*(TIN-27)
TCELLR=UP+TP*TIN*CB+TP
IF (FLWR.TE.6) TCELLR=(S+TA*CB*UB/(CB+UB))/UT*CB**2/
+ (CB+UB))
TCELL=TCELLR
27 CONTINUE
C
TEMP=TCELL
IF (MODE.EQ.5.OR.ME.6) TEMP=TCELLR
CALL SOLCEL (TCELLR,TEMPS,NCP,BETAS,IC,ITER,NPP,INFO7,A,AR,
+MODE,LWIN,28)
CALL LINKCK('TYPE50','SOLCEL',1,99)
28 K2=1. + K1*PR*BETA*(CB+UB)/CB
IF (S.LT.1.E-5) PRS=0.
IF (S.GE.1.E-5) PRS=PR/S
FP=UF*K1*(1.-PRS*(1.+BETA*(TA-TCELLR)))/K2
ULAB=UF*K1*(UT+PR*BETA)/(K2*FP)
UL=ULAB/AR
ULO=UT/AR
29 CONTINUE
IF (F.WRT-1.E-5) 34,34,30
30 CONTINUE
IF (FP*UL*A/(FLWRT*CPF)).LT.0.01) GO TO 31
FR=FLWRT*CPF*(1.0-EXP(-FP*UL*A/(FLWRT*CPF)))/(A*UL)
GO TO 32
31 CONTINUE
FR=FP
32 HRT=HRT*(1.-ETAA/ALF)
IF (MODE.GE.5) HRT=HRT
QU=FR*(HRT*TAUALF-UL*(TIN-TR))/UL
QE=TAU*HR*ETAA*(1.-BA*(FR*(TIN+TR)+(TAUALF*HRT/UL)*(1.-FR))
IF (MODE.LE.4) GO TO 33
QE=PR*(1.+BETA*(TCELL-TCELLR))/AR
33 CONTINUE
TOUT=QU/FLWRT*A/CPF+TIN
GO TO 36
34 Q=0.0
IF (MODE.LE.4) GO TO 35
QE=PR/AR
TCELLR=(S-PR+TAUALF-UL*(TIN-TR))/UL
TCELL=TCELLR
TEMP=TCELL
TOUT=TCELL*(1.-UB/(UB+CB)+TAUB/UB+CB)
FLWRT=0.
GO TO 39
35 CONTINUE
ULO=UL+TAU*HR*ETAA*BA
QU=TAU*HR*ETAA*(ULO-TRUALF*HR*BA)/UL
FLWRT=0.0
TOUT=TAUALF*HR-QU/ULO+TA
36 CONTINUE
TM=(TIN+TOUT)/2.0
IF (MODE.GE.5) GO TO 38
TCELL=TM
IF (HR.LE.1.E-5.AND.MODE.LE.4) GO TO 44
IF (ETAR.LT.1.E-5) TCELL=TC
IF (ETAR.LT.1.E-5) GO TO 37
TCELL=TC-(ETAR*(1.-TR))/TC
37 IF (MODE.LE.4) GO TO 44
38 TP=QU/AR+UIT
TCELLR=UP*(TP*UC+TC+TP)
TCELL=UP*(TP*UC+TC+TP)
39 CONTINUE
PRSAVE=PR
BETAS=BETAS
ITER=1
CALL SOLCEL (TCELLR,TEMPS,NCP,BETAS,IC,ITER,NPP,INFO7,A,AR,
+MODE,LWIN,391)
CALL LINKCK('TYPE50','SOLCEL',1,99)
391 IF (PR.LT.1.E-5.AND.PRSAVE.LT.1.E-5) GO TO 40
IF (PR.LT.1.E-5) GO TO 42
IF (ABS(PR-PRSAVE)/PR).GT.0.05) GO TO 42
40 IF (BETA.LT.1.E-5.AND.BETAS.LT.1.E-5) GO TO 41
41 ITER=0
42 CONTINUE
IF (MODE.EQ.5.OR.MODE.EQ.7) GO TO 43
IF (ITER.GT.0) GO TO 25
43 CONTINUE
ICT=ICT+1
IF (ITER.GT.0) GO TO 28
IF (ICT.LE.2) GO TO 28
44 CONTINUE
GO TO (45,25,45,25,45,25,45,25), MODE
45 CONTINUE
OUT(1)=TOUT
OUT(2)=FLWRT
OUT(3)=QU/AR
OUT(4)=UL
OUT(5)=TAUALF
OUT(6)=QE/AR
OUT(7)=TCELL
OUT(8)=ULO
OUT(9)=0.
OUT(10)=0.
OUT(11)=0.
OUT(12)=0.
C******INSERT FR AS OUT(13) FOR TESTING****DC
OUT(13)=FR
OUT(14)=PR
C***************************************************************************
GO TO (47,47,47,46,46,46,46), MODE
46 OUT(4)=ULO
OUT(8)=UL
OUT(9)=V
OUT(11)=TCELLR
OUT(12)=ITER
IF (V LT 1.E-5) GO TO 48
OUT(10)=QE*A/(V*3.6)
47 CONTINUE
RETURN 1
48 OUT(10)=0.
GO TO 47
END
TYPE 555- Unglazed air PV/T flat plate collector
*The code is not available
TYPE 560- Unglazed PV/T collector with fluid stream passing through tubes bonded to an absorber plate located beneath the PV cells

SUBROUTINE TYPE560(TIME,XIN,OUT,T,DTDT,PAR,INFO,ICNTRL,*)

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C DESCRIPTION:
C THIS SUBROUTINE MODELS AN UNGLAZED PV/ THERMAL COLLECTOR. IN THIS VERSION, THE WORKING FLUID IS WATER
C CARRIED IN TUBES BONDED TO A PLATE. THE PV MATERIAL IS ADHERED TO THE TOP OF THIS PLATE. THE PV SYSTEM C IS ASSUMED TO BE WORKING UNDER THE MAXIMUM POWER POINT ASSUMPTION.
C
C THIS MODEL IS BASED ON A DERIVATION BY JEFF THORNTON OF THERMAL ENERGY SYSTEM SPECIALISTS FROM THE STANDARD TUBE-FIN SOLAR COLLECTOR ALGORITHMS PRESENTED BY DUFFIE AND BECKMAN IN THE CLASSIC "SOLAR ENGINEERING OF THERMAL PROCESSES" - SPECIFICALLY CHAPTER SIX.
C
C LAST MODIFIED:
C FEBRUARY 2004 - JWT - INITIAL PROGRAMMING
C MODIFIED APRIL 2004 - FIXED THE PV POWER EQUATION TO INCLUDE XKAT AND TAU-ALPHA FACTORS
C
C
C------------------------------------
C
C REQUIRED TRNSYS DIMENSIONS
DIMENSION XIN(NI),OUT(NOUT),PAR(NP),YCHECK(NI),OCECHECK(NOUT),T(ND),
1 DDTDT(ND)
C
C
C----------------------------------
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
DOUBLE PRECISION TAUALF,ANGLE_INC,B0,RDCONV,LNGTH,WIDTH,THICK_BOND,B0*
1 THICK_ABSORBER,K_ABSORBER,DIA_TUBE,WIDTH_BOND,THICK_BOND,
1 K_BOND,R_ADHESIVE,R_BACK,CP_FLUID,REFLECTANCE,EMISSIVITY,
1 T_FLUID_IN,FLOW_IN,TAUAMT,T_SKY,T_F,GT,THICK_GND,REFL_GND,
1 SLOPE,H_CONV,T_H_CONV,H_FLUID,AREA,W,FLUID_OUT,QU,POWER,
1 EFF_PV,EFF_THERMAL_F,PLATE_MEAN_T_FLUID_MEAN,XKAT,
1 Q_TOP,QU_PRIME,T_PV_MEAN,T_PV_MEAN_BASE,
1 T_PV_MEAN_FIN
C

C--------------------------------------
C
C DATA STATEMENTS
DATA RDCONV/0.017453292/
C
C
C-----------------------------------
C
FUNCTIONS
TAUALF(ANGLE_INC,B0,RDCONV,LNGTH,WIDTH,THICK_BOND,B0*
1 THICK_ABSORBER,K_ABSORBER,DIA_TUBE,WIDTH_BOND,THICK_BOND,
1 K_BOND,R_ADHESIVE,R_BACK,CP_FLUID,REFLECTANCE,EMISSIVITY,
1 T_FLUID_IN,FLOW_IN,TAUAMT,T_SKY,T_F,GT,THICK_GND,REFL_GND,
1 SLOPE,H_CONV,T_H_CONV,H_FLUID,AREA,W,FLUID_OUT,QU,POWER,
1 EFF_PV,EFF_THERMAL_F,PLATE_MEAN_T_FLUID_MEAN,XKAT,
1 Q_TOP,QU_PRIME,T_PV_MEAN,T_PV_MEAN_BASE,
1 T_PV_MEAN_FIN
C

C----------------------------------
C
C SET THE VERSION INFORMATION FOR TRNSYS
IF(INFO(7)=16) THEN
INFO(12)=16
RETURN
ENDIF
C

C------------------------------------------

C DO ALL THE VERY LAST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(8).EQ.-1) THEN
    RETURN 1
ENDIF

C PERFORM ANY "AFTER-ITERATION" MANIPULATIONS THAT ARE REQUIRED
IF (INFO(13).GT.0) THEN
    RETURN 1
ENDIF

C DO ALL THE VERY FIRST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(7).EQ.-1) THEN
    RETRIEVE THE UNIT NUMBER AND TYPE NUMBER FOR THIS COMPONENT FROM THE INFO
    ARRAY
    IUNIT=INFO(1)
    ITYPE=INFO(2)
    DATA YCHECK/'TE1','MF1','TE1','TE1','TE1','IR1','IR1','IR1',
               'DM1','DG1','DG1','HT1','HT1','HT1'/
    DATA OCHECK/'TE1','MF1','PW1','PW1','DM1','DM1','DM1','TE1',
               1 'TE1','DM1','PW1','PW1','PW1','PW1','HT1','HT1',
               1 'HT1','PW1','PW1'/
    CALL THE YCHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO
    WHAT IS SUPPLIED
    CALL TYPECK(IUNIT,INFO,NP,ND)
    CALL THE YCHECK SUBROUTINE TO CONTAIN THE CORRECT VARIABLE TYPES FOR
    THE INPUTS AND OUTPUTS
    CALL RCHECK(YCHECK,1,INFO,INFO,INFO,INFO,INFO,INFO,INFO,INFO,INFO,INFO,INFO)
    CALL THE RCHECK SUBROUTINE TO SET THE CORRECT INPUT AND OUTPUT TYPES FOR THIS
    COMPONENT
    CALL RCHECK(INFO,YCHECK,OCHECK)
    RETURN TO THE CALLING PROGRAM
    RETURN 1
ENDIF

C DO ALL OF THE INITIAL TIMESTEP MANIPULATIONS HERE - THERE ARE NO ITERATIONS AT THE
INITIAL TIME
IF (TIME.LT.(TIME0+DELT/2.D0)) THEN
    SET THE UNIT NUMBER FOR FUTURE CALLS
    IUNIT=INFO(1)
    ITYPE=INFO(2)

C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
THICK_ABSORBER=PAR(3)
K_ABSORBER=PAR(4)
N_TUBES=FIX(PAR(5)+0.5)
DIA_TUBE=PAR(6)
WIDTH_BOND=PAR(7)
THICK_BOND=PAR(8)
K_BOND=PAR(9)
R_ADHESIVE=PAR(10)
R_BACK=PAR(11)
CP_FLUID=PAR(12)
REFLECTANCE=PAR(13)
EMISSIVITY=PAR(14)
B0=PAR(15)
T_REF=PAR(16)
GT_REF=PAR(17)
EFF_PV_REF=PAR(18)
EFF_CORR_T=PAR(19)
EFF_CORR_I=PAR(20)
C CHECK THE PARAMETERS FOR PROBLEMS AND RETURN FROM THE SUBROUTINE IF AN
ERROR IS FOUND
IF (LENGTH.LE.0.) CALL TYPECK(-4,INFO,0,1,0)
IF (WIDTH.LE.0.) CALL TYPECK(-4,INFO,0,2,0)
IF (THICK_ABSORBER.LE.0.) CALL TYPECK(-4,INFO,0,3,0)
IF (N_TUBES.LT.1) CALL TYPECK(-4,INFO,0,5,0)
IF (DIA_TUBE.LE.0.) CALL TYPECK(-4,INFO,0,6,0)
IF (N_TUBES*DIA_TUBE.GT.WIDTH) CALL TYPECK(-4,INFO,0,6,0)
IF (R_ADHESIVE.LE.0.) CALL TYPECK(-4,INFO,0,10,0)
IF (R_BACK.LE.0.) CALL TYPECK(-4,INFO,0,11,0)
IF (CP_FLUID.LE.0.) CALL TYPECK(-4,INFO,0,12,0)
IF (T_REF.LE.0.) CALL TYPECK(-4,INFO,0,13,0)
IF (GT_REF.LE.0.) CALL TYPECK(-4,INFO,0,14,0)
IF (EFF_PV_REF.LE.0.) CALL TYPECK(-4,INFO,0,15,0)
IF (EFF_CORR_T.LE.0.) CALL TYPECK(-4,INFO,0,15,0)
IF (EFF_CORR_I.LE.0.) CALL TYPECK(-4,INFO,0,15,0)
IF(EFF_PV_REF.GT.1.) CALL TYPECK(-4,INFO,0,18,0)

C PERFORM ANY REQUIRED CALCULATIONS TO SET THE INITIAL VALUES OF THE OUTPUTS HERE
OUT(1)=XIN(1)
OUT(2:7)=0.
OUT(8)=XIN(1)
OUT(9)=XIN(1)
OUT(10:19)=0.
C RETURN TO THE CALLING PROGRAM
RETURN 1
ENDIF

C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C *** ITS AN ITERATIVE CALL TO THIS COMPONENT ***
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C RE-READ THE PARAMETERS IF ANOTHER UNIT OF THIS TYPE HAS BEEN CALLED
IF(INFO(1).NE.IUNIT) THEN
C RESET THE UNIT NUMBER
IUNIT=INFO(1)
ITYPE=INFO(2)
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
THICK_ABSORBER=PAR(3)
K_ABSORBER=PAR(4)
N_TUBES=FIX(PAR(5)+0.5)
DIA_TUBE=PAR(6)
WIDTH_BOND=PAR(7)
THICK_BOND=PAR(8)
K_BOND=PAR(9)
R_ADHESIVE=PAR(10)
R_BACK=PAR(11)
CP_FLUID=PAR(12)
REFLECTANCE=PAR(13)
EMISSIVITY=PAR(14)
B0=PAR(15)
T_REF=PAR(16)
GT_REF=PAR(17)
EFF_PV_REF=PAR(18)
EFF_CORR_T=PAR(19)
EFF_CORR_J=PAR(20)
ENDIF

C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C RETRIEVE THE CURRENT VALUES OF THE INPUTS TO THIS MODEL FROM THE XIN ARRAY IN SEQUENTIAL ORDER
T_FLUID_IN=XIN(1)
FLOW_IN=XIN(2)
T_AMB=XIN(3)
T_SKY=XIN(4)
T_BACK=XIN(5)
GT=XIN(6)
GH=XIN(7)
GD=XIN(8)
REFL_GROUND=XIN(9)
ANGLE_INC=XIN(10)
SLOPE=XIN(11)
H_CONV_T=XIN(12)
H_CONV_B=XIN(13)
H_FLUID=XIN(14)
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C PERFORM ALL THE CALCULATION HERE FOR THIS MODEL.
C SET PI
PI=4*DATAN(1.D0)
C CALCULATE THE AREA OF THE COLLECTOR
AREA=LENGTH*WIDTH
C CALCULATE THE TUBE-TO-TUBE DISTANCE
W=WIDTH/DIBLE(N_TUBES)
C SET THE TRANSMITTANCE AT NORMAL INCIDENCE
TAUALPHAN=1.-REFLECTANCE
C DETERMINE INCIDENCE ANGLE MODIFIER
IF(GT_LT.0. .AND. ANGLE_INC_LT.90.) THEN
C USE RELATIONS OF BRANDEMUEHL FOR EFFECTIVE INCIDENCE ANGLES FOR DIFFUSE

EFFSKY=59.680.1388*SLOPE+0.001497*SLOPE*PD
COSSLP=DOS/SLOPE*RD

C SET THE INCIDENCE ANGLE MODIFIERS

XKATB=TAUALF(ANGLE_INC)
XKATD=GDSKY+XKATD*GDGDND*REFL*GND*GD

C SET THE RESISTANCE FROM THE PV SURFACE TO THE ABSORBER

R_T=R_ADHESIVE
C SET THE RESISTANCE FROM THE ABSORBER TO THE BACK

R_B=R_BACK+1/H_CONV_B
C SEE IF THE DEVICE HAS FLUID FLOW

IF (FLOW_IN.LE.0.) THEN
C GUESS A PV SURFACE TEMPERATURE

T_PV=T_AMB+1
T_PV_OLD=T_PV
ICOUNT=1
C CALCULATE THE PV CELL EFFICIENCY

10 FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
FACTOR_I=1+EFF_CORR_I*(T_PV-T_REF)
EFF_PV=DMAX1(0.,FACTOR_T*FACTOR_I*EFF_PV_REF)
C GET THE RADIATION HEAT TRANSFER COEFFICIENT

H_RAD=H_RADIATION(T_PV,T_SKY,EMISSIVITY)
C SET THE ABSORBED SOLAR ENERGY

S=TAUALPHAN*XKAT*GT*(1-EFF_PV)
C GET THE NEXT GUESS FOR THE PV TEMPERATURE FROM THE PV SURFACE ENERGY BALANCE

T_PV=S*(R_T+R_B)+H_RAD*T_SKY*(R_T+R_B)+R_BACK+H_CONV_T*(R_T+R_B)
1 (R_T+R_B)*T_AMB+1.1+H_RAD*(R_T+R_B)+H_CONV_T*(R_T+R_B))
C CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED

IF(DABS(T_PV_OLD-T_PV)/GT.0.001) AND.
1 (ICOUNT.1000) THEN
T_PV_OLD=T_PV
ICOUNT=ICOUNT+1
GOTO 10
ENDIF
C SET THE ABSORBER PLATE TEMPERATURE FROM AN ENERGY BALANCE ON THE ABSORBER PLATE

T_PV_MEAN=T_PV
T_PMEA=(R_T*R_BACK+R_B*T_PV_MEAN)/(R_T+R_B)
C SET THE OUTLET FLUID CONDITIONS

T_FLUID_MEAN=T_PMEA
T_FLUID_OUT=T_FLUID_MEAN
C SET THE COLLECTOR USEFUL ENERGY GAIN TERMS AND THE THERMAL EFFICIENCY

QU=0.
Q_BASE-0.
Q_FIN=0.
EFF_THERMAL=0.
C CALCULATE THE POWER OUTPUT FROM THE CELL EFFICIENCY
POWER=TAUALPHAN*XKAT*EFF_PV*AREA*GT
C SET SOME COLLECTOR CONSTANTS
FR=0.
C CALCULATE THE TOP CONVECTIVE LOSSES

Q_TOP_CONV=AREA*H_CONV_T*(T_PV_MEAN-T_AMB)
C CALCULATE THE TOP RADIATIVE LOSSES

Q_TOP_RAD=AREA*H_RAD*(T_PV_MEAN-T_SKY)
C CALCULATE THE BACK CONVECTIVE LOSSES

Q_BACK=AREA*H_BACK*(T_PV_MEAN-T_BACK)
C CALCULATE THE ABSORBED SOLAR RADIATION

Q_ABS=AREA*GT*(1-EFF_PV)*TAUALPHAN*XKAT
C CALCULATE THE COLLECTOR OVERALL LOSS COEFFICIENT

IF(T_PV_MEAN.EQ.T_AMB) THEN
UL=9999.
ELSE
UL=S(T_PV_MEAN-T_AMB)
ENDIF
C CALCULATE THE TUBE-TO-PLATE BOND RESISTANCE

IF((K_BOND.LE.0.) OR (WIDTH_BOND.LE.0.)) THEN
R_BOND=0.
ELSE
R_BOND=THICK_BOND/K_BOND/WIDTH_BOND
ENDIF

C GUESS A PV SURFACE TEMPERATURE
T_PV=T_AMB+1.
T_PV_OLD=T_PV
ICOUNT=1

C CALCULATE THE PV CELL EFFICIENCY
FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
FACTOR_I=1+EFF_CORR_I*(GT-GT_REF)
EFF_PV=DMAX1(0.,(FACTOR_T*FACTOR_I*EFF_PV_REF))

C GET THE RADIATION HEAT TRANSFER COEFFICIENT
H_RAD=H_RADIATION(T_PV,T_SKY,EMISSIVITY)

C SET THE ABSORBED SOLAR ENERGY
S=TAUALPHAN*XKAT*GT*(1.-EFF_PV)

C SET SOME VARIABLES WE'LL NEED THROUGHOUT THE MODEL
FPRIME=1./(H_RAD*R_T+H_CONV_T*R_T+1./R_B/FPRIME)

B=S+H_RAD*T_SKY+H_CONV_T*T_AMB+T_BACK/R_B/FPRIME
J_FACTOR=1./R_T/FPRIME+1./R_B/FPRIME-1./R_T

M=(FPRIME*K_ABSORBER/THICK_ABSORBER)**0.5
N=2.*K_ABSORBER*THICK_ABSORBER*M*DTANH(M*(W-DIA_TUBE)/2.)/(W-DIA_TUBE)

U=DIA_TUBE*FPRIME*(H_RAD+H_CONV_T+1./R_B/FPRIME)
EPSILON=DIA_TUBE*FPRIME*(B+N*B/F) J_FACTOR
SIGMA=U/N
THETA=1+Z*U+N*Z

C THE DERIVATION OF THIS MODEL IS EXPLAINED IN GREAT DETAIL IN THE ACCOMPANYING TECHNICAL MANUAL: TYPE560.PDF

C SET THE FLUID OUTLET TEMPERATURE
T_FLUID_OUT=(T_FLUID_IN+EPSILON/SIGMA)*DEXP(N_TUBES*SIGMA/THETA/FLOW_IN/CP_FLUID)-EPSILON/SIGMA/(LENGTH*N_TUBES/THETA/FLOW_IN/CP_FLUID)

C CALCULATE THE ENERGY TO THE FLUID FROM THE BASE OF THE FIN
Q_BASE=FPRIME*N_TUBES*DIA_TUBE*(S+H_RAD*T_SKY+H_CONV_T+1./R_B/FPRIME)

C CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED
IF((DABS(T_PV_OLD-T_PV).GT.0.001).AND.(ICOUNT.LT.1000)) THEN
T_PV_OLD=T_PV
ICOUNT=ICOUNT+1
GOTO 20
ENDIF

C WITH THE MEAN FLUID TEMPERATURE KNOWN, CALCULATE THE MEAN BASE TEMPERATURE
T_BASE_MEAN=T_FLUID_MEAN+QU_PRIME*Z

C WITH THE MEAN BASE TEMPERATURE KNOWN, CALCULATE THE MEAN TEMPERATURE FOR THE FIN ALONG THE X-AXIS
T_FIN_MEAN=B/J_FACTOR+2.*(T_BASE_MEAN-B/J_FACTOR)*DTANH(M*(W-DIA_TUBE)/2.)/(M*(W-DIA_TUBE))

C WE CAN ALSO CALCULATE THE MEAN ABSORBER TEMPERATURE
T_BASE_MEAN=R_T*FPRIME*(S+H_RAD*T_SKY+H_CONV_T+T_AMB+1./R_T)
T_FIN_MEAN=R_T*FPRIME*(S+H_RAD*T_SKY+H_CONV_T+T_AMB+1./R_T)
T_FIN_MEAN=2.*K_ABSORBER*THICK_ABSORBER*M*(B+N*B/F)/J_FACTOR

C SET THE MEAN FLUID TEMPERATURE IN THE Y-DIRECTION
T_FLUID_MEAN=(T_FLUID_IN+EPSILON/THETA)*DEXP(N_TUBES/THETA/flows_INCP_FLUID)-EPSILON/THETA/N_TUBES

C WITH THE OUTLET TEMPERATURE KNOWN, CALCULATE THE USEFUL ENERGY GAIN QU=(FLOW_INCP_FLUID-T_FLUID_OUT-T_FLUID_IN)

C CALCULATE THE THERMAL EFFICIENCY
EFF_THERMAL=QU/AREA/GT

C CALCULATE THE ENERGY TO THE FLUID FROM THE FIN
Q_FIN=2.*K_ABSORBER*THICK_ABSORBER*(B/J_FACTOR-T_BASE_MEAN)*DTANH(M*(W-DIA_TUBE)/2.)/(M*(W-DIA_TUBE))

C CALCULATE THE POWER OUTPUT FROM THE CELL EFFICIENCY
POWER=TAUALPHAN*XKAT*EFF_PV*AREA*GT
C       CALCULATE THE TOP CONVECTIVE LOSSES
Q_TOP_CONV=AREA*H_CONV*(T_PV_MEAN - T_AMB)

C       CALCULATE THE TOP RADIATIVE LOSSES
Q_TOP_RAD=AREA*H_RAD*(T_PV_MEAN - T_SKY)

C       CALCULATE THE BACK CONVECTIVE LOSSES
Q_BACK=AREA*(T_PLATE_MEAN - T_BACK)/R_B

C       CALCULATE THE ABSORBED SOLAR RADIATION
Q_ABS=AREA*GT*(1-EFF_PV)*TAUALPHAN*XKAT

C       NOW SOLVE FOR THE FICTIONAL UL FROM QU=AREA*(S-UL*(T_PLATE-T_AMB))
IF(T_PLATE_MEAN.EQ.T_AMB) THEN
   UL=9999.
ELSE
   UL=(S-QU/AREA)/(T_PLATE_MEAN-T_AMB)
ENDIF

C       NOW CALCULATE THE COLLECTOR HEAT REMOVAL FACTOR FR
IF((S-UL*(T_FLUID_IN-T_AMB)).EQ.0.) THEN
   FR=0.
ELSE
   FR=QU/AREA*(S-UL*(T_FLUID_IN-T_AMB))
ENDIF

C-----------------------------------------------------------------------------------------------------------------------
C------------------------------------
C    SET THE OUTPUTS FROM THIS MODEL IN SEQUENTIAL ORDER AND GET OUT
OUT(1)=T_FLUID_OUT
OUT(2)=FLOW_IN
OUT(3)=QU
OUT(4)=POWER
OUT(5)=EFF_PV
OUT(6)=EFF_THERMAL
OUT(7)=FR
OUT(8)=T_PV_MEAN
OUT(9)=T_FLUID_MEAN
OUT(10)=XKAT
OUT(11)=Q_TOP_CONV
OUT(12)=Q_TOP_RAD
OUT(13)=Q_BACK
OUT(14)=Q_ABS
OUT(15)=UL
OUT(16)=FR*TAUALPHAN
OUT(17)=FR*UL
OUT(18)=Q_BASE
OUT(19)=Q_FIN

RETURN 1
TYPE 563- Unglazed PV/T collector with fluid stream passing through tubes bonded to an absorber plate located beneath the PV cells (considering conduction between the back of the collector and the roof)

SUBROUTINE TYPE563(TIME,XIN,OUT,T,DTDT,PAR,INFO,ICNTRL,*)

C=======================================================================================
C DESCRIPTION:
C THIS SUBROUTINE MODELS AN UNGLASED PV/ THERMAL COLLECTOR. IN THIS VERSION, THE WORKING FLUID IS WATER
C CARRIED IN TUBES BONDED TO A PLATE. THE PV MATERIAL IS ADHERED TO THE TOP OF THIS PLATE. THE PV SYSTEM
C IS ASSUMED TO BE WORKING UNDER THE MAXIMUM POWER POINT ASSUMPTION.
C THIS MODEL IS BASED ON A DERIVATION BY JEFF THORNTON OF THERMAL ENERGY SYSTEM SPECIALISTS FROM THE
C STANDARD TUBE-FIN SOLAR COLLECTOR ALGORITHMS PRESENTED BY DUFFIE AND BECKMAN IN THE CLASSIC "SOLAR
C ENGINEERING OF THERMAL PROCESSES" - SPECIFICALLY CHAPTER SIX.
C LAST MODIFIED:
C FEBRUARY 2004 - JWT - INITIAL PROGRAMMING
C MODIFIED APRIL 2004 - FIXED THE PV POWER EQUATION TO INCLUDE XKAT AND TAU-ALPHA FACTORS
C
C=======================================================================================
C Copyright © 2006 Thermal Energy System Specialists, LLC. All rights reserved.
C=======================================================================================
C ACCESS TRNSYS FUNCTIONS
USE TrnsysConstants
USE TrnsysFunctions
C=======================================================================================
C REQUIRED BY THE MULTI-DLL VERSION OF TRNSYS
*DECLATTRIBUTES DLLEXPORT : TYPE563
C=======================================================================================
C TRNSYS DECLARATIONS
IMPLICIT NONE
DOUBLE PRECISION XIN,OUT,TIME,PAR,T,DTDT,TIMED,TFINAL,DELT
INTEGER*4 INFO(15),NP,NL,NOUT,NJ,UUNIT,ITYPE,ICNTRL
CHARACTER*3 YCHECK,OCHECK
C=======================================================================================
C USER DECLARATIONS
PARAMETER(NP=21,NL=13,NOUT=20,NJ=0)
C=======================================================================================

