THERMISOL V4.9

User Guide

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AIRBUS DEFENCE AND SPACE

*To the attention of*systema.business@airbus.com

Z.I. du Palays

31 rue des Cosmonautes

31402 TOULOUSE CEDEX 4

FRANCE

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Temperature Solver Overview

The temperature solver of THERMISOL is the main module of this package. It is based on the ESATAN language and may be linked with THERMICA through the skeleton module of THERMISOL. In the nodal method, also called "lumped parameter method", the problem is described by a set of nodes, each with:

- **thermal properties (temperature, thermal capacitance, area, etc.)**
- **exchanges with the other nodes**
- **internal and external powers.**

Refer to Chapter "Nodal Description Module" in the THERMICA User Manual to get a detailed explanation of the nodal method.

The network properties are as follows:

Network properties	Symbol	Type	Entity type
Node status *'D' for diffusive* *'B' for boundary* *'X' for inactive*	NS	Character	Nodal
Model status *'A' for active* *'X' for inactive*	MS	Character	Nodal
Temperature	T	Real	Nodal
Capacitance	C	Real	Nodal
Area	A	Real	Nodal
Epsilon	EPS	Real	Nodal
Epsilon with wavelength dependency	EPSWLB	Real Array	Nodal
Alpha	ALP	Real	Nodal
Solar flux	QS	Real	Nodal
Planet IR fluxes	QE	Real	Nodal
Planet albedo fluxes	QA	Real	Nodal
Internal fluxes	QI	Real	Nodal

Residual fluxes	QR	Real	Nodal
Conductive coupling	GL	Real	Coupling
Radiative coupling	GR	Real	Coupling
Radiative coupling with wavelength dependency	GRWLB	Real Array	Coupling
One-way linear coupling	GF	Real	Coupling
Conductive coupling status	GLS	Character	Coupling
Radiative coupling status	GRS	Character	Coupling
Radiative coupling with wavelength dependency status	GRWLBS	Character	Coupling
One-way linear coupling status	GFS	Character	Coupling

	*Only T, C, QS, QE, QA, QI and QR are used in the solution routines (energy balance for each node).*
	*Wavelength dependent properties are available only if it has been enable in the $ENTITIES block by declaring a wavelength band discretization.*

Each datum can be time-dependent or can depend on any criterion defined by the user. Here, the objective is to compute the node temperatures for steady-state or time-dependent cases. In this approach, the thermal problem is a mere numerical integration. Broadly defined, THERMISOL is a numerical integrator dealing with steady-state and transient thermal equations.

Temperature computation methods

Some classical numerical methods are provided (including Newton Raphson and Crank Nicholson schemes), improved by an automatic management of time steps and the management of different time steps within a thermal network. Some other functions are also available to compute heat transfers or to make dynamic changes during the solution.

	*These routines have been intensively validated and used on real projects such as:MEX, Pleiades, Ariane5, Arabsat, VEX, Melfi, Intelsat10, Immarsat4, HotBird8, Metop, Amazonas, Anik, W3A, ISS, Gaia, LHP, etc.*

Input data

The selected language format is based on the European standard language ESATAN. Since its creation, the THERMISOL language, as the ESATAN one, has evolved so they may have differences. However, even if new specific THERMISOL features have been developed, the compatibility with ESATAN input files is largely maintained.

The input data are described in text file(s), with a Fortran-like syntax to define the nodal network and a Fortran-like language to program any arbitrary behavior (time-dependent phenomena, temperature-dependent data, etc). The input data are translated into a Fortran code, compiled and linked with a computation library; this produces an executable program which generates the solution. The selection of a Fortran-like language provides a very flexible approach and is a solution to complex problems. The Fortran used is called "Mortran" and provides simple access to nodal entities, couplings or any THERMISOL specific datum.

Free and Fixed formats

In order to avoid Fortran compilation problem, the THERMISOL pre-processor automatically shift the beginning of the lines to the 6th column (except in the cases described bellow) and cut them so they don't exceed 72 columns.

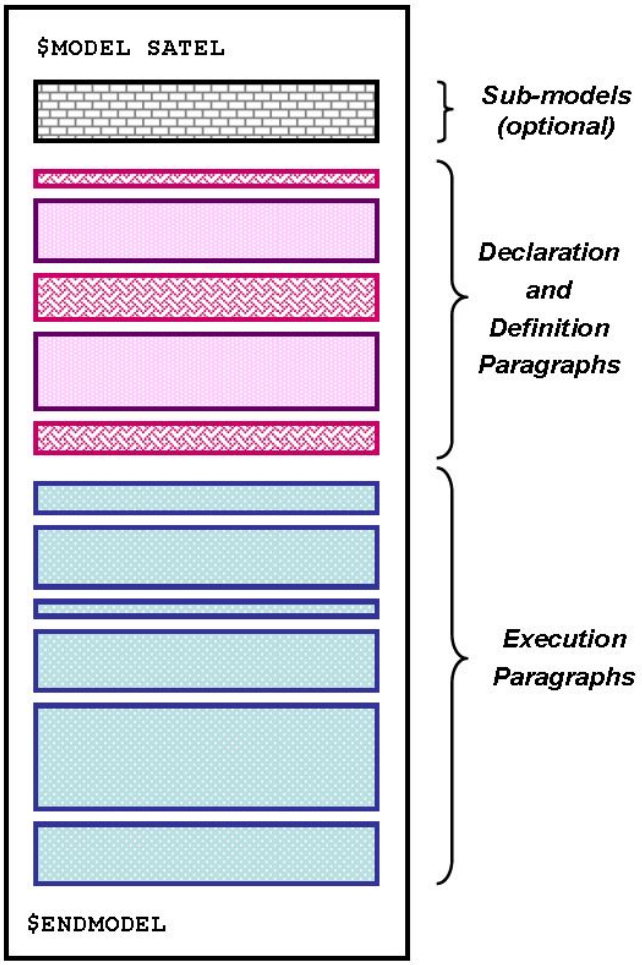
	**The automatic column positioning requires the following restrictions on the FORTRAN language:**

- ***The character used to specify that a line is the continuity of the previous one is ' & '*** *(it is automatically positioned to the 5th column, as specified by the FORTRAN)*
- ***A line beginning with a series of number written in the first columns is interpreted as a tag and is not modified by the preprocessor*** |

However, for compatibility with older version of THERMISOL or with ESATAN files which are in fixed format (meaning that all lines shall start at column 6 and a first character on column 5 indicates a line continuation), THERMISOL also checks the meaning of a line when it starts with a character on the 5th column. If the instruction does not make sense, it is automatically interpreted as the continuation of the previous line. This behavior is called the MIXED format (meaning that it handles both free and fixed formats). In rare cases, the mixed interpretation of the format may fail to interpret correctly a fixed format input file, when this one is written with lines starting on the 5th column that could be interpret as they are (this is not very smart to write this kind of input files, but it is allowed by the FORTRAN77 fixed format). For this reason, it is possible to modify the interpretation of the input file by specifying that a strict fixed format shall be interpreted only. The option for free format only is also available even if it may not be required.
The file format may be specified at the beginning of the file with the instruction: !FORMAT = MIXED *(default value)* !FORMAT = FIXED !FORMAT = FREE

Structure of the input file

A model is a combination of different blocks of instructions. Some are used to define the thermal network, others to declare constants, variables or arrays, and finally some are executive instructions called at different moments of the solver execution.



Schematic view of a THERMISOL Input File

Input and Output Files

Usually, the whole process is launched with only one parameter: the name of the main input file. Then, several output files are produced. In most cases, their name is based on the name of the input file, with a "zz_" prefix and a suffix which depends on the file type. The "zz_prefix" is a way to gather all these files in a file explorer. The following tables present the different INPUT and OUTPUT files:

INPUT Files

Name	File function	Description
filename	Main input file	This is the only input the user has to specify to the solver.
(any name)	Other input files	Any arbitrary number of files, used by means of $INCLUDE instructions, or by sub-modeling techniques.

OUTPUT Files

Name	File function	Description
zz_filename_for.f *zz_filename_com.fi*	Fortran code file	These files contain the output of the Fortran-like language translation
zz_filename_for.o	Compiled code	Compiled code
zz_filename_prg_SYS	Solution program	(SYS refers to the operating system)
Filename.log	Log file	This file relates the main events occurring during the translation task
filename.out	Text file	This file contains the standard output text generated during the calculation
filename.csv	Spreadsheet run report	Spreadsheet run report
Modelname.temp.h5	V4 result file	New result file in the HDF5 format
(any name)	Other specific output files	Other specific output files, depending on the solver subroutines called during the calculation
(any name)	User specific output files	User specific output files, which may be created by user subroutines

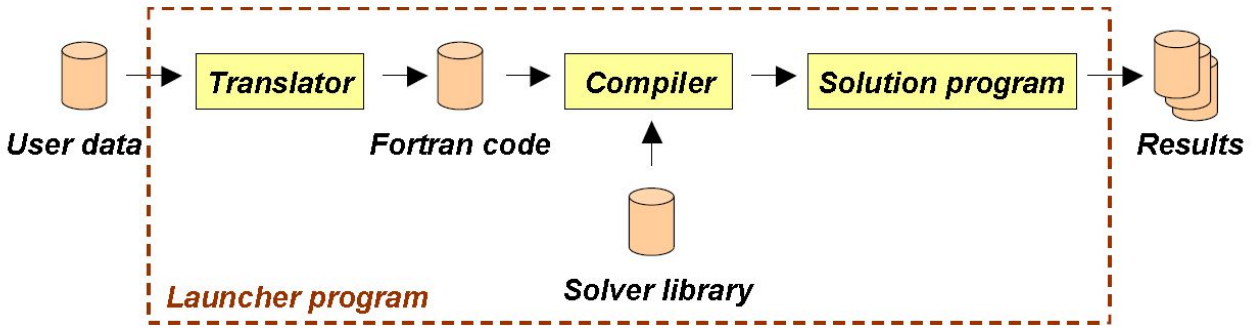
The results are returned into an ASCII output file. The output data consist of node temperatures, and optionally all the properties required for a complete analysis of heat transfers. The user can access several output subroutines (including spreadsheet formats) and can also define his own data storage. A comma-separated values file is also updated during the execution of the resolution program so the user can check the convergence of the model. There are no results but the convergence criteria only. More complete results are exported to a hdf5 binary file for post-processing use. This file is compatible with SYSTEMA (for graphic post-processing) and with POSTHER (for tabulated post-processing analysis) or BPLOT (for curve creations).

Software Architecture

The temperature solver includes three main parts:

- ***A translator*** *, which loads the input data and produces the corresponding Fortran code.*
- ***A computation library*** *, which provides a set of solution routines and several other services.*
- ***A Fortran compiler*** *, which produces the solution program. In general, any compiler can be used (depending on the computer configuration). However, the use of a generic compiler (GNU) is recommended.*