RETURN 1
C=======================================================================================
C DECLARATIONS AND DEFINITIONS FOR THE USER VARIABLES
DOUBLE PRECISION TAUALF,ANGLE_INC,B0,RDCONV,LENGTH,WIDTH,
1 THICK_ABSORBER,K_ABSORBER,DIA_TUBE,WIDTH_BOND,THICK_BOND,
1 R_BOND,R_ADHESIVE,R_BACK,CP_FLUID,REFLECTANCE,EMISSIVITY,
1 T_FLUID_IN,FLOW_IN,AMBIENT_SKYTE,T_SKYTE_INSIDE,GT,GH,GD,REFL_GROUND,
1 SLOPE,HEIGHT_CONV,T_HEIGHT,AREA_W,T_FLUID_OUT,QU_POWER,
1 EFF_PV,EFF_THERMAL,FR,T_PLATE_MEAN,T_FLUID_MEAN,XKAT,T_BACK,
1 Q_TOP_CONV,Q_TOP_RAD,Q_BACK,Q_BASE,Q_FIN,Q_ABS,FPRI,T+
1 TAULPHAN,EFF_SKY,EFF_GND,COS_SLP,FSKY,FGND,GDSKY,GDGND,XKATB,
1 XKATDS,XKATDG,T_REF,GT_REF,EF_PV,EF_THERMAL,EF_CORR_T,EF_CORR_I,
1 R_T,P_B,T_pv,T_pv_OLD,FACTOR_T,FACTOR_I,TH_RAD_H,RADITION_S,
1 T_MEAN_B,J_FACTOR,MNUUR_BOND,ZPI_EPSILON_SIGMA_THETA,
1 QU_PRIME,T_BASE_MEAN,T_FIN_MEAN,T_PV_MEAN_BASE,
1 T_PV_MEAN_FI,U_ROOF,
1 INTEGER N_TUBES,ICOUNT
C=======================================================================================
C REQUIRED TRNSYS DIMENSIONS
DIMENSION XIN(N),OUT(NOUT),PAR(NP),YCHECK(NI),OCHECK(NOUT),T(ND),
1 DTDT(ND)
C=======================================================================================
C DECLARATIONS AND DEFINITIONS FOR THE USER VARIABLES
DOUBLE PRECISION TAUALF,ANGLE_INC,B0,RDCONV,LENGTH,WIDTH,
1 THICK_ABSORBER,K_ABSORBER,DIA_TUBE,WIDTH_BOND,THICK_BOND,
1 R_BOND,R_ADHESIVE,R_BACK,CP_FLUID,REFLECTANCE,EMISSIVITY,
1 T_FLUID_IN,FLOW_IN,AMBIENT_SKYTE,T_SKYTE_INSIDE,GT,GH,GD,REFL_GROUND,
1 SLOPE,HEIGHT_CONV,T_HEIGHT,AREA_W,T_FLUID_OUT,QU_POWER,
1 EFF_PV,EFF_THERMAL,FR,T_PLATE_MEAN,T_FLUID_MEAN,XKAT,T_BACK,
1 Q_TOP_CONV,Q_TOP_RAD,Q_BACK,Q_BASE,Q_FIN,Q_ABS,FPRI,T+
1 TAULPHAN,EFF_SKY,EFF_GND,COS_SLP,FSKY,FGND,GDSKY,GDGND,XKATB,
1 XKATDS,XKATDG,T_REF,GT_REF,EF_PV,EF_THERMAL,EF_CORR_T,EF_CORR_I,
1 R_T,P_B,T_pv,T_pv_OLD,FACTOR_T,FACTOR_I,TH_RAD_H,RADITION_S,
1 T_MEAN_B,J_FACTOR,MNUUR_BOND,ZPI_EPSILON_SIGMA_THETA,
1 QU_PRIME,T_BASE_MEAN,T_FIN_MEAN,T_PV_MEAN_BASE,
1 T_PV_MEAN_FI,U_ROOF,
1 INTEGER N_TUBES,ICOUNT
C=======================================================================================

IEA SHC – Task 35 – PV/Thermal Solar Systems 21
C DO ALL THE VERY LAST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(8).EQ.-1) THEN
RETURN 1
ENDIF

C PERFORM ANY 'AFTER-ITERATION' MANIPULATIONS THAT ARE REQUIRED
IF(INFO(13).GT.0) THEN
RETURN 1
ENDIF

C DO ALL THE VERY FIRST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(7).EQ.-1) THEN
C RETRIEVE THE UNIT NUMBER AND TYPE NUMBER FOR THIS COMPONENT FROM THE INFO
ARRAY
IUNIT=INFO(1)
ITYPE=INFO(2)
C SET SOME INFO ARRAY VARIABLES TO TELL THE TRNSYS ENGINE HOW THIS TYPE IS TO
WORK
INFO(6)=NOUT
INFO(9)=1
INFO(10)=0
C CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO
WHAT IS SUPPLIED
CALL TYPECK(IINFO,NLNP,N)
C SET THE YCHECK AND OCHECK ARRAYS TO CONTAIN THE CORRECT VARIABLE TYPES FOR
THE INPUTS AND OUTPUTS
DATA YCHECK/’TE1’,’MF1’,’TE1’,’TE1’,’IR1’,’IR1’,’IR1’,
’DM1’,’DG1’,’HT1’,’HT1’,’HT1’,’HT1’,
’HT1’,’PW1’,’PW1’,’PW1’,’PW1’,’PW1’,’PW1’,’PW1’/
DATA OCHECK/’TE1’,’MF1’,’PW1’,’PW1’,’DM1’,’DM1’,’DM1’,’TE1’,
’TE1’,’DM1’,’PW1’,’PW1’,’PW1’,’PW1’,’HT1’,’HT1’,’DM1’,
’DM1’,’DM1’,’DM1’,’DM1’,
C CALL THE RCHECK SUBROUTINE TO SET THE CORRECT INPUT AND OUTPUT TYPES FOR THIS
COMPONENT
CALL RCHECK(INFO,YCHECK,OCHECK)
C RETURN TO THE CALLING PROGRAM
RETURN 1
ENDIF

C DO ALL OF THE INITIAL TIMESTEP MANIPULATIONS HERE - THERE ARE NO ITERATIONS AT THE
INITIAL TIME
IF (TIME.LT.(TIME0+DELT/2.D0)) THEN
C SET THE UNIT NUMBER FOR FUTURE CALLS
IUNIT=INFO(1)
ITYPE=INFO(2)
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
K_ABSORBER=PAR(4)
N_TUBES=JFIX(PAR(5)+0.5)
WIDTH_BOND=PAR(7)
K_BOND=PAR(9)
R_ADHESIVE=PAR(10)
R_BACK=PAR(11)
U_ROOF=PAR(12)
REFERENCES=PAR(14)
EMISSIVITY=PAR(15)
B0=PAR(16)
T_REF=PAR(17)
GT_REF=PAR(18)
EFF_PV_REF=PAR(19)
EFF_CORR_T=PAR(20)
EFF_CORR_I=PAR(21)
C CHECK THE PARAMETERS FOR PROBLEMS AND RETURN FROM THE SUBROUTINE IF AN
ERROR IS FOUND
IF(LENGTH.LE.0.) CALL TYPECK(-4,INFO,0,1,0)
IF(WIDTH.LE.0.) CALL TYPECK(-4,INFO,0,2,0)
IF(K_ABSORBER.LE.0.) CALL TYPECK(-4,INFO,0,3,0)
IF(N_TUBES.LT.1) CALL TYPECK(-4,INFO,0,5,0)
IF(DBLE(N_TUBES)*DIA_TUBE.GT.WIDTH) CALL TYPECK(-4,INFO,0,6,0)
IF(R_ADHESIVE.LE.0.) CALL TYPECK(-4,INFO,0,10,0)
IF(R_BACK.LE.0.) CALL TYPECK(-4,INFO,0,11,0)
IF(U_ROOF.LE.0.) CALL TYPECK(-4,INFO,0,12,0)
IF(CP_FLUID.LE.0.) CALL TYPECK(-4,INFO,0,13,0)
IF(REFERENCE.LT.0.) CALL TYPECK(-4,INFO,0,14,0)
IF(REFERENCE.GT.1.) CALL TYPECK(-4,INFO,0,15,0)
IF(REFERENCE.LT.0.) CALL TYPECK(-4,INFO,0,16,0)
IF(R_BACK.LE.0.) CALL TYPECK(-4,INFO,0,17,0)
IF(REFERENCE.LT.0.) CALL TYPECK(-4,INFO,0,18,0)
IF(EFF_PV_REF.LT.0.) CALL TYPECK(-4,INFO,0,19,0)
IF(EFF_PV_REF.GT.1.) CALL TYPECK(-4,INFO,0,19,0)
C PERFORM ANY REQUIRED CALCULATIONS TO SET THE INITIAL VALUES OF THE OUTPUTS HERE
   OUT(1)=XIN(1)
   OUT(2:7)=0.
   OUT(8)=XIN(1)
   OUT(9)=XIN(1)
   OUT(10:19)=0.
   OUT(20)=XIN(5)
C RETURN TO THE CALLING PROGRAM
RETURN 1
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C    *** ITS AN ITERATIVE CALL TO THIS COMPONENT ***
C-----------------------------------------------------------------------------------------------------------------------
C RE-READ THE PARAMETERS IF ANOTHER UNIT OF THIS TYPE HAS BEEN CALLED IF(INFO(1).NE.IUNIT) THEN
C RESET THE UNIT NUMBER
   IUNIT=INFO(1)
   ITYPE=INFO(2)
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
   LENGTH=PAR(1)
   WIDTH=PAR(2)
   THICK_ABSORBER=PAR(3)
   K_ABSORBER=PAR(4)
   N_TUBES=FIX(PAR(5)+0.5)
   DIA_TUBE=PAR(6)
   WIDTH_BOND=PAR(7)
   THICK_BOND=PAR(8)
   K_BOND=PAR(9)
   R_ADHESIVE=PAR(10)
   R_BACK=PAR(11)
   U_ROOF=PAR(12)
   CP_FLUID=PAR(13)
   REFLECTANCE=PAR(14)
   EMISSIVITY=PAR(15)
   B0=PAR(16)
   T_REF=PAR(17)
   GT_REF=PAR(18)
   EFF_PV_REF=PAR(19)
   EFF_CORR_T=PAR(21)
C-----------------------------------------------------------------------------------------------------------------------
C RETRIEVE THE CURRENT VALUES OF THE INPUTS TO THIS MODEL FROM THE XIN ARRAY IN SEQUENTIAL ORDER
   T_FLUID_IN=XIN(1)
   FLOW_IN=XIN(2)
   T_AMB=XIN(3)
   T_SKY=XIN(4)
   T_INSIDE=XIN(5)
   GT=XIN(6)
   GH=XIN(7)
   GD=XIN(8)
   REFLECTANCE_GROUND=XIN(9)
   ANGLE_INC=XIN(10)
   SLOPE=XIN(11)
   H_CONV_T=XIN(12)
   H_FLUID=0.0
C-----------------------------------------------------------------------------------------------------------------------
C CHECK THE INPUTS FOR PROBLEMS
IF(FLOW_IN.LT.0.) CALL TYPECK(-3,INFO,2,0,0)
IF(GT.LT.0.) CALL TYPECK(-3,INFO,6,0,0)
IF(GH.LT.0.) CALL TYPECK(-3,INFO,7,0,0)
IF(GD.LT.0.) CALL TYPECK(-3,INFO,8,0,0)
IF(REFLECTANCE_GROUND.LT.0.) CALL TYPECK(-3,INFO,9,0,0)
IF(REFLECTANCE_GROUND.GT.1.) CALL TYPECK(-3,INFO,9,0,0)
IF(H_CONV_T.LE.0.) CALL TYPECK(-3,INFO,12,0,0)
IF(H_FLUID.LE.0.) CALL TYPECK(-3,INFO,13,0,0)
IF(ERRORFOUND()) RETURN 1
C-----------------------------------------------------------------------------------------------------------------------
C PERFORM ALL THE CALCULATION HERE FOR THIS MODEL.
C SET PI
   PI=4*DATAN(1.0)
C CALCULATE THE AREA OF THE COLLECTOR
   AREA=LENGTH*WIDTH
C CALCULATE THE TUBE-TO-TUBE DISTANCE
   W=WIDTH/DBLE(N_TUBES)
C SET THE TRANSMITTANCE AT NORMAL INCIDENCE
   TAU_ALPHA=1.0-REFLECTANCE
C DETERMINE INCIDENCE ANGLE MODIFIER
IF (GT .GT. 0. .AND. ANGLE_INC .LT. 90.) THEN
C USE RELATIONS OF BRANDMUEHL FOR EFFECTIVE INCIDENCE ANGLES FOR DIFFUSE
EFFSKY=59.68-0.1388*SLOPE+0.001497*SLOPE*SLOPE
EFFGND=90.-0.5788*SLOPE+0.002693*SLOPE*SLOPE
COSSLSP=D*COS(SLOPE*RDCONV)
FSKY=(1.+COSSLSP)/2.
FGND=(1.-COSSLSP)/2.
GDSKY=FSKY*GD
GDGND=REFL_GROUND*FGND*GH
C SET THE INCIDENCE ANGLE MODIFIERS
XKATB=TAUALF(ANGLE_INC)
XKATDS=TAUALF(EFFSKY)
XKATDG=TAUALF(EFFGND)
XKAT=(XKATB*(GT-GDSKY-GDGND)+XKATDS*GDSKY+XKATDG*GDGND)/GT
IF(XKAT.LE.0.) XKAT=0.
ELSE
XKAT=0.
ENDIF
C SET THE RESISTANCE FROM THE PV SURFACE TO THE ABSORBER
R_T=R_ADHESIVE
C SET THE RESISTANCE FROM THE ABSORBER TO THE BACK SURFACE (ZONE AIR/ROOF INTERFACE)
R_B=R_BACK+1./U_ROOF
C SEE IF THE DEVICE HAS FLUID FLOW
IF(FLOW_IN.LE.0.) THEN
C GUESS A PV SURFACE TEMPERATURE
T_PV=T_AMB+1.
T_PV_OLD=T_PV
ICOUNT=1
C CALCULATE THE PV CELL EFFICIENCY
10 FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
FACTOR_I=1+EFF_CORR_I*(GT-GT_REF)
EFF_PV=DMAX1(0.,(FACTOR_T*FACTOR_I*EFF_PV_REF))
C GET THE RADIATION HEAT TRANSFER COEFFICIENT
H_RAD=H_RADATION(T_PV,T_SKY,EMISSIVITY)
C SET THE ABSORBED SOLAR ENERGY
S=TAUALPHAN*XKAT*GT*(1.-EFF_PV)
C GET THE NEXT GUESS FOR THE PV TEMPERATURE FROM THE PV SURFACE ENERGY BALANCE
T_PV=(S*(R_T+R_B)+H_RAD*T_SKY+(R_T+R_B)*T_INSIDE+H_CONV_T*(R_T+R_B))/
1.0/(R_T+R_B)**T_AMB+(1.+H_RAD**(R_T+R_B)+H_CONV_T**(R_T+R_B))
C CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED
IF((DABS(T_PV_OLD-T_PV).GT.0.01).AND.
1.0/(ICOUNT.LT.1000)) THEN
T_PV_OLD=T_PV
ICOUNT=ICOUNT+1
GOTO 10
ENDIF
C SET THE ABSORBER PLATE TEMPERATURE FROM AN ENERGY BALANCE ON THE ABSORBER PLATE
T_PV_MEAN=T_PV
T_PLATE_MEAN=(R_T*T_INSIDE+R_B*T_PV_MEAN)/(R_T+R_B)
C SET THE OUTLET FLUID CONDITIONS
T_FLUID_MEAN=T_PV_MEAN
T_FLUID_OUT=T_FLUID_MEAN
C SET THE COLLECTOR USEFUL ENERGY GAIN TERMS AND THE THERMAL EFFICIENCY
QU=0.
Q_BASE=0.
Q_FIN=0.
EFF_THERMAL=0.
C CALCULATE THE POWER OUTPUT FROM THE CELL EFFICIENCY
POWER=TAUALPHAN*XKAT*EFF_PV*AREA*GT
C SET SOME COLLECTOR CONSTANTS
FR=0.
C CALCULATE THE TOP CONVECTIVE LOSSES
Q_TOP_CONV=AREA*H_CONV_T*(T_PV_MEAN-T_AMB)
C CALCULATE THE TOP RADIATIVE LOSSES
Q_TOP_RAD=AREA*H_RAD*(T_PV_MEAN-T_SKY)
C CALCULATE THE BACK CONVECTIVE LOSSES
Q_BACK=AREA*(T_PLATE_MEAN-T_INSIDE)/R_B
C CALCULATE THE ABSORBED SOLAR RADIATION
Q_ABS=AREA*GT-(1-EFF_PV)*TAUALPHAN*XKAT
C CALCULATE THE TEMPERATURE OF THE INTERFACE BETWEEN THE COLLECTOR AND THE ROOF
T_BACK=T_PLATE_MEAN-Q_BACK/R_BACK
C CALCULATE THE COLLECTOR OVERALL LOSS COEFFICIENT
U_T=U_BASE+(T_PV_MEAN-Q_BACK/T_AMB)
C IF(U_T.LT.9999.9)
ELSE
U_T=U_T
ENDIF
ELSE
C CALCULATE THE TUBE-TO-PLATE BOND RESISTANCE
IF((K_BOND.LE.0.).OR.(WIDTH_BOND.LE.0.)) THEN
  R_BOND=0.
ELSE
  R_BOND=THICK_BOND/K_BOND/WIDTH_BOND
ENDIF
C GUESS A PV SURFACE TEMPERATURE
T_PV=T_AMB+1.
T_PV_OLD=T_PV
ICOUNT=1
C CALCULATE THE PV CELL EFFICIENCY
FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
FACTOR_I=1+EFF_CORR_I*(GT-GT_REF)
EFF_PV=DMAX1(0.,(FACTOR_T*FACTOR_I*EFF_PV_REF))
C GET THE RADIATION HEAT TRANSFER COEFFICIENT
H_RAD=H_RADIATION(T_PV,T_SKY,EMISSIVITY)
C SET THE ABSORBED SOLAR ENERGY
S=TAUALPHAN*XKAT*GT*(1.-EFF_PV)
C SET SOME VARIABLES WELL NEED THROUGHOUT THE MODEL
FPRIME=1./(H_RAD*R_T+H_CONV_T*R_T+1.)
B=S+H_RAD*T_SKY+H_CONV_T*T_AMB+T_INSIDE/R_B/FPRIME
J_FACTOR=1./R_T/FPRIME+1./R_B/FPRIME-1./R_T
M=(FPRIME*J_FACTOR/K_ABSORBER/THICK_ABSORBER)**0.5
N=2.*K_ABSORBER*THICK_ABSORBER*M*DTANH(M*(W-DIA_TUBE)/2.)/W
U=DIA_TUBE*FPRIME/(H_RAD+H_CONV_T+1./R_B/FPRIME)
Z=1./H_FLUID/DIA_TUBE+R_BOND
EPISILON=DIA_TUBE*FPRIME+B/N/J_FACTOR
SIGMA=S/1./H_RADIATION(T_PV,T_SKY,EMISSIVITY)
THETA=1+Z*U+N*Z
C THE DERIVATION OF THIS MODEL IS EXPLAINED IN GREAT DETAIL IN THE ACcompanyING TECHNICAL
C DESCRIPTION MANUAL: TYPE563.PDF
C SET THE FLUID OUTLET TEMPERATURE
T_FLUID_OUT=T_FLUID_IN+EPISILON/PI/GT/SIGMA*DEXP/N_TUBES/SIGMA*LENGTH/T_THETA/FLOW_INCNP_FLUID/EPISILON/SIGMA
C WITH THE OUTLET TEMPERATURE KNOWN, CALCULATE THE USEFUL ENERGY GAIN
QU=FLOW_INCNP_FLUID/T_FLUID_OUT*T_FLUID_IN)
QU_PRIME=QU/N_TUBES/LENGTH
C SET THE MEAN FLUID TEMPERATURE IN THE Y-DIRECTION
T_FLUID_MEAN=T_FLUID_MEAN+QU_PRIME*Z
C WITH THE MEAN FLUID TEMPERATURE KNOWN, CALCULATE THE MEAN BASE TEMPERATURE
T_BASE_MEAN=T_FLUID_MEAN+QU_PRIME*Z
C WITH THE MEAN BASE TEMPERATURE KNOWN, CALCULATE THE MEAN TEMPERATURE FOR THE FIN ALONG THE X AXIS
T_FIN_MEAN=R_T*FPRIME*(S+H_RAD*T_SKY+H_CONV_T*T_AMB+T_BASE_MEAN/R_T)
C NOW WE CAN CALCULATE THE MEAN ABSORBER TEMPERATURE
T_PLATE_MEAN=(DIA_TUBE*T_BASE_MEAN+H_DIA_TUBE*T_FIN_MEAN)/W
C WE CAN ALSO CALCULATE THE MEAN TEMPERATURE OF THE PV SURFACE ABOVE THE BASE AND FIN
T_PV_MEAN_BASE=R_T*FPRIME*(S+H_RAD*T_SKY+H_CONV_T*T_AMB+T_BASE_MEAN/R_T)
T_PV_MEAN_FIN=R_T*FPRIME*(S+H_RAD*T_SKY+H_CONV_T*T_AMB+T_FIN_MEAN/R_T)
C NOW WE CAN CALCULATE THE MEAN PV SURFACE TEMPERATURE
T_PV_MEAN=(DIA_TUBE*T_PV_MEAN_BASE+(W-DIA_TUBE)*T_PV_MEAN_FIN)/W
C CALCULATE THE THERMAL EFFICIENCY
EFFECT_THERMAL=QU/AREA/GT
C CALCULATE THE ENERGY TO THE FLUID FROM THE BASE OF THE FIN
Q_BASE=FPRIME*N_TUBES*DIA_TUBE*(S+H_RAD*T_SKY+H_CONV_T*T_AMB+T_BASE_MEAN/R_B/FPRIME)
C CALCULATE THE ENERGY TO THE FLUID FROM THE FIN
Q_FIN=2.*K_ABSORBER*THICK_ABSORBER*M*DTANH(M*(W-DIA_TUBE)/2.)/(W-DIA_TUBE)*N_TUBES*(W-DIA_TUBE)
C DESIGN THE THERMAL EFFICIENCY
EFFECT_THERMAL=QU/AREA/GT
ELSE
EFFECT_THERMAL=0.
C       CALCULATE THE POWER OUTPUT FROM THE CELL EFFICIENCY
POWER=TAUALPHAN*XKAT*EFF_PV*AREA*GT

C       CALCULATE THE TOP CONVEXTIVE LOSSES
Q_TOP_CONV=AREA*H_CONV_T*(T_PV_MEAN-T_AMB)

C       CALCULATE THE TOP RADIATIVE LOSSES
Q_TOP_RAD=AREA*H_RAD*(T_PV_MEAN-T_SKY)

C       CALCULATE THE BACK CONVEXTIVE LOSSES
Q_BACK=AREA*(T_PLATE_MEAN-T_INSIDE)/R_B

C       CALCULATE THE ABSORBED SOLAR RADIATION
Q_ABS=AREA*GT*(1-EFF_PV)*TAUALPHAN*XKAT

C       CALCULATE THE TEMPERATURE OF THE INTERFACE BETWEEN THE COLLECTOR AND THE ROOF
T_BACK=T_PLATE_MEAN-Q_BACK*R_BACK/AREA

C NOW SOLVE FOR THE FICTIONAL UL FROM QU=AREA*(S-UL*(T_PLATE-T_AMB))
IF(T_PLATE_MEAN.EQ.T_AMB) THEN
   UL=9999.
ELSE
   UL=(S-QU/AREA)/(T_PLATE_MEAN-T_AMB)
ENDIF

C NOW CALCULATE THE COLLECTOR HEAT REMOVAL FACTOR FR
IF(S-UL*(T_FLUID_IN-T_AMB)).EQ.0.) THEN
   FR=0.
ELSE
   FR=QU/AREA/(S-UL*(T_FLUID_IN-T_AMB))
ENDIF

C-----------------------------------------------------------------------------------------------------------------------
C    SET THE OUTPUTS FROM THIS MODEL IN SEQUENTIAL ORDER AND GET OUT
OUT(1)=T_FLUID_OUT
OUT(2)=FLOW_IN
OUT(3)=QU
OUT(4)=POWER
OUT(5)=EFF_PV
OUT(6)=EFF_THERMAL
OUT(7)=FR
OUT(8)=T_PV_MEAN
OUT(9)=T_FLUID_MEAN
OUT(10)=XKAT
OUT(11)=Q_TOP_CONV
OUT(12)=Q_TOP_RAD
OUT(13)=Q_BACK
OUT(14)=Q_ABS
OUT(15)=UL
OUT(16)=FR*TAUALPHAN
OUT(17)=FR*UL
OUT(18)=Q_BASE
OUT(19)=Q_FIN
OUT(20)=T_BACK

C-----------------------------------------------------------------------------------------------------------------------
DESCRIPTION:

C THIS COMPONENT MODELS A BUILDING-INTEGRATED PHOTOVOLTAIC SYSTEM. IN THIS MODEL THERE IS ASSUMED TO BE A SINGLE GLASS COVER OVER THE PV MATERIAL. THE BACK OF THE BIPV SYSTEM INTERACTS WITH MODELS WHERE THE BACK-SIDE AIR TEMPERATURE AND BACK-SIDE RADIATIVE SURFACE TEMPERATURE ARE KNOWN. THE CONVECTION CALCULATIONS ARE FROM CORRELATIONS PROVIDED BY "INTRODUCTION TO HEAT TRANSFER" BY INCROPERA AND DEWITT.

INTRODUCTION TO HEAT TRANSFER, P. ATMA, DECLARATIONS AND DEFINITIONS FOR THE USER, REQUIRED PARAMETERS FOR THE SIZING OF THE ARRAYS, TRNSYS DECLARATIONS, ACCESS TRNSYS FUNCTIONS, USE TrnsysConstants, USE TrnsysFunctions.

DOUBLE PRECISION RDCONV, ANGLE_INC, TAU_ALF, B0

1 AREA, FLOW_IN, T_AMBIENT, GROUND, SLOPE, EMISS, COVER, TAUALPHAN, EFFSKY, EFFGND, COSSLP, PSKY, FGND, DSKY, GDGND, XKATB

XKATDS, F PRIME, XKATDG, T FLUID MEAN, T SKY, H CONV, T X(2), H CONV, B H FLUID, Q EFFECT, THERMAL, 5, R, 1, R, 2, R, 3, 0, Q TOP, CONV, N, 0, Q TOP, RAD, Q ABS, H RADIATION, EMISS, 1, EMISS, 2, EMISS, BACK, T ZONE, T ZONE, RAD, Q BACK, CONV, Q BACK, RAD, T 1, T 2, T 3, H RADIATION, 1, H RADIATION, GRAY, PRIME, MAA, CC, K, COVER, THICK, COVER, R1, COVER, EXT, COVER, ABS, PLATE, EFF, PV, Y(1), EFF, PV, REF, T REF, GT, REF, EFF, CORR, T EFF, CORR, I, T FLUID, IN, KL, COVER, RHO, DIFFUSE, TAU, ALPHA, COSSLOPE, XKAT, T COVER, T PV, T PV, OLD, FACTOR, T, FACTOR, LPV, EFF, POWER, H RAD, T H RAD, B H, PRIME, I, T FLUID, OUT, AIRPROPS(5), PL, LENGTH, WIDTH, THICK, CHANNEL, P ATM, P, KPA, DIAMETER, T PROPS, K RATIO, AIR, VISC, AIR, RANDTL, AIR, K, RATIO, CP, AIR, REYNOLDS, NUSSELT, T 1, K T 2, K T SURF

INTEGER ICOUNT, MODE IAM, MODE EFF, LL DATA, N TEMPS, N RADS, NX(2)

CHARACTER LEN=MAXMESSAGELENGTH, MESSAGE1
C-----------------------------------------------------------------------------------------------------------------------
C DO ALL THE VERY LAST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(8).EQ.-1) THEN
RETURN 1
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C PERFORM ANY "AFTER-ITERATION" MANIPULATIONS THAT ARE REQUIRED
IF (INFO(13).GT.0) THEN
RETURN 1
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C DO ALL THE VERY FIRST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(7).EQ.-1) THEN
C RETRIEVE THE UNIT NUMBER AND TYPE NUMBER FOR THIS COMPONENT FROM THE INFO ARRAY
IUNIT=INFO(1)
ITYPE=INFO(2)
C SET SOME INFO ARRAY VARIABLES TO TELL THE TRNSYS ENGINE HOW THIS TYPE IS TO WORK
INFO(6)=NOUT
INFO(9)=1
INFO(10)=0
C SET THE NUMBER OF PARAMETERS AND INPUTS
NPAR=13
NIN=15
IF (MODE_IAM.LT.1) CALL TYPECK(-4,INFO,NIN,NPAR,ND)
ELSE IF (MODE_IAM.GT.2) CALL TYPECK(-4,INFO,NIN,NPAR,ND)
ENDIF
IF (ERRORFOUND()) RETURN 1
IF (MODE_IAM.EQ.1) THEN
NPAR=NPAR+2
ELSE IF (MODE_IAM.EQ.2) THEN
NPAR=NPAR+3
ENDIF
IF (MODE_EFF.EQ.1) THEN
NPAR=NPAR+5
ELSE IF (MODE_EFF.EQ.2) THEN
NPAR=NPAR+3
ELSE IF (MODE_EFF.EQ.3) THEN
NIN=NIN+1
ENDIF
C CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO WHAT IS SUPPLIED IN
C THE TRNSYS INPUT FILE
CALL TYPECK(1,INFO,NIN,NPAR,ND)
C SET THE YCHECK AND OCHECK ARRAYS TO CONTAIN THE CORRECT VARIABLE TYPES FOR THE INPUTS AND OUTPUTS
DATA YCHECK/'TE1','MF1','TE1','TE1','TE1','IR1','IR1',
1 'IR1','DM1','DG1','DG1','HT1','HT1','PR2','DM1'/
DATA OCHECK/'TE1','MF1','PW1','DM1','PW1','DM1','TE1','TE1',
1 'TE1','TE1','TE1','TE1','DM1','PW1','PW1',
1 'PW1','PW1'/
C CALL THE RCHECK SUBROUTINE TO SET THE CORRECT INPUT AND OUTPUT TYPES FOR THIS COMPONENT
CALL RCHECK(INFO,YCHECK,OCHECK)
C RETURN TO THE CALLING PROGRAM
RETURN 1
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C DO ALL OF THE INITIAL TIMESTEP MANIPULATIONS HERE - THERE ARE NO ITERATIONS AT THE INITIAL TIME
IF (TIME.LT.(TIME0+DELT/2.D0)) THEN
C SET THE UNIT NUMBER FOR FUTURE CALLS
IUNIT=INFO(1)
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
EMISS_COVER=PAR(3)
K_COVER=PAR(4)
THICK_COVER=PAR(5)
EMISS_1=PAR(7)
EMISS_2=PAR(8)
EMISS_BACK=PAR(10)
THICK_CHANNEL=PAR(11)
MODE_IAM=JFIX(PAR(12)+0.5)
C-----------------------------------------------------------------------------------------------------------------------
MODE_EFF=JFIX(PAR(13)+0.5)
NPAR=13

C CHECK THE PARAMETERS FOR PROBLEMS AND RETURN FROM THE SUBROUTINE IF AN ERROR IS FOUND
IF(LENGTH.LE.0.) CALL TYPECK(-4,INFO,0,1,0)
IF(WIDTH.LE.0.) CALL TYPECK(-4,INFO,0,2,0)
IF(EMISS_COVER.LT.0.) CALL TYPECK(-4,INFO,0,3,0)
IF(EMISS_COVER.GT.1.) CALL TYPECK(-4,INFO,0,3,0)
IF(K_COVER.LE.0.) CALL TYPECK(-4,INFO,0,4,0)
IF(THICK_COVER.LE.0.) CALL TYPECK(-4,INFO,0,5,0)
IF(R_2.LE.0.) CALL TYPECK(-4,INFO,0,6,0)
IF(EMISS_1.LT.0.) CALL TYPECK(-4,INFO,0,7,0)
IF(EMISS_1.GT.1.) CALL TYPECK(-4,INFO,0,7,0)
IF(EMISS_2.LT.0.) CALL TYPECK(-4,INFO,0,8,0)
IF(EMISS_2.GT.1.) CALL TYPECK(-4,INFO,0,8,0)
IF(R_3.LE.0.) CALL TYPECK(-4,INFO,0,9,0)
IF(EMISS_BACK.LT.0.) CALL TYPECK(-4,INFO,0,10,0)
IF(EMISS_BACK.GT.1.) CALL TYPECK(-4,INFO,0,10,0)
IF(THICK_CHANNEL.LT.0.) CALL TYPECK(-4,INFO,0,11,0)
IF(ERRORFOUND()) RETURN 1

C GET THE IAM MODE SPECIFIC PARAMETERS
IF(MODE_IAM.EQ.1) THEN
TAUALPHAN=PAR(NPAR+1)
B0=PAR(NPAR+2)
IF(TAUALPHAN.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(TAUALPHAN.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(B0.LT.0.) CALL TYPECK(-4,INFO,0,NPAR+2,0)
IF(B0.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+2,0)
NPAR=NPAR+2
ELSE IF(MODE_IAM.EQ.2) THEN
ABS_PLATE=PAR(NPAR+1)
RI_COVER=PAR(NPAR+2)
EXT_COVER=PAR(NPAR+3)
IF(ABS_PLATE.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(ABS_PLATE.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(RI_COVER.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+2,0)
IF(EXT_COVER.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+3,0)
NPAR=NPAR+3
ENDIF

C GET THE PV EFFICIENCY SPECIFIC PARAMETERS
IF(MODE_EFF.EQ.1) THEN
EFF_PV_REF=PAR(NPAR+1)
T_REF=PAR(NPAR+2)
GT_REF=PAR(NPAR+3)
EFF_CORR_T=PAR(NPAR+4)
EFF_CORR_I=PAR(NPAR+5)
ELSE IF(MODE_EFF.EQ.2) THEN
LU_DATA=JFIX(PAR(NPAR+1)+0.5)
N_TEMPS=JFIX(PAR(NPAR+2)+0.5)
N_RADS=JFIX(PAR(NPAR+3)+0.5)
ELSE IF(MODE_EFF.EQ.3) THEN
ENDIF

C PERFORM ANY REQUIRED CALCULATIONS TO SET THE INITIAL VALUES OF THE OUTPUTS HERE
OUT(1)=XIN(1)
OUT(2:6)=0.
OUT(7)=T_AMB
OUT(8)=T_AMB
OUT(9)=XIN(1)
OUT(10)=XIN(1)
OUT(11)=XIN(1)
OUT(12)=T_ZONE
OUT(13:18)=0.

C RETURN TO THE CALLING PROGRAM
RETURN 1

C-------------------------------------------------------------------------------------------
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
EMISS_COVER=PAR(3)
K_COVER=PAR(4)
THICK_COVER=PAR(5)
R_2=PAR(6)
EMISS_1=PAR(7)
EMISS_2=PAR(8)
R_3=PAR(9)
EMISS_BACK=PAR(10)
THICK_CHANNEL=PAR(11)
MODE_IAM=JFIX(PAR(12)+0.5)
MODE_EFF=JFIX(PAR(13)+0.5)
NPAR=13
IF(MODE_IAM.EQ.1) THEN
TAUALPHAN=PAR(NPAR+1)
B0=PAR(NPAR+2)
ELSE IF(MODE_IAM.EQ.2) THEN
RI_COVER=PAR(NPAR+2)
EXT_COVER=PAR(NPAR+3)
ENDIF
IF(MODE_EFF.EQ.1) THEN
EFF_PV_REF=PAR(NPAR+1)
T_REF=PAR(NPAR+2)
GT_REF=PAR(NPAR+3)
EFF_CORR_T=PAR(NPAR+4)
EFF_CORR_I=PAR(NPAR+5)
ELSE IF(MODE_EFF.EQ.2) THEN
LU_DATA=JFIX(PAR(NPAR+1)+0.5)
N_TEMPS=JFIX(PAR(NPAR+2)+0.5)
N_RADS=JFIX(PAR(NPAR+3)+0.5)
ENDIF
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C PERFORM ALL THE CALCULATION HERE FOR THIS MODEL.
C SET SOME GEOMETRIC PARAMETERS
AREA=LENGTH*WIDTH
DIAMETER=4.*WIDTH*THICK_CHANNEL/(2.*WIDTH+2.*THICK_CHANNEL)
C SET THE INCIDENCE ANGLE MODIFIER BASED ON THE MODE
XKAT=1.
IF(MODE_IAM.EQ.1) THEN
C DETERMINE INCIDENCE ANGLE MODIFIER
IF(GT .GT. 0. .AND. ANGLE_INC .LT. 90.) THEN
C USE RELATIONS OF BRANDMUEHL FOR EFFECTIVE INCIDENCE ANGLES FOR DIFFUSE
EFFSKY=-59.68-0.1388*SLOPE+0.001497*SLOPE*SLOPE
EFFGND=90.-0.5788*SLOPE+0.002693*SLOPE*SLOPE
COSSLP=DCOS(SLOPE*RDCO
ELSE
FIERERRORFOUND() RETURN 1
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C CHECK THE INPUTS FOR PROBLEMS
IF(FLOW_IN.LT.0.) CALL TYPECK(-3,INFO,2,0,0)
IF(GH.LT.0.) CALL TYPECK(-3,INFO,8,0,0)
IF(GDH.LT.0.) CALL TYPECK(-3,INFO,9,0,0)
IF(REFL_GROUND.LT.0.) CALL TYPECK(-3,INFO,13,0,0)
IF(REFL_GROUND.GT.1.) CALL TYPECK(-3,INFO,14,0,0)
IF(P_ATM.LE.0.) CALL TYPECK(-3,INFO,15,0,0)
IF(EFF_PV.LT.0.) CALL TYPECK(-3,INFO,16,0,0)
IF(EFF_PV.GT.1.) CALL TYPECK(-3,INFO,16,0,0)
ERRORFOUND() RETURN 1
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C RETRIEVE THE CURRENT VALUES OF THE INPUTS TO THIS MODEL FROM THE XIN ARRAY IN SEQUENTIAL ORDER
T_FLUID_IN=XIN(1)
FLOW_IN=XIN(2)
T_AMB=XIN(3)
T_SKY=XIN(4)
T_ZONE=XIN(5)
T_ZONE_RAD=XIN(6)
GT=XIN(7)
GH=XIN(8)
GDH=XIN(9)
REFL_GROUND=XIN(10)
ANGLE_INC=XIN(11)
SLOPE=XIN(12)
H_CONV_T=XIN(13)
H_CONV_B=XIN(14)
P_ATM=XIN(15)

IEA SHC – Task 35 – PV/Thermal Solar Systems 30
FGND=(1.-COSSLP)/2.
GDSKY=FSKY*GDH
GDGND=REFL_GROUND*FGND*GH

C SET THE INCIDENCE ANGLE MODIFIERS
XKATB=TAUALF(ANGLE_INC)
XKATDS=TAUALF(EFFSKY)
XKATDG=TAUALF(EFGND)
XKAT=(XKATB*(GT-GDSKY-GDGND)+XKATDS*GDSKY+XKATDG*GDGND)/GT
IF(XKAT.LE.0.) XKAT=0.
ELSE
   ELSE IF(MODE_IAM.EQ.2) THEN
C GET THE TRANSMITTANCE-ABSORPTANCE PRODUCT AT NORMAL INCIDENCE AND THE
REFLECTANCE OF THE COVER
C TO DIFFUSE RADIATION
KL_COVER=THICK_COVER*EXT_COVER
TAUALPHAN=TAU_ALPHA(1,0.D0,KL_COVER,RI_COVER,ABS_PLATE,
1 RHO_DIFFUSE)/TAUALPHAN
XKATDS=TAU_ALPHA(1,EFFSKY,KL_COVER,RI_COVER,ABS_PLATE,
1 RHO_DIFFUSE)/TAUALPHAN
XKATDG=TAU_ALPHA(1,EFFGND,KL_COVER,RI_COVER,ABS_PLATE,
1 RHO_DIFFUSE)/TAUALPHAN
C USE THE TAU_ALPHA FUNCTION FOR THE COMPONENT IAM VALUES
XKATDS=TAU_ALPHA(1,EFFSKY,RI_COVER,RI_COVER,ABS_PLATE,
1 RHO_DIFFUSE)/TAUALPHAN
XKATDG=TAU_ALPHA(1,EFFGND,RI_COVER,RI_COVER,ABS_PLATE,
1 RHO_DIFFUSE)/TAUALPHAN
XKATB=TAU_ALPHA(1,ANGLE_INC,RI_COVER,RI_COVER,ABS_PLATE,
1 RHO_DIFFUSE)/TAUALPHAN
C CALCULATE THE OVERALL IAM
IF(GT.GT.0.) THEN
   XKAT=(XKATB*(GT-GDSKY-GDGND)+XKATDS*GDSKY+XKATDG*GDGND)/GT
   ELSE
   XKAT=0.
ENDIF
ENDIF
C GUESS A COVER TEMPERATURE
T_COVER=(T_SKY+T_AMB)/2.
C GUESS A BACK COLLECTOR SURFACE TEMPERATURE
T_3=(T_ZONE+T_ZONE_RAD)/2.
C GUESS UPPER AND LOWER FLOW CHANNEL SURFACE TEMPERATURES
T_1=T_FLUID_IN
T_2=T_FLUID_IN
C GUESS A PV CELL TEMPERATURE
T_PV=(T_COVER+T_2)/2.
T_PV_OLD=T_PV
C GUESS A MEAN FLUID TEMPERATURE
T_FLUID_MEAN=T_FLUID_IN
C INITIALIZE THE COUNTER
ICOUNT=1
C GET THE TOP SURFACE RADIATION COEFFICIENT
10 H_RAD_T=H_RADIATION(T_COVER,T_SKY,EMISS_COVER)
C GET THE BOTTOM SURFACE RADIATION COEFFICIENT
H_RAD_B=H_RADIATION(T_3,T_ZONE_RAD,EMISS_BACK)
C GET THE INNER-CHANNEL RADIATION COEFFICIENT
H_RAD_12=H_RAD_GRAY(T_1,T_2,EMISS_1,EMISS_2)
C GET THE PV CELL EFFICIENCY
IF(MODE_EFF.EQ.1) THEN
   FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
   FACTOR_I=1+EFF_CORR_I*(GT-GT_REF)
   PV_EFFICIENCY=DMAX1(0.,(FACTOR_T*FACTOR_I*EFF_PV_REF))
ELSE IF(MODE_EFF.EQ.2) THEN
   X(2)=GT
   X(1)=T_PV
   NX(2)=N_RADS
   NX(1)=N_TEMPS
   CALL DYNAMICDATA(LU_DATA,2,NX,1,X,Y,INFO,*20)
   CALL LINKCK('TYPE 542','DYNAMICDATA',1,99)
   20 IF(ERRORFOUND()) RETURN 1
   X(2)=GT
   X(1)=T_PV
   NX(2)=N_RADS
   NX(1)=N_TEMPS
   CALL DYNAMICDATA(LU_DATA,2,NX,1,X,Y,INFO,*20)
   CALL LINKCK('TYPE 542','DYNAMICDATA',1,99)
   20 IF(ERRORFOUND()) RETURN 1
   PV_EFFICIENCY=DMAX1(0.,(X(2)*X(1)))
ELSE
   PV_EFFICIENCY=EFF_PV
ENDIF
C SET THE PROPERTIES OF THE AIR STREAM
T_PROPS_K=T_FLUID_MEAN+273.15
P_KPA=P_ATM*101.325
CALL AIRPROP(T_PROPS_K,P_KPA,AIRPROPS)
RHO_AIR=1./AIRPROPS(1)  !KG/M3
VISC_AIR=AIRPROPS(2)*3600.  !KG/M/HR
PRANDTL_AIR=AIRPROPS(3)  !DIMENSIONLESS
K_AIR=AIRPROPS(4)*3.6  !KJ/K/M/K
CP_AIR=AIRPROPS(5)  !KJ/KG/K

C CALCULATE THE REYNOLDS NUMBER
REYNOLDS=4.*FLOW_IN/PI/DIAMETER/VISC_AIR

C CALCULATE THE FLUID CONVECTION COEFFICIENT
IF(REYNOLDS.LE.0.) THEN
        CALL THE SUBROUTINE TO CALCULATE THE NUSSELT NUMBER FOR INCLINED FLAT PLATES
T_1_K=T_1+273.15
T_2_K=T_2+273.15
CALL NUFLATPLATE(SLOPE,T_1_K,T_2_K,THICK_CHANNEL,P_KPA,NUSSELT)
C       SET THE NATURAL CONVECTION HEAT TRANSFER COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER
ELSE IF(REYNOLDS.LE.2300.) THEN
C       SET THE NUSSELT NUMBER (BASED ON A CONSTANT SURFACE TEMPERATURE)
T_SURF=(T_1+T_2)/2.
IF(T_SURF.GE.T_FLUID_MEAN) THEN
        N=0.4
ELSE
        N=0.3
ENDIF
NUSSELT=0.023*(REYNOLDS**0.8)*(PRANDTL_AIR**N)
C       SET THE LAMINAR CONVECTION COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER
ELSE
C       SET THE NUSSELT NUMBER (BASED ON THE DITTUUS BOELTER EQUATION)
T_SURF=(T_1+T_2)/2.
IF(T_SURF.GE.T_FLUID_MEAN) THEN
        N=0.4
ELSE
        N=0.3
ENDIF
NUSSELT=0.023*(REYNOLDS**0.8)*(PRANDTL_AIR**N)
C       SET THE TURBULENT CONVECTION COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER
ENDIF

C CALCULATE THE ABSORBED SOLAR RADIATION PER UNIT AREA
S=TAUALPHAN*XKAT*GT*(1.-PV_EFFICIENCY)
C CALCULATE THE RESISTANCE DUE TO THE COVER MATERIAL
R_INV=THICK_COVER/R_COVER

C SET SOME CONSTANTS WE'LL NEED
F_PRIME=1.+R_INV*H_CONV_T+R_INV*H_RAD_T
H_PRIME=1.+R_INV*H_CONV_B+R_INV*H_RAD_B
G_PRIME=1.+R_INV*H_CONV_T+R_INV*H_CONV_B
J=H_RAD_12/H_FLUID+1./R_INV/H_PRIME/R_INV
M=1./R_INV*G_PRIME+R_INV*H_CONV_B+R_INV*H_CONV_T+R_INV*H_CONV_B

C REFORMULATE THE 6 ENERGY BALANCES TO FIND qu''=AA*T_fluid+CC
AA=-2.*H_FLUID+H_CONV_B*T_ZONE+H_RAD_B*T_ZONE_RAD+H_CONV_T*T_AMB/H_PRIME/G_PRIME/M+H_CONV_T*T_AMB/H_PRIME/G_PRIME/M+H_CONV_T*T_AMB/H_PRIME/G_PRIME/M

C SET THE CASE WITH NO FLOW
IF(FLOW_IN.LE.0.) THEN
C       SET THE USEFUL ENERGY GAIN
QU=0.
C       SET THE MEAN FLUID TEMPERATURE FROM QU=AA(T)+CC
T_FLUID_MEAN=-CC/AA
C       SET THE UPPER CHANNEL SURFACE TEMPERATURE
T_1=S/G_PRIME/M+H_CONV_T*T_AMB/H_PRIME+H_RAD_T*T_SKY/H_PRIME+R_INV*H_CONV_T*T_AMB/H_PRIME
C       SET THE LOWER CHANNEL SURFACE TEMPERATURE
T_2=H_CONV_B*T_ZONE+H_CONV_B*T_ZONE_RAD/M/H_PRIME
C       SET THE PV TEMPERATURE
T_PV=S/G_PRIME+H_CONV_T*T_AMB/H_PRIME/G_PRIME+H_RAD_T*T_SKY/H_PRIME+R_INV*G_PRIME+R_INV*H_CONV_T*T_AMB/H_PRIME/G_PRIME+R_INV*H_CONV_B*T_ZONE/H_PRIME
C       SET THE BACK SURFACE TEMPERATURE
T_3=T_2/H_PRIME+R_INV*H_CONV_B*T_ZONE/H_PRIME+R_INV*H_CONV_B*T_ZONE/H_PRIME
C SET THE COVER TEMPERATURE
T_COVER=T_PV/F_PRIME+R_1*H_CONV_T*T_AMB/F_PRIME+
1 R_1*H_RAD_T*T_SKY/F_PRIME

C SET THE FLUID OUTLET TEMPERATURE
T_FLUID_OUT=T_FLUID_MEAN

ELSE

C FIND THE FLUID OUTLET TEMPERATURE BY INTEGRATING THE FLUID DIFFERENTIAL EQUATION
T_FLUID_OUT=(T_FLUID_IN+CC/AA)*DEXP(AA*AREA/FLOW_IN/CP_AIR)/
1 (AA*AREA/FLOW_IN/CP_AIR)-(T_FLUID_IN+CC/AA)/AA*AREA/
FLOW_IN/CP_AIR+CC/AA

C FIND THE MEAN FLUID TEMPERATURE BY INTEGRATING THE LOCAL FLUID TEMPERATURE EQUATION
T_FLUID_MEAN=(T_FLUID_IN+CC/AA)*DEXP(AA*AREA/FLOW_IN/CP_AIR)/
1 (AA*AREA/FLOW_IN/CP_AIR)-(T_FLUID_IN+CC/AA)/AA*AREA/
FLOW_IN/CP_AIR)+(AA*AREA/FLOW_IN/CP_AIR)

C KNOWING THE INLET AND OUTLET TEMPERATURES CALCULATE THE COLLECTOR USEFUL ENERGY GAIN
QU=FLOW_IN*CP_AIR*(T_FLUID_OUT-T_FLUID_IN)

C SET THE UPPER CHANNEL SURFACE TEMPERATURE
T_1=SG*PRIME/M+H_CONV_T*T_AMB/F_PRIME/G_PRIME/M+H_RAD_T*T_SKY+
1 R_1*H_CAMERA*T_ZONE/M/J+R_2*H_RAD_12*H_CONV_B*T_ZONE/R_2/G_PRIME

C SET THE PV TEMPERATURE
T_PV=S/G_PRIME+H_CONV_T*T_AMB/F_PRIME+H_RAD_T*T_SKY/
1 R_1*H_CAMERA/T_ZONE/R_1/G_PRIME

C SET THE LOWER CHANNEL SURFACE TEMPERATURE
T_2=H_RAD_T*12*T_1/J+H_FLUID_T*FLUID_MEAN/M/J+H_CONV_B*T_ZONE/3/
1 H_PRIME+H_RAD_B*T_ZONE/R_2/G_PRIME

C SET THE BACK SURFACE TEMPERATURE
T_3=T_2/H_PRIME+R_3*H_CONV_B*T_ZONE/H_PRIME+R_3*H_RAD_B*
1 T_ZONE/R_2/G_PRIME

C SET THE COVER TEMPERATURE
T_COVER=T_PV/F_PRIME+R_1*H_CONV_T*T_AMB/F_PRIME+
1 R_1*H_RAD_T*T_SKY/F_PRIME

ENDIF

C CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED
IF(DABS(T_PV_OLD-T_PV).GT.0.001).AND.
1 (ICOUNT.LT.1000)) THEN
T_PV_OLD=T_PV
ICOUNT=ICOUNT+1
GOTO 10
ENDIF

C CALCULATE THE THERMAL EFFICIENCY
IF(GT.GT.0.) THEN
EFF_THERMAL=QU/AREA/GT
ELSE
EFF_THERMAL=0.
ENDIF

C CALCULATE THE HEAT TRANSFERS
Q_TOP_CONV=H_CONV_T*AREA*(T_COVER-T_AMB)
Q_TOP_RAD=H_RAD_T*AREA*(T_COVER-T_SKY)
Q_BACK_CONV=H_CONV_B*AREA*(T_3-T_ZONE)
Q_BACK_RAD=H_RAD_B*AREA*(T_3-T_ZONE_RAD)
Q_ABS=AREA*GT*TAUALPHAN*XKAT*(1.-PV_EFFICIENCY)

C CALCULATE THE PV POWER PRODUCTION
POWER=AREA*TAUALPHAN*XKAT*GT*PV_EFFICIENCY

C SET THE OUTPUTS
OUT(1)=T_FLUID_OUT
OUT(2)=FLOW_IN
OUT(3)=QU
OUT(4)=EFF_THERMAL
OUT(5)=POWER
OUT(6)=PV_EFFICIENCY
OUT(7)=T_COVER
OUT(8)=T_PV
OUT(9)=T_1
OUT(10)=T_FLUID_MEAN
OUT(11)=T_2
OUT(12)=T_3
OUT(13)=XKAT
OUT(14)=Q_TOP_CONV
OUT(15)=Q_TOP_RAD
OUT(16)=Q_BACK_CONV
OUT(17)=Q_BACK_RAD
OUT(18)=Q_ABS

C KILL THE SIMULATION IF THE SYSTEM WAS UNABLE TO SOLVE
IF(ICOUNT.GE.1000) THEN
CALL MESSAGES(-1,MESSAGE1,'FATAL',IUNIT,ITYPE)
ENDIF