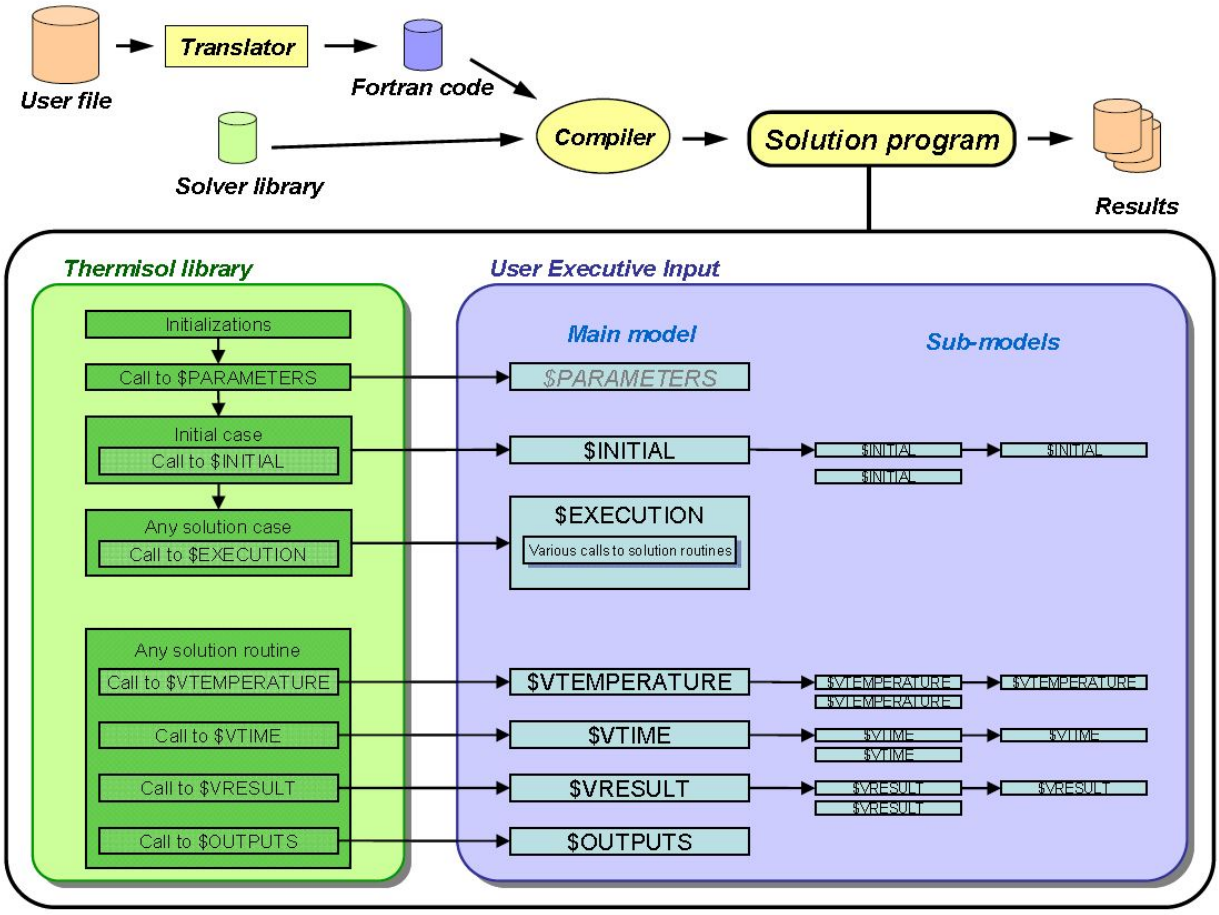
The user input file is translated into a Fortran code, which is compiled and linked with the solver library; this produces a solution program which generates the required results. A launcher program automatically performs the chaining of all these tasks.



Mimic diagram of the software architecture

Temperature Calculation

The solution program is a merging of the Fortran code written by the user and the solver computation library. After some initialization operations, the program makes a call to the user subroutine $INITIAL from which some specific initializations can be performed, and then calls the user subroutine $EXECUTION from which solution routines are called, typically for a steady-state calculation followed by one or more transient calculations. Each solution routine will make some regular calls to the user subroutines $VTEMPERATURE, $VTIME, $VRESULT and $OUTPUTS, at moments which depend on the solution routine (at each time step, at each iteration, …). For the user, its is an effective way to program specific events: temperature-dependent data (such as conductive couplings or capacitance), time-dependent data (such as activation/deactivation of heaters or dissipation of equipment), through a Fortran-like language which enables any arbitrary complex programming. These calls concern the main model as well as sub-models. Sub-model routines are called before their father, so that the father model's instructions will take precedence.

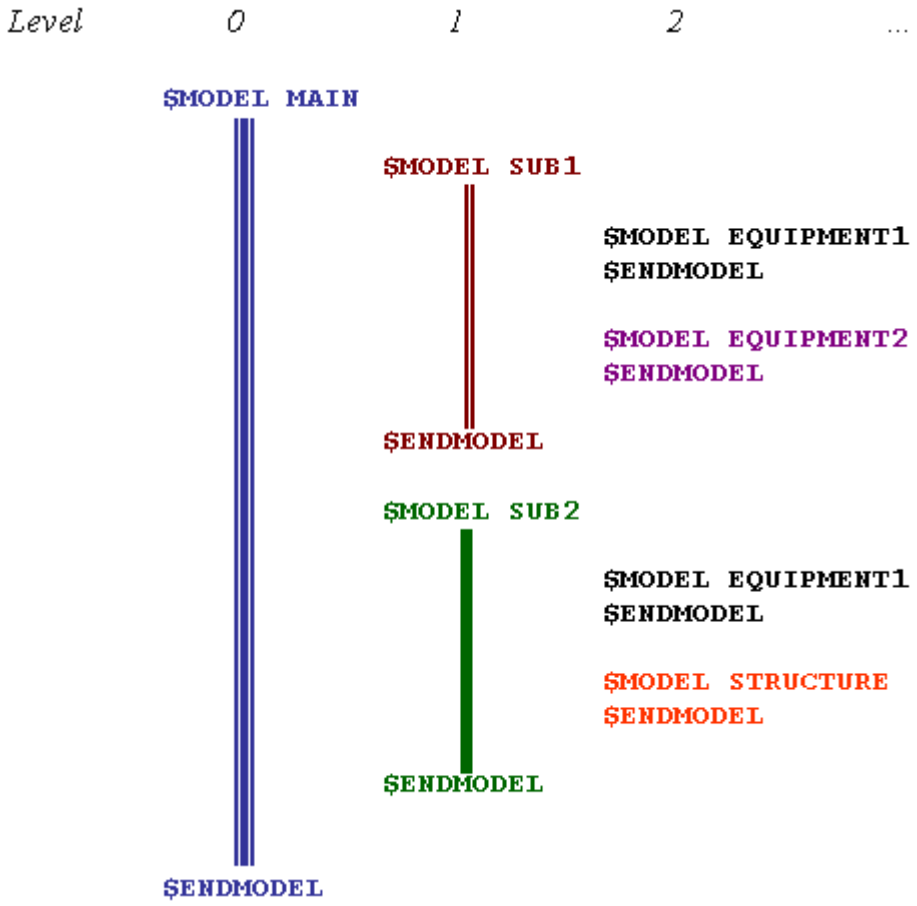


User Input Data Structure

Model definition

The user input is text data, contained in one or several files. The language is based on the ESATAN standard language.
Comments can be inserted anywhere in the file. The sharp symbol (#) indicates the beginning of a comment, until the end of line.
A thermal model can be a standalone model or can include sub-models, whose declarations have to be placed before the definition paragraphs of the father model. There is no restriction on the number of submodels and a submodel can be used many times as long as the path are unique.

	*There are different ways to insert a Submodel. Those are described in section 1.5*



Example of submodel hierarchy

The information of one model is divided into several paragraphs. There are classified in two families:

- ***Declaration and definition paragraphs*** *Definition of nodes and couplings, Declaration of variables, arrays and tables. Each paragraph uses a Fortran-like syntax to declare the data. The number of columns is not limited. The original specification for those paragraphs is that all instruction lines end by a semi-coma character. There is no line continuity character. Since v4.5.0, the semi-coma at the end of instructions is not required but may be advised for compatibility with the ESATAN language.*
- ***Execution paragraphs*** *Definition of user subroutines and solver special subroutines.They use the Mortran language, a thermal-oriented Fortran-like language, based on Fortran 77. The format is free meaning that there is no limitation on the number of columns or on the column index to start a command. The continuation character is advised to be the '&' character. However for compatibility with the older fixed format, any meaningless character placed on the 5^{th} column will also be interpreted as a continuation character. This behavior is called mixed format.*

A thermal model begins with a $MODEL instruction and ends with a $ENDMODEL instruction. The definition paragraphs and execution paragraphs are inserted between them.
All these data are not necessarily stored in the same input file; it is possible to organize data in several files. The $INCLUDE instruction enables users to include the contents of an external file into a DCK file by copying and inserting the entire file at the position of the instruction. This feature is particularly useful for incorporating submodels into a main model. The $INCLUDE instruction can be expanded using the -i option (or "expand $INCLUDE" task in the GUI). However, expansion is not required to execute the calculation.

Declaration paragraphs

Any type of declarative paragraph may appear several times in one model and in any order. They can also be mixed with the definition paragraphs.

$LOCALS

This paragraph contains the declaration of constants available in all the definition paragraphs.
The constants can be: integers, reals or strings. They cannot be modified at any time.
The type may be defined using the sub-blocks $REAL, $INTEGER and $CHARACTER (like in example 1) or using individual type definitions (like in example 2).

Example of a $LOCALS paragraph (1/2)

```
$LOCALS
$REAL
RL111 =4.4;#conductivity longi nida 20*0.3
RL112 =1.5;#conductivity trans nida 20*0.3
RL115 =20.6E-3;#thickness nida 20*0.3
RL119 = (32.*900.*20.E-3) + (2700.*900.*2.*0.3E-3);
$INTEGER
NB_CELLS = 4;
```

Example of a $LOCALS paragraph (2/2)

```
$LOCALS
REAL* RL111 = 4.4;
INTEGER* NB_CELLS = 4;
INTEGER IFLAG = 3;
CHARACTER* CASE1 = 'NOMINAL_HOT';
```

The local constants may be defined equal to expressions involving literal values and local constants of the same type, provided that the latter have already been defined themselves.
They may be referenced in the declaration, the definition and the execution blocks. They must be defined before they can be referenced.
Local constants must be preferred to variables one if they are not updated during the simulation. It will save memory but also the use of those constants will not generate unnecessary GENMOR code (see paragraph on the GENMOR code).

	*Since Version 4.2.3, the local variables are accessible in all the code.* *Real values are stored in double precision.*
	*Since Version 4.5.0, the type definition may be written without the '*' symbol.*

$VARIABLES

This paragraph contains the declaration of variables (integers, reals, strings) available in all the execution paragraphs. These variables can be used in Mortran expressions (i.e. definition of node temperature, etc.).

	*This paragraph was previously known as $CONSTANTS but due to its definition its name has changed since version 4.3.0. However the old name $CONSTANTS is still admitted for compatibility with previous THERMISOL models and with ESATAN ones.*

The variables can be: integers, reals or strings and are declared like in the $LOCALS paragraph.
Unlike the variables declared in $LOCALS, they can be modified by the user.
If a constant is used to define another in the $VARIABLES block or in any other declarative block, then changing the value of the first during a solution run will automatically cause that of the second to be recalculated accordingly. The second one will be referenced by a specific code used to make such automated updates, the GENMOR subroutine.
The GENMOR subroutine is generated in the same order than the instructions of the input file. It is called at each end of $VTEMPERATURE call (which is the one the most often called). If an update is explicitly necessary, then the user can make a call to that routine anywhere in its code.

Example of a $VARIABLES paragraph

```
$VARIABLES
# Characteristics of air at 20° C
REAL*rho_air= 1.2;# kh/m3
REAL*Cp_air= 1.2;# kh/m3

# Characteristics of MLI
$REAL
cond_MLI=0.019;# W/m2K
rad_MLI=0.014;# m2/m2
MCp_MLI=235.0;# J/K/m2 per face
Rho_MLI=0.26;# kg/m2
Cp_MLI=1090.0;# J/kg/K
EFF_MLI=1.D0;
$INTEGER
NCAS=99;
ISLARG=0;
NEWDEPRESSU=1;
$CHARACTER
CASE='NOMINAL_COLD;
HEATER_PZ='OFF';
```

$CONTROL

This paragraph contains the definition of variables used by the solution routines during computation. The control variables have specific names. User's variables cannot be defined here. Their values can be changed during the solution (i.e. in the $INITIAL, $VTEMPERATURE, $VTIME, $VRESULT or $EXECUTION subroutines).