C----------------------------------------------------------------------

C----------------------------------------------------------------------

C----------------------------------------------------------------------

C----------------------------------------------------------------------

C----------------------------------------------------------------------

C EVERYTHING IS DONE - RETURN FROM THIS SUBROUTINE AND MOVE ON
RETURN 1
**TYPE 567** - Building integrated photovoltaic system (glazed, air) (No convective and radiative losses at the back of the collector)

```plaintext
SUBROUTINE TYPE567(TIME,XIN,OUT,T,DTDT,PAR,INFO,ICNTRL,*)
C*******************************************************************
C DESCRIPTION:
C THIS COMPONENT MODELS A BUILDING-INTEGRATED PHOTOVOLTAIC SYSTEM. IN THIS
C MODEL THERE IS ASSUMED TO BE
C A SINGLE GLASS COVER OVER THE PV MATERIAL. THE BACK OF THE BIPV SYSTEM
C INTERACTS WITH ZONE MODELS WHERE
C THE SURFACE TEMPERATURE IS CALculated BY THE ZONE MODEL. THE FLUID CONVECTION
C CALcULATION ARE FROM
C CORRELATIONS PROVIDED BY 'INTRODUCTION TO HEAT TRANSFER' BY INCROPERA AND
C DEWITT.
C
C LAST MODIFIED:
C APRIL 2004 - JEFF THORNTON - ORIGINAL CODING
C
C ! Copyright © 2006 Thermal Energy System Specialists, LLC. All rights reserved.
C !DEC$ATTRIBUTES DLLEXPORT :: TYPE567
C !Export this subroutine for its use in external DLLs.
C
C ACCESS TRNSYS FUNCTIONS
USE TrnsysFunctions
USE TrnsysConstants
C
C TRNSYS DECLARATIONS
IMPLICIT NONE
DOUBLE PRECISION RDCONV,ANGLE_INC,TAUALF,B0,Q_BACK,T_1,T_2,
AREA,FLOW_IN,T_AMB,GT,GH,GDH,REFL_GROUND,SLOPE,EMISS_COVER,
TAUAlPHA,EFF_SKY,EFFGND,COSSLP,PSKY,FGND,GDSKY,GDGND,XXATB,
XXATD,F_PRIME,XKATDG,T_FLUID_MEAN,T_SKY,H_CONV_X,T_X(2),NUSSELT,
H_FLUID,QU,EFF_THERMAL,S,R_1,R_2,R_3,Q_TOP_CONV,N,H_RAD_12,
Q_TOP_RAD,Q_ABS,H_RADIATION,EMISS_1,H_EMIS_2,H_RAD_GRAY,G_PRIME,
M_AA,CC,K_COVER,THICK_COVER,RI_COVER,T_1,K_2,K_T,SURF,CP_AIR,
EXT_COVER,ABS_P,PLATE,EFF_PV,Y(1),EFF_PV_REF,T_REF,GT_REF,K_AIR,
EFF_CORR,T_EFF_CORR,T_1,T_2,FN,DIAMETER,T_PV,H_THICK,AIRPROPS(5),PLIEN,
WIDTH,THICK_CHANNEL_P,ATM,P,KPA,DIAMETER,T_PROPS,K_R,H_AIR,
VISC_AIR,PRANDTL_AIR,
CHARACTER(LEN=MAXMESSAGELENGTH)::MESSAGE1

INTEGER ICOUNT,MODE_IAM,MODE_EFF,LU_DATA,N_TEMPS,N_RADS,NX(2)
CHARACTER(LEN=MAXMESSAGELENGTH)::MESSAGE1
C*******************************************************************
C DATA STATEMENTS
DATA RDCONV/0.017453292/,PI/3.14159265358979/
C*******************************************************************
C FUNCTIONS
C
FUNCTION
TAU_AlPHA(ANGLE_INC)=1.-B0*(1./DMAX(0.5,DCOS(ANGLE_INC*RDCONV))-1.)
+ Q_BACK/DMAX(1.60,ANGLE_INC*RDCONV))1.30.
C*******************************************************************
C ERROR MESSAGES
MESSAGE1='The BIPV model was unable to find a solution for the cell
1l temperature at the given timestep. Please report this error to
1your TRNSYS distributor.'
C*******************************************************************
C GET GLOBAL TRNSYS SIMULATION VARIABLES
TIME0=getSimulationStartTime()
TFINAL=getSimulationStopTime()
DELTA=getSimulationTimeSteps()
C*******************************************************************
C SET THE VERSION INFORMATION FOR TRNSYS
C IF(INFO(7)=EQ.-2) THEN
INFO(12)=16
RETURN
ENDIF
C*******************************************************************
```
C DO ALL THE VERY LAST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(8).EQ.-1) THEN
  RETURN 1
ENDIF
C
C PERFORM ANY "AFTER-ITERATION" MANIPULATIONS THAT ARE REQUIRED
IF (INFO(13).GT.0) THEN
  RETURN 1
ENDIF
C
C DO ALL THE VERY FIRST CALL OF THE SIMULATION MANIPULATIONS HERE
IF (INFO(7).EQ.-1) THEN
  C RETRIEVE THE UNIT NUMBER AND TYPE NUMBER FOR THIS COMPONENT FROM THE INFO
  IUNIT=INFO(1)
  ITYPE=INFO(2)
  C SET SOME INFO ARRAY VARIABLES TO TELL THE TRNSYS ENGINE HOW THIS TYPE IS TO WORK
  INFO(6)=NOUT
  INFO(9)=1
  INFO(10)=0
  C SET THE NUMBER OF PARAMETERS AND INPUTS
  MODE_IAM=JFIX(PAR(11)+0.5)
  MODE_EFF=JFIX(PAR(12)+0.5)
  NPAR=12
  IF(MODE_IAM.LT.1) CALL TYPECK(-4,INFO,0,11,0)
  IF(MODE_IAM.GT.2) CALL TYPECK(-4,INFO,0,11,0)
  IF(MODE_EFF.LT.1) CALL TYPECK(-4,INFO,0,12,0)
  IF(MODE_EFF.GT.3) CALL TYPECK(-4,INFO,0,12,0)
  IF(ERRORFOUND()) RETURN 1
  IF(MODE_IAM.EQ.1) THEN
    NPAR=NPAR+2
  ELSE IF(MODE_IAM.EQ.2) THEN
    NPAR=NPAR+3
 ENDIF
  IF(MODE_EFF.EQ.1) THEN
    NPAR=NPAR+5
  ELSE IF(MODE_EFF.EQ.2) THEN
    NPAR=NPAR+3
  ELSE IF(MODE_EFF.EQ.3) THEN
    NIN=NIN+1
  ENDIF
  C CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO WHAT IS SUPPLIED IN
  CALL TYPECK(1,INFO,NIN,NPAR,ND)
  C SET THE YCHECK AND OCHECK ARRAYS TO CONTAIN THE CORRECT VARIABLE TYPES FOR THE INPUTS AND OUTPUTS
  DATA YCHECK/'TE1','MF1','TE1','TE1','TE1','IR1','IR1','IR1','
               'DM1','DG1','DG1','HT1','PR2','DM1','
  DATA OCHECK/'TE1','MF1','PW1','DM1','PW1','DM1','TE1','TE1','
               'TE1','TE1','TE1','DM1','PW1','PW1','PW1','
  NPAR=12
  IF(MODE_IAM.EQ.1) THEN
    NPAR=NPAR+2
  ELSE IF(MODE_IAM.EQ.2) THEN
    NPAR=NPAR+3
  ENDIF
  IF(MODE_EFF.EQ.1) THEN
    NPAR=NPAR+5
  ELSE IF(MODE_EFF.EQ.2) THEN
    NPAR=NPAR+3
  ELSE IF(MODE_EFF.EQ.3) THEN
    NIN=NIN+1
  ENDIF
  C CALL THE RCHECK SUBROUTINE TO SET THE CORRECT INPUT AND OUTPUT TYPES FOR THIS COMPONENT
  CALL RCHECK(INFO,YCHECK,OCHECK)
  C RETURN TO THE CALLING PROGRAM
  RETURN 1
ENDIF
C
C DO ALL OF THE INITIAL TIMESTEP MANIPULATIONS HERE - THERE ARE NO ITERATIONS AT THE INITIAL TIME
IF (TIME.LT.(TIME0+DELT/2.D0)) THEN
  C SET THE UNIT NUMBER FOR FUTURE CALLS
  IUNIT=INFO(1)
  C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
  LENGTH=PAR(1)
  WIDTH=PAR(2)
  EMISS_COVER=PAR(3)
  K_COVER=PAR(4)
  THICK_COVER=PAR(5)
  R_2=PAR(6)
  EMISS_1=PAR(7)
  THICK_CHANNEL=PAR(10)
  MODE_IAM=JFIX(PAR(11)+0.5)
  MODE_EFF=JFIX(PAR(12)+0.5)
  NPAR=12
ENDIF
C CHECK THE PARAMETERS FOR PROBLEMS AND RETURN FROM THE SUBROUTINE IF AN ERROR IS FOUND
IF(LENGTH.LE.0.) CALL TYPECK(-4,INFO,0,1,0)
IF(WIDTH.LE.0.) CALL TYPECK(-4,INFO,0,3,0)
IF(K_COVER.LE.0.) CALL TYPECK(-4,INFO,0,4,0)
IF(THICK_COVER.LE.0.) CALL TYPECK(-4,INFO,0,5,0)
IF(R_2.LE.0.) CALL TYPECK(-4,INFO,0,6,0)
IF(EMISS_1.LT.0.) CALL TYPECK(-4,INFO,0,7,0)
IF(EMISS_2.LT.0.) CALL TYPECK(-4,INFO,0,8,0)
IF(R_3.LE.0.) CALL TYPECK(-4,INFO,0,9,0)
IF(THICK_CHANNEL.LT.0.) CALL TYPECK(-4,INFO,0,10,0)

IF(ERRORFOUND()) RETURN 1
C GET THE IAM MODE SPECIFIC PARAMETERS
IF(MODE_IAM.EQ.1) THEN
TAUALPHAN=PAR(NPAR+1)
B0=PAR(NPAR+2)
IF(TAUALPHAN.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(TAUALPHAN.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(B0.LT.0.) CALL TYPECK(-4,INFO,0,NPAR+2,0)
IF(B0.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+2,0)
NPAR=NPAR+2
ELSE IF(MODE_IAM.EQ.2) THEN
ABS_PLATE=PAR(NPAR+1)
RI_COVER=PAR(NPAR+2)
EXT_COVER=PAR(NPAR+3)
IF(ABS_PLATE.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(ABS_PLATE.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(RI_COVER.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+2,0)
IF(EXT_COVER.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+3,0)
NPAR=NPAR+3
ENDIF
C GET THE PV EFFICIENCY SPECIFIC PARAMETERS
IF(MODE_EFF.EQ.1) THEN
EFF_PV_REF=PAR(NPAR+1)
T_REF=PAR(NPAR+2)
GT_REF=PAR(NPAR+3)
IF(EFF_PV_REF.LT.0.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(EFF_PV_REF.GT.1.) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(GT_REF.LE.0.) CALL TYPECK(-4,INFO,0,NPAR+3,0)
ELSE IF(MODE_EFF.EQ.2) THEN
LU_DATA=JFIX(PAR(NPAR+1)+0.5)
N_TEMPS=JFIX(PAR(NPAR+2)+0.5)
N_RADS=JFIX(PAR(NPAR+3)+0.5)
IF(LU_DATA.LT.10) CALL TYPECK(-4,INFO,0,NPAR+1,0)
IF(N_TEMPS.LT.2) CALL TYPECK(-4,INFO,0,NPAR+2,0)
IF(N_RADS.LT.2) CALL TYPECK(-4,INFO,0,NPAR+3,0)
ENDIF
C PERFORM ANY REQUIRED CALCULATIONS TO SET THE INITIAL VALUES OF THE OUTPUTS HERE
OUT(1)=XIN(1)
OUT(2:6)=0.
OUT(7)=T_AMB
OUT(8)=T_AMB
OUT(9)=XIN(1)
OUT(10)=XIN(1)
OUT(11)=XIN(1)
OUT(12)=XIN(5)
OUT(13:17)=0.
C RETURN TO THE CALLING PROGRAM
RETURN 1
C
-----------------------------------------------------------------------------------------------------------------------
C
-----------------------------------------------------------------------------------------------------------------------
C *** ITS AN ITERATIVE CALL TO THIS COMPONENT ***
C
-----------------------------------------------------------------------------------------------------------------------
EMISS_COVER=PAR(3)
K_COVER=PAR(4)
THICK_COVER=PAR(5)
R_2=PAR(6)
EMISS_1=PAR(7)
EMISS_2=PAR(8)
THICK_CHANNEL=PAR(10)
MODE_IAM=FIX(PAR(11)+0.5)
MODE_EFF=FIX(PAR(12)+0.5)
NPAR=12
IF(MODE_IAM.EQ.1) THEN
TAUALPHAN=PAR(NPAR+1)
B0=PAR(NPAR+2)
NPAR=NPAR+2
ELSE IF(MODE_IAM.EQ.2) THEN
ABS_PLATE=PAR(NPAR+1)
RI_COVER=PAR(NPAR+2)
EXT_COVER=PAR(NPAR+3)
NPAR=NPAR+3
ENDIF
IF(MODE_EFF.EQ.1) THEN
EFF_PV_REF=PAR(NPAR+1)
T_REF=PAR(NPAR+2)
GT_REF=PAR(NPAR+3)
EFF_CORR_T=PAR(NPAR+4)
EFF_CORR_I=PAR(NPAR+5)
ELSE IF(MODE_EFF.EQ.2) THEN
LTDATA=FIX(PAR(NPAR+1)+0.5)
N_TEMPS=FIX(PAR(NPAR+2)+0.5)
N_RADS=FIX(PAR(NPAR+3)+0.5)
ENDIF
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C    RETRIEVE THE CURRENT VALUES OF THE INPUTS TO THIS MODEL FROM THE XIN ARRAY IN SEQUENTIAL ORDER
T_FLUID_IN=XIN(1)
FLOW_IN=XIN(2)
T_AMBI=XIN(3)
T_SKY=XIN(4)
T_SURF=XIN(5)
GT=XIN(6)
GH=XIN(7)
GDH=XIN(8)
REFL_GROUND=XIN(9)
ANGLE_INC=XIN(10)
SLOPE=XIN(11)
H_CONV_T=XIN(12)
P_ATM=XIN(13)
K_COVER=XIN(14)
EMISS_COVER=XIN(15)
THICK_COVER=XIN(16)
R_2=XIN(17)
EMISS_1=XIN(18)
EMISS_2=XIN(19)
R_3=XIN(20)
THICK_CHANNEL=XIN(21)
MODE_IAM=XIN(22)
MODE_EFF=XIN(23)
NPAR=XIN(24)
IF(MODE_IAM.EQ.1) THEN
TAUALPHAN=XIN(NPAR+1)
B0=XIN(NPAR+2)
NPAR=NPAR+2
ELSE IF(MODE_IAM.EQ.2) THEN
ABS_PLATE=XIN(NPAR+1)
RI_COVER=XIN(NPAR+2)
EXT_COVER=XIN(NPAR+3)
NPAR=NPAR+3
ENDIF
IF(MODE_EFF.EQ.1) THEN
EFF_PV_REF=XIN(NPAR+1)
T_REF=XIN(NPAR+2)
GT_REF=XIN(NPAR+3)
EFF_CORR_T=XIN(NPAR+4)
EFF_CORR_I=XIN(NPAR+5)
ELSE IF(MODE_EFF.EQ.2) THEN
LTDATA=FIX(XIN(NPAR+1)+0.5)
N_TEMPS=FIX(XIN(NPAR+2)+0.5)
N_RADS=FIX(XIN(NPAR+3)+0.5)
ENDIF
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C    CHECK THE INPUTS FOR PROBLEMS
IF(FLOW_IN.LT.0.) CALL TYPECK(-3,INFO,2,0,0)
IF(GT.LT.0.) CALL TYPECK(-3,INFO,7,0,0)
IF(GH.LT.0.) CALL TYPECK(-3,INFO,8,0,0)
IF(GDH.LT.0.) CALL TYPECK(-3,INFO,9,0,0)
IF(REFL_GROUND.LT.0.) CALL TYPECK(-3,INFO,10,0,0)
IF(REFL_GROUND.GT.1.) CALL TYPECK(-3,INFO,11,0,0)
IF(H_CONV_T.LT.0.) CALL TYPECK(-3,INFO,12,0,0)
IF(P_ATM.LE.0.) CALL TYPECK(-3,INFO,13,0,0)
IF(EFF_PV.LE.0.) CALL TYPECK(-3,INFO,14,0,0)
IF(EFF_PV.GT.1.) CALL TYPECK(-3,INFO,15,0,0)
ELSE IF(ERRORFOUND()) RETURN 1
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C    PERFORM ALL THE CALCULATION HERE FOR THIS MODEL.
C    SET SOME GEOMETRIC PARAMETERS
AREA=LENGTH*WIDTH
DIAMETER=4.*WIDTH*THICK_CHANNEL/(2.*WIDTH+2.*THICK_CHANNEL)
C    SET THE INCIDENCE ANGLE MODIFIER BASED ON THE MODE
XKAT=1.
IF(MODE_IAM.EQ.1) THEN
C       DETERMINE INCIDENCE ANGLE MODIFIER
IF(GT.GT.0. .AND. ANGLE_INC.LT.90.) THEN
C          USE RELATIONS OF BRANDEMUEHL FOR EFFECTIVE INCIDENCE ANGLES FOR DIFFUSE
EFFSKY=59.68-0.1388*SLOPE+0.001497*SLOPE*SLOPE
EFFGND=90.-0.5788*SLOPE+0.002693*SLOPE*SLOPE
COSLP=DCOS(RDCONV)
FSKY=(1.+COSLP)/2.
FGND=(1.-COSLP)/2.
GDGND=FSKY*GDH
GDGND=REFL_GROUND*FGND*GH
ENDIF
ENDIF
C    SET THE INCIDENCE ANGLE MODIFIERS
XKATB=TAUALF(ANGLE_INC)
XKATDS=TAUALF(EFFSKY)
XKATDG=TAUALF(EFFGND)
C    DETERMINE INCIDENCE ANGLE MODIFIER
IF(GT.GT.0. .AND. ANGLE_INC.LT.90.) THEN
C USE RELATIONS OF BRANDEMUEHL FOR EFFECTIVE INCIDENCE ANGLES FOR DIFFUSE
EFFSKY=59.68-0.1388*SLOPE+0.001497*SLOPE*SLOPE
EFFGND=90.-0.5788*SLOPE+0.002693*SLOPE*SLOPE
COSLP=DCOS(RDCONV)
FSKY=(1.+COSLP)/2.
FGND=(1.-COSLP)/2.
GDGND=FSKY*GDH
GDGND=REFL_GROUND*FGND*GH
ENDIF
C    SET THE INCIDENCE ANGLE MODIFIERS
XKATB=TAUALF(ANGLE_INC)
XKATDS=TAUALF(EFFSKY)
XKATDG=TAUALF(EFFGND)
XKAT=XKATB*(GT-GDSKY-GDGND)+XKATDS*GDSKY+XKATDG*GDGND)/GT
ELSE
XKAT=0.
ENDIF
ELSE IF(MODE_IAM.EQ.2) THEN
C       GET THE TRANSMITTANCE-ABSORPTANCE PRODUCT AT NORMAL INCIDENCE AND THE
C       REFLECTANCE OF THE COVER
KL_COVER=THICK_COVER*EXT_COVER
RHO_DIFFUSE=1.
TAUALPHAN=TAU_ALPHA(1,0.D0,KL_COVER,RI_COVER,ABS_PLATE,
  1             RHO_DIFFUSE) 
C       USE THE RELATIONS OF BRANDEMUEHL TO GET THE EFFECTIVE INCIDENCE ANGLES FOR
C       DIFFUSE RADIATION
EFFSKY=59.68-0.1388*SLOPE+0.001497*SLOPE*SLOPE
COSSLOPE=DCOS(SLOPE*RDCONV)
FSKY=(1.+COSSLOPE)/2.
GDSKY=FSKY*GDH
GDGND=REFL_GROUND*FGND*GH
C       USE THE TAU_ALPHA FUNCTION FOR THE COMPONENT IAM VALUES
XKATDS=TAU_ALPHA(1,EFFSKY,RI_COVER,ABS_PLATE,
  1             RHO_DIFFUSE)/TAUALPHAN
XKATDG=TAU_ALPHA(1,EFFGND,RI_COVER,ABS_PLATE,
  1             RHO_DIFFUSE)/TAUALPHAN
XKATB=TAU_ALPHA(1,ANGLE_INC,RI_COVER,ABS_PLATE,
  1             RHO_DIFFUSE)/TAUALPHAN
C       CALCULATE THE OVERALL IAM
IF(GT.GT.0.) THEN
XKAT=XKATB*(GT-GDSKY-GDGND)+XKATDS*GDSKY+XKATDG*GDGND)/GT
ELSE
XKAT=0.
ENDIF
ENDIF
C GUESS A COVER TEMPERATURE
T_COVER=T_Sky+T_AMB/2.
C GUESS UPPER AND LOWER FLOW CHANNEL SURFACE TEMPERATURES
T_1=T_FLUID_IN
T_2=T_FLUID_IN
C GUESS A PV CELL TEMPERATURE
T_PV=(T_COVER+T_2)/2.
\[ T_1_K = T_1 + 273.15 \]
\[ T_2_K = T_2 + 273.15 \]
\[ \text{CALL NUFLATPLATE(SLOPE,T_1_K,T_2_K,THICK_CHANNEL,P_KPA,NUSSELT)} \]

C SET THE NATURAL CONVECTION HEAT TRANSFER COEFFICIENT
\[ \text{H_FLUID}=\text{NUSSELT} \times \text{K_AIR} / \text{DIAMETER} \]

ELSE IF(REYNOLDS.LE.2300.) THEN
C SET THE NUSSELT NUMBER (BASED ON A CONSTANT SURFACE TEMPERATURE)
\[ \text{NUSSELT}=3.66 \]

C SET THE LAMINAR CONVECTION COEFFICIENT
\[ \text{H_FLUID}=\text{NUSSELT} \times \text{K_AIR} / \text{DIAMETER} \]

ELSE
C SET THE NUSSELT NUMBER (BASED ON THE DITTMUS BOELTER EQUATION)
\[ T_{\text{SURF}}=(T_1+T_2)/2. \]
\[ \text{IF}(T_{\text{SURF}}.\geq.T_{\text{FLUID MEAN}}) \text{ THEN} \]
\[ N=0.4 \]
\[ \text{ELSE} \]
\[ N=0.3 \]
\[ \text{ENDIF} \]
\[ \text{NUSSELT}=0.023 \times (\text{REYNOLDS}^{-0.8}) \times (\text{PRANDTL}_{\text{AIR}}^{-N}) \]

C SET THE TURBULENT CONVECTION COEFFICIENT
\[ \text{H_FLUID}=\text{NUSSELT} \times \text{K_AIR} / \text{DIAMETER} \]

ENDIF

C CALCULATE THE ABSORBED SOLAR RADIATION PER UNIT AREA
\[ s=\text{TAUuPHAN} \times \text{KAT} \times \text{G} \times (1.-\text{PV EFFICIENCY}) \]

C CALCULATE THE RESISTANCE DUE TO THE COVER MATERIAL
\[ R_{\text{THICK COVER}}=R_{\text{COVER}} \]

C SET SOME CONSTANTS WE'LL NEED
\[ F_{\text{PRIME}}=1.+1/R_1/H_{\text{CONV, T}}+R_1+1/R_2+1/R_1/F_{\text{PRIME}} \]
\[ J=H_{\text{RAD, 12}}+H_{\text{FLUID}} \times 1/R_3 \]
\[ M=1.-1/R_2/G_{\text{PRIME}}+R_2+H_{\text{FLUID}}+R_2+H_{\text{RAD, 12}}+R_2+H_{\text{RAD, 12}} \]
\[ \text{H}_{\text{RAD, 12}/} \]

C REFORMULATE THE 6 ENERGY BALANCES TO FIND \( q_{\text{fluid}}=AA \times T_{\text{fluid}}+CC \)
\[ AA=2 \times H_{\text{FLUID}}+H_{\text{FLUID}}+H_{\text{FLUID}}+H_{\text{FLUID}} \times R_{\text{2}}+H_{\text{FLUID}}+R_{\text{2}} \]
\[ 1 \times R_{\text{M}} \]
\[ 1 \times H_{\text{RAD, 12}}+H_{\text{FLUID}}+2/MJ+H_{\text{FLUID}}+H_{\text{RAD, 12}}+R_{\text{2}}+H_{\text{RAD, 12}}+H_{\text{FLUID}} \]

C SET THE CASE WITH NO FLOW
IF(FLFLOW_IN.LE.0.) THEN
C SET THE USEFUL ENERGY GAIN
\[ Q_{\text{U}}=0. \]

C SET THE MEAN FLUID TEMPERATURE FROM \( QU=AA(T)+CC \)
\[ T_{\text{FLUID MEAN}}=CC/AA \]

C SET THE UPPER CHANNEL SURFACE TEMPERATURE
\[ T_{-1}=s/G_{\text{PRIME}}+H_{\text{CONV, T}}+H_{\text{ambi}}+H_{\text{rad, T}}+H_{\text{sky}} \]
\[ 1 \times F_{\text{PRIME}}+G_{\text{PRIME}}+1/R_1/R_2/G_{\text{PRIME}}+H_{\text{FLUID}}+H_{\text{FLUID MEAN}}+R_2+H_{\text{rad, 12}} \]
\[ 1 \times H_{\text{FLUID}}+H_{\text{FLUID MEAN}}+R_2+H_{\text{rad, 12}}+T_{\text{SURF}}/R_3 \]

C SET THE PV TEMPERATURE
\[ T_{\text{PV}}=G_{\text{PRIME}}+H_{\text{CONV, T}}+H_{\text{ambi}}+H_{\text{rad, T}}+H_{\text{sky}} \]
\[ 1 \times F_{\text{PRIME}}+G_{\text{PRIME}}+1/R_1/R_2/G_{\text{PRIME}} \]

C SET THE LOWER CHANNEL SURFACE TEMPERATURE
\[ T_{-2}=H_{\text{rad, 12}}+T_{-1}+H_{\text{fluid}}+H_{\text{FLUID MEAN}}+T_{\text{SURF}}/R_3 \]

C SET THE COVER TEMPERATURE
\[ T_{\text{COVER}}=T_{\text{PV}}+F_{\text{PRIME}}+1/R_1+H_{\text{CONV, T}}+H_{\text{ambi}}+H_{\text{rad, T}}+H_{\text{sky}} \]
\[ 1 \times R_1+H_{\text{rad, T}}+H_{\text{sky}}+F_{\text{PRIME}} \]

C SET THE FLUID OUTLET TEMPERATURE
\[ T_{\text{FLUID OUT}}=T_{\text{FLUID MEAN}} \]

ELSE
C FIND THE FLUID OUTLET TEMPERATURE BY INTEGRATING THE FLUID DIFFERENTIAL EQUATION
\[ T_{\text{FLUID OUT}}=(T_{\text{FLUID IN}}+CC/AA) \times \text{DEXP}(AA \times \text{AREA}/\text{FLOW INCP A IR}) \]
\[ 1 \times CC/AA \]

C FIND THE MEAN FLUID TEMPERATURE BY INTEGRATING THE LOCAL FLUID TEMPERATURE EQUATION
\[ T_{\text{FLUID MEAN}}=(T_{\text{FLUID IN}}+CC/AA) \times \text{DEXP}(AA \times \text{AREA}/\text{FLOW INCP A IR}) \]
\[ 1 \times AA \times \text{FLOW INCP A IR}+T_{\text{FLUID IN}}+CC/AA \times AA \times \text{AREA} \]
\[ 1 \times \text{FLOW INCP A IR}+CC/AA \]
C KNOWING THE INLET AND OUTLET TEMPERATURES CALCULATE THE COLLECTOR USEFUL ENERGY GAIN
    QU=FLOW_IN*CP_AIR*(T_FLUID_OUT-T_FLUID_IN)
C SET THE UPPER CHANNEL SURFACE TEMPERATURE
    T_1=SG_PRIME/M+H_CONV_T*T_AMB/F_PRIME+G_PRIME/M+H_RAD_T*T_SKY
    H_FLUID*T_FLUID_MEAN/M+R_2*H_RAD_12*T_SURF/M/R_3
C SET THE PV TEMPERATURE
    T_PV=SG_PRIME+H_CONV_T*T_AMB/F_PRIME+H_RAD_T*T_SKY/F_PRIME
C SET THE LOWER CHANNEL SURFACE TEMPERATURE
   T_2=H_RAD_12*T_1/J/H_FLUID*T_FLUID_MEAN/J+T_SURF/J/R_3
C SET THE COVER TEMPERATURE
    T_COVER=T_PV/F_PRIME+R_1*H_CONV_T*T_AMB/F_PRIME+
    R_1*H_RAD_T*T_SKY/F_PRIME
ENDIF
C CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED
IF(DABS(T_PV_OLD-T_PV).GT.0.001).AND.
   (ICOUNT.LT.1000)) THEN
   T_PV_OLD=T_PV
   ICOUNT=ICOUNT+1
GOTO 10
ENDIF
C CALCULATE THE THERMAL EFFICIENCY
IF(GT.GT.0.) THEN
    EFF_THERMAL=QU/AREA/GT
ELSE
    EFF_THERMAL=0.
ENDIF
C CALCULATE THE HEAT TRANSFERS
   Q_TOP_CONV=H_CONV_T*AREA*(T_COVER-T_AMB)
   Q_TOP_RAD=H_RAD_T*AREA*(T_COVER-T_SKY)
   Q_BACK=AREA*(T_2-T_SURF)/R_3
   Q_ABS=AREA*GT*TAUALPHAN*XKAT*(1.-PV_EFFICIENCY)
C CALCULATE THE PV POWER PRODUCTION
   POWER=TAUALPHAN*XKAT*GT*PV_EFFICIENCY
C SET THE OUTPUTS
   OUT(1)=T_FLUID_OUT
   OUT(2)=FLOW_IN
   OUT(3)=QU
   OUT(4)=EFF_THERMAL
C KILL THE SIMULATION IF THE SYSTEM WAS UNABLE TO SOLVE
   IF(ICOUNT.GE.1000) THEN
      CALL MESSAGES(1,MESSAGE1,'FATAL',IUNIT,ITYPE)
   ENDIF
   ------------------------------------------------------------------------------------------------------
   ------------------------------------------------------------------------------------------------------
C EVERYTHING IS DONE - RETURN FROM THIS SUBROUTINE AND MOVE ON
RETURN 1
END
C EVERYTHING IS DONE - RETURN FROM THIS SUBROUTINE AND MOVE ON
TYPE 568-Un glazed building integrated photovoltaic system (air) (No convective and radiative losses at the back of the collector)

SUBROUTINE TYPE568(TIME,XIN,OUT,T,DTDT,PAR,INFO,ICNTRL,*)

C-----------------------------------------------------------------------
C DESCRIPTION:
C THIS COMPONENT MODELS A BUILDING-INTEGRATED PHOTOVOLATIC SYSTEM. IN THIS
C MODEL, THERE IS NO COVER OVER THE PV MATERIAL. THE BACK OF THE BIPV SYSTEM INTERACTS WITH ZONE MODELS
C WHERE THE SURFACE TEMPERATURE IS CALCULATED BY THE ZONE MODEL. THE FLUID CONVECTION CALCULATIONS ARE FROM CORRELATIONS
C PROVIDED BY "INTRODUCTION TO HEAT TRANSFER" BY INCRONEPA AND DEWITT.
C-----------------------------------------------------------------------
C LAST MODIFIED:
C APRIL 2004 - JEFF THORNTON - ORIGINAL CODING
C-----------------------------------------------------------------------
!
C Copyright © 2006 Thermal Energy System Specialists, LLC. All rights reserved.
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C ACCESS TRNSYS FUNCTIONS
USE TrnsysConstants
USE TrnsysFunctions
C-----------------------------------------------------------------------
C TRNSYS DECLARATIONS
IMPLICIT NONE
DOUBLE PRECISION XIN,OUT,T,DTDT,TIM0,TFINAL,DELT
INTEGER*4 INFO(15),NP,NL,NOUT,ND,IUNIT,ITYPE,ICNTRL,NPAR,NIN
CHARACTER*3 YCHECK,OCHECK
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C REQUIRED PARAMETERS FOR THE SIZING OF THE ARRAYS
PARAMETER (NP=15,NL=10,NOUT=15,ND=0)
C-----------------------------------------------------------------------
C REQUIRED TRNSYS DIMENSIONS
DIMENSION XIN(NI),OUT(NOUT),PAR(NP),YCHECK(NI),OCHECK(NOUT)
C-----------------------------------------------------------------------
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
DOUBLE PRECISION Q_BACK,T_I,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,
1 TAU,PHAN_F,PRIME,T_FLUID_MEAN,T_SKY,H_CONV_T,X_2,NUSSELT,
1 H_FLUID_QU,EFF_THERMAL,S_R,T_2,R_2,TOP_CONV,N_H,RAD_12,
1 Q_TOP_RAD,Q_ABS,H_RADIATION,EMISS_1,EMISS_2,H_RAD_GRAY,
1 M_AA,CC,T_1,K_T_2,K_SURF_CP_AIR,ABS_PLATE,EFF_PV_Y(1),
1 EFF_PV_R,T.Ref,GT,REF_K,REF_AIR,EFF_CORR_T,EFF_CORR_L,T_FLI
1 D_IN,EMISS_1,EMISS_2,H_RAD_GRAY,TAU_ALPHAN,F_PRIME
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C VERSION INFORMATION FOR TRNSYS
IF(INFO(7).EQ.2) THEN
INFO(12)=16
RETURN 1
ENDIF
C-----------------------------------------------------------------------
C DO ALL THE VERY LAST CALL OF THE SIMULATION MANIPULATIONS HERE
IF(INFO(8).EQ.1) THEN
RETURN 1
ENDIF
C-----------------------------------------------------------------------
C PERFORM ANY "AFTER-ITERATION" MANIPULATIONS THAT ARE REQUIRED
CHARACTER(LEN=MAXMESSAGELENGTH)::MESSAGE1
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
!
IF(INFO(1).EQ.1) THEN
C-----------------------------------------------------------------------
! Export this subroutine for its use in external DLLs
! *DECSATTRIBUTES DDLEXPORT : TYPE568
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
!
! This subroutine is called for calculations of the convective heat transfer
! between the fluid and the solar collector.
!
SUBROUTINE TYPE568(TIME,XIN,OUT,T,DTDT,PAR,INFO,ICNTRL,*)
!
! Subroutine Description:
! This subroutine calculates the convective heat transfer between the fluid and the solar collector.
!
! Parameters:
! TIME - Current time of the simulation.
! XIN - Input variables for the solar collector.
! OUT - Output variables for the solar collector.
! T - Fluid temperature.
! DTDT - Time step.
! PAR - Parameters related to the solar collector.
! INFO - Information flags.
! ICNTRL - Control flags.
!
! Returns:
! VOID
!
! Examples:
! CALL TYPE568(TIME,XIN,OUT,T,DTDT,PAR,INFO,ICNTRL,*)
!
! Notes:
! This subroutine is designed to be called from the main simulation routine.
!
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!
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
!
! **End of subroutine TYPE568**
!
IF(INFO(13).GT.0) THEN
RETURN 1
ENDIF

C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    DO ALL THE VERY FIRST CALL OF THE SIMULATION MANIPULATIONS HERE
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    RETRIEVE THE UNIT NUMBER AND TYPE NUMBER FOR THIS COMPONENT FROM THE INFO
ARRAY
IUNIT=INFO(1)
ITYPE=INFO(2)
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    SET SOME INFO ARRAY VARIABLES TO TELL THE TRNSYS ENGINE HOW THIS TYPE IS TO
WORK
INFO(6)=NOUT
INFO(9)=1
INFO(10)=0
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO
WHAT IS SUPPLIED IN
CALL TYPECK(1,INFO,YCHECK,OCHECK)
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    CALL THE RCHECK SUBROUTINE TO SET THE CORRECT INPUT AND OUTPUT TYPES FOR THIS
COMPONENT
CALL RCHECK(INFO,YCHECK,OCHECK)
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    RETURN TO THE CALLING PROGRAM
RETURN 1
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    DO ALL OF THE INITIAL TIMESTEP MANIPULATIONS HERE - THERE ARE NO ITERATIONS AT
THE INITIAL TIME
IF (TIME.LT.(TIME0+DELT/2.D0)) THEN
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    SET THE UNIT NUMBER FOR FUTURE CALLS
IUNIT=INFO(1)
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
ABS_PLATE=PAR(3)
EMISS_PLATE=PAR(4)
R_2=PAR(5)
EMISS_1=PAR(6)
EMISS_2=PAR(7)
R_3=PAR(8)
THICK_CHANNEL=PAR(9)
MODE_EFF=JFIX(PAR(10)+0.5)
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    CHECK THE PARAMETERS FOR PROBLEMS AND RETURN FROM THE SUBROUTINE IF AN
ERROR IS FOUND
IF(LENGTH.LE.0.) CALL TYPECK(-4,INFO,0,10,0)
IF(WIDTH.LE.0.) CALL TYPECK(-4,INFO,0,2,0)
IF(ABS_PLATE.LT.0.) CALL TYPECK(-4,INFO,0,3,0)
IF(ABS_PLATE.GT.1.) CALL TYPECK(-4,INFO,0,3,0)
IF(EMISS_PLATE.LT.0.) CALL TYPECK(-4,INFO,0,4,0)
IF(EMISS_PLATE.GT.1.) CALL TYPECK(-4,INFO,0,4,0)
IF(R_2.LE.0.) CALL TYPECK(-4,INFO,0,5,0)
IF(EMISS_1.LT.0.) CALL TYPECK(-4,INFO,0,6,0)
IF(EMISS_1.GT.1.) CALL TYPECK(-4,INFO,0,6,0)
IF(EMISS_2.LT.0.) CALL TYPECK(-4,INFO,0,7,0)
IF(EMISS_2.GT.1.) CALL TYPECK(-4,INFO,0,7,0)
IF(R_3.LE.0.) CALL TYPECK(-4,INFO,0,8,0)
IF(THICK_CHANNEL.LT.0.) CALL TYPECK(-4,INFO,0,9,0)
MODE_EFF=JFIX(PAR(10)+0.5)
C-----------------------------------------------------------------------------
C-----------------------------------------------------------------------------
C    GET THE PV EFFICIENCY SPECIFIC PARAMETERS
IF(MODE_EFF.EQ.1) THEN
EFF_PV_REF=PAR(11)
ENDIF

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T_REF=PAR(12)
GT_REF=PAR(13)
EFF_CORR_T=PAR(14)
EFF_CORR_I=PAR(15)

IF(EFF_PV_REF.LT.0.) CALL TYPECK(-4,INFO,0,11,0)
IF(EFF_PV_REF.GT.1.) CALL TYPECK(-4,INFO,0,11,0)
IF(GT_REF.LE.0.) CALL TYPECK(-4,INFO,0,13,0)
ELSE IF(MODE_EFF.EQ.2) THEN
LU_DATA=JFIX(PAR(11)+0.5)
N_TEMPS=JFIX(PAR(12)+0.5)
N_RADS=JFIX(PAR(13)+0.5)
IF(LU_DATA.LT.10) CALL TYPECK(-4,INFO,0,11,0)
IF(N_TEMPS.LT.2) CALL TYPECK(-4,INFO,0,12,0)
IF(N_RADS.LT.2) CALL TYPECK(-4,INFO,0,13,0)
ENDIF

C PERFORM ANY REQUIRED CALCULATIONS TO SET THE INITIAL VALUES OF THE OUTPUTS HERE
OUT(1)=XIN(1)
OUT(2:6)=0.
OUT(7)=T_AMB
OUT(8)=T_AMB
OUT(9)=XIN(1)
OUT(10)=XIN(1)
OUT(11)=XIN(5)
OUT(12:15)=0.
C RETURN TO THE CALLING PROGRAM
RETURN 1
C-----------------------------------------------------------------------------------------------------------------------

C RETRIEVE THE CURRENT VALUES OF THE INPUTS TO THIS MODEL FROM THE XIN ARRAY IN SEQUENTIAL ORDER
60 T_FLUID_IN=XIN(1)
FLOW_IN=XIN(2)
T_AMB=XIN(3)
T_SKY=XIN(4)
T_SURF=XIN(5)
GT=XIN(6)
SLOPE=XIN(7)
H_CONV_T=XIN(8)
P_ATM=XIN(9)
IF(MODE_EFF.EQ.3) THEN
EFF_PV=XIN(10)
ELSE
EFF_PV=0.
ENDIF
C-----------------------------------------------------------------------------------------------------------------------

C CHECK THE INPUTS FOR PROBLEMS
IF(FLOW_IN.LT.0.) CALL TYPECK(-3,INFO,2,0,0)
IF(GT.LT.0.) CALL TYPECK(-3,INFO,6,0,0)
IF(H_CONV.T.LT.0.) CALL TYPECK(-3,INFO,8,0,0)
IF(P_ATM.LE.0.) CALL TYPECK(-3,INFO,9,0,0)
IF(EFF_PV.LT.0.) CALL TYPECK(-3,INFO,10,0,0)
IF(EFF_PV_GT.1.) CALL TYPECK(-3,INFO,10,0,0)
IF(ERRORFOUND()) RETURN 1
C-----------------------------------------------------------------------------------------------------------------------
C PERFORM ALL THE CALCULATION HERE FOR THIS MODEL.
C SET SOME GEOMETRIC PARAMETERS
AREA=LENGTH*WIDTH
DIAMETER=4.*WIDTH*THICK_CHANNEL/(2.*WIDTH+2.*THICK_CHANNEL)
C SET THE INCIDENCE ANGLE MODIFIER
XKAT=1.
TAUALPHAN=ABS_PLATE
C GUESS UPPER AND LOWER FLOW CHANNEL SURFACE TEMPERATURES
T_1=T_FLUID_IN
T_2=T_FLUID_I
N
C GUESS A PV CELL TEMPERATURE
T_PV=T_AMB
T_PV_OLD=T_PV
C GUESS A MEAN FLUID TEMPERATURE
T_FLUID_MEAN=T_FLUID_IN
C INITIALIZE THE COUNTER
ICOUNT=1
C GET THE TOP SURFACE RADIATION COEFFICIENT
10 H_RAD_T=H_RADIATION(T_PV,T_SKY,EMISS_PLATE)
C GET THE INNER-CHANNEL RADIATION COEFFICIENT
H_RAD_12=H_RAD_GRAY(T_1,T_2,EMISS_1,EMISS_2)
C GET THE PV CELL EFFICIENCY
IF(MODE_EFF.EQ.1) THEN
FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
FACTOR_I=1+EFF_CORR_I*(T_PV-T_REF)
PV_EFFICIENCY=DMAX1(0.,(FACTOR_T*FACTOR_I*EFF_PV_REF))
ELSE IF(MODE_EFF.EQ.2) THEN
X(2)=GT
X(1)=T_PV
NX(2)=N_RADS
NX(1)=N_TEMPS
CALL DYNAMICDATA(LU_DATA,2,NX,1,X,Y,INFO,*20)
CALL LINKCK('TYPE 542','DYNAMICDATA',1,99)
20 IF(ERRORFOUND()) RETURN 1
ELSE
PV_EFFICIENCY=EFF_PV
ENDIF
C SET THE PROPERTIES OF THE AIR STREAM
T_PROPS_K=T_FLUID_MEAN+273.15
P_KPA=P_ATM*101.325
CALL AIRPROPT_PROPS_K_P_KPA,AIRPROPS)
RHO_AIR=1./AIRPROPS(1) ! KG/M3
VISC_AIR=AIRPROPS(2)*3600. ! KG/M/HR
PRANDTL_AIR=AIRPROPS(3) ! DIMENSIONLESS
K_AIR=AIRPROPS(4)*3.6 ! KJ/HR/K
CP_AIR=AIRPROPS(5) ! KJ/KG/K
C CALCULATE THE REYNOLDS NUMBER
REYNOLDS=4.*FLOW_IN/P/DIAMETER/VISC_AIR
C CALCULATE THE FLUID CONVECTION COEFFICIENT
IF(REYNOLDS.LE.0.) THEN
C CALL THE SUBROUTINE TO CALCULATE THE NUSSELT NUMBER FOR INCLINED FLAT PLATES
T_1_K=T_1+273.15
T_2_K=T_2+273.15
CALL NUFLATPLATE(SLOPE,T_1_K,T_2_K,THICK_CHANNEL,P_KPA,NUSSELT)
C SET THE NATURAL CONVECTION HEAT TRANSFER COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER
ELSE IF(REYNOLDS.LE.2300.) THEN
C SET THE NUSSELT NUMBER (BASED ON A CONSTANT SURFACE TEMPERATURE)
NUSSELT=3.66
C SET THE LAMINAR CONVECTION COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER
ELSE
C SET THE NUSSELT NUMBER (BASED ON THE DITTIUS BOELTER EQUATION)
T_SURF=(T_1+T_2)/2.
IF(T_SURF.GE.T_FLUID_MEAN) THEN
N=0.4
ELSE
N=0.3
ENDIF
NUSSELT=0.023*(REYNOLDS**0.8)*(PRANDTL_AIR**N)
C SET THE TURBULENT CONVECTION COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER
C    CALCULATE THE ABSORBED SOLAR RADIATION PER UNIT AREA
S=TAUALPHAN*KhAT*GT*(1.-PV_EFFICIENCY)
C    SET SOME CONSTANTS WE'LL NEED
F_PRIME=R_2*R_CONV_T+R_2*R_RAD_T+1.
J=H_RAD_12+H_FLUID+H_RAD_12*R_2/R_3
M=1./R_2-1./R_2/F_PRIME+H_FLUID+H_RAD_12*R_2/R_3
C    REFORMULATE THE 6 ENERGY BALANCES TO FIND qe''=AA*T_flow+CC
AA=-2.*H_FLUID
1  +H_FLUID*H_FLUID/M
1  +H_FLUID*H_RAD_12*H_FLUID/2./M/J
1  +H_FLUID*H_RAD_12*H_RAD_12*H_FLUID/J/M/J
1  +H_FLUID*H_FLUID/J
CC=H_FLUID*S/F_PRIME/M
1  +H_FLUID*H_CONV_T*T_AMB/F_PRIME/M
1  +H_FLUID*H_RAD_T*T_SKY/F_PRIME/M
1  +H_FLUID*H_rad_12*T_SURF/M/J/R_3
1  +H_FLUID*T_SURF/R_3
C    SET THE CASE WITH NO FLOW
IF(FLOW_IN.LE.0.) THEN
C       SET THE USEFUL ENERGY GAIN
QU=0.
C       SET THE MEAN FLUID TEMPERATURE FROM QU=AA*T_flow+CC
T_FLOW_MEAN=-CC/AA
C       SET THE UPPER CHANNEL SURFACE TEMPERATURE
T_1=S/F_PRIME+H_CONV_T*T_AMB/F_PRIME+H_RAD_T*T_SKY
1  +F_PRIME+H_RAD_12*T_FLOW_MEAN/M+H_RAD_12*H_RELUID/M/2./J
1  +H_RELUID*TFLOW_MEAN/J+H_RAD_12*T_SURF/M/J/R_3
C       SET THE PV TEMPERATURE
T_PV=R_2*(S/F_PRIME+H_CONV_T*T_AMB/F_PRIME+H_RAD_T*T_SKY/
1  +F_PRIME+T_1/R_2/F_PRIME)
C       SET THE LOWER CHANNEL SURFACE TEMPERATURE
T_2=H_RAD_12*T_1/J+H_FLUID*T_FLOW_MEAN/M+T_SURF/J/R_3
C       SET THE FLUID OUTLET TEMPERATURE
T_FLOW_OUT=T_FLOW_MEAN
ENDIF
C    CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED
IF((DABS(T_PV
1   OLD-T_PV).GT.0.001).AND.
1   (ICOUNT.LT.1000)) THEN
T_PV_OLD=T_PV
ICOUNT=ICOUNT+1
GOTO 10
ENDIF
C    CALCULATE THE THERMAL EFFICIENCY
IF(GT.GT.0.) THEN
EFF_THERMAL=QU/AREA/GT
ELSE
EFF_THERMAL=0.
ENDIF
C    CALCULATE THE HEAT TRANSFERS
Q_TOP_CONV=H_CONV_T*AREA*(T_PV-T_AMB)
Q_TOP_RAD=H_RAD_T*AREA*(T_PV-T_SKY)
Q_BACK=AREA*T_2*T_SURF/J/R_3
Q_ABS=AREA*GT*TAUALPHAN*XKAT*(1.-PV_EFFICIENCY)
C CALCULATE THE PV POWER PRODUCTION
POWER=TAU*ALPHAN*XKAT*GT*PV_EFFICIENCY

C SET THE OUTPUTS
OUT(1)=T_FLUID_OUT
OUT(2)=FLOW_IN
OUT(3)=QU
OUT(4)=EFF_THERMAL
OUT(5)=POWER
OUT(6)=PV_EFFICIENCY
OUT(7)=T_PV
OUT(8)=T_1
OUT(9)=T_FLUID_MEAN
OUT(10)=T_2
OUT(11)=T_SURF
OUT(12)=Q_TOP_CONV
OUT(13)=Q_TOP_RAD
OUT(14)=Q_BACK
OUT(15)=Q_ABS

C KILL THE SIMULATION IF THE SYSTEM WAS UNABLE TO SOLVE
IF(ICOUNT.GE.1000) THEN
CALL MESSAGES(-1,MESSAGE1,'FATAL',IUNIT,ITYPE)
ENDIF

C EVERYTHING IS DONE - RETURN FROM THIS SUBROUTINE AND MOVE ON
RETURN 1
END
TYPE 569—Un glazed building integrated photovoltaic system (air) (Convective and radiative losses at the back of the collector)

SUBROUTINE TYPE569(TIME,XIN,OUT,T,DT,PAR,INFO,ICNTRL,*)

C ********************************************************************************************************************
C DESCRIPTION:
C THIS COMPONENT MODELS A BUILDING-INTEGRATED PHOTOVOLTAIC SYSTEM. IN THIS MODEL THERE IS NO COVER
C OVER THE PV MATERIAL. THE BACK OF THE BIPV SYSTEM INTERACTS WITH MODELS WHERE
C TEMPERATURE AND BACK-SIDE RADIATIVE SURFACE TEMPERATURE ARE KNOWN. THE
C CONVECTION CALCULATIONS
C ARE FROM CORRELATIONS PROVIDED BY ‘INTRODUCTION TO HEAT TRANSFER’ BY
C INCROPERA AND DEWITT.
C
C LAST MODIFIED:
C APRIL 2004 - JEFF THORNTON - ORIGINAL CODING

C ! Copyright © 2006 Thermal Energy System Specialists, LLC. All rights reserved.
C !DEC$ATTRIBUTES DLLEXPORT :: TYPE569
C !Export this subroutine for its use in external DLLs.
*Export this subroutine for its use in external DLLs.
DEC$ATTRIBUTES DLLEXPORT :: TYPE569
C
C ACCESS TRNSYS FUNCTIONS
C USE TrnsysConstants
C USE TrnsysFunctions
C
C TRNSYS DECLARATIONS
C IMPLICIT NONE
C DOUBLE PRECISION XIN,OUT,TIME,PAR,T,DT,TIME0,TFINAL,DELT
C
C INTEGER ICOUNT,MODE_EFF,LU_DATA,N_TEMPS,N_RADS,NX(2)
C CHARACTER*5 INFO(15),NP,NL,NOUT,ND,JUNIT,TYPE,ICNTRL,NPAR,NIN
C CHARACTER*5 YCHECK,OCHECK
C
C C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C PV_EFFICIENCY,POWER,H,RAD,T,T,FLUID_OUT,AIRPROPS,P,PL
C WIDTH,THICK,CHANNEL_P,ATM,P,KA,DIAMETER,T,PROP,TH,RO,H,AIR,
C VISC_AIR,P,AN,U,D,AL_R,LENGTH,T,ZONE,T,ZONE,RAD,H,CONV,B,T,3,
C H,RAD,B,H,PRIME,Q,BACK,CONV,Q,BACK,RAD
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C PV_EFFICIENCY,POWER,H,RAD,T,T,FLUID_OUT,AIRPROPS,P,PL
C WIDTH,THICK,CHANNEL_P,ATM,P,KA,DIAMETER,T,PROP,TH,RO,H,AIR,
C VISC_AIR,P,AN,U,D,AL_R,LENGTH,T,ZONE,T,ZONE,RAD,H,CONV,B,T,3,
C H,RAD,B,H,PRIME,Q,BACK,CONV,Q,BACK,RAD
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C PV_EFFICIENCY,POWER,H,RAD,T,T,FLUID_OUT,AIRPROPS,P,PL
C WIDTH,THICK,CHANNEL_P,ATM,P,KA,DIAMETER,T,PROP,TH,RO,H,AIR,
C VISC_AIR,P,AN,U,D,AL_R,LENGTH,T,ZONE,T,ZONE,RAD,H,CONV,B,T,3,
C H,RAD,B,H,PRIME,Q,BACK,CONV,Q,BACK,RAD
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C PV_EFFICIENCY,POWER,H,RAD,T,T,FLUID_OUT,AIRPROPS,P,PL
C WIDTH,THICK,CHANNEL_P,ATM,P,KA,DIAMETER,T,PROP,TH,RO,H,AIR,
C VISC_AIR,P,AN,U,D,AL_R,LENGTH,T,ZONE,T,ZONE,RAD,H,CONV,B,T,3,
C H,RAD,B,H,PRIME,Q,BACK,CONV,Q,BACK,RAD
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C PV_EFFICIENCY,POWER,H,RAD,T,T,FLUID_OUT,AIRPROPS,P,PL
C WIDTH,THICK,CHANNEL_P,ATM,P,KA,DIAMETER,T,PROP,TH,RO,H,AIR,
C VISC_AIR,P,AN,U,D,AL_R,LENGTH,T,ZONE,T,ZONE,RAD,H,CONV,B,T,3,
C H,RAD,B,H,PRIME,Q,BACK,CONV,Q,BACK,RAD
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C PV_EFFICIENCY,POWER,H,RAD,T,T,FLUID_OUT,AIRPROPS,P,PL
C WIDTH,THICK,CHANNEL_P,ATM,P,KA,DIAMETER,T,PROP,TH,RO,H,AIR,
C VISC_AIR,P,AN,U,D,AL_R,LENGTH,T,ZONE,T,ZONE,RAD,H,CONV,B,T,3,
C H,RAD,B,H,PRIME,Q,BACK,CONV,Q,BACK,RAD
C
C DECLARATIONS AND DEFINITIONS FOR THE USER-VARIABLES
C DOUBLE PRECISION T_1,T_2,AREA,FLOW_IN,T_AMB,GT,SLOPE,EMISS,EMISS_BACK,
C TAUALPHA,P_PRIME,T_FLUID_MEAN,T SKY,H_CONV_T,T,etest,NUSSELT,
C H_FLUID,QU,EFF, THERMAL,S_R_2_R_1,Q,TOP_CONV,N,RAD_12,
C Q,TOP_RAD,Q_ABS,RAD,RADIATION,EMISS_1,EMISS_2,H,RAD,GRAY,
C M,AA,CC,T_1,K,T_2,K,TT,SURF_CP,AIR,BLATE,EMISS_AIR,EFF_PV,Y(1),
C EFF_PV_REF,T_REF,GT,REF,K,AIR,EFF_CORR_T,EFF_CORR,GT,EFF_R,K,EFF_E,F,EMISS_PLATE,
C K_AIR,EFF_CORR_T,EFF_CORR_I,T,REYNOLDS,EMISS_PLATE,
C -------------------------------------------------------------
C PERFORM ANY "AFTER-ITERATION" MANIPULATIONS THAT ARE REQUIRED
C IF(INFO(13).GT.0) THEN
C RETURN 1
CENDIF
C-------------------------------------------------------------
C DO ALL THE VERY FIRST CALL OF THE SIMULATION MANIPULATIONS HERE
C IF(INFO(7).EQ.-1) THEN
C RETRIEVE THE UNIT NUMBER AND TYPE NUMBER FOR THIS COMPONENT FROM THE INFO
C ARRAY
IUNIT=INFO(1)
ITYPE=INFO(2)
C SET SOME INFO ARRAY VARIABLES TO TELL THE TRNSYS ENGINE HOW THIS TYPE IS TO
C WORK
INFO(6)=NOUT
INFO(9)=1
INFO(10)=0
C SET THE NUMBER OF PARAMETERS AND INPUTS
MODE_EFF=JFIX(PAR(11)+0.5)
NPAR=11
NIN=11
IF(MODE_EFF.LT.1) CALL TYPECK(-4,INFO,0,10,0)
IF(MODE_EFF.GT.3) CALL TYPECK(-4,INFO,0,10,0)
IF(ERRORFOUND()) RETURN 1
IF(MODE_EFF.EQ.1) THEN
NPAR=NPAR+5
ELSE IF(MODE_EFF.EQ.2) THEN
NPAR=NPAR+3
ELSE IF(MODE_EFF.EQ.3) THEN
NIN=NIN+1
ENDIF
C CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO
C THE TRNSYS INPUT FILE
CALL TYPECK(1,INFO,NIN,NPAR,ND)
C CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO WHAT IS SUPPLIED IN
C THE TRNSYS INPUT FILE
CALL TYPECK(1,INFO,NIN,NPAR,ND)
C CALL THE TYPE CHECK SUBROUTINE TO COMPARE WHAT THIS COMPONENT REQUIRES TO WHAT IS SUPPLIED IN
C THE TRNSYS INPUT FILE
CALL TYPECK(1,INFO,NIN,NPAR,ND)
C READING THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
ABS_PLATE=PAR(3)
EMISS_PLATE=PAR(4)
R_2=PAR(5)
EMISS_1=PAR(6)
EMISS_2=PAR(7)
R_3=PAR(8)
EMISS_BACK=PAR(9)
THICK_CHANNEL=PAR(10)
MODE_EFF=JFIX(PAR(11)+0.5)
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
ABS_PLATE=PAR(3)
EMISS_PLATE=PAR(4)
R_2=PAR(5)
EMISS_1=PAR(6)
EMISS_2=PAR(7)
R_3=PAR(8)
EMISS_BACK=PAR(9)
THICK_CHANNEL=PAR(10)
MODE_EFF=JFIX(PAR(11)+0.5)
C CALL THE RCHECK SUBROUTINE TO SET THE CORRECT INPUT AND OUTPUT TYPES FOR THIS
C COMPONENT
CALL RCHECK(INFO,YCHECK,OCHECK)
C RETURN TO THE CALLING PROGRAM
RETURN 1
C-------------------------------------------------------------
C DO ALL OF THE INITIAL TIMESTEP MANIPULATIONS HERE - THERE ARE NO ITERATIONS AT THE
C INITIAL TIME
IF(TIME.LT.(TIME0+DELT/2.D0)) THEN
C SET THE UNIT NUMBER FOR FUTURE CALLS
IUNIT=INFO(1)
C READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
LENGTH=PAR(1)
WIDTH=PAR(2)
ABS_PLATE=PAR(3)
EMISS_PLATE=PAR(4)
R_2=PAR(5)
EMISS_1=PAR(6)
EMISS_2=PAR(7)
R_3=PAR(8)
EMISS_BACK=PAR(9)
THICK_CHANNEL=PAR(10)
MODE_EFF=JFIX(PAR(11)+0.5)
C CHECK THE PARAMETERS FOR PROBLEMS AND RETURN FROM THE SUBROUTINE IF AN
C ERROR IS FOUND
IF(LENGTH.LE.0.) CALL TYPECK(-4,INFO,0,1,0)
IF(WIDTH.LE.0.) CALL TYPECK(-4,INFO,0,2,0)
IF(ABS_PLATE.LE.0.) CALL TYPECK(-4,INFO,0,3,0)
IF(ABS_PLATE.GT.1.) CALL TYPECK(-4,INFO,0,3,0)
IF(EMISS_PLATE.LE.0.) CALL TYPECK(-4,INFO,0,4,0)
IF(EMISS_PLATE.GT.1.) CALL TYPECK(-4,INFO,0,4,0)
IF(R_2.LE.0.) CALL TYPECK(-4,INFO,0,5,0)
IF(R_2.GT.0.) CALL TYPECK(-4,INFO,0,5,0)
IF(EMISS_1.LE.0.) CALL TYPECK(-4,INFO,0,6,0)
IF(EMISS_1.GT.1.) CALL TYPECK(-4,INFO,0,6,0)
IF(EMISS_2.LE.0.) CALL TYPECK(-4,INFO,0,7,0)
IF(EMISS_2.GT.1.) CALL TYPECK(-4,INFO,0,7,0)
IF(R_3.LE.0.) CALL TYPECK(-4,INFO,0,8,0)
IF(R_3.GT.0.) CALL TYPECK(-4,INFO,0,8,0)
IF(EMISS_BACK.LE.0.) CALL TYPECK(-4,INFO,0,9,0)
IF(EMISS_BACK.GT.1.) CALL TYPECK(-4,INFO,0,9,0)
IF(THICK_CHANNEL.LE.0.) CALL TYPECK(-4,INFO,0,10,0)
IF(THICK_CHANNEL.GT.1.) CALL TYPECK(-4,INFO,0,10,0)
IF(ERRORFOUND()) RETURN 1
GET THE PV EFFICIENCY SPECIFIC PARAMETERS

IF(MODE_EFF.EQ.1) THEN
    EFF_PV_REF=PAR(12)
    T_REF=PAR(13)
    GT_REF=PAR(14)
    EFF_CORR_T=PAR(15)
    EFF_CORR_I=PAR(16)
    IF(EFF_PV_REF.LT.0.) CALL TYPECK(-4,INFO,0,12,0)
    IF(EFF_PV_REF.GT.1.) CALL TYPECK(-4,INFO,0,12,0)
    IF(GT_REF.LE.0.) CALL TYPECK(-4,INFO,0,14,0)
ELSE IF(MODE_EFF.EQ.2) THEN
    LU_DATA=JFIX(PAR(12)+0.5)
    N_TEMPS=JFIX(PAR(13)+0.5)
    N_RADS=JFIX(PAR(14)+0.5)
    IF(LU_DATA.LT.10) CALL TYPECK(-4,INFO,0,12,0)
    IF(N_TEMPS.LT.2) CALL TYPECK(-4,INFO,0,13,0)
    IF(N_RADS.LT.2) CALL TYPECK(-4,INFO,0,14,0)
ENDIF

PERFORM ANY REQUIRED CALCULATIONS TO SET THE INITIAL VALUES OF THE OUTPUTS HERE

OUT(1)=XIN(1)
OUT(2:6)=0.
OUT(7)=T_AMB
OUT(8)=XIN(1)
OUT(9)=XIN(1)
OUT(10)=XIN(1)
OUT(11)=XIN(5)
OUT(12:16)=0.