General Controls

Name	*Type*	*Typical value*	*Description*
TABS	R	273.15	Conversion from Kelvin to the user unit (generally degree Celsius) • If TABS = 0, the unit of input and output files is Kelvin

Name	*Type*	*Typical value*	*Description*
			• If TABS = 273.15, the unit of input and output files is degree Celsius
DAMPT	R	1.0	Damping factor for iterative resolution. If this value is equal to 1, it is automatically updated during computation
STEFAN	R	5.67e-8	Stefan-Boltzman constant.
CSV_FREQ	I	2	The csv control file will be written at this frequency
H5_FREQ	I	2	Results will be stored every *n* iteration
H5_RES0	S	NS,MS,C, A,ALP,EPS, GL, GR, GF	Results stored upon initialization. See the Posther paragraph for more details
H5_RES1	S	T,QS,QA, QE,QI,QR	Results stored with the H5_FREQ frequency

Steady-State Controls

Name	*Type*	*Typical value*	*Description*
RELXCA	R	1e-4	Maximum permissible temperature change between two iterations
INBALA	R	1e-3	Maximum allowable absolute flux exchange between diffusive nodes and boundary nodes
INBALR	R	1e-6	Maximum allowable relative flux exchange between diffusive nodes and boundary nodes
INBALT	R	1e-3	Maximum allowable sum of all diffusive nodes flux budget (is equivalent to INBALA but takes into account all unbalanced fluxes between diffusive nodes)
NLOOP	I	10000	Maximum number of iterations allowed
RELXCC	R		Maximum temperature change obtained between two iterations
NRLXCC	I		Node on which the maximum temperature change has been obtained

Name	*Type*	*Typical value*	*Description*
ENBALA	R		Absolute flux exchange between diffusive nodes and boundary nodes
ENBALR	R		Relative flux exchange between diffusive nodes and boundary nodes
ENBALT	R		Sum of all diffusive nodes flux budgets
LOOPCT	I		Number of iterations performed

Transient Controls

Name	*Type*	*Typical value*	*Description*
TIMEO	R	0	Simulation start time
TIMEND	R	>0	Simulation end time
DTIMEI	R	>0	Time step specified
OUTINT	R	>0	Time interval to execute a $OUTPUT paragraph. DTIMEU can be automatically adjusted to reflect an OUTINT time.
RELXCA	R	1e-4	Maximum allowed temperature change between two iterations, for a given time step
INBALT	R	1e-3	Maximum allowable sum of all diffusive nodes flux budget (including capacitive fluxes)
NLOOP		10000	Maximum allowed number of iterations, for a given time step
ERRMIN	R	1e-4	Minimum error allowed on temperature solution when using auto-adaptative algorithms
ERRMAX	R	1e-4	Maximum error (see errmin)
SRATIO	R	0.9	Necessary ratio of nodes respecting the maximum error in order to create a sub time step
TIMEM	R		Current time
TIMEO	R		Initial time of current time-step

Name	*Type*	*Typical value*	*Description*
TIMEN	R		End time of current time-step
DTIMEU	R		Time step used by the solution routine
RELXCC	R		Maximum temperature change obtained between two iterations, for a given time step
NRLXCC	I		Node on which the maximum temperature change has been obtained (internal numbering)
ENBALT	R		Sum of all diffusive nodes flux budgets
LOOPCT	I		Number of iterations performed

Example of a $CONTROL paragraph

```
$CONTROL
STEFAN=5.6686E-08;
RELXCA=0.0001;
NLOOP=5000;
TIMEND=24.*3600.0;
TIMEO=.0000E+00
DTIMEI=60.D0
OUTINT=1200.D0
```

$ARRAYS

This paragraph contains the definition of user arrays. These arrays can be of 1 or 2 dimensions. They can be integers, reals or strings. They are declared with the same convention than for the $LOCALS and $VARIABLES.
An array is declared with its dimensions into parenthesis. If 2 dimensions are declared the first dimension is the number of columns and the second is the number of lines. The last dimension may left to '*' in order to adjust automatically the size of the array according to the declared elements (number of lines in case of a 2D array).
For 2D arrays if the number of declared elements is not a multiple of the number of columns an error will be raised and the program will stop. Otherwise, if the second dimension is set to '*', it will be automatically adjusted to the number of lines. If the second dimension is valued and is greater than the number of declared elements, it will also be adjusted to the number of declared lines. In case the specified dimension is smaller than the number of declared elements an error will be raised and the program will stop.
In case an array shall be declared with more elements than specified in the instantiation of the array, a parameter called SIZE may be used to force the size of the array. For 2D array, the specified size shall be a multiple of the number of column otherwise an error is raised. If the declared size is greater than the number of declared elements, the array will keep the original size given and will not be automatically adjusted. On the other hand if the declared size is too small an error is raised.
It exist two instantiation modes for setting the array values:

- ***Values separated by commas***
- ***A repeated value defined by using the @ character (number of iteration @ value to be affected)***

These two modes can be used together (see the above examples).
For the repetition mode, it is possible to use the '*' character meaning the total number of array element. Of course using *@value is meaningless in the case of a variable length array.

Example of a $ARRAYS paragraph (1/2)

```
 $ARRAYS
 $REAL
 QI_ES (2,4) =
 0.,28.60,
 1708.,28.60,
 1708.5,20.00,
 99999.,20.00,
 REAL*HconvPret (2,*) =
 .0,1.5,
 3.0,1.5,
 10.0,80.0,
 20.0,200.0,
 30.0,350.0,
 80.0,140.0,
 100.0,50.0,
 120.0,0.0,
 99999.0,0.0;
 REAL*CF_ES_(4)=8.79, 11.3, 13.5, 13.9;
 REAL*CF_EPED(*)=48.9, 62.8, 74.8, 76.9;
```

Example of a $ARRAYS paragraph (2/2)

```
 $ARRAYS
 $REAL
 NN (99999)=99999@0;
 REAL*MeanQR(99)=1.0, 2.0, 96@0.0D0, 1.0;
 CHARACTER*LineName(99)=*@'Initial name';
```

Since version 4.3.2, $LOCALS references can be used in addition to explicit values. $VARIABLES (or $CONSTANTS) references are however not allowed (no GENMOR code created for $ARRAYS definitions).
In some cases, it may be required to instantiate some elements of an array from the definition block so it may be used in other following declaration or definition blocks.
To set a value at a specific location of an array, the command SET can be used:

Example of an $ARRAYS setting and usage

```
 $ARRAYS
# Definition of panel elements existence (default value is exist)
 INTEGER FillPanel(8,6)= *@1;
# Define holes in panel
 SET FillPanel(3,2) = 0;
 SET FillPanel(5,2) = 0;
 $NODES
 DO I=1,8
   DO J=1,6
     IF (FillPanel(I,J).EQ.1) THEN
       INUM = I*1000+J
       D:INUM = 'Panel Node';
```

```
      ENDIF
    ENDDO
  ENDDO
```

$TABLES

This paragraph contains the definition of user tables. Tables are similar to arrays but are defined in a spreadsheet-like syntax. They contain real values only.
As for $ARRAYS element, since version 4.3.2, $LOCALS references can be used in addition to explicit values. $VARIABLES (or $CONSTANTS) references are however not allowed (no GENMOR code created for $ARRAYS definitions).

Because of a special storage, tables can be used only through solver interpolation routines.

2D Tables

Those tables can be considered as a function v = f(x,y), where x and y are independent variables.
The syntax of a 2D table is:
TAB(X,Y)
X = x1, … , xn,
Y= y1, v11, … , vn1,
…
Y= ym, v1m, … , vnm;
A table can be defined with both classical (example 1) and transposed (example 2) definitions.

Example of a 2D $TABLES paragraph (1/2)

```
$TABLES
TAB1 (TI, TE)
TE = 20.0, 50.0,70.0,
TI= 100.0,120.0,150.0,170.0,
TI= 200.0,220.0,250.0,270.0,
TI= 300.0,320.0,350.0,370.0;
```

Example of a 2D $TABLES paragraph (transposed table) – (2/2)

```
$TABLES
TAB2 (TI, TE)
TI =100.0,200.0,300.0,
TE= 20.0,120.0,220.0,320.0,
TE= 50.0,150.0,250.0,20.0,
TE= 70.0,320.0,350.0,370.0;
```

In spite of this transposition, the tables TAB1 and TAB2 defined in these 2 examples produce the same table in memory.

3D Tables

Those tables can be interpreted as a function v = f(x,y,z), where x, y and z are independent variables.
Those tables have been newly implemented in version 4.4.0 for some specific cases and for compatibility with ESATAN models which allow those definitions. However if the complete ESATAN definition handles many ways to specify those tables, only the most understandable and the most used ones have been implemented (the others may leading to unclear interpretations by the user).
The following definitions are supported, with all the possible permutations of the X, Y and Z specifications:

- Definition 1: Customized Table

This definition allows the specification of a customized table in the sense that it does not define a 3D matrix but values for given triplets (x,y,z) not necessary aligned in all dimensions. The syntax is the following:
TAB(X,Y,Z)
X = x1,Y = y1,z1, v1, … , zk, vk,
…
Y = ym,z1, v1, … , zk', vk',
…
X = xn, Y = y1,z1, v1, … , zk", vk",
…
Y = ym',z1, v1, … , zk"', vk"';

- Definition 2: Condensed Table

In this definition, 2 dimensions are constant vectors and the values of the other one are not necessary the same for all pairs of the 2 first dimensions.
TAB(X,Y,Z)
Z = z1, … , zk,
X = x1, Y = y1,v111, … , v11k,
…
Y = ym, v1m1, … , v1mk,
…
X = xn, Y = y1,vn11, … , vn1k,
…
Y = ym', vnm'1, … , vnm'k;
In this example, the values of y may be different depending on the specific occurrence of x but the order of x, y and z may be also be switched.

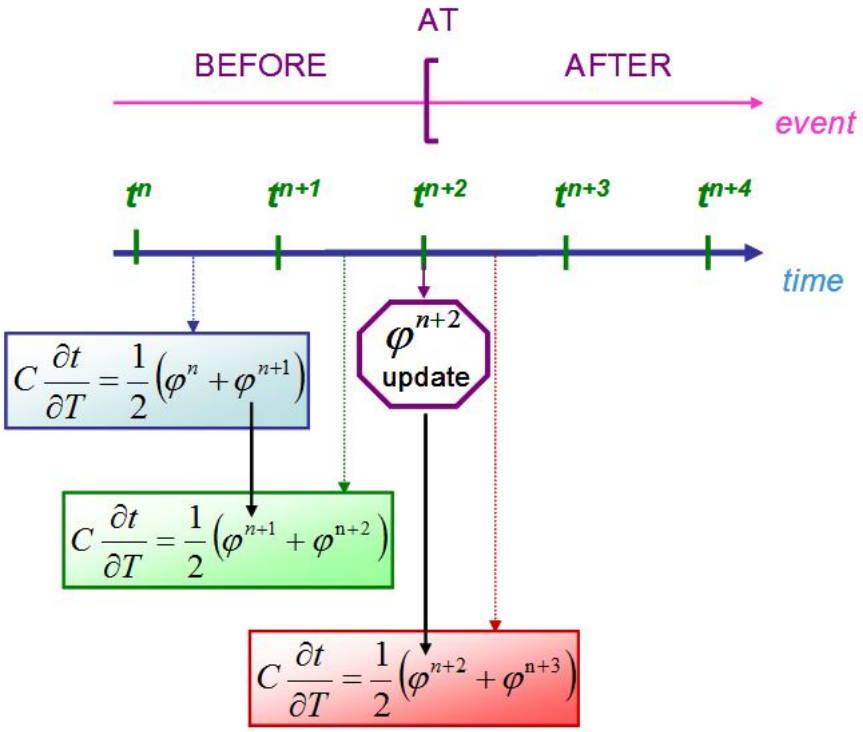
- **NOT SUPPORTED**: Expended 3D matrix

This definition allows the specification of a full 3D matrix, meaning that values are given for triplets (x,y,z) where x, y and z are constant vectors. The syntax is the following:
TAB(X,Y,Z)
X = x1, … , xn
Y = y1, … , ym
Z= z1, v111, v211, … , v121, …, vnm1
… Z= zk, v11k, v21k, … , v12k, …, vnmk

$EVENTS

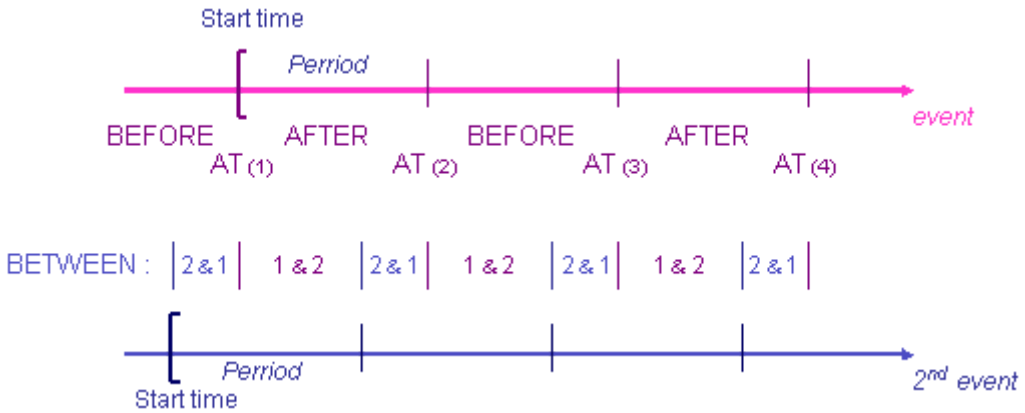
An event defines a time where the user either wants to call the output block or to update the thermal model. The first category of event is declared by "$OUTPUT" events and the second one by "$TIMESTEP" events.
Any event forces the end of transient analysis time-step to coincide with the event time. In the case of an output event the $OUTPUTS block is called at that specific time.
In the case of a time-step event, the transient analysis knows that there may be a discontinuity in the model or in its environment and it updates the flux at that time so the final flux of the time-step just before the event and the initial flux of the next one are not identical but take into account the discontinuity. The next figure shows the relationships between the computed fluxes at the different times involved by the solution routine. This scheme is respected independently from the use of the time-step event in executive blocks (call to BEFORE, AFTER, AT or BETWEEN test

cases).