RETURN TO THE CALLING PROGRAM
RETURN 1

-----------------------------------------------------------------------------------------------------------------------

RE-READ THE PARAMETERS IF ANOTHER UNIT OF THIS TYPE HAS BEEN CALLED

IF(INFO(1).NE.IUNIT) THEN
    IUNIT=INFO(1)
    ITYPE=INFO(2)
    READ IN THE VALUES OF THE PARAMETERS IN SEQUENTIAL ORDER
    LENGTH=PAR(1)
    WIDTH=PAR(2)
    ABS_PLATE=PAR(3)
    EMISS_PLATE=PAR(4)
    R_2=PAR(5)
    EMISS_1=PAR(6)
    EMISS_2=PAR(7)
    R_3=PAR(8)
    EMISS_BACK=PAR(9)
    THICK_CHANNEL=PAR(10)
    MODE_EFF=JFIX(PAR(11)+0.5)
    IF(MODE_EFF.EQ.1) THEN
        EFF_PV=PAR(12)
        T_REF=PAR(13)
        GT_REF=PAR(14)
        EFF_CORR_T=PAR(15)
        EFF_CORR_I=PAR(16)
    ELSE IF(MODE_EFF.EQ.2) THEN
        LU_DATA=JFIX(PAR(12)+0.5)
        N_TEMPS=JFIX(PAR(13)+0.5)
        N_RADS=JFIX(PAR(14)+0.5)
    ENDIF
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------

RETRIEVE THE CURRENT VALUES OF THE INPUTS TO THIS MODEL FROM THE XIN ARRAY IN SEQUENTIAL ORDER

60 T_FLUID_IN=XIN(1)
FLOW_IN=XIN(2)
T_AMB=XIN(3)
T_SKY=XIN(4)
T_ZONE=XIN(5)
T_ZONE_RAD=XIN(6)
GT=XIN(7)
SLOPE=XIN(8)
H_CONV_T=XIN(9)
H_CONV_B=XIN(10)
P_ATM=XIN(11)
IF(MODE_EFF.EQ.3) THEN
    EFF_PV=XIN(12)
ELSE
    EFF_PV=0.
ENDIF
C-----------------------------------------------------------------------------------------------------------------------
C-----------------------------------------------------------------------------------------------------------------------
C CHECK THE INPUTS FOR PROBLEMS
IF(FLOW_IN.LT.0.) CALL TYPECK(-3,INFO,2,0,0)
IF(GT.LT.0.) CALL TYPECK(-3,INFO,7,0,0)
IF(H_CONV_T.LT.0.) CALL TYPECK(-3,INFO,9,0,0)
IF(H_CONV_B.LT.0.) CALL TYPECK(-3,INFO,10,0,0)
IF(P_ATM.LE.0.) CALL TYPECK(-3,INFO,11,0,0)
IF(EFF_PV.LT.0.) CALL TYPECK(-3,INFO,12,0,0)
IF(EFF_PV.GT.1.) CALL TYPECK(-3,INFO,12,0,0)
IF(ERRORFOUND()) RETURN 1

C PERFORM ALL THE CALCULATION HERE FOR THIS MODEL.

C SET SOME GEOMETRIC PARAMETERS
AREA=LENGTH*WIDTH
DIAMETER=4.*WIDTH*THICK_CHANNEL/(2.*WIDTH+2.*THICK_CHANNEL)

C SET THE INCIDENCE ANGLE MODIFIER
XKAT=1.
TAUALPHAN=ABS_PLATE

C GUESS UPPER AND LOWER FLOW CHANNEL SURFACE TEMPERATURES
T_1=T_FLUID_IN
T_2=T_FLUID_IN

C GUESS A BACK COLLECTOR SURFACE TEMPERATURE
T_3=(T_ZONE+T_ZONE_RAD)/2.

C GUESS A PV CELL TEMPERATURE
T_PV=T_AMB
T_PV_OLD=T_PV

C GUESS A MEAN FLUID TEMPERATURE
T_FLUID_MEAN=T_FLUID_IN

C INITIALIZE THE COUNTER
ICOUNT=1

C GET THE TOP SURFACE RADIATION COEFFICIENT
10 H_RAD_T=H_RADIATION(T_PV,T_SKY,EMISS_PLATE)

C GET THE BOTTOM SURFACE RADIATION COEFFICIENT
H_RAD_B=H_RADIATION(T_3,T_ZONE_RAD,EMISS_BACK)

C GET THE INNER-CHANNEL RADIATION COEFFICIENT
H_RAD_12=H_RAD_GRAY(T_1,T_2,EMISS_1,EMISS_2)

C GET THE PV CELL EFFICIENCY
IF(MODE_EFF.EQ.1) THEN
FACTOR_T=1+EFF_CORR_T*(T_PV-T_REF)
FACTOR_I=1+EFF_CORR_I*(GT-GT_REF)
PV_EFFICIENCY=DMAX1(0.,(FACTOR_T*FACTOR_I*EFF_PV_REF))
ELSE IF(MODE_EFF.EQ.1) THEN
X(2)=GT
X(1)=T_PV
NX(2)=N_RADS
NX(1)=N_TEMPS
CALL DYNAMICDATA(LU_DATA,2,NX,1,X,Y,INFO,*20)
CALL LINKCK('TYPE 542','DYNAMICDATA',1,99)
20 IF(ERRORFOUND()) RETURN 1
ELSE
PV_EFFICIENCY=Y(1)
ENDIF

C SET THE PROPERTIES OF THE AIR STREAM
T_PROPS_K=T_FLUID_MEAN+273.15
P_KPA=P_ATM*101.325
CALL AIRPROP(T_PROPS_K,P_KPA,AIRPROPS)
RHO_AIR=1./AIRPROPS(1) ! KG/M3
VISC_AIR=AIRPROPS(2)*3600. ! KG/M/HR
PRANDTL_AIR=AIRPROPS(3) ! DIMENSIONLESS
K_AIR=AIRPROPS(4)*3.6 ! KJ/H/M/K
CP_AIR=AIRPROPS(5) ! K/J/KG/K

C CALCULATE THE REYNOLDS NUMBER
REYNOLDS=4.*FLOW_IN/PDIAETER/VISC_AIR

C CALCULATE THE FLUID CONVECTION COEFFICIENT
IF(REYNOLDS.LE.0.) THEN
C CALL THE SUBROUTINE TO CALCULATE THE NUSSELT NUMBER FOR INCLINED FLAT PLATES
T_1,K=T_1+273.15
T_2,K=T_2+273.15
CALL NUFLATPLATE(SLOPE,T_1,K,T_2,K,THICK_CHANNEL,P_KPA,NUSSELT)
ELSE IF(REYNOLDS.LE.2300.) THEN
C SET THE NATURAL CONVECTION HEAT TRANSFER COEFFICIENT
H_FLUID=NUSSELT*K_AIR/PDIAETER
ELSE IF(REYNOLDS.LT.2300.) THEN
C SET THE NUSSELT NUMBER (BASED ON A CONSTANT SURFACE TEMPERATURE)
NUSSELT=T_2
C SET THE LAMINAR CONVECTION COEFFICIENT
H_FLUID=NUSSELT*K_AIR/PDIAETER
ELSE}

IAE SHC – Task 35 – PV/Thermal Solar Systems 51
C SET THE NUSSELT NUMBER (BASED ON THE DITTUUS BOELTER EQUATION)
T_SURF=(T_1+T_2)/2.

IF(T_SURF.GE.T_FLUID_MEAN) THEN
  N=0.4
ELSE
  N=0.3
ENDIF

NUSSELT=0.023*(REYNOLDS**0.8)*(PRANDTL_AIR**N)

C SET THE TURBULENT CONVECTION COEFFICIENT
H_FLUID=NUSSELT*K_AIR/DIAMETER

C CALCULATE THE ABSORBED SOLAR RADIATION PER UNIT AREA
S=TAUALPHAN*XKAT*GT*(1.-PV_EFFICIENCY)

C SET SOME CONSTANTS WE'LL NEED
F_PRIME=R_2*H_CONV_T+R_2*H_RAD_T+1.
H_PRIME=1.+R_3*H_CONV_B+R_3*H_RAD_B
J=H_RAD_12+H_FLUID+1./R_3
H_PRIME=1.+R_3*H_CONV_B+R_3*H_RAD_B
M=1./R_2
F_PRIME=1.+R_3*H_CONV_B+R_3*H_RAD_B

C REFORMAT THE 6 ENERGY BALANCES TO FIND qf''=AA*T_fluid+CC
AA=-2.*H_FLUID
CC=H_FLUID*S/F_PRIME/M

C SET THE CASE WITH NO FLOW
IF(FLOW_IN.LE.0.) THEN
  T_1=T_2=0.
  QF=0.
ELSE
  FIND THE FLUID OUTLET TEMPERATURE BY INTEGRATING THE FLUID DIFFERENTIAL EQUATION
  T_FLUID_OUT=(T_FLUID_IN+CC/AA)*DEXP(AA*AREA/FLOW_IN/CP_AIR)-CC/AA
  T_FLUID_MEAN=(T_FLUID_IN+CC/AA)*DEXP(AA*AREA/FLOW_IN/CP_AIR)/(AA*AREA/FLOW_IN/CP_AIR)
  CC/AA
  QF=FLOW_IN*CP_AIR*(T_FLUID_OUT-T_FLUID_IN)
ENDIF

C SET THE MEAN FLUID TEMPERATURE FROM QU=AA(T)+CC
T_FLUID_MEAN=CC/AA

C SET THE UPPER CHANNEL SURFACE TEMPERATURE
T_1=H_CONV_T*T_AMB/F_PRIME/M
  +H_CONV_T*T_SKY/F_PRIME/M
  +H_CONV_T*T_ZONE/M/H_Prime

C SET THE LOWER CHANNEL SURFACE TEMPERATURE
T_2=T_1/H_Primem+R_3*H_CONV_B*T_ZONE/M/H_Prime

C SET THE BACK SURFACE TEMPERATURE
T_3=T_1/H_Primem+R_3*H_CONV_B*T_ZONE/M/H_Prime

C SET THE FLUID OUTLET TEMPERATURE
T_FLUID_OUT=T_FLUID_MEAN

C KNOWING THE INLET AND OUTLET TEMPERATURES CALCULATE THE COLLECTOR USEFUL ENERGY GAIN
QU=FLOW_IN*CP_AIR*(T_FLUID_OUT-T_FLUID_IN)

C SET THE UPPER CHANNEL SURFACE TEMPERATURE
T_1=H_CONV_T*T_AMB/F_PRIME/M
  +H_CONV_T*T_SKY/F_PRIME/M
  +H_CONV_T*T_ZONE/M/H_Prime

C SET THE LOWER CHANNEL SURFACE TEMPERATURE
T_2=T_1/H_Primem+R_3*H_CONV_B*T_ZONE/M/H_Prime

C SET THE BACK SURFACE TEMPERATURE
T_3=T_1/H_Primem+R_3*H_CONV_B*T_ZONE/M/H_Prime

C SET THE FLUID OUTLET TEMPERATURE
T_FLUID_OUT=T_FLUID_MEAN

C KNOWING THE INLET AND OUTLET TEMPERATURES CALCULATE THE COLLECTOR USEFUL ENERGY GAIN
QU=FLOW_IN*CP_AIR*(T_FLUID_OUT-T_FLUID_IN)
C SET THE PV TEMPERATURE
T_PV=R_2*(S/F_PRIME+H_CONV_T*T_AMB/F_PRIME+H_RAD_T*T_SKY/
1  H_PRIME+H_RAD_B*T_ZONE_RAD/M/J/H_PRIME)
C SET THE LOWER CHANNEL SURFACE TEMPERATURE
T_2=H_RAD_12*T_1/J+H_FLUID*T_FLUID_MEAN/J+H_CONV_B*T_ZONE/J/
1  H_PRIME+H_RAD_B*T_ZONE_RAD/J/H_PRIME
C SET THE BACK SURFACE TEMPERATURE
T_3=T_2/H_PRIME+R_3*H_CONV_B*T_ZONE/H.PRIME+R_3*H_RAD_B*
1  T_ZONE_RAD/H_PRIME
ENDIF
C CHECK TO SEE IF MORE ITERATIONS ARE REQUIRED
IF((DABS(T_PV_OLD-T_PV).GT.0.001).AND.
1   (ICOUNT.LT.1000)) THEN
   T_PV_OLD=T_PV
   ICOUNT=ICOUNT+1
   GOTO 10
ENDIF
C CALCULATE THE THERMAL EFFICIENCY
IF(GT.GT.0.) THEN
   EFF_THERMAL=QU/AREA/GT
ELSE
   EFF_THERMAL=0.
ENDIF
C CALCULATE THE HEAT TRANSFERS
Q_TOP_CONV=H_CONV_T*AREA*(T_PV-T_AMB)
Q_TOP_RAD=H_RAD_T*AREA*(T_PV-T_SKY)
Q_BACK_CONV=H_CONV_B*AREA*(T_3-T_ZONE)
Q_BACK_RAD=H_RAD_B*AREA*(T_3-T_ZONE_RAD)
Q_ABS=AREA*GT*TAUALPHAN*XKAT*(1.-PV_EFFICIENCY)
C CALCULATE THE PV POWER PRODUCTION
POWER=TAUALPHAN*XKAT*GT*PV_EFFICIENCY
C SET THE OUTPUTS
OUT(1)=T_FLUID_OUT
OUT(2)=FLOW_IN
OUT(3)=QU
OUT(4)=EFF_THERMAL
OUT(5)=POWER
OUT(6)=PV_EFFICIENCY
OUT(7)=T_PV
OUT(8)=T_1
OUT(9)=T_FLUID_MEAN
OUT(10)=T_2
OUT(11)=T_3
OUT(12)=Q_TOP_CONV
OUT(13)=Q_TOP_RAD
OUT(14)=Q_BACK_CONV
OUT(15)=Q_BACK_RAD
OUT(16)=Q_ABS
C KILL THE SIMULATION IF THE SYSTEM WAS UNABLE TO SOLVE
IF((COUNT.GE.1000)) THEN
   CALL MESSAGES(-1,MESSAGE1,FATAL,IUNIT,ITYPE)
ENDIF
C EVERYTHING IS DONE - RETURN FROM THIS SUBROUTINE AND MOVE ON
RETURN 1
END
Appendix B
Input and Output Parameters for TRNSYS Solar Thermal, PV, and PV/T Collector Models
## TYPE 1: Flat Plate Solar Collector

### TYPE 1a- Flat Plate Solar collector (No incidence angle modification)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number in series</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector area</td>
<td>Inlet flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Efficiency mode</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Tested flow rate</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>6</td>
<td>Intercept efficiency</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Efficiency slope</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Efficiency curvature</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Optical Mode 1</td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 1b- Flat Plate Solar collector (2nd order incidence angle modifiers)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number in series</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector area</td>
<td>Inlet flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Efficiency mode</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Tested flow rate</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>6</td>
<td>Intercept efficiency</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>7</td>
<td>Efficiency slope</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>8</td>
<td>Efficiency curvature</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>9</td>
<td>Optical mode 2</td>
<td>Collector slope</td>
</tr>
<tr>
<td>10</td>
<td>1st-order IAM</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2nd-order IAM</td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 1c- Flat Plate Solar collector (Modifiers=f(incidence angle))

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number in series</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector area</td>
<td>Inlet flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Efficiency mode</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Tested flow rate</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>6</td>
<td>Intercept efficiency</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>7</td>
<td>Efficiency slope</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>8</td>
<td>Efficiency curvature</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>9</td>
<td>Optical mode 3</td>
<td>Collector slope</td>
</tr>
<tr>
<td>10</td>
<td>Plate absorbance</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>No. of IAM's in file</td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 1d- Flat Plate Solar collector (Cover and absorber properties)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number in series</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector area</td>
<td>Inlet flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Efficiency mode</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Tested flow rate</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>6</td>
<td>Intercept efficiency</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>7</td>
<td>Efficiency slope</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>8</td>
<td>Efficiency curvature</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>9</td>
<td>Optical mode 4</td>
<td>Collector slope</td>
</tr>
<tr>
<td>10</td>
<td>Plate absorbance</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>No. of identical covers</td>
<td></td>
</tr>
</tbody>
</table>
### TYPE 1e- Flat Plate Solar collector (Biaxial incidence angle modifiers)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Index of refraction</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Extinction</td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 2: ON/Off Differential

#### TYPE 2a-On/off Differential Controller for temperatures (New control strategy)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New control mode</td>
<td>Upper input temperature Th</td>
</tr>
<tr>
<td>2</td>
<td>High limit cut-out</td>
<td>Lower input temperature Ti</td>
</tr>
<tr>
<td>3</td>
<td>High limit reset</td>
<td>Monitoring temperature Tin</td>
</tr>
<tr>
<td>4</td>
<td>Input control function</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Upper dead band dT</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lower dead band dT</td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 2b- On/off Differential Controller for temperatures (Old control strategy)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of oscillations</td>
<td>Upper input temperature Th</td>
</tr>
<tr>
<td>2</td>
<td>High limit cut-out</td>
<td>Lower input temperature Ti</td>
</tr>
<tr>
<td>3</td>
<td>Monitoring temperature Tin</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Input control function</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Upper dead band dT</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lower dead band dT</td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 2c- On/off Differential Controller-generic (New control strategy)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New control mode</td>
<td>Upper input value</td>
</tr>
<tr>
<td>2</td>
<td>High limit cut-out</td>
<td>Lower input value</td>
</tr>
<tr>
<td>3</td>
<td>High limit reset</td>
<td>Monitoring value</td>
</tr>
<tr>
<td>4</td>
<td>Input control function</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Upper dead band</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lower dead band</td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 2d- On/off Differential Controller-generic (Old control strategy)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of oscillations</td>
<td>Upper input value</td>
</tr>
<tr>
<td>2</td>
<td>High limit cut-out</td>
<td>Lower input value</td>
</tr>
<tr>
<td>3</td>
<td>Monitoring value</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Input control function</td>
<td></td>
</tr>
</tbody>
</table>
### TYPE 4: Stratified Fluid Storage Tank

#### TYPE 4a/b - Stratified Fluid Storage Tank Fixed inlets (a- Uniform losses b-Non-uniform losses)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixed inlet positions</td>
<td>Hot-side temperature</td>
</tr>
<tr>
<td>2</td>
<td>Tank volume</td>
<td>Hot-side flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Cold-side temperature</td>
</tr>
<tr>
<td>4</td>
<td>Fluid density</td>
<td>Cold-side flowrate</td>
</tr>
<tr>
<td>5</td>
<td>Tank loss coefficient</td>
<td>Environment temperature</td>
</tr>
<tr>
<td>6</td>
<td>Height of node</td>
<td>Control signal for element-1</td>
</tr>
<tr>
<td>7</td>
<td>Auxiliary heater mode</td>
<td>Control signal for element-2</td>
</tr>
<tr>
<td>8</td>
<td>Node containing heating element 1</td>
<td>Energy rate to load</td>
</tr>
<tr>
<td>9</td>
<td>Node containing thermostat 1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Set point temperature for element 1</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Deadband for heating element 1</td>
<td>Energy rate from heat source</td>
</tr>
<tr>
<td>12</td>
<td>Maximum heating rate of element 1</td>
<td>Average tank temperature</td>
</tr>
<tr>
<td>13</td>
<td>Node containing heating element 2</td>
<td>Temperature of node 1+</td>
</tr>
<tr>
<td>14</td>
<td>Node containing thermostat 2</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Set point temperature for element 2</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Deadband for heating element 2</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Maximum heating rate of element 2</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Not used (Flue UA)</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Not used (Tflue)</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Boiling point</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Incremental loss coefficient for node</td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 4c/d - Stratified Fluid Storage Tank Variable inlets (c- Uniform losses d-Non-uniform losses)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Variable inlet positions</td>
<td>Hot-side temperature</td>
</tr>
<tr>
<td>2</td>
<td>Tank volume</td>
<td>Hot-side flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Cold-side temperature</td>
</tr>
<tr>
<td>4</td>
<td>Fluid density</td>
<td>Cold-side flowrate</td>
</tr>
<tr>
<td>5</td>
<td>Tank loss coefficient</td>
<td>Environment temperature</td>
</tr>
<tr>
<td>6</td>
<td>Height of node</td>
<td>Control signal for element-1</td>
</tr>
<tr>
<td>7</td>
<td>Auxiliary heater mode</td>
<td>Control signal for element-2</td>
</tr>
<tr>
<td>8</td>
<td>Node containing heating element 1</td>
<td>Auxiliary heating rate</td>
</tr>
<tr>
<td>9</td>
<td>Node containing thermostat 1</td>
<td>Element 1 power</td>
</tr>
<tr>
<td>10</td>
<td>Set point temperature for element 1</td>
<td>Element 2 power</td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>11 Deadband for heating element 1</td>
<td></td>
<td>Energy rate from heat source</td>
</tr>
<tr>
<td>12 Maximum heating rate of element 1</td>
<td></td>
<td>Average tank temperature</td>
</tr>
<tr>
<td>13 Node containing heating element 2</td>
<td></td>
<td>Temperature of node 1+</td>
</tr>
<tr>
<td>14 Node containing thermostat 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Set point temperature for element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Deadband for heating element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 Maximum heating rate of element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 Not used (Flue UA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Not used (Tflue)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Boiling point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 Incremental loss coefficient for node</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 4ef- Stratified Fluid Storage User-designated inlets (e- Uniform losses f-Non-uniform losses)**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 User-specified inlet positions</td>
<td>Hot-side temperature</td>
<td>Temperature to heat source</td>
</tr>
<tr>
<td>2 Tank volume</td>
<td>Hot-side flowrate</td>
<td>Flowrate to heat source</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Cold-side temperature</td>
<td>Temperature to load</td>
</tr>
<tr>
<td>4 Fluid density</td>
<td>Cold-side flowrate</td>
<td>Flowrate to load</td>
</tr>
<tr>
<td>5 Tank loss coefficient</td>
<td>Environment temperature</td>
<td>Thermal losses</td>
</tr>
<tr>
<td>6 Height of node</td>
<td>Control signal for element-1</td>
<td>Energy rate to load</td>
</tr>
<tr>
<td>7 Auxiliary heater mode</td>
<td>Control signal for element-2</td>
<td>Internal energy change</td>
</tr>
<tr>
<td>8 Node containing heating element 1</td>
<td></td>
<td>Auxiliary heating rate</td>
</tr>
<tr>
<td>9 Node containing thermostat 1</td>
<td></td>
<td>Element 1 power</td>
</tr>
<tr>
<td>10 Set point temperature for element 1</td>
<td></td>
<td>Element 2 power</td>
</tr>
<tr>
<td>11 Deadband for heating element 1</td>
<td></td>
<td>Energy rate from heat source</td>
</tr>
<tr>
<td>12 Maximum heating rate of element 1</td>
<td></td>
<td>Average tank temperature</td>
</tr>
<tr>
<td>13 Node containing heating element 2</td>
<td></td>
<td>Temperature of node 1+</td>
</tr>
<tr>
<td>14 Node containing thermostat 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Set point temperature for element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Deadband for heating element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 Maximum heating rate of element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 Not used (Flue UA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Not used (Tflue)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Boiling point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 Entering node for hot-source flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 Entering node for cold-side</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TYPE 10: Rock Bed Thermal Storage

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>fluid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Incremental loss coefficient for node</td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 38: Algebraic Tank (Plug-Flow)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific heat of air</td>
<td>Temperature into top</td>
</tr>
<tr>
<td>2</td>
<td>Length of rock bed</td>
<td>Flowrate into top</td>
</tr>
<tr>
<td>3</td>
<td>Cross-sectional area</td>
<td>Temperature into bottom</td>
</tr>
<tr>
<td>4</td>
<td>Perimeter</td>
<td>Flowrate into bottom</td>
</tr>
<tr>
<td>5</td>
<td>Specific heat of rock</td>
<td>Environment temperature</td>
</tr>
<tr>
<td>6</td>
<td>Apparent rock bed density</td>
<td>Rate of energy supply</td>
</tr>
<tr>
<td>7</td>
<td>Loss coefficient</td>
<td>Environment losses</td>
</tr>
<tr>
<td>8</td>
<td>Effective thermal conductivity</td>
<td>Average temperature</td>
</tr>
</tbody>
</table>