Crank-Nicholson scheme using time-step events

Events define a "BEFORE", an "AT" and an "AFTER as shown in the previous figure.
Both time step and output events can be periodic. Periodic events allow an event to repeat at regular intervals.
A periodic event also has a definition for the "BEFORE", "AT" and "AFTER" states as shown in the next figure. The notion of "BETWEEN" between two periodic events is also represented (concerns only periodic element with the same period)



Periodic event states

The declaration of events is made through the $EVENTS block. It is possible to give literal values, local constants, variables or expressions using literal values, local constants and variables.
For more convenience, the periods can be declared in a preliminary "$PERIOD" block bellow the "$EVENTS" one. Those are considered as real local values.

Example of an $EVENTS block

```
$EVENTS
$PERIOD # Those are a real local constants
ORBITAL_PERIOD = 5250.4;
P_EQUIP1 = ORBITAL_PERIOD / 20;
$TIMESTEP
My_event = 123.45; # A time-step event
New_event = My_event + 300; # Another time event
SWITCH_EQUIP1 = 32.0 [P_EQUIP1]; # A periodic time-step event
SWITCH_EQUIP2 = 41.0 [P_EQUIP1]; # A periodic time-step event
$OUTPUT
Out_event = 680.0; # A output event
Periodic_out = 500.0 [500.0];
```

	*The OUTINT control parameter already defines a periodic output event. It is considered to be the standard periodic ouput (i.e. it is not necessary to redefine that event in this block)*

Definition paragraphs

Those paragraphs describe the network configuration, i.e. the nodes and the couplings.
The symbols related to the defined network are called "Mortran symbols" (node numbers, temperatures, fluxes, areas…, couplings).
The Mortran syntax is described in the "execution paragraphs" section. It is however possible to use Mortran expressions to affect a nodal property or a coupling.

	*Any network data (nodal entity or coupling) defined with formulas or Mortran expressions will be automatically added to the GENMOR subroutine.*

$NODES

This paragraph contains the declaration of thermal nodes, defined by a node number and initial properties. The syntax is as follows:
Type number = 'name', properties_list;
where:

- **type = D (diffusive), B (boundary) or X (inactive)**
- **number = a positive integer (up to 9 digits)**
- **'name' = a string, with single quotes**
- **properties_list = initial values of node properties (temperature, capacitance, etc.), separated by commas.**

Mortran expressions are available and are applied automatically during the $VTEMPERATURE routine via the GENMOR code (see the MORTRAN language section).
A boundary node is used to represent a mathematical boundary to the problem, the temperature being prescribed by the user as a fixed value, or one varying with respect to time, or possibly some other quantity. Boundary node temperatures are not changed by the solution.
A diffusive node is one whose temperature will be calculated during solution.
Inactive nodes are ignored by solution routines, but may be re-activated at any point during the solution by library functions. Similarly, "active" nodes (i.e. diffusion or boundary) may be made inactive during solution.
Nodes are defined by the appropriate type symbol (D, B or X), followed by a user-chosen reference integer. This may be either a literal value or a local index. The index can have any name but shall not conflict with any other local

constant declared in the model. Fortran loops FOR can also be used to implicitly declare nodes.
Expressions are not allowed in a node declaration since it might conflict with a supernode definition.

	*Supernodes are described in section dealing with the submodels.*

Since 4.9.4P2 version, Thermisol now automatically truncates labels that exceed 64 characters. this prevents possible silent errors or memory overflows caused by excessively long labels. By default, truncation is enabled, but users can override this behavior by setting a specific environment variable "THERMISOL_TRUNC_LABELS".

Value	Associated option
0	Will truncate the end of labels (default)
1	Will remove all spaces in labels but will not truncate, so label can still exceed the 64 limit and an error message will be displayed
2	Will remove all spaces in labels and truncate the end if needed
3	Will keep only the 64 last caracters of the label = will truncate the begin of labels
4	Will not truncate and an error will be displayed for each label exceeding 64 caracters

The default properties of a THERMISOL node are:

- **T** for the temperature
- **C** for the capacitance
- **QS** for the absorbed solar flux
- **QA** for the absorbed albedo flux
- **QE** for the absorbed IR planet flux
- **QI** for the internal dissipation
- **QR** for the residual flux

The following properties are also default properties but are not directly used by THERMISOL:

- **A** for the radiative area
- **ALP** for the thermo-optical coefficient alpha
- **EPS** for the thermo-optical coefficient epsilon
- **EPSWLB** for wavelength dependent epsilon

In the Mortran code it is also possible to call the following properties:

- **NS** for the node status
- **L** for the node label

The nodes can be declared with many syntax possibilities. Here are some examples that demonstrate them.

Example of a $NODES paragraph (1/6)

```
$NODES
D115 ='<6,5,7,1> Strap / Rectang0',
T =.000E+00,
C =1.0000E+01,
A =3.3480E-02,
ALP =.300, EPS =.030;
D4142 = 'Mur-Z/-X', T = 0.0D0;
X12028 = 'LIQUID MMH SIDE', T = 20.00D0;
B 9999 = 'space node', T =-269.0D0;
```

Example of a $NODES paragraph using loops (ESATAN-like syntax) (2/6)

```
$NODES
FOR INODE = 1 TO 6 DO
M1 = INODE + 770;
M2 = INODE + 760;
D M1 = 'MEMBRANE 1', T = 27.5, C = 8.43E-01*517.0, A = 8.43E-01;
D:M2 = 'MEMBRANE 2', T = 27.5, C = 9.529E-01*517,0, A = 9.529E-01;
END DO
```

Example of a $NODES paragraph using loops (FORTRAN-like syntax) (3/6)

```
$NODES
DO INODE = 1, 6
M1 = INODE + 770;
M2 = INODE + 760;
D M1 = 'MEMBRANE 1', T = 27.5, C = 8.43E-01*517.0, A = 8.43E-01;
D:M2 = 'MEMBRANE 2', T = 27.5, C = 9.529E-01*517,0, A = 9.529E-01;
END DO
```

Since version 4.3.2, a FORTRAN-like syntax has also been added for the loop declarations in order to have more consistency with the FORTRAN/MORTRAN syntax used in the executive blocks.

Example of a $NODES paragraph using pre-defined numbers (4/6)

```
$LOCALS
$INTEGER
PZ = 101 ;
MZ = 201 ;
PY = 301 ;
MY = 401 ;
$NODES
D PZ = 'Equipment +Z, T = 0.0, C = 18000.0;
D:MZ = 'Equipment -Z', T = 0.0, C = 4500.0;
D:PY = 'Equipment +Y', T = 0.0, C = 27000.0;
D:MY = 'Equipment -Y', T = 0.0, C = 32000.0;
```

Example of a $NODES paragraph using variables and Mortran syntax (5/6)

```
$NODES
D12004 = 'CYL INT.SUP', T = 40.5,
C = 159.4D-9 *ROPTRH * NTRP1(T12004,CPPTRH,1);
```

Example of a $NODES paragraph using wavelength dependencies (6/6)

```
$NODES
D115 ='Wavelength dependent structure', T= 0.0, C= 2500.0,
EPS = EPSWLBEF(), EPSWLB= [0.9, 0.8, 0.7, 0.83, 0.85],
ALP = 0.35 ;
```

The EPSWLB vector has to be valued using square parenthesis beacause this property is already in a list of properties separated by commas. There shall be exactly NWLBANDS declared values.

The function EPSWLBEF() may be used in order to assign to the standard EPS parameter the effective epsilon of the node according to its wavelength definition (EPSWLB) and to its temperature.

	*Since version 4.5.0, it is important to notice that a node declaration using a symbol has to be mandatory written with two dots or with at least a blank* DSYMBOL *is no longer accepted because of a possible confusion with a symbol starting with a D character* D:SYMBOL *or* D SYMBOL *are accepted*

$ENTITIES

The "Entities" block can be used to declare new nodal entities (interger, real or character – i.e. string of 24 characters) that will be attached to the nodes in addition to the ones already known.
The entities are attached to the nodes of the model or sub-model on which it has been declared. This property ensures that a stand alone model on which new nodal entities have been declared would not affect the nodal properties of an existing model that would be its son or its father. If a nodal entity is request in different model, the $ENTITIES block should be present in each one of them.

	**The $ENTITIES block should be placed before the $NODES block.** **The "Entities" block replaces the obsolete USRNOD.DAT file.**

Example of a $ENTITIES paragraph

```
$ENTITIES
REAL ON_DISSIP;
REAL OFF_DISSIP;
CHARACTER STATE
```

The new entities can be directly specified in the $NODES block like in the following example or can be used in any Mortran expression like the original nodal entities.

	*User nodal entities can also be called in output routines like PRNDTB to write their values in the text output file*

Example of a $NODES paragraph with user nodal entities

```
$NODES
D:PZ = 'Equipment +Z', T=0.0, C=18000.0, ON_DISSIP=120, OFF_DISSIP=30,
STATE='ON';
D:MZ = 'Equipment -Z', T=0.0, C=4500.0, ON_DISSIP=70, OFF_DISSIP=0,
```

```
STATE='ON';
D:PY = 'Equipment +Y', T=0.0, C=27000.0, ON_DISSIP=150, OFF_DISSIP=50,
STATE='ON';
D:MY = 'Equipment -Y', T=0.0, C=32000.0, ON_DISSIP=120, OFF_DISSIP=10,
STATE='OFF';
```

When a wavelength discretization is required for modelling the thermal behavior of non-grey bodies, the definition of the wavelength bands shall be placed in the $ENTITIES block. It will then enable the nodal property EPSWLB and the coupling GRWLB in the current model. Any node with an EPSWLB or any GRWLB coupling declared in this model will refer to this wavelength discretization.
The declaration of a wavelength discretization is done as in the following example:

Example of a wavelength discretization declaration

```
$ENTITIES
WLBANDS (NWLBANDS=6) 0, 0.5, 2.0, 5.0, 10.0, 20.0, 1000.0;
```

WLBANDS is a real vector defining the wavelength bounds. If the number of wavelength bands is NWLBANDS, the vector WLBANDS shall be declared with exactly NWLBANDS+1 values. The unit of wavelength is micro-meter. The adequate extreme values of this vector are 0 to a sufficiently large value, typically 1000, so the integration of the fractional blackbody emissive power is equal to 1 over the total wavelength interval.

Note: If the model includes sub-models, an $ENTITIES block with a definition of the wavelength bands is also required in each sub-models.

$EDGES

This paragraph contains the declaration of the edges used for the conduction computation. In previous versions edges where considered as standard nodes but their specific meaning has lead to split their definitions. This especially ensures that they are properly handled by the user and the software. The connectivity between the nodes and their edges is also known thanks to its specific declaration so the conductive heat transfer between shapes may be known through the standard FLUXL, FLUXT, FLUXGL etc… even if the shapes are not directly connected but through the edges.
The declaration of edges is made as follow:
E = connectivity list, A=value;
where:

- **Connectivity list = node reference |E edge reference relative to the node**
- **A means the area of the edge (thickness times length)** that may be used for further contact resistance declarations.

The declaration of one edge is made by connecting the node edges together. Indeed a free border will reference only one node edge and an edge with contacts will reference several node edges.
A node edge, i.e. an edge referenced by its node belonging, shall appear only once in the $EDGES section otherwise THERMISOL will raise an error. The identification of an edge relatively to a node may be any number not necessarily sequential (but THERMICA creates the edge database using sequential numbers).