#### TYPE 39: Variable Volume Tank

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tank operation mode</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Overall tank volume</td>
<td>Inlet flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Minimum fluid volume</td>
<td>Flow rate to load</td>
</tr>
<tr>
<td>4</td>
<td>Maximum fluid volume</td>
<td>Environment temperature</td>
</tr>
<tr>
<td>5</td>
<td>Tank circumference</td>
<td>Fluid volume</td>
</tr>
<tr>
<td>6</td>
<td>Cross-sectional area</td>
<td>Enthalpy difference</td>
</tr>
<tr>
<td>7</td>
<td>Wetted loss coefficient</td>
<td>Environment losses</td>
</tr>
<tr>
<td>8</td>
<td>Dry loss coefficient</td>
<td>Internal energy change</td>
</tr>
<tr>
<td>9</td>
<td>Fluid specific heat</td>
<td>Level indicator</td>
</tr>
<tr>
<td>10</td>
<td>Fluid density</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Initial fluid temperature</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Initial fluid volume</td>
<td></td>
</tr>
</tbody>
</table>
TYPE 40-Microprocessor Controller

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of comparators (up to 5)</td>
<td>Comparator high input i</td>
</tr>
<tr>
<td>2</td>
<td>Temperature difference on deadband, comp.i</td>
<td>Comparator low input i</td>
</tr>
<tr>
<td>3</td>
<td>Temperature difference off deadband, comp.i</td>
<td></td>
</tr>
</tbody>
</table>

TYPE 45: Thermosiphon Collector with Integral Storage

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Collector area</td>
<td>Total incident radiation</td>
</tr>
<tr>
<td>2</td>
<td>Intercept efficiency</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>3</td>
<td>Efficiency slope</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>4</td>
<td>Tested flow rate</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>5</td>
<td>Incidence angle modifier constant</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>6</td>
<td>Collector slope</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>7</td>
<td>Logical unit</td>
<td>Replacement temperature</td>
</tr>
<tr>
<td>8</td>
<td>Number of data points</td>
<td>Load flowrate</td>
</tr>
<tr>
<td>9</td>
<td>Riser diameter</td>
<td>Environment temperature</td>
</tr>
<tr>
<td>10</td>
<td>Header diameter</td>
<td>Control signal</td>
</tr>
<tr>
<td>11</td>
<td>Header length</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Number of collector nodes</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Collector inlet to outlet distance</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Collector inlet to tank outlet distance</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Collector inlet diameter</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Length of collector inlet</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Number of inlet bends</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Inlet pipe loss coefficient</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Collector outlet diameter</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Length of collector outlet</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Number of outlet bends</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Outlet pipe loss coefficient</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Inlet position mode</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Tank volume</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Tank height</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Height of collector return</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Fluid specific heat</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Fluid density</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Thermal conductivity</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Tank configuration</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Overall Loss Coefficient</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Insulation ratio</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Initial temperature</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Maximum heating rate</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Auxiliary height</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Thermostat height</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Set point temperature</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Temperature deadband</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Flue loss coefficient</td>
<td></td>
</tr>
</tbody>
</table>
### Type 47: Battery

#### TYPE 47a- Electrical Storage battery Power as an input (dQ/dt=Peff)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Power to or from battery</td>
<td>State of charge</td>
</tr>
<tr>
<td>2 Cell Energy Capacity</td>
<td></td>
<td>Fractional state of charge</td>
</tr>
<tr>
<td>3 Cells in parallel</td>
<td></td>
<td>Power</td>
</tr>
<tr>
<td>4 Cells in series</td>
<td></td>
<td>Power lost during charge</td>
</tr>
<tr>
<td>5 Charging efficiency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 47b- Electrical Storage battery Power as an input (Shepherd equation)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Power to or from battery</td>
<td>State of charge</td>
</tr>
<tr>
<td>2 Cell Energy Capacity</td>
<td></td>
<td>Fractional state of charge</td>
</tr>
<tr>
<td>3 Cells in parallel</td>
<td></td>
<td>Power</td>
</tr>
<tr>
<td>4 Cells in series</td>
<td></td>
<td>Power lost during charge</td>
</tr>
<tr>
<td>5 Charging efficiency</td>
<td></td>
<td>Total current</td>
</tr>
<tr>
<td>6 Max. current per cell charging</td>
<td>Total voltage</td>
<td>Max. Power for charge</td>
</tr>
<tr>
<td>7 Max. current per cell discharge</td>
<td></td>
<td>Max. Power for discharge</td>
</tr>
<tr>
<td>8 Max. charge voltage per cell</td>
<td></td>
<td>Discharge cutoff voltage (DCV)</td>
</tr>
<tr>
<td>9 Calculate discharge cutoff voltage</td>
<td></td>
<td>Discharge cutoff voltage (DCV)</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Power corresponding to DCV</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Charge cutoff voltage (CCV)</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Power corresponding to CCV</td>
</tr>
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#### TYPE 47c- Electrical Storage battery Power as an input (Shepherd modified Hyman equation)

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<th>PARAMETERS</th>
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<td>State of charge</td>
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<tr>
<td>2 Cell Energy Capacity</td>
<td></td>
<td>Fractional state of charge</td>
</tr>
<tr>
<td>3 Cells in parallel</td>
<td></td>
<td>Power</td>
</tr>
<tr>
<td>4 Cells in series</td>
<td></td>
<td>Power lost during charge</td>
</tr>
<tr>
<td>5 Charging efficiency</td>
<td></td>
<td>Total current</td>
</tr>
<tr>
<td>6 Max. current per cell charging</td>
<td>Total voltage</td>
<td>Max. Power for charge</td>
</tr>
<tr>
<td>7 Max. current per cell discharge</td>
<td></td>
<td>Max. Power for discharge</td>
</tr>
<tr>
<td>8 Max. charge voltage per cell</td>
<td></td>
<td>Discharge cutoff voltage (DCV)</td>
</tr>
<tr>
<td>9 Calculate discharge cutoff voltage</td>
<td></td>
<td>Discharge cutoff voltage (DCV)</td>
</tr>
<tr>
<td>10 Tolerance for charging current calculation</td>
<td>Power corresponding to DCV</td>
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</tr>
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<td></td>
<td>Charge cutoff voltage (CCV)</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Power corresponding to CCV</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
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#### TYPE 47d- Electrical Storage battery Current as an Input (Shepherd equation)

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<th>INPUT</th>
<th>OUTPUT</th>
</tr>
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<td>Fractional state of charge</td>
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<tr>
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</tr>
<tr>
<td>2</td>
<td>Cells in parallel</td>
<td>Power</td>
</tr>
<tr>
<td>3</td>
<td>Cells in series</td>
<td>Power lost during charge</td>
</tr>
<tr>
<td>4</td>
<td>Charging efficiency</td>
<td>Total current</td>
</tr>
<tr>
<td>5</td>
<td>Max. current per cell charging</td>
<td>Total voltage</td>
</tr>
<tr>
<td>6</td>
<td>Max. current per cell discharge</td>
<td>Max. Power for charge</td>
</tr>
<tr>
<td>7</td>
<td>Max. charge voltage per cell</td>
<td>Max. Power for discharge</td>
</tr>
<tr>
<td>8</td>
<td>Calculate charge voltage cutoff</td>
<td>Discharge cutoff voltage (DCV)</td>
</tr>
<tr>
<td>9</td>
<td>Power corresponding to DCV</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Charge cutoff voltage (CCV)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Power corresponding to CCV</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>TYPE 47e- Electrical Storage battery Current as an Input (Shepherd modified Hyman equation)</td>
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</tr>
<tr>
<td></td>
<td>PARAMETERS</td>
<td>INPUT</td>
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<tr>
<td>2</td>
<td>Cell Energy Capacity</td>
<td>Fractional state of charge</td>
</tr>
<tr>
<td>3</td>
<td>Cells in parallel</td>
<td>Power</td>
</tr>
<tr>
<td>4</td>
<td>Cells in series</td>
<td>Power lost during charge</td>
</tr>
<tr>
<td>5</td>
<td>Charging efficiency</td>
<td>Total current</td>
</tr>
<tr>
<td>6</td>
<td>Max. current per cell charging</td>
<td>Total voltage</td>
</tr>
<tr>
<td>7</td>
<td>Max. current per cell discharge</td>
<td>Max. Power for charge</td>
</tr>
<tr>
<td>8</td>
<td>Max. charge voltage per cell</td>
<td>Max. Power for discharge</td>
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<tr>
<td>9</td>
<td>Power corresponding to DCV</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Power corresponding to DCV</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Charge cutoff voltage (CCV)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Power corresponding to CCV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TYPE 48: Regulator/Inverter</td>
<td></td>
</tr>
<tr>
<td>Type 48a- Regulator/Inverter (System without battery storage)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>PARAMETERS</td>
<td>INPUT</td>
</tr>
<tr>
<td>1</td>
<td>Mode</td>
<td>Input power</td>
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<tr>
<td>2</td>
<td>Efficiency</td>
<td>Load power</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Excess power</td>
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<td></td>
<td>Type 48b- Regulator/Inverter (System with battery storage-MPP Tracking-SOC monitoring only)</td>
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</tr>
<tr>
<td></td>
<td>PARAMETERS</td>
<td>INPUT</td>
</tr>
<tr>
<td>1</td>
<td>Mode</td>
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</tr>
<tr>
<td>2</td>
<td>Regulator efficiency</td>
<td>Load power</td>
</tr>
<tr>
<td>3</td>
<td>Inverter efficiency</td>
<td>Battery fractional state of charge</td>
</tr>
<tr>
<td>4</td>
<td>High limit on fractional state of charge (FSOC)</td>
<td>Dumped generated power</td>
</tr>
<tr>
<td>5</td>
<td>Low limit on FSOC</td>
<td>Power from grid</td>
</tr>
<tr>
<td>6</td>
<td>charge to discharge limit on FSOC</td>
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</tr>
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</table>
### Type 48c- Regulator/Inverter (System with battery storage-MPP Tracking-SOC and SOV monitoring)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
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</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Input power</td>
<td>Power in from generation</td>
</tr>
<tr>
<td>2 Regulator efficiency</td>
<td>Load power</td>
<td>Power to or from battery</td>
</tr>
<tr>
<td>3 Inverter efficiency (DC to AC)</td>
<td>Battery fractional state of charge</td>
<td>Power to load</td>
</tr>
<tr>
<td>4 High limit on fractional state of charge (FSOC)</td>
<td>Battery voltage (BV)</td>
<td>Dumped generated power</td>
</tr>
<tr>
<td>5 Low limit on FSOC</td>
<td>Max battery input</td>
<td>Power from grid</td>
</tr>
<tr>
<td>6 charge to discharge limit on FSOC</td>
<td>Min. battery output</td>
<td></td>
</tr>
<tr>
<td>7 Power output limit</td>
<td>lower limit on battery voltage</td>
<td></td>
</tr>
<tr>
<td>8 Inverter efficiency (AC to DC)</td>
<td>Power corresponding to BV</td>
<td></td>
</tr>
<tr>
<td>9 Current for grid charging of battery</td>
<td>High limit on BV</td>
<td></td>
</tr>
<tr>
<td>10 Upper limit on FSOC for grid charging</td>
<td>Power corresponding to high limit on BV</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Start time for grid battery charging</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Stop time for grid battery charging</td>
<td></td>
</tr>
</tbody>
</table>

### Type 48d- Regulator/Inverter (System with battery storage-Array V=Battery V)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Input power</td>
<td>Power in from generation</td>
</tr>
<tr>
<td>2 Regulator efficiency</td>
<td>Load power</td>
<td>Power to or from battery</td>
</tr>
<tr>
<td>3 Inverter efficiency (DC to AC)</td>
<td>Battery fractional state of charge</td>
<td>Power to load</td>
</tr>
<tr>
<td>4 High limit on fractional state of charge (FSOC)</td>
<td>Battery voltage (BV)</td>
<td>Dumped generated power</td>
</tr>
<tr>
<td>5 Low limit on FSOC</td>
<td>Max battery input</td>
<td>Power from grid</td>
</tr>
<tr>
<td>6 charge to discharge limit on FSOC</td>
<td>Min. battery output</td>
<td>Current in from generator</td>
</tr>
<tr>
<td>7 Power output limit</td>
<td>lower limit on battery voltage</td>
<td>Current to or from battery</td>
</tr>
<tr>
<td>8 Inverter efficiency (AC to DC)</td>
<td>Power corresponding to BV</td>
<td>Current to load</td>
</tr>
<tr>
<td>9 Current for grid charging of battery</td>
<td>High limit on BV</td>
<td>Dumped generated current</td>
</tr>
<tr>
<td>10 Upper limit on FSOC for grid charging</td>
<td>Power corresponding to high limit on BV</td>
<td>Current from grid</td>
</tr>
<tr>
<td>11</td>
<td>Start time for grid battery charging</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Stop time for grid battery charging</td>
<td></td>
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</table>

### Type 50: Flat Plate PV/T Collector

**TYPE 50a-Flat Plate Collector (Constant losses)**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Inlet fluid temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>2 Collector Area</td>
<td>Fluid mass flow rate</td>
<td>Fluid flowrate</td>
</tr>
<tr>
<td></td>
<td>Collector Efficiency Factor</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>4</td>
<td>Fluid thermal capacitance</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Collector plate absorptance</td>
<td>Cell efficiency</td>
</tr>
<tr>
<td>6</td>
<td>Collector loss coefficient</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Cover transmittance</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Temperature coefficient of solar cell efficiency</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Reference temperature for cell efficiency</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Packing factor</td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 50b- Flat Plate Collector (Losses=f(temperature, wind, geometry))**

<table>
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<tr>
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<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mode</td>
<td>Inlet fluid temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector Area</td>
<td>Fluid mass flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Collector Efficiency Factor</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Fluid thermal capacitance</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Collector plate absorptance</td>
<td>Windspeed</td>
</tr>
<tr>
<td>6</td>
<td>Number of glass covers</td>
<td>Cell Efficiency at reference conditions</td>
</tr>
<tr>
<td>7</td>
<td>Collector plate emittance</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Loss coefficient for bottom and edge losses</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Collector slope</td>
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</tr>
<tr>
<td>10</td>
<td>Transmittance absorptance product</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Temperature coefficient of PV cell efficiency</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Temperature for cell reference efficiency</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Packing factor</td>
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**TYPE 50c- Flat Plate Collector (Angular dependence of transmittance)**

<table>
<thead>
<tr>
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<th>OUTPUT</th>
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</thead>
<tbody>
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<td>Mode</td>
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<td>2</td>
<td>Collector Area</td>
<td>Fluid mass flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Collector Efficiency Factor</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Fluid thermal capacitance</td>
<td>Incident beam radiation</td>
</tr>
<tr>
<td>5</td>
<td>Collector plate absorptance</td>
<td>Incident diffuse radiation</td>
</tr>
<tr>
<td>6</td>
<td>Number of glass covers</td>
<td>Incidence angle of beam radiation</td>
</tr>
<tr>
<td>7</td>
<td>Collector loss coefficient</td>
<td>Cell efficiency</td>
</tr>
<tr>
<td>8</td>
<td>Extinction coefficient thickness product</td>
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</tr>
<tr>
<td>9</td>
<td>Temperature coefficient of PV cell efficiency</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Temperature for cell reference efficiency</td>
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</tr>
<tr>
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<td>Packing factor</td>
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</table>

**TYPE 50d- Flat Plate Collector (Losses=f(temperature, wind, geometry) and t=f(angle))**

<table>
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<th>OUTPUT</th>
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<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
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<tbody>
<tr>
<td>Mode</td>
<td>Inlet fluid temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>Collector Area</td>
<td>Fluid mass flow rate</td>
<td>Fluid flowrate</td>
</tr>
<tr>
<td>Collector Efficiency Factor</td>
<td>Ambient temperature</td>
<td>Rate of useful energy gain</td>
</tr>
<tr>
<td>Fluid thermal capacitance</td>
<td>Incident radiation</td>
<td>Collector loss coefficient</td>
</tr>
<tr>
<td>Collector plate absorptance</td>
<td>Incident diffuse radiation</td>
<td>transmittance-absorptance product</td>
</tr>
<tr>
<td>Number of glass covers</td>
<td>Incidence angle of beam radiation</td>
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</tr>
<tr>
<td>Collector plate emittance</td>
<td>Windspeed</td>
<td>Average cell temperature</td>
</tr>
<tr>
<td>Collector slope</td>
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<td></td>
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<tr>
<td>Extinction coefficient thickness product</td>
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</tr>
<tr>
<td>Temperature coefficient of PV cell efficiency</td>
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<tr>
<td>Temperature for cell reference efficiency</td>
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**TYPE 50e- Concentrating collectors (Constant Losses- No cell operating voltage)**

<table>
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<th>Input</th>
<th>Output</th>
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<td>Mode</td>
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<td>Outlet fluid temperature</td>
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<tr>
<td>Collector Area</td>
<td>Fluid mass flow rate</td>
<td>Fluid flowrate</td>
</tr>
<tr>
<td>Ratio of aperture to absorber area</td>
<td>Ambient temperature</td>
<td>Rate of useful energy gain</td>
</tr>
<tr>
<td>Fluid thermal capacitance</td>
<td>Incident radiation</td>
<td>Collector loss coefficient</td>
</tr>
<tr>
<td>Plate absorptance</td>
<td>transmittance-absorptance product</td>
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</tr>
<tr>
<td>fin efficiency area ratio</td>
<td>Electical power output</td>
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</tr>
<tr>
<td>Back loss coefficient for no-flow condition</td>
<td>Average cell temperature</td>
<td></td>
</tr>
<tr>
<td>Thermal conductance between cells and absorber</td>
<td>Apparent thermal loss coefficient</td>
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<tr>
<td>Heat transfer coefficient</td>
<td>Array voltage</td>
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<tr>
<td>Cover plate transmittance</td>
<td>Array current</td>
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<td>Front loss coefficient for cells</td>
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</tbody>
</table>

**TYPE 50f- Concentrating collectors (Top Loss-f(wind, T) No cell operating voltage)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Inlet fluid temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>Collector Area</td>
<td>Fluid mass flow rate</td>
<td>Fluid flowrate</td>
</tr>
<tr>
<td>Ratio of aperture to absorber area</td>
<td>Ambient temperature</td>
<td>Rate of useful energy gain</td>
</tr>
<tr>
<td>Fluid thermal capacitance</td>
<td>Incident radiation</td>
<td>Collector loss coefficient</td>
</tr>
<tr>
<td>Plate absorptance</td>
<td>Wind speed</td>
<td>transmittance-absorptance product</td>
</tr>
<tr>
<td>fin efficiency area ratio</td>
<td>Collector slope</td>
<td>Electrical power output</td>
</tr>
<tr>
<td>Back loss coefficient for no-flow condition</td>
<td>Average cell temperature</td>
<td></td>
</tr>
<tr>
<td>Thermal conductance between cells and absorber</td>
<td>Apparent thermal loss coefficient</td>
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</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
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</tr>
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<td>9 Heat transfer coefficient</td>
<td>Array voltage</td>
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</tr>
<tr>
<td>10 Cover plate transmittance</td>
<td>Array current</td>
<td></td>
</tr>
<tr>
<td>11 Number of glass covers</td>
<td>Cell temperature at collector inlet</td>
<td></td>
</tr>
<tr>
<td>12 Absorber plate emittance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Logical unit for SOLCEL data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 50g: Concentrating collectors (Constant Losses- Cell operating V is input)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Inlet fluid temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>2 Collector Area</td>
<td>Fluid mass flow rate</td>
<td>Fluid flow rate</td>
</tr>
<tr>
<td>3 Ratio of aperture to absorber area</td>
<td>Ambient temperature</td>
<td>Rate of useful energy gain</td>
</tr>
<tr>
<td>4 Fluid thermal capacitance</td>
<td>Incident radiation</td>
<td>Collector loss coefficient</td>
</tr>
<tr>
<td>5 Plate absorptance</td>
<td>Voltage applied to array</td>
<td>transmittance-absorptance product</td>
</tr>
<tr>
<td>6 Fin efficiency area ratio</td>
<td></td>
<td>Electrical power output</td>
</tr>
<tr>
<td>7 Back loss coefficient for no-flow condition</td>
<td></td>
<td>Average cell temperature</td>
</tr>
<tr>
<td>8 Thermal conductance between cells and absorber</td>
<td></td>
<td>Apparent thermal loss coefficient</td>
</tr>
<tr>
<td>9 Heat transfer coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Cover plate transmittance</td>
<td></td>
<td>Array current</td>
</tr>
<tr>
<td>11 Front loss coefficient for cells</td>
<td></td>
<td>Cell temperature at collector inlet</td>
</tr>
<tr>
<td>12 Logical unit for SOLCEL data file</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 50h: Concentrating collectors (Top Loss-f(wind, T) Cell operating voltage is input)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mode</td>
<td>Inlet fluid temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>2 Collector Area</td>
<td>Fluid mass flow rate</td>
<td>Fluid flow rate</td>
</tr>
<tr>
<td>3 Ratio of aperture to absorber area</td>
<td>Ambient temperature</td>
<td>Rate of useful energy gain</td>
</tr>
<tr>
<td>4 Fluid thermal capacitance</td>
<td>Incident radiation</td>
<td>Collector loss coefficient</td>
</tr>
<tr>
<td>5 Plate absorptance</td>
<td>Wind speed</td>
<td>transmittance-absorptance product</td>
</tr>
<tr>
<td>6 Fin efficiency area ratio</td>
<td>Collector slope</td>
<td>Electrical power output</td>
</tr>
<tr>
<td>7 Back loss coefficient for no-flow condition</td>
<td>Voltage applied to array</td>
<td>Average cell temperature</td>
</tr>
<tr>
<td>8 Thermal conductance between cells and absorber</td>
<td></td>
<td>Apparent thermal loss coefficient</td>
</tr>
<tr>
<td>9 Heat transfer coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Cover plate transmittance</td>
<td></td>
<td>Array current</td>
</tr>
<tr>
<td>11 Number of glass covers</td>
<td></td>
<td>Cell temperature at collector inlet</td>
</tr>
<tr>
<td>12 Absorber plate emittance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Logical unit for SOLCEL data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Type 60: Detailed Fluid Storage with Heaters**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 User-specified inlet positions</td>
<td>Flow rate at inlet 1</td>
<td>Flow rate at inlet 1</td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>--------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>2 Tank volume</td>
<td>Flow rate at outlet 1</td>
<td>Flowrate at outlet 1</td>
</tr>
<tr>
<td>3 Tank height</td>
<td>Used or not (flow inlet 2)</td>
<td>Used or not (inlet 2 flow)</td>
</tr>
<tr>
<td>4 Horizontal cylinder or Tank</td>
<td>Used or not (flow outlet 2)</td>
<td>Used or not (outlet 2 flow)</td>
</tr>
<tr>
<td>Perimeter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Height of flow inlet 1</td>
<td>Temperature at inlet 1</td>
<td>Temperature of outlet flow 1</td>
</tr>
<tr>
<td>6 Height of flow outlet 1</td>
<td>Used or not (temp inlet 2)</td>
<td>Used or not (temp flow 2)</td>
</tr>
<tr>
<td>7 Not used (inlet 2)</td>
<td>Environment temperature</td>
<td>Thermal losses</td>
</tr>
<tr>
<td>8 Not used (outlet 2)</td>
<td>Control signal for element 1</td>
<td>Energy supplied by inlet 1</td>
</tr>
<tr>
<td>9 Fluid specific heat</td>
<td>Control signal for element 2</td>
<td>Energy removed by outlet 1</td>
</tr>
<tr>
<td>10 Fluid density</td>
<td>Flow rate for heat exchanger</td>
<td>Used or not (energy inlet 2)</td>
</tr>
<tr>
<td>11 Tank loss coefficient</td>
<td>Inlet temperature for heat exchanger</td>
<td>Used or not (energy outlet 2)</td>
</tr>
<tr>
<td>12 Fluid thermal conductivity</td>
<td>Nusselt constant for heat exchanger</td>
<td>Auxiliary heating rate</td>
</tr>
<tr>
<td>13 Destratification conductivity</td>
<td>Nusselt exponent for heat exchanger</td>
<td>Element 1 power</td>
</tr>
<tr>
<td>14 Boiling temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Auxiliary heater mode</td>
<td>Losses to gas flue</td>
<td></td>
</tr>
<tr>
<td>16 Height of 1st aux. heater</td>
<td>Internal energy change</td>
<td></td>
</tr>
<tr>
<td>17 Height of 1st thermostat</td>
<td>Average tank temperature</td>
<td></td>
</tr>
<tr>
<td>18 Set point temperature for</td>
<td>Static pressure difference - tank</td>
<td></td>
</tr>
<tr>
<td>element 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Deadband for heating</td>
<td>Static pressure difference - outlet 1</td>
<td></td>
</tr>
<tr>
<td>element 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Maximum heating rate of</td>
<td>Used or not (pressure outlet 2)</td>
<td></td>
</tr>
<tr>
<td>element 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 Height of heating element 2</td>
<td>Used or not (pressure inlet 2)</td>
<td></td>
</tr>
<tr>
<td>22 Height of thermostat 2</td>
<td>Energy input from heat exchanger</td>
<td></td>
</tr>
<tr>
<td>23 Set point temperature for</td>
<td>Temperature of fluid exiting</td>
<td></td>
</tr>
<tr>
<td>element 2</td>
<td>heat exchanger</td>
<td></td>
</tr>
<tr>
<td>24 Deadband for heating</td>
<td>Tank temperature at outlet of</td>
<td></td>
</tr>
<tr>
<td>element 2</td>
<td>heat exchanger</td>
<td></td>
</tr>
<tr>
<td>25 Maximum heating rate of</td>
<td>LMTD of heat exchanger</td>
<td></td>
</tr>
<tr>
<td>element 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 Overall loss coefficient for</td>
<td>UA of heat exchanger</td>
<td></td>
</tr>
<tr>
<td>gas flue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 Flue temperature</td>
<td>Tank temperature - top</td>
<td></td>
</tr>
<tr>
<td>28 Fraction of critical timestep</td>
<td>Tank temperature - bottom</td>
<td></td>
</tr>
<tr>
<td>29 Gas heater?</td>
<td>Temperature of node 1+</td>
<td></td>
</tr>
<tr>
<td>30 Number of internal heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>exchangers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 Node heights supplied</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 Additional loss coeff's</td>
<td></td>
<td></td>
</tr>
<tr>
<td>supplied</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33 HX Fluid Indicator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34 Fraction of glycol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 Heat exchanger inside diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 Heat exchanger outside</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37 Heat exchanger fin diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38 Total surface area of heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>exchanger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39 Fins per meter for heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>exchanger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 Heat exchanger length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>41 Heat exchanger wall conductivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42 Heat exchanger material conductivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43 Height of heat exchanger inlet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44 Height of heat exchanger outlet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45 Height of node</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46 Additional loss coefficient for node</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 71: Evacuated Tube Solar Collector**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Efficiency mode</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Flow rate at test conditions</td>
<td>Incident diffuse radiation</td>
<td></td>
</tr>
<tr>
<td>6 Intercept efficiency</td>
<td>Solar incidence angle</td>
<td></td>
</tr>
<tr>
<td>7 Negative of first order efficiency coefficient</td>
<td>Solar zenith angle</td>
<td></td>
</tr>
<tr>
<td>8 Negative of second order efficiency coefficient</td>
<td>Solar azimuth angle</td>
<td></td>
</tr>
<tr>
<td>9 Logical unit of file containing biaxial IAM data</td>
<td>Collector slope</td>
<td></td>
</tr>
<tr>
<td>10 Number of longitudinal angles for which IAMs are provided</td>
<td>Collector azimuth</td>
<td></td>
</tr>
<tr>
<td>11 Number of transverse angles for which IAMs are provided</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 71: Unglazed transpired collector system (Flat plate, no convective losses at the top of the collector, no PV)**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Collector area</td>
<td>Month of the year</td>
<td>Plenum air temperature</td>
</tr>
<tr>
<td>2 Collector height</td>
<td>Hour of month</td>
<td>Collector outlet air temperature</td>
</tr>
<tr>
<td>3 Collector hole diameter</td>
<td>Radiation incident on the collector</td>
<td>Mixed air temperature</td>
</tr>
<tr>
<td>4 Collector hole pitch, distance between centers of holes</td>
<td>Ambient temperature</td>
<td>Supply air temperature</td>
</tr>
<tr>
<td>5 Collector emissivity</td>
<td>Sky temperature</td>
<td>Collector surface temperature</td>
</tr>
<tr>
<td>6 Collector absorptivity</td>
<td>Atmospheric pressure</td>
<td>Energy savings rate</td>
</tr>
<tr>
<td>7 Plenum depth</td>
<td>Internal gains due to people, equipment, etc.</td>
<td>Convection from collector</td>
</tr>
<tr>
<td>8 Emissivity of the wall behind the collector</td>
<td>Supply air flow rate from collector air-handling units</td>
<td>Convection from wall</td>
</tr>
<tr>
<td>9 R-value of the wall behind the collector</td>
<td>Minimum outdoor air flow rate through collector/summer bypass damper</td>
<td>Radiation from collector</td>
</tr>
<tr>
<td>10 Total UA-value of the</td>
<td>Supply air flow rate from no-</td>
<td>Radiation from wall</td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>building walls and roof</td>
<td>collector air-handling units</td>
<td></td>
</tr>
<tr>
<td>11 Room air temperature</td>
<td>Outdoor air flow rate through no collector</td>
<td>Conduction through wall</td>
</tr>
<tr>
<td>12 Ambient air temperature above which the summer bypass damper is opened</td>
<td></td>
<td>Reduced conduction through wall because of collector</td>
</tr>
<tr>
<td>13 Maximum auxiliary heat rate available</td>
<td></td>
<td>Absorbed energy rate</td>
</tr>
<tr>
<td>14 Night bypass</td>
<td></td>
<td>Auxiliary heating rate</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Outdoor air flow rate through collector/summer bypass damper</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Heat exchanger effectiveness of collector</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Solar efficiency of the collector</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Pressure drop across collector plate</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Bypass damper position = 0 if open =1 if closed</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Heat rate supplied by a traditional heating system</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>Additional fan power required</td>
</tr>
</tbody>
</table>