	*You may refer to the Conduction chapter of the THERMICA User's Manual for more details on the edge creation..*

The properties of a THERMISOL edge are:

- **T** for the temperature. This property is however read-only.
- **A** for the area (length times thickness), in case a contact resistance is applied to that edge

There is no capacitance or power on edges.
The edges can be declared with many syntax possibilities. Here are some examples that demonstrate them.

Example of a $EDGES paragraph (1/2)

```
$EDGES
E = 100|E1, A=0.0024;
E = 100|E2, 200|E3;
E = 200|E4, 150|E2, A=0.0015 ;
```

Example of a $EDGES paragraph using loops (FORTRAN-like syntax) (2/2)

```
$EDGES
DO INODE = 1, 6
M1 = INODE + 770;
M2 = INODE + 760;
E= M1|E2, M2|E3;
END DO
```

$CONDUCTORS

This paragraph contains the declaration of couplings between nodes. Linear conductive couplings (GL), linear one-way couplings (GF), non-linear radiative couplings (GR) and wavelength dependent non-linear radiative coupling (GRWLB) are available.
Couplings can be declared between nodes of the current model or with nodes of any sub-model by indicating the path of the sub-model from the current one.
It is also possible to define several couplings between the same nodes and at any model level. They can then be accessed via a third index giving the position of the coupling in the model structure. If no coupling index is specified when referencing a coupling, it is assume to be the first one.
As for the nodes, the couplings can be declared using loops and local index. The local index name is not restricted to the ESATAN syntax KL*n* but can be any name of 16 characters. The index can also be combined with mathematical formulae eventually involving other local constants.
The syntax is as follows:
type (n1, n2) = expression;
where:

- **type = GL, GR, GF, GV or GRWLB.**
- **n1, n2 = node numbers, with eventual model references and/or mathematical expression using local index and local constants.**
- **expression = a value or an expression.Mortran expressions are available and are applied automatically during the $VTEMPERATURE routine through the GENMOR code.**

Example of a $CONDUCTORS paragraph (1/4)

```
$CONDUCTORS
# S/C Conductive Couplings
GL (16350, 16355) =0.9;
GL (16360, 4116) =0.067;
GL (33333, 33332) =200.*0.017*0.001/(0.0624/2.+0.12865/2.);
# Radiation links
GR (5210, 5213) =0.035566; # Lower box, electronics to housing
GR (5210, 5211) =0.004321; # Lower box, base to housing
```

Example of a $CONDUCTORS paragraph using a loop declaration (2/4)

```
FOR KL1 = 100 TO 110 DO
  GL(KL1, SUB1:(KL1+900)) = 0,082;
END DO
```

Example of a $CONDUCTORS paragraph using the Mortran syntax (3/4)

```
GL (15101, 15151) = A15101*INTRP1 (T15101+T15151)/2.0,SUB1,1)/6.32D-03;
GL (15102, 15152) = A15102*INTRP1 (T15102+T15152)/2.0,SUB1,1)/6.32D-03;
GL (15103, 15153) = A15103*INTRP1 (T15103+T15153)/2.0,SUB1,1)/6.32D-03;
```

⚠	**The expression on the right side of the equal sign must not exceed 1020 characters (Mortran string caption limit)**

Example of a $CONDUCTORS paragraph using wavelength dependencies (4/4)

$CONDUCTORS
GRWLB (16350, 16355) =0.8, 0.7, 0.72, 0.75, 0.68, 0.65;

A wavelength dependent radiative coupling GRWLB is a vector of radiative couplings for each wavelength band. It shall be declared with exactly NWLBANDS values.

Execution paragraphs

Generalities

The user can control the solution using some specific blocks that are executed during the execution. The language used in those blocks is called Mortran which is derived from the Fortran language and has specific syntax related to the thermal model. It is so possible to access all the data of the model by use of their name, i.e. any declared local constant, variable, array or table, any coupling or node property.
The execution blocks are the following:

- EXECUTION
- INITIAL
- OUTPUTS

Complete mode:
- VTEMPERATURE
- VTIME
- VRESULT

or Standard mode:
- VARIABLES1
- VARIABLES2

In addition to those paragraphs, the user can define its own subroutines and functions. Those can then be called from any of the previous blocks.

- SUBROUTINES

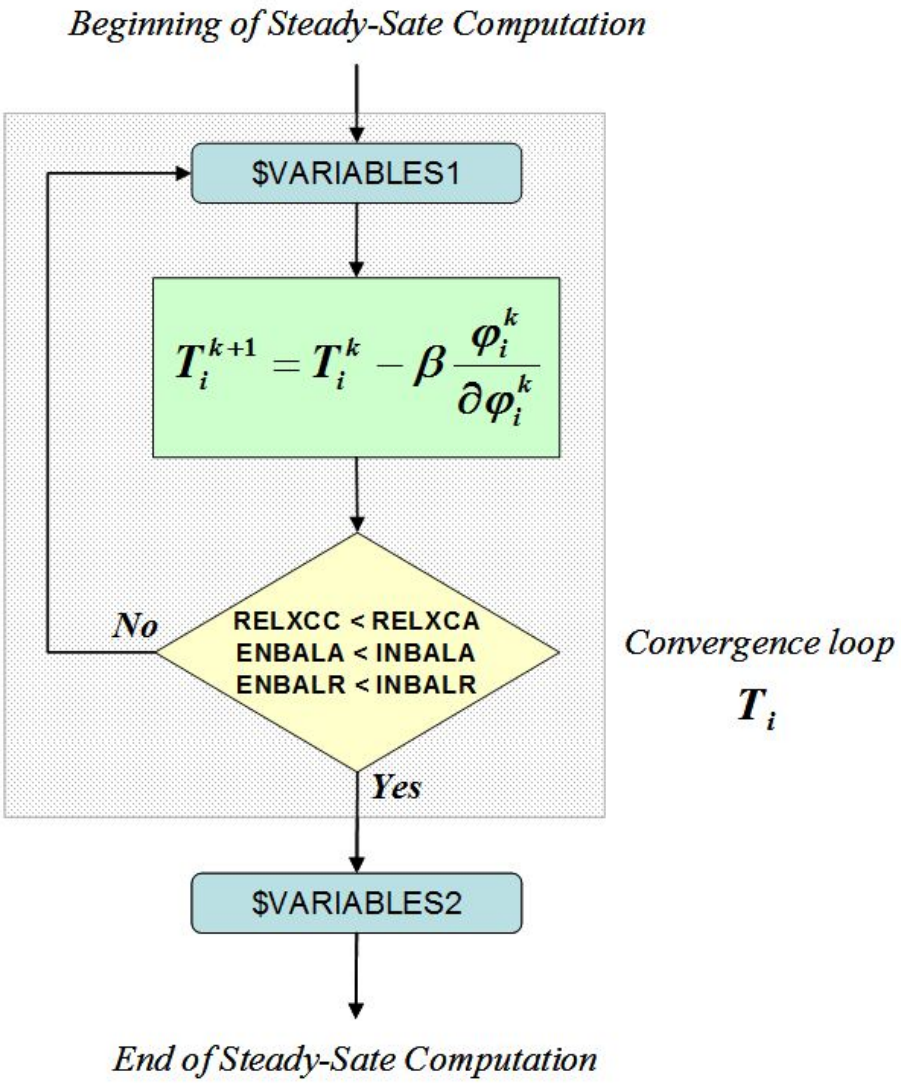
All the data of Thermisol are stored in double precision. The pre-processor translate any single precision real value to avoid problems during the solution. It is however recommended that the user checks that no confusion between integer and double precision can be made.
The blocks used to update the data during the solution computation are of 2 kinds:

1. ***Standard mode*** *($VARIABLES1 / $VARIABLES2)*

2. ***Complete mode*** *($VTEMPERATURE / VTIME / $VRESULT)*

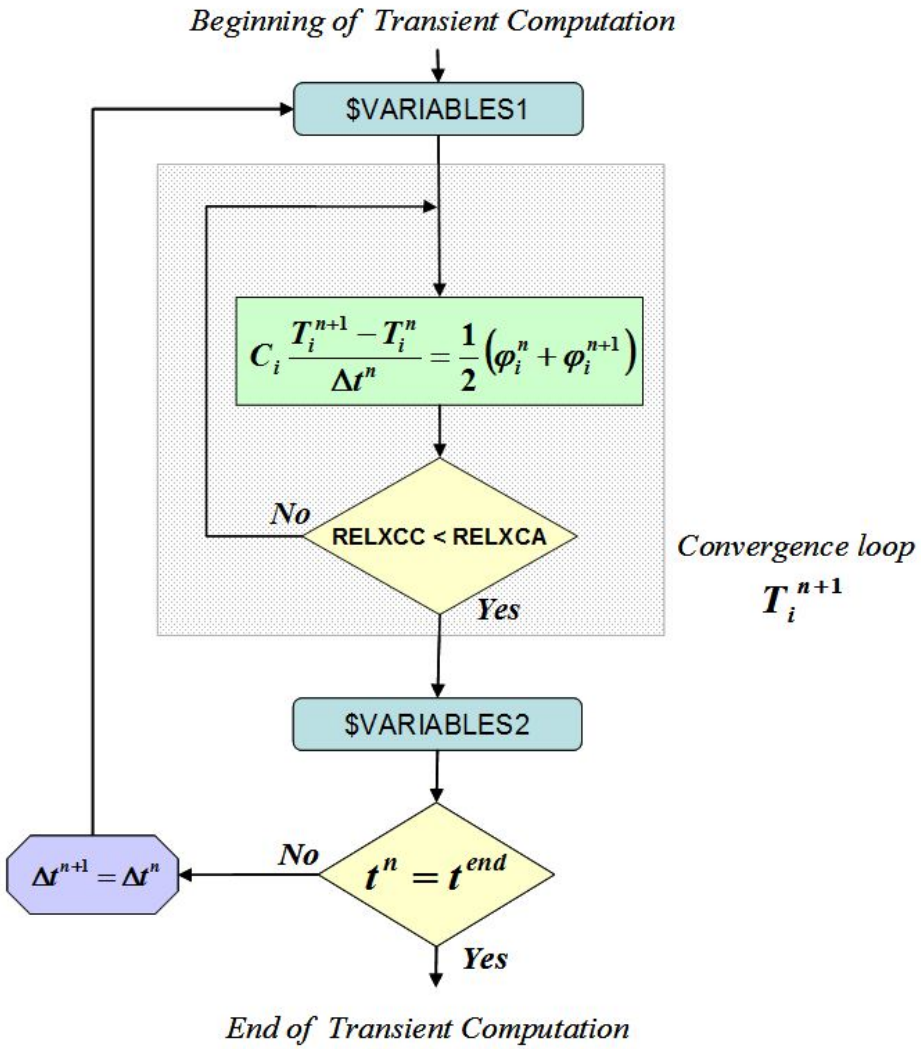
To understand the mean of the blocks, the following figures present the execution process of steady-state and transient analysis:

Standard Executive blocks



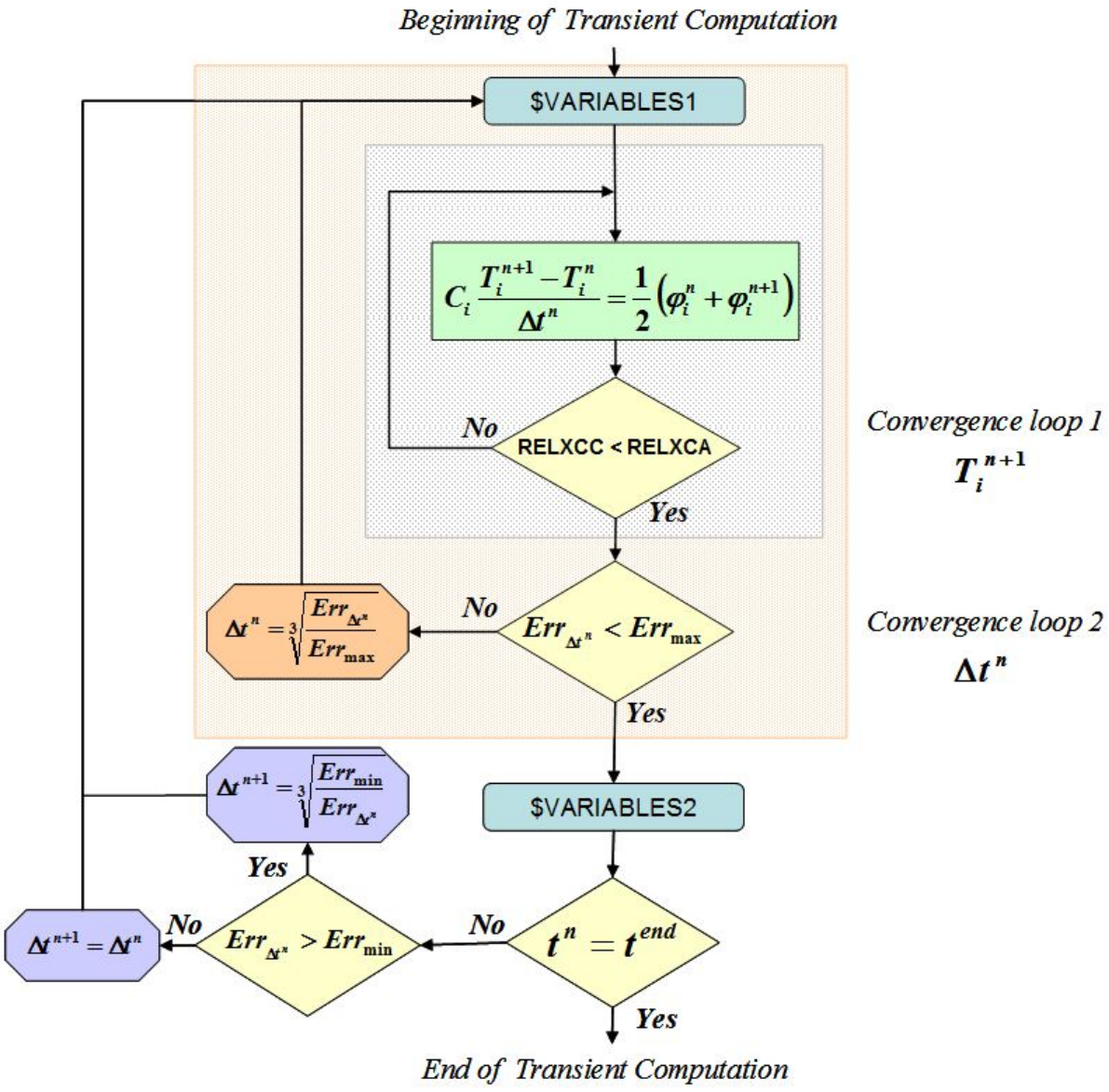
Steady-state computation process with standard executive blocks

In a steady-state process, $VARIABLES1 is used to update temperature dependent data.
$VARIABLES2 is used to update data depending on the converged results.



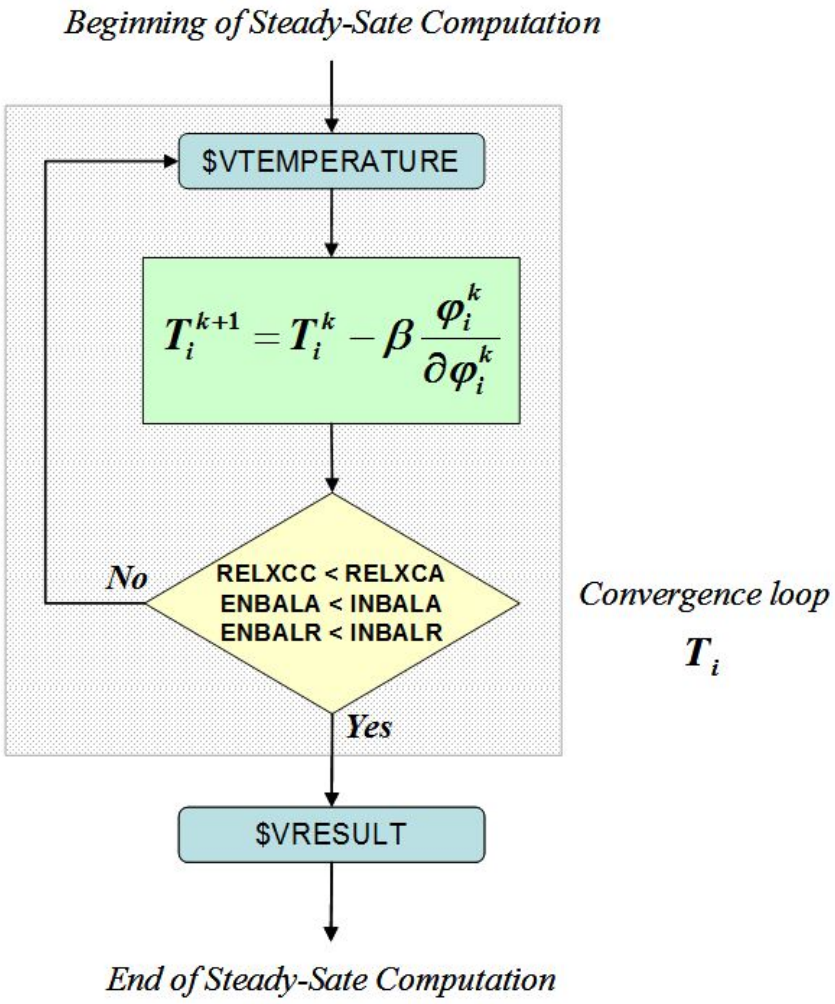
Transient computation process with standard executive blocks

In a transient case, $VARIABLES1 is used to update time dependent data.
For time dependencies, since we are computing the temperature and fluxes at the end time of the current time-step, note that the TIMEM used for the Crank-Nicholson scheme is in fact TIMEN.
$VARIABLES2 is used to update data after the solution have computed for the current time-step.
About temperature dependencies, they can be updated in either $VARIABLES1 or $VARIABLES2. It is important to notice that those dependencies are not solved during the convergence loop. Temperature dependencies are so discretized with a fixed value during an entire time-step.



Automatic time-step control Transient computation process with standard executive blocks

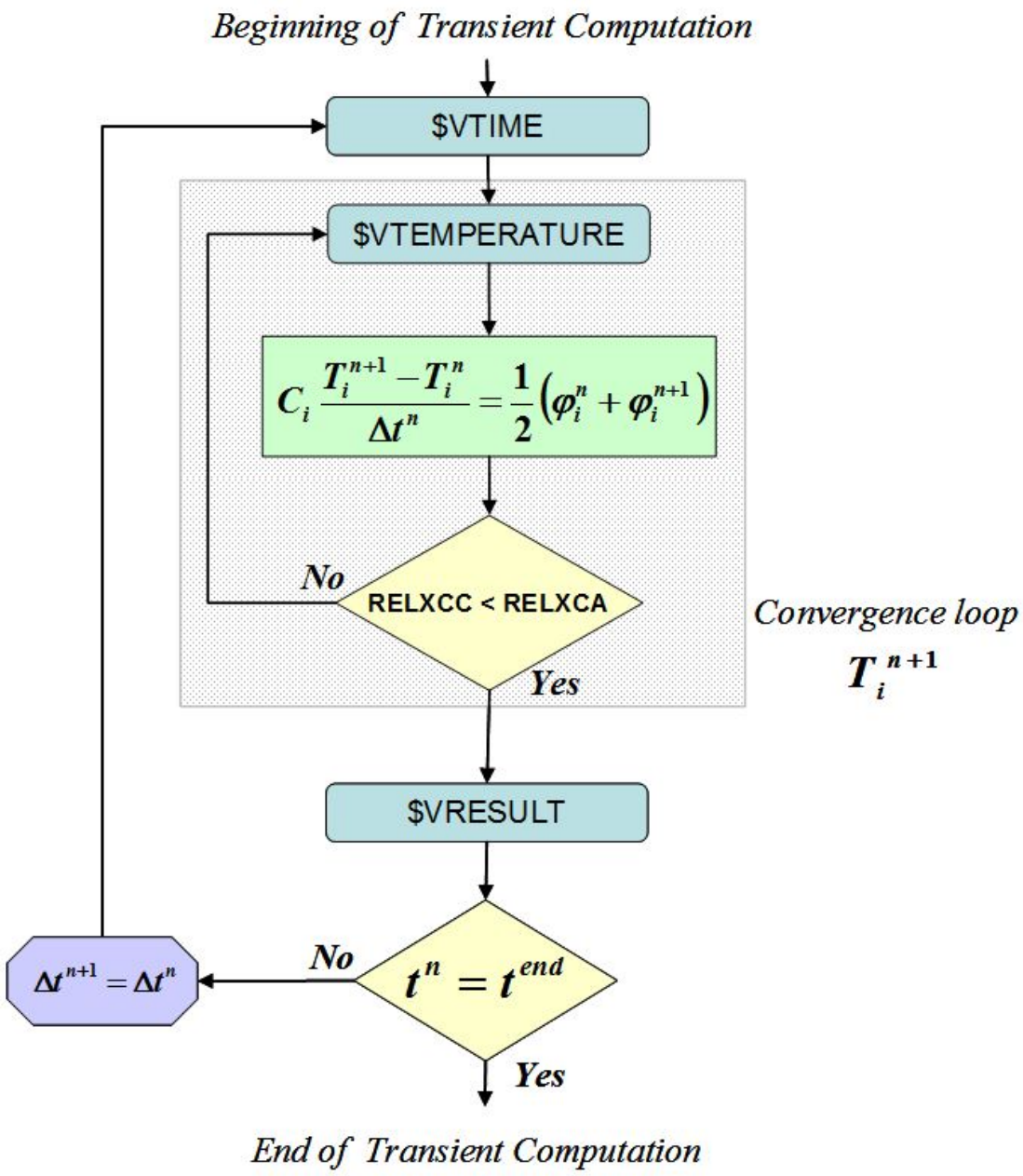
Complete Executive blocks



Steady-state computation process with complete execute blocks

For steady-state computation, using standard or complete executive blocks are equivalent.
$VTEMPEATURE is used to update temperature dependant data.
$VRESULT updates data after the results have converged.

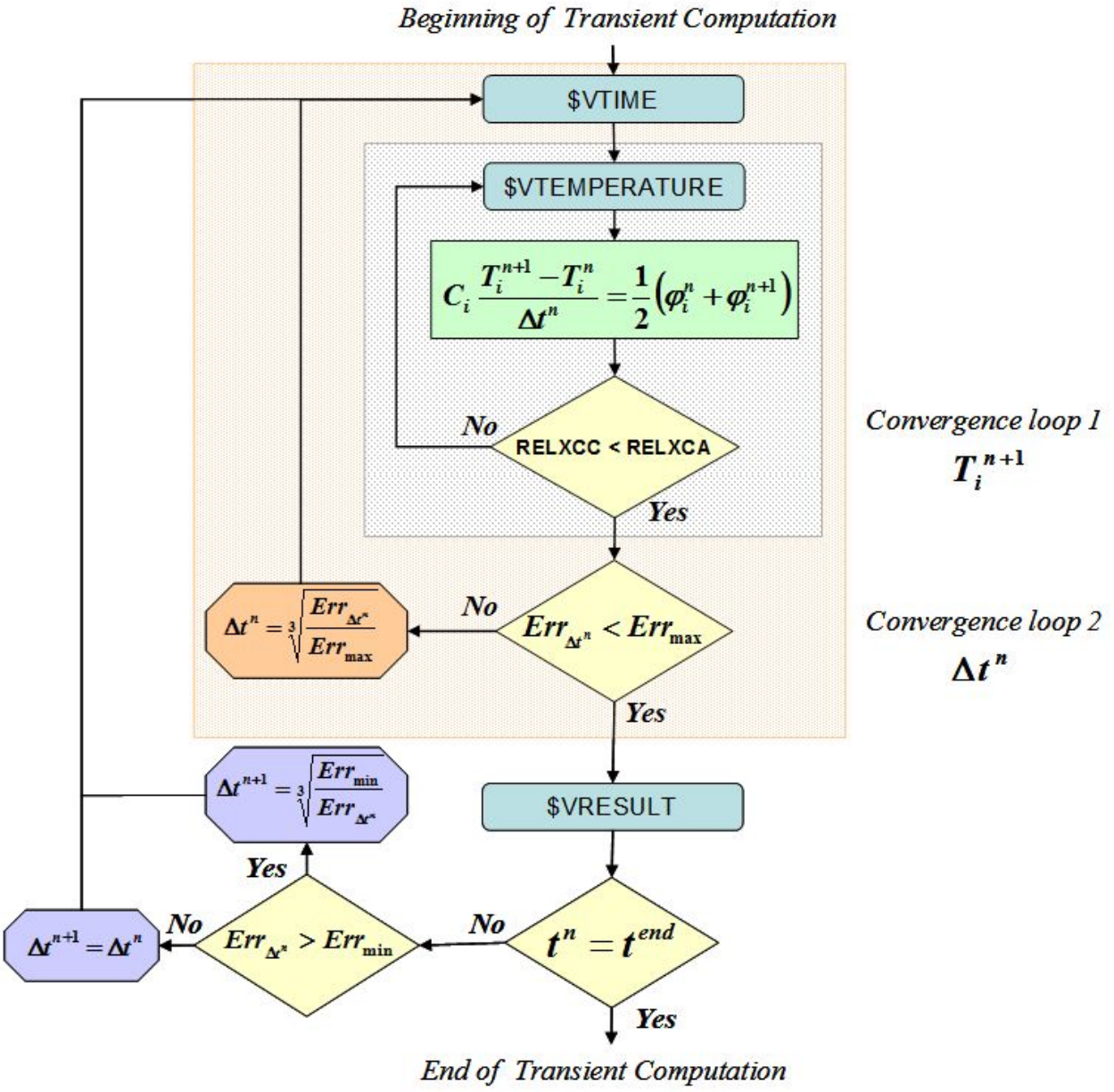
	For Steady-State analysis: • *$VTEMPERATURE is equivalent to $VARIABLES1* • *$VRESULT is equivalent to $VARIABLES2*



Transient computation process with complete executive blocks

In this case, compared to the classical blocks, we have a more complete setting of data updates.

	For Steady-State analysis: • *$VTIME is equivalent to $VARIABLES1* • *$VTEMPERATURE has no equivalent* • *$VRESULT is equivalent to $VARIABLES2*



Transient computation process using automatic time-step control with complete executive blocks

Advantages of the complete definition blocks

- **Clear definition of blocks purposes**

In the complete executive block mode, each block has a specific meaning. It is then easy to find the best location for a specific update.
In the standard executive block mode, except for $VARIABLES2 which is completely equivalent to $VRESULTS, $VARIABLES1 is required to update temperature dependant data in steady-state cases or temperature plus time dependant data in transient cases.
To give a meaning of the $VARAIABLES1 block, additional statement such as "**IF (SOLVER.EQ.'TR') THEN**" are usually required.

- **Real update of temperature dependant properties**

In the complete executive blocks mode, the temperature is updated properly at each convergence loop of a transient run.
If, for convergence or other matter, some temperature dependant data require being discontinuously updated (i.e. with a constant value during a time-step), it is then possible to update those in the $VRESULT block.

Use of EVENTS

The events can then be used in executive blocks through the keywords "BEFORE", "AT", "AFTER" and "BETWEEN". Note that if you use an "OUTPUT" event to modify thermal data or any data that influence the thermal environment, the event should also be placed in the $TIMESTEP block (using a different name) in order to correct the flux at that specific time.
The correct syntaxes to use the events are:

Examples of AFTER and BEFORE

```
AFTER My_event DO # The instructions will be executed only
[instructions] # if the current time is after the event
ENDDO
BEFORE (My_event) DO # The instruction will be executed only
[instructions] # if the current time is before the event
ENDDO# (note that the parentheses are optional)
BEFORE SWITCH_EQUIP1 DO # The instruction will be executed only
[instructions] # if the current time is before any odd
ENDDO # occurrence of the periodic event
AFTER (SWITCH_EQUIP1,2) DO # The instruction will be executed only
[instructions] # if the current time is after the
ENDDO # 2nd occurrence of the periodic event
```

Examples of AT

```
AT My_event DO # The instructions will be executed only
[instructions] # at the event time
ENDDO
AT (My_event) DO # Same than previous with parentheses
[instructions]
ENDDO
AT SWITCH_EQUIP1 DO # The instruction will be executed only
[instructions] # at the occurrences of the periodic event
ENDDO
AT (SWITCH_EQUIP1,2) DO # The instruction will be executed only
[instructions] # at the 2nd occurrence of the
ENDDO # periodic event
```

Examples of BETWEEN

```
BETWEEN My_event & New_event DO # The instructions will be
[instructions] # executed between the two
ENDDO # events
BETWEEN (My_event & New_event) DO # Same with parentheses
[instructions]
ENDDO
BETWEEN (SWITCH_EQUIP1 & SWITCH_EQUIP2) DO # The instructions will
[instructions] # executed according to
```

```
ENDDO # definition given fig. 3
It is also possible to call event test cases inside an event test case.
```

	*Getting close to an event forces the transient solution program to adapt the time-step. This is generally made 2 time-steps before being at one event time. The time-step retrieve its original value once the event has been met.*

$SUBROUTINES

This paragraph contains user functions and subroutines, written in the Mortran language. The pre-processor translates all the Mortran code into Fortran, whereas mere Fortran routines are not changed.
Each function or subroutine is available during the solution program.
The syntax is as follows:

	Syntax	Description
Declaration	SUBROUTINE MYSUB(arg1,arg2,…)	Mortran subroutine
	SUBROUTINE MYSUB(arg1,arg2,…)LANG=MORTRAN	Mortran subroutine
	SUBROUTINE MYSUB(arg1,arg2,…)SPLIT=N	Mortran subroutine
	SUBROUTINE MYSUB(arg1,arg2,…) LANG=FORTRAN	Fortran subroutine
	TYPE FUNCTION MYFTN(arg1,arg2,…)	Mortran function
	TYPE FUNCTION MYFTN(arg1,arg2,…) LANG=MORTRAN	Mortran function
	TYPE FUNCTION MYFTN(arg1,arg2,…) LANG=FORTRAN	Fortran function
End	RETURN END	Classical Fortran ending instructions

where:

- ***TYPE* is the type of returned values: INTEGER, CHARACTER or DOUBLE PRECISION.**
- **** represents the blank character; in the context of Fortran, each new line must begin after 6 blank spaces.**
- ***arg1, arg2, …* are the input / output parameters of the subroutine or function.**
- ***The LANG=MORTRAN or LANG=FORTRAN* instruction refers to the type of subroutine / function, and is optional. By default, the Mortran language is used (this means that the LANG=MORTRAN instruction may be absent).**
- **The *SPLIT=N* can be used with the Mortran subroutine to automatically split the routine every N line.**

Between the declaration and the end, the user can perform programming tasks as in a classical Fortran code, with the 2 following sections:

- Declaration of variables
- Instructions.

In a FUNCTION, the value is returned as follows:
MYFTN = <value>
where:

- ***MYFTN* is the name of the function**
- ***<value>* is the value to be returned: an integer, a real or a string.**

Example of a $SUBROUTINES paragraph (1/2)

```
# MODIFY ABSORBED SOLAR FLUX
SUBROUTINE REDQ (QQ,CENT)
CENTU = CENT/100.
FACTOR = CENTU
QQ = QQ*FACTOR
RETURN
END
SUBROUTINE CHNGQR (TM1,TMA,PM1,PD) LANG = MORTRAN
DOUBLE PRECISION TM1,TMA,PM1,MAXT,MIDT,PD
MIDT = TMA + 0.1D0
MAXT = TMA + 1.0D0
IF (TM1.LT.TMA.OR.TM1.GT.MAXT) THEN
PM1 = PM1 + PD*(MIDT-TM1)
IF (PM1.LT.0.0D0) THEN
PM1 = 0.0D0
ENDIF
ENDIF
RETURN
END
```

Example of a $SUBROUTINES paragraph (2/2)

```
DOUBLE PRECISION FUNCTION GL_raccord(DIAM1,DIAM2) LANG = FORTRAN
DOUBLE PRECISION DIAM1, DIAM2
DOUBLE PRECISION S1, S2
DOUBLE PRECISION GG1, GG2
DIAM1 = .001*DIAM1
DIAM2 = .001*DIAM2
S1 = PI*(.5*DIAM1)**2
S2 = PI*(.5*DIAM2)**2
GG1 = KL_cable*S1/h_raccord
GG2 = LAM_connect*S2/(0.5*L_connect)
GL-raccord = 1./(1./GG1 + 1./GG2)
RETURN
END
```

$INITIAL

This paragraph contains the subroutine called by the solution program at the beginning of its execution or for any "INITIAL" case called from the $PARAMETERS block.
The user will use this paragraph to initialize some data:

- ***Definition of cases,***
- ***Initial values of capacitance and fluxes,***
- ***Initialization of temperatures (using classical instructions or loading an external file).***

$EXECUTION

This paragraph contains the subroutine called by the solution program at the beginning of its execution. It can be considered as the main subroutine that controls the calculation; the calls to solution routines are generally placed in this paragraph.
This block may be called many times if specified in a $PARAMETERS block.

$VTEMPERATURE – Complete Mode

The user will use this paragraph to define temperature-dependent data (capacitance, conductive couplings…).
This paragraph is called at each iteration of the temperature convergence loop. During transient analysis, this paragraph is also called before the beginning of computation, just after the $INITIAL paragraph. During steady-state analysis, if using the iterative Newton-Raphson algorithm (called by the syntax SOLVIT), the execution of this block is optimized in order to prevent any divergence due to the fact that the initial temperatures are far from the converged results.

$VTIME – Complete Mode

VTIME is used to update continuous time-dependant phenomena that will be taken into account for the current time-step, like external heat fluxes. This paragraph is called during transient analysis at the appropriate moment with the correct value of TIMEM in order to evaluate the heat balance of each node at the correct time (usually, for a Crank-Nicholson resolution, TIMEM is equal to TIMEN in order to estimate the flux at the end of the current time-step). This paragraph is also called before the beginning of transient computation, just after the $INITIAL paragraph
When using an automatic time-step control, VTIME is recalled if the definition of the current time-step has changed.

	*To model discreet time-dependant phenomena, it is recommended to use events so the fluxes are updated to take into account the discontinuity at that specific time.*

$VRESULT – Complete Mode

This paragraph is called at the end of each time-step of a transient analysis or at the end of a steady-state analysis. It is also called before the beginning of transient computation, just after the $INITIAL paragraph. This paragraph can be used when converged results are required. It can be used to compute user data depending on the results at a given time, which is the end time of the time-step (TIMEN) or at the end of a steady-state analysis.
It should be used to post-process the results at a given time (user defined data storage, computation of user data not influencing the thermal analysis).
It is however possible to code a change that influence the thermal data (T, GL, GR, GF, QS, QA, QE, QI, QR). This will impact the flux computation of the time t^{n+1} of the next time-step which means that the change in the thermal environment of the model is taken into account during the next time-step (at its middle time exactly).

If such a modification needs to be taken into account at the exact time of the current TIMEN, it is possible to call a function **UPDATE_FLUX** that will force the initial flux of the next time-step to be re-evaluated instead of using the final flux of the current one. The change is so taken into account immediately in the simulation.

$VARIABLES1 – Standard Mode

The definition of this block varies depending on the solution kind:
For steady-state analysis, it is used to update temperature dependant data (equivalent to $VTEMPERATURE).
For transient analysis, it is used to update both time and temperature data. Temperature data remain constants during a time-step.
Due to the inconstant use of the block, it is often required to use statements such as
"IF (SOLVER.EQ.'SS') THEN" or "IF (SOLVER.EQ.'TR') THEN"
in order to specify to context of the block.

$VARIABLES2 – Standard Mode

This block is equivalent to $VERSULTS from the complete Mode

$OUTPUTS

This block is automatically called by the solution routine:

- ***After the solution in steady-state solution routines,***
- ***Regularly with a periodicity defined by the OUTINT control constant or at each OUTPUT event during transient solution routine***

  It can contain any Mortran instruction but is primarily concerned with instructions for the output of information. Only the main-model $OUTPUTS block is executed.

Parametric Cases

An additional block in THERMISOL allows the user to define cases for parametric analysis, for example determining the sensitivity of predicted temperatures to the material and optical properties used in a model. The solution is performed repeatedly with certain parameters in the model being varied for each run, as prescribed by the user.
If the paragraph $PARAMETERS is present, the model defined in the output file, the *nominal* case, is run as normal prior to any parameter cases being executed.
The results from a parametric run are stored in a single text file (for the ASCII outputs). However the hdf5 results are split into several files. In this case, the default name is reserved for the nominal case and the others are combined with the parameter case name.