### Type 72: Performance Map Solar Collector

#### TYPE 72a-Performance Map Solar Collector (No incidence angle modification)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Efficiency mode</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Logical Unit</td>
<td>Windspeed</td>
<td></td>
</tr>
<tr>
<td>6 Number of DT/IT points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Number of radiation curves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Number of wind speed curves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Optical Mode 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 72b- Performance Map Solar Collector (2nd order incidence angle modifiers)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Efficiency mode</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Logical Unit</td>
<td>Windspeed</td>
<td></td>
</tr>
<tr>
<td>6 Number of DT/IT points</td>
<td>Total horizontal radiation</td>
<td></td>
</tr>
<tr>
<td>7 Number of radiation curves</td>
<td>Horizontal diffuse radiation</td>
<td></td>
</tr>
<tr>
<td>8 Number of wind speed curves</td>
<td>Ground reflectance</td>
<td></td>
</tr>
<tr>
<td>9 Optical mode 2</td>
<td>Incidence angle</td>
<td></td>
</tr>
<tr>
<td>10 1st-order IAM</td>
<td>Collector slope</td>
<td></td>
</tr>
<tr>
<td>11 2nd-order IAM</td>
<td></td>
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</tr>
</tbody>
</table>
### TYPE 72c- Performance Map Solar Collector (Modifiers=f(incidence angle))

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Efficiency mode</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Logical Unit</td>
<td>Windspeed</td>
<td></td>
</tr>
<tr>
<td>6 Number of DT/IT points</td>
<td>Total horizontal radiation</td>
<td></td>
</tr>
<tr>
<td>7 Number of radiation curves</td>
<td>Horizontal diffuse radiation</td>
<td></td>
</tr>
<tr>
<td>8 Number of wind speed curves</td>
<td>Ground reflectance</td>
<td></td>
</tr>
<tr>
<td>9 Optical mode 3</td>
<td>Incidence angle</td>
<td></td>
</tr>
<tr>
<td>10 Logical unit</td>
<td>Collector slope</td>
<td></td>
</tr>
<tr>
<td>11 No. of IAM's in file</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 72d- Performance Map Solar Collector (Cover and absorber properties)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Efficiency mode</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Logical Unit</td>
<td>Windspeed</td>
<td></td>
</tr>
<tr>
<td>6 Number of DT/IT points</td>
<td>Total horizontal radiation</td>
<td></td>
</tr>
<tr>
<td>7 Number of radiation curves</td>
<td>Horizontal diffuse radiation</td>
<td></td>
</tr>
<tr>
<td>8 Number of wind speed curves</td>
<td>Ground reflectance</td>
<td></td>
</tr>
<tr>
<td>9 Optical mode 4</td>
<td>Incidence angle</td>
<td></td>
</tr>
<tr>
<td>10 Plate absorptance</td>
<td>Collector slope</td>
<td></td>
</tr>
<tr>
<td>11 No. of identical covers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Index of refraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Extinction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 72e- Performance Map Solar Collector (Biaxial incidence angle modifiers)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Efficiency mode</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Logical Unit</td>
<td>Windspeed</td>
<td></td>
</tr>
<tr>
<td>6 Number of DT/IT points</td>
<td>Total horizontal radiation</td>
<td></td>
</tr>
<tr>
<td>7 Number of radiation curves</td>
<td>Horizontal diffuse radiation</td>
<td></td>
</tr>
<tr>
<td>8 Number of wind speed curves</td>
<td>Ground reflectance</td>
<td></td>
</tr>
<tr>
<td>9 Optical mode 5</td>
<td>Incidence angle</td>
<td></td>
</tr>
<tr>
<td>10 Logical unit</td>
<td>Collector slope</td>
<td></td>
</tr>
<tr>
<td>11 Number of values</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 73: Theoretical Flat Plate Solar Collector

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Number in series</td>
<td>Inlet temperature</td>
<td>Outlet temperature</td>
</tr>
<tr>
<td>2 Collector area</td>
<td>Inlet flowrate</td>
<td>Outlet flowrate</td>
</tr>
<tr>
<td>3 Fluid specific heat</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Collector fin efficiency factor</td>
<td>Incident radiation</td>
<td></td>
</tr>
<tr>
<td>5 Bottom, edge loss coefficient</td>
<td>Windspeed</td>
<td></td>
</tr>
</tbody>
</table>
### TYPE 74: Compound Parabolic Concentrating Collector

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number in series</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector area</td>
<td>Inlet flowrate</td>
</tr>
<tr>
<td>3</td>
<td>Fluid specific heat</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Collector fin efficiency factor</td>
<td>Incident radiation</td>
</tr>
<tr>
<td>5</td>
<td>Overall Loss Coefficient</td>
<td>Horizontal radiation</td>
</tr>
<tr>
<td>6</td>
<td>Wall reflectivity</td>
<td>Horizontal diffuse</td>
</tr>
<tr>
<td>7</td>
<td>Half-acceptance angle</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>8</td>
<td>Truncation ratio</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>9</td>
<td>Axis orientation</td>
<td>Zenith angle</td>
</tr>
<tr>
<td>10</td>
<td>Absorptance of absorber plate</td>
<td>Solar azimuth angle</td>
</tr>
<tr>
<td>11</td>
<td>Number of covers</td>
<td>Collector slope</td>
</tr>
<tr>
<td>12</td>
<td>Index of refraction of cover</td>
<td>Collector azimuth angle</td>
</tr>
<tr>
<td>13</td>
<td>Extinction coeff. thickness product</td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 94: Photovoltaic Panel

#### TYPE 94a- Photovoltaic Panel (Crystalline module)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Module short-circuit current at reference conditions</td>
<td>Total incident radiation</td>
</tr>
<tr>
<td>2</td>
<td>Module open-circuit voltage at reference conditions</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>3</td>
<td>Reference temperature</td>
<td>Load voltage</td>
</tr>
<tr>
<td>4</td>
<td>Reference insolation</td>
<td>Flag for convergence promotion</td>
</tr>
<tr>
<td>5</td>
<td>Module voltage at max power point and reference conditions</td>
<td>Array slope</td>
</tr>
<tr>
<td>6</td>
<td>Module current at max power point and reference conditions</td>
<td>Beam radiation</td>
</tr>
<tr>
<td>7</td>
<td>Temperature coefficient of Isc at (ref. cond.)</td>
<td>Diffuse radiation</td>
</tr>
<tr>
<td>8</td>
<td>Temperature coefficient of Voc (ref. cond.)</td>
<td>Incidence angle of beam radiation</td>
</tr>
<tr>
<td>9</td>
<td>Number of cells wired in series</td>
<td>Short circuit current</td>
</tr>
<tr>
<td>10</td>
<td>Number of modules in series</td>
<td>Array fill factor</td>
</tr>
<tr>
<td>11</td>
<td>Number of modules in parallel</td>
<td>Array temperature</td>
</tr>
<tr>
<td>12</td>
<td>Module temperature at</td>
<td></td>
</tr>
</tbody>
</table>
### PARAMETERS

<table>
<thead>
<tr>
<th>NOCT</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Ambient temperature at NOCT</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Insolation at NOCT</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Module area</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>$\tau \alpha$ product for normal incidence</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Semiconductor bandgap</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Slope of IV curve at $I_{sc}$</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Module series resistance</td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 94b- Photovoltaic Panel (Thin film module)**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Module short-circuit current at reference conditions</td>
<td>Total incident radiation</td>
</tr>
<tr>
<td>2</td>
<td>Module open-circuit voltage at reference conditions</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>3</td>
<td>Reference temperature</td>
<td>Load voltage</td>
</tr>
<tr>
<td>4</td>
<td>Reference insolation</td>
<td>Flag for convergence promotion</td>
</tr>
<tr>
<td>5</td>
<td>Module voltage at max power point and reference conditions</td>
<td>Array slope</td>
</tr>
<tr>
<td>6</td>
<td>Module current at max power point and reference conditions</td>
<td>Beam radiation</td>
</tr>
<tr>
<td>7</td>
<td>Temperature coefficient of $I_{sc}$ at (ref. cond.)</td>
<td>Diffuse radiation</td>
</tr>
<tr>
<td>8</td>
<td>Temperature coefficient of $V_{oc}$ (ref. cond.)</td>
<td>Incidence angle of beam radiation</td>
</tr>
<tr>
<td>9</td>
<td>Number of cells wired in series</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Number of modules in series</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Number of modules in parallel</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Module temperature at NOCT</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Ambient temperature at NOCT</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Insolation at NOCT</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Module area</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>$\tau \alpha$ product for normal incidence</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Semiconductor bandgap</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Slope of IV curve at $I_{sc}$</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Module series resistance</td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 186: Serpentine Collector**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>number of turns</td>
<td>temperature of fluid entering collector</td>
</tr>
<tr>
<td>2</td>
<td>inner tube diameter</td>
<td>mass flowrate of fluid entering collector</td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>3</td>
<td>outer tube diameter</td>
<td>ambient temperature of collector surroundings</td>
</tr>
<tr>
<td>4</td>
<td>plate thickness</td>
<td>Radiation incident on collector surface</td>
</tr>
<tr>
<td>5</td>
<td>length of each turn</td>
<td>wind speed</td>
</tr>
<tr>
<td>6</td>
<td>tube spacing</td>
<td>total radiation on horizontal surface</td>
</tr>
<tr>
<td>7</td>
<td>plate conductivity</td>
<td>diffuse radiation on horizontal surface</td>
</tr>
<tr>
<td>8</td>
<td>loss coefficient from back and edge of collector per unit aperture area</td>
<td>ground reflectance</td>
</tr>
<tr>
<td>9</td>
<td>absorber plate emittance</td>
<td>incidence angle of beam radiation</td>
</tr>
<tr>
<td>10</td>
<td>absorber plate absorptance</td>
<td>collector slope</td>
</tr>
<tr>
<td>11</td>
<td>number of glass covers</td>
<td>dynamic viscosity</td>
</tr>
<tr>
<td>12</td>
<td>refractive index of glass covers</td>
<td>specific heat of collector</td>
</tr>
<tr>
<td>13</td>
<td>product of extinction coefficient and thickness of cover plates</td>
<td>fluid thermal conductivity</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>fluid density</td>
</tr>
</tbody>
</table>

**TYPE 555- Unglazed air PV/T flat plate collector**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total collector area</td>
<td>Inlet temperature</td>
</tr>
<tr>
<td>2</td>
<td>Fluid specific heat</td>
<td>Inlet flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Reflectance</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Emissivity</td>
<td>Sky temperature</td>
</tr>
<tr>
<td>5</td>
<td>1st order IAM</td>
<td>Back-surface environment temperature</td>
</tr>
<tr>
<td>6</td>
<td>PV cell reference temperature</td>
<td>Incident solar radiation</td>
</tr>
<tr>
<td>7</td>
<td>PV cell reference radiation</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>8</td>
<td>PV efficiency at reference condition</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>9</td>
<td>Efficiency modifier-temperature</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>10</td>
<td>Efficiency modifier-radiation</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>11</td>
<td>Resistance of substrate material</td>
<td>Collector slope</td>
</tr>
<tr>
<td>12</td>
<td>Resistance of back material</td>
<td>Top loss convection coefficient</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Back loss coefficient</td>
</tr>
<tr>
<td>14</td>
<td>Fluid heat transfer coefficient</td>
<td>Fluid heat transfer</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Absorbed solar radiation</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Collector F</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Collector U_L</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>F_R\alpha_N</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>F_RU_L</td>
</tr>
</tbody>
</table>
### TYPE 56(Mode) – PVT Systems

**Type 560 - Unglazed PV/T collector with fluid stream passing through tubes bonded to an absorber plate located beneath the PV cells**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Length</td>
<td>Inlet temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>2 Width</td>
<td>Inlet flow rate</td>
<td>Flow rate at outlet</td>
</tr>
<tr>
<td>3 Absorber thickness</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Thermal conductivity of the absorber</td>
<td>Sky temperature</td>
<td>PV power</td>
</tr>
<tr>
<td>5 Number of tubes</td>
<td>Back-surface environment temperature</td>
<td>PV efficiency</td>
</tr>
<tr>
<td>6 Tube diameter</td>
<td>Incident solar radiation</td>
<td>Thermal efficiency</td>
</tr>
<tr>
<td>7 Bond width</td>
<td>Total horizontal radiation</td>
<td>Collector $F_R$</td>
</tr>
<tr>
<td>8 Bond thickness</td>
<td>Horizontal diffuse radiation</td>
<td>Plate (PV) temperature</td>
</tr>
<tr>
<td>9 Bond thermal conductivity</td>
<td>Ground reflectance</td>
<td>Mean fluid temperature</td>
</tr>
<tr>
<td>10 Resistance of substrate material</td>
<td>Incidence angle</td>
<td>Overall IAM</td>
</tr>
<tr>
<td>11 Resistance of back material</td>
<td>Collector slope</td>
<td>Collector top losses-convective</td>
</tr>
<tr>
<td>12 Fluid specific heat</td>
<td>Top loss convection coefficient</td>
<td>Collector top losses-radiative</td>
</tr>
<tr>
<td>13 Reflectance</td>
<td>Back loss coefficient</td>
<td>Back losses</td>
</tr>
<tr>
<td>14 Emissivity</td>
<td>Fluid heat transfer coefficient</td>
<td>Absorbed solar radiation</td>
</tr>
<tr>
<td>15 $1^{st}$ order IAM</td>
<td>Collector $U_I$</td>
<td></td>
</tr>
<tr>
<td>16 PV cell reference</td>
<td>$F_R\tau\alpha_N$</td>
<td></td>
</tr>
<tr>
<td>17 PV cell reference radiation</td>
<td>$F_RU_{IL}$</td>
<td></td>
</tr>
<tr>
<td>18 PV efficiency at reference condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Efficiency modifier-temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Efficiency modifier-radiation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 563- Unglazed PV/T collector with fluid stream passing through tubes bonded to an absorber plate located beneath the PV cells (considering conduction between the back of the collector and the roof)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Length</td>
<td>Inlet temperature</td>
<td>Outlet fluid temperature</td>
</tr>
<tr>
<td>2 Width</td>
<td>Inlet flow rate</td>
<td>Flow rate at outlet</td>
</tr>
<tr>
<td>3 Absorber thickness</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Thermal conductivity of the absorber</td>
<td>Sky temperature</td>
<td>PV power</td>
</tr>
<tr>
<td>5 Number of tubes</td>
<td>Back-surface temperature</td>
<td>PV efficiency</td>
</tr>
<tr>
<td>6 Tube diameter</td>
<td>Incident solar radiation</td>
<td>Thermal efficiency</td>
</tr>
<tr>
<td>7 Bond width</td>
<td>Total horizontal radiation</td>
<td>Collector $F_R$</td>
</tr>
<tr>
<td>8 Bond thickness</td>
<td>Horizontal diffuse radiation</td>
<td>Mean PV temperature</td>
</tr>
<tr>
<td>9 Bond thermal conductivity</td>
<td>Ground reflectance</td>
<td>Mean fluid temperature</td>
</tr>
<tr>
<td>10 Resistance of substrate material</td>
<td>Incidence angle</td>
<td>Overall IAM</td>
</tr>
<tr>
<td>11 Resistance of back material</td>
<td>Collector slope</td>
<td>Collector top losses-convective</td>
</tr>
<tr>
<td>12 U-value of roof material</td>
<td>Top loss convection coefficient</td>
<td>Collector top losses-radiative</td>
</tr>
<tr>
<td>13 Fluid specific heat</td>
<td>Fluid heat transfer coefficient</td>
<td>Back losses</td>
</tr>
<tr>
<td>14 Reflectance</td>
<td></td>
<td>Absorbed solar radiation</td>
</tr>
<tr>
<td>15 Emissivity</td>
<td></td>
<td>Collector $U_I$</td>
</tr>
<tr>
<td>16 $1^{st}$ order IAM</td>
<td>$F_R\tau\alpha_N$</td>
<td></td>
</tr>
<tr>
<td>17 PV cell reference</td>
<td>$F_RU_{IL}$</td>
<td></td>
</tr>
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</table>
### PARAMETERS

<table>
<thead>
<tr>
<th></th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>PV cell reference radiation</td>
<td>$Q_{\text{BASE}}$</td>
</tr>
<tr>
<td>19</td>
<td>PV efficiency at reference condition</td>
<td>$Q_{\text{FIN}}$</td>
</tr>
<tr>
<td>20</td>
<td>Efficiency modifier-temperature</td>
<td>$T_{\text{back}}$</td>
</tr>
<tr>
<td>21</td>
<td>Efficiency modifier-radiation</td>
<td></td>
</tr>
</tbody>
</table>

#### TYPE 566-Building integrated photovoltaic system (glazed, air)

<table>
<thead>
<tr>
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<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Collector length</td>
<td>Inlet air temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector width</td>
<td>Inlet air flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Collector emissivity</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Thermal conductivity of cover material</td>
<td>Sky temperature</td>
</tr>
<tr>
<td>5</td>
<td>Thickness of cover</td>
<td>Back-surface environment temperature</td>
</tr>
<tr>
<td>6</td>
<td>Resistance of substrate material</td>
<td>Back-surface radiant temperature</td>
</tr>
<tr>
<td>7</td>
<td>Emissivity – top surface of flow channel</td>
<td>Incident solar radiation</td>
</tr>
<tr>
<td>8</td>
<td>Emissivity – bottom surface of flow channel</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>9</td>
<td>Resistance of back material</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>10</td>
<td>Emissivity – back surface</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>11</td>
<td>Channel height</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>12</td>
<td>IAM mode</td>
<td>Collector slope</td>
</tr>
<tr>
<td>13</td>
<td>PV mode</td>
<td>Top loss convection coefficient</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Back loss convection coefficient</td>
</tr>
<tr>
<td>15</td>
<td>Atmospheric pressure</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Back losses - convective</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Back losses - radiative</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Absorbed solar radiation</td>
</tr>
</tbody>
</table>

If IAM Mode=1 (Nb of parameters=15)

<table>
<thead>
<tr>
<th></th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Transmittance-absorptance product at normal incidence</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1st order IAM</td>
<td></td>
</tr>
</tbody>
</table>

If IAM Mode=2 (Nb of parameters=16)

<table>
<thead>
<tr>
<th></th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Absorptance of PV surface</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Cover index of refraction</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Extinction coefficient</td>
<td></td>
</tr>
</tbody>
</table>

If PV Mode =1

<table>
<thead>
<tr>
<th></th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPAR+1</td>
<td>PV efficiency at reference condition</td>
<td></td>
</tr>
<tr>
<td>NPAR+2</td>
<td>PV cell reference temperature</td>
<td></td>
</tr>
<tr>
<td>NPAR+3</td>
<td>PV cell reference radiation</td>
<td></td>
</tr>
<tr>
<td>NPAR+4</td>
<td>Efficiency modifier-temperature</td>
<td></td>
</tr>
<tr>
<td>NPAR+5</td>
<td>Efficiency modifier-radiation</td>
<td></td>
</tr>
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</table>

If PV Mode=2

<table>
<thead>
<tr>
<th></th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPAR+1</td>
<td>Logical unit for data file</td>
<td></td>
</tr>
<tr>
<td>NPAR+2</td>
<td>Number of temperature</td>
<td></td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>NPAR+3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If PV Mode=3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>PV efficiency</td>
<td></td>
</tr>
</tbody>
</table>

**TYPE 567-Building integrated photovoltaic system (glazed, air) (No convective and radiative losses at the back of the collector)**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Collector length</td>
<td>Inlet air temperature</td>
</tr>
<tr>
<td>2</td>
<td>Collector width</td>
<td>Inlet air flow rate</td>
</tr>
<tr>
<td>3</td>
<td>Collector emissivity</td>
<td>Ambient temperature</td>
</tr>
<tr>
<td>4</td>
<td>Thermal conductivity of cover material</td>
<td>Sky temperature</td>
</tr>
<tr>
<td>5</td>
<td>Thickness of cover</td>
<td>Back-surface temperature</td>
</tr>
<tr>
<td>6</td>
<td>Resistance of substrate material</td>
<td>Incident solar radiation</td>
</tr>
<tr>
<td>7</td>
<td>Emissivity – top surface of flow channel</td>
<td>Total horizontal radiation</td>
</tr>
<tr>
<td>8</td>
<td>Emissivity – bottom surface of flow channel</td>
<td>Horizontal diffuse radiation</td>
</tr>
<tr>
<td>9</td>
<td>Resistance of back material</td>
<td>Ground reflectance</td>
</tr>
<tr>
<td>10</td>
<td>Channel height</td>
<td>Incidence angle</td>
</tr>
<tr>
<td>11</td>
<td>IAM mode</td>
<td>Collector slope</td>
</tr>
<tr>
<td>12</td>
<td>PV mode</td>
<td>Top loss convection coefficient</td>
</tr>
<tr>
<td>13</td>
<td>Atmospheric pressure</td>
<td>Overall IAM</td>
</tr>
<tr>
<td>14</td>
<td>Top losses – convective</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Top losses – radiative</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Back losses</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Absorbed solar radiation</td>
<td></td>
</tr>
</tbody>
</table>

If IAM Mode=1 (Nb of parameters=14)

| 13 | Transmittance-absorptance product at normal incidence |
| 14 | 1st order IAM |

If IAM Mode=2 (Nb of parameters=15)

| 13 | Absorptance of PV surface |
| 14 | Cover index of refraction |
| 15 | Extinction coefficient |

If PV Mode = 1

| NPAR+1 | PV efficiency at reference condition |
| NPAR+2 | PV cell reference temperature |
| NPAR+3 | PV cell reference radiation |
| NPAR+4 | Efficiency modifier-temperature |
| NPAR+5 | Efficiency modifier-radiation |

If PV Mode=2

| NPAR+1 | Logical unit for data file |
| NPAR+2 | Number of temperature points |
| NPAR+3 | Number of radiation points |

If PV Mode=3

| 16 | PV efficiency |
### TYPE 568 - Unglazed building integrated photovoltaic system (air) (No convective and radiative losses at the back of the collector)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Collector length</td>
<td>Inlet air temperature</td>
<td>Outlet air temperature</td>
</tr>
<tr>
<td>2 Collector width</td>
<td>Inlet air flow rate</td>
<td>Outlet air flow rate</td>
</tr>
<tr>
<td>3 Absorptance of PV surface</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Emissivity of PV surface</td>
<td>Sky temperature</td>
<td>Thermal efficiency</td>
</tr>
<tr>
<td>5 Resistance of substrate material</td>
<td>Back-surface temperature</td>
<td>Electrical power</td>
</tr>
<tr>
<td>6 Emissivity – top surface of flow channel</td>
<td>Incident solar radiation</td>
<td>Electrical efficiency</td>
</tr>
<tr>
<td>7 Emissivity – bottom surface of flow channel</td>
<td>Collector slope</td>
<td>PV cell temperature</td>
</tr>
<tr>
<td>8 Resistance of back material</td>
<td>Top loss convection coefficient</td>
<td>Upper air channel surface temperature</td>
</tr>
<tr>
<td>9 Channel height</td>
<td>Atmospheric pressure</td>
<td>Lower air channel surface temperature</td>
</tr>
<tr>
<td>10 PV mode</td>
<td></td>
<td>Back surface temperature</td>
</tr>
<tr>
<td>11 Back surface temperature</td>
<td>Top losses – convective</td>
<td></td>
</tr>
<tr>
<td>12 Top losses – radiative</td>
<td>Back losses</td>
<td></td>
</tr>
<tr>
<td>13 Absorbed solar radiation</td>
<td>Logical unit for data file</td>
<td></td>
</tr>
<tr>
<td>14 Efficiency modifier temperature</td>
<td>Number of temperature points</td>
<td></td>
</tr>
<tr>
<td>15 Efficiency modifier radiation</td>
<td>Number of radiation points</td>
<td></td>
</tr>
<tr>
<td>16 If PV Mode=1, 11</td>
<td><strong>PV efficiency at reference condition</strong></td>
<td></td>
</tr>
<tr>
<td>17 PV cell reference temperature</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>18 PV cell reference radiation</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>19 Efficiency modifier temperature</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>20 Efficiency modifier radiation</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>21 If PV Mode=2, 11</td>
<td>Logical unit for data file</td>
<td></td>
</tr>
<tr>
<td>22 Number of temperature points</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>23 Number of radiation points</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>24 If PV Mode=3, 10</td>
<td>PV efficiency</td>
<td></td>
</tr>
</tbody>
</table>

### TYPE 569 - Unglazed building integrated photovoltaic system (air) (Convective and radiative losses at the back of the collector)

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>INPUT</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Collector length</td>
<td>Inlet air temperature</td>
<td>Outlet air temperature</td>
</tr>
<tr>
<td>2 Collector width</td>
<td>Inlet air flow rate</td>
<td>Outlet air flow rate</td>
</tr>
<tr>
<td>3 Absorptance of PV surface</td>
<td>Ambient temperature</td>
<td>Useful energy gain</td>
</tr>
<tr>
<td>4 Emissivity of PV surface</td>
<td>Sky temperature</td>
<td>Thermal efficiency</td>
</tr>
<tr>
<td>5 Resistance of substrate material</td>
<td>Back-surface environment temperature</td>
<td>Electrical power</td>
</tr>
<tr>
<td>6 Emissivity – top surface of flow channel</td>
<td>Back-surface radiant temperature</td>
<td>Electrical efficiency</td>
</tr>
<tr>
<td>7 Emissivity – bottom surface of flow channel</td>
<td>Incident solar radiation</td>
<td>PV cell temperature</td>
</tr>
<tr>
<td>8 Resistance of back material</td>
<td>Collector slope</td>
<td>Upper air channel surface temperature</td>
</tr>
<tr>
<td>9 Emissivity – back surface</td>
<td>Top loss convection</td>
<td>Mean fluid temperature</td>
</tr>
<tr>
<td>PARAMETERS</td>
<td>INPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Channel height</td>
<td>Back loss convection coefficient</td>
<td>Lower air channel surface temperature</td>
</tr>
<tr>
<td>PV mode</td>
<td>Atmospheric pressure</td>
<td>Back surface temperature</td>
</tr>
<tr>
<td></td>
<td>Top losses – convective</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Top losses – radiative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back losses - convective</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back losses - radiative</td>
<td></td>
</tr>
<tr>
<td>Absorbed solar radiation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If PV Mode=1

| 12  | PV efficiency at reference condition |                     |
| 13  | PV cell reference temperature |                     |
| 14  | PV cell reference radiation |                     |
| 15  | Efficiency modifier-temperature |                     |
| 16  | Efficiency modifier-radiation |                     |

If PV Mode=2

| 12  | Logical unit for data file |                     |
| 13  | Number of temperature points |                     |
| 14  | Number of radiation points |                     |

If PV Mode=3

| 10  | PV efficiency |                     |