INITIAL and FINAL cases

Following the $PARAMETERS marker, each parameter case definition takes the form
!INITIAL|!FINAL [PARNAM = name]
command
…
There may be any number of parameter cases.
Two types of parameter case are available, *initial* and *final*. An initial parameter case first restore the state of the model to that defined by the data blocks, and then executes the content of the $INITIAL block. Next, the parameter case commands are enacted, after which the model's $EXECUTION block is obeyed.
Final parameter cases execute the commands and the $EXECUTION block only; i.e. the state of the model at a start of a final case is its current state when the previous solution is completed.

Parametric commands

The CHANGE/ command assigns a new value to the entity specified.
The OFF/ and ON/ commands turn on and off couplings or submodels.

Example of $PARAMETERS use

```
$PARAMETERS
!INITIAL PARNAM='HOT_CASE1'
CHANGE/ C:SUB1:2059 = 4500
CHANGE/ GL(1000,SUB1:234) = 0.2
!FINAL PARNAM='HOT_CASE2'
CHANGE/ N4500 = X
OFF/ GF(8300, 6500)
ON/ GF(8400, 6500)
```

The MORTRAN language

Use of MORTRAN syntax

The THERMISOL input language is based on the FORTRAN language but provides to the user a set of direct references to nodal entities, couplings or control variables. Those specific accesses define the MORTRAN language. The reason for providing a MORTRAN language is to create an easy and understandable language interface which does not require the knowledge of the internal memory structure of the solver. Since the user is dealing with its own node numbering, the MORTRAN language is entirely based on the user's node ids.
In THERMISOL, there are four types of possible MORTRAN syntax:

- ***Explicit references***

An explicit reference is when the node ids are explicitly given using either integer values or local integer constants (defined in the $LOCALS block). A model path can also be included.
Explicit references can be used in declaration or definition blocks to create dependencies between the declared entity and the reference included in its value (see the GENMOR section).

- ***Semi-explicit references***

In definition blocks it is possible to use loops to create new entities (see examples in $NODES or $CONDUCTORS sections). The index of the loops or any new integer value created inside the loop (as long as it does not depend on an external variable) can be used as a reference to either create the entity or to set a dependency with another MORTRAN reference.
This type of reference is semi-explicit because it is using a parameter that is resolved by the THERMISOL pre-processor.

- ***Implicit references***

This functionality has been introduced in version 4.3.2.
In executive blocks, it is possible to set references to entities which depend on variables (using loops or declared variables). In that case the reference is not resolved at the pre-process level but during the execution of the code. The implicit references are expressed exactly like the implicit ones but contain in the node ids variables or formulae instead of integers. Model path are so allowed.
If formulae are used it has to be written between brackets and preceded by ":" in order to set the operation priorities and to avoid ambiguities.

	*Whenever an implicit reference is given, the preprocessor cannot check the existence of the nodes and/or couplings. If the reference is not correct, an error will be raised during the execution of the code.*

- ***Macro references***

This functionality has been introduced in version 4.3.3.
In executive blocks, it is now also possible to set or modify the values of a group of references at once using a ZNODES descriptor (see next section).
Unlike the previous MORTRAN syntax, the macros are a complete statement and cannot be included into another statement (i.e. the macro defines a full line instruction and cannot be a sub-part of more complete instruction). The structure of the macro is as following:

```
[nodal entity] : 'ZNODES' [operator] [right member]
[coupling entity] ([Node 1 reference], 'ZNODES') [operator] [right member]
```

The nodal entity can either be any nodal entity except N (for the internal node number) which not modifiable.
The coupling entities can be GL, GLS, GR, GRS, GF or GFS.
The operator may be = to assign the right member value to all entities or *= to multiply the entity's values by the right member.
The right member can be as any other right members allowed in the executive blocks and as consequence cannot use itself a 'ZNODES' reference.
For couplings, the first node reference can be either explicit or implicit.
The functionality is particularly interesting for coupling modifications, since a development of the macro expressed with a loop is not possible (due to the fact that not all couplings from a node to the others exist).
Here are some examples of correct syntaxes:

For nodal entities

(N, NS, L, T, C, A, ALP, EPS, QS, QA, QE, QR, QI, or user defined entity)

- Using an integer: **T**100, **T** 100, **T:**100
- Using a symbol: **T:**SYMBOL
- Using an expression: **T:(**SYMBOL1+SYMBOL2 - 300**)**
- In a submodel: **T:SUBMOD:**100
  T:SUBMOD:SYMBOL
  T:SUBMOD:(SYMBOL1+SYMBOL2 - 300**)**
- Using a macro: **T:'#100-300'** = 10.0
  T: SUBMOD:'#100-300' *= 10.0

It is worth mentioning that all possible syntax available for nodal entities, except the Mortran macro, may be also used with wavelength dependent emissivities adding a reference to the wavelength band:

- **EPSWLB**100(**WLB=**2), **EPSWLB** 100 (**WLB=**2), **EPSWLB:**100(**WLB=**2)
- **EPSWLB:SUBMOD:**100(**WLB=**IWL+1)
- ~~**EPSWLB:'#100-200'**(**WLB=**IWL) + 0.28~~ (Mortran macro are not supported)

For couplings

(GL,GLS, GF, GFS, GR, GRS, GV)

- Using integers: **GL(**100, 101**)**
- Using symbols: **GL(**SYMBOL, 101**)GL(**SYMBOL1, SYMBOL2**)**
- Using an expression: **GL(**SYMBOL1+SYMBOL2 – 300, 101**)**
- In a submodel: **GL(SUBMOD:**100, **SUBMOD:**101**)**
  GL:SUBMOD:(100, 101**)**
  GL(SUBMOD:SYMBOL, **SUBMOD:**101**)**
  GL(SUBMOD:(SYMBOL–300), **SUBMOD:**101**)**
- Using a macro: **GLS(**1000**, '#100-300')** = 'X' *(or 'OFF')*
  GR(SUBMOD:SYMBOL**, '#100-300')** *{}= COEFF

It is worth mentioning that the wavelength dependent radiative coupling GRWLB may be used in executive blocks as other GL, GR or GF couplings with the addition of a wavelength band reference. All explicit and implicit spellings of GRWLB are possible. Mortran macro are however not accessible.

- **GRWLB**(100,101,**WLB=**3)
- **GRWLB**(**SUBMOD:**100, **SUBMOD:**101, **WLB=**3), **GRWLB:SUBMOB:**(100,101,**WLB=**3)
- ~~**GRWLBS**(1000,**'#100-300'**)= 'X'~~ (Mortran macro are not supported)

The wavelength band reference shall always be placed last.

Note: When using sub-models, the wavelength discretization reference of a GRWLB is the one of the model in which the coupling is declared.

Node specifications (ZNODES)

Many output routines have an argument describing the list of nodes concerned by the output. This specification is given as a character string based on the following rules:

- *A ZNODES specification can be a combination of different singular ZNODES separated by ';'*
- *Any singular ZNODES specification can be additive or subtractive if it is prefixed by the character '!'*
- *A singular ZNODES specification can be :*
  - **ALL** *: all the nodes belonging to the current model (sub-models included)*
  - **@ [model path]** *: all the nodes belonging to the model specified by its relative path from the current model (sub-models included)*
  - **@[model path]:ONLY** *: all the nodes belonging to the model specified by its relative path from the current model (sub-model excluded)*
  - **#[node list]** *: all the nodes listed (see node list definitions bellow)*
  - **[label]** *: all the nodes from the current model and its sub-models that have the sub-string 'label' in their names*
  - **[model path]:[label]** *: all the nodes of the specified sub-model from the current model and its sub-models that have the sub-string 'label' in their names*
  - **ONLY:[label]** *: all the nodes from the current model (excluding its sub-models) that have the sub-string 'label' in their names*
  - **[model path]:ONLY:[label]** *: all the nodes of the specified sub-model from the current model (excluding its sub-models) that have the sub-string 'label' in their names*

- *A node list is formed by singular nodal specifications separated by comas. A singular nodal specification ca be:*
  - **X** *: A user node number of current model*
  - **[model path]:X** *: A user node number of the sub-model given by the model path from the current model*
  - **X-Y** *: A range of numbers of the current model. The node X must be an existing node number of the model. The node number Y can either be an existing node or not*
  - **[model path]:X-Y** *: A range of user node numbers of the sub-model given by the model path from the current model. The node X must be an existing node number of the specified sub-model. The node number Y can either be an existing node or not*

Examples of ZNODES specifications

```
 'ALL'                        # all the nodes of current model
 '#1255'                      # node 1255
 '#100-199'                   # all the nodes in the range 100-199
 '#1255,100-199'              # node 1255, and all nodes in the range 100-199
 '@SUB1'                      # all the nodes of sub-model SUB1 and its sub-
models
 '@SUB1:ONLY'                 # all the nodes of sub-model SUB1 only
 'SUB1:350'                   # node 350 of sub-model SUB1
 'SUB1:300-399'               # range of nodes 300-399 of sub-model SUB1
 'Equipment'                  # all the nodes with 'Equipment' in their names
 'SUB1:Equipment'             # all the nodes of SUB1 and its sub-models with
```

```
'Equipment" in their names
 'ALL;!#1255'                 # all the nodes of current model except node 1255
 'SUB1;#1255,100-199;!Equip'  # all the nodes of SUB1 plus nodes 100 to 199 from
current model except nodes having 'Equip' in their names
```

Parsing nodes in loops

For parsing nodes and access to their properties or couplings it is possible to do generate a parsing group and to iterate on this group.
To set a group from a node group specification (znodes):

CALL SETGROUP_LABEL ('ZNODES',CURRENT)

To set a group from a coupling type or from all couplings:

CALL SETGROUP_GL (N100)or CALL SETGROUP_GL (N:SYMBOL)
CALL SETGROUP_GR (N100) or CALL SETGROUP_GR (N:SYMBOL)
CALL SETGROUP_GF (N100) or CALL SETGROUP_GF (N:SYMBOL)
CALL SETGROUP_ALLG (N100) or CALL SETGROUP_ALLG (N:SYMBOL)

To get the number of elements within the group:

N = GETGROUP_NBELEM()

To get the user node number of an element of the group:

UNODE = GETGROUP_NUMBER(I)

To get the internal node number of an element of the group:

INODE = GETGROUP_INTNOD(I)

To get the internal model number of an element of the group:

IMODEL = GETGROUP_INTMOD(I)

To get the node model name of an element of the group: *(see SUBMDN function for type description)*

MODELN = GETGROUP_SUBMDN(I, TYPE)

Example of node parsing

```
CALL SETGROUP_GR(N:3200)
N = GETGROUP_NBELEM()
DO I=1,N
UNODE = GETGROUP_NUMBER(I)
GR(3200,UNODE) = GR(3200,UNODE) * A:UNODE * 0.01
ENDDO
```

Use of sub-models

A model can have one or several sub-model(s), declared before its definition paragraphs. A sub-model can also include sub-models. The ways to declare sub-models are described in the following sections.
All the data defined in a sub-model are accessible by the father: nodes, couplings, constants, arrays, subroutines. For that purpose, the model names are used as prefixes:

- ***A:HGA:100* is the area of node 100 of sub-model HGA.**
- ***HGA:COMPUTEHEAT (Q100,1.0)* is the call to the COMPUTEHEAT function coded in the HGA sub-model.**
- ***C:SUB1:SUB2:100* is the capacitance of node 100 of the SUB2 sub-model contained in the SUB1 sub-model.**
- ***HGA:POWER* is the POWER variable defined in the HGA sub-model.**

Sub-models need to be linked together and with their father; for that purpose, the user can define couplings between them or super nodes.
A coupling between models is a classical coupling involving 2 nodes from different models.

Do not use spaces and operators in sub-model names.

Example of coupling between models

```
GL(100, NOZZLE:230) = 1.5;
```

Using super nodes

Super nodes are a way to merge several nodes, usually coming from different models. When a super node is defined, all the nodes merged are removed and all the couplings previously defined with these nodes are associated with the super node.
If a supernode connects a node of the current model, the keyword CURRENT must be explicit.

Example of super node definition

```
D1000 = 'Antenna baseplate' = HGA:10 + BASE:3300, T = 0.0;
D2000 = 'Equipement baseplat' = CURRENT:425 + EQUIP:8260;
```

Inline definition of a sub-model

As a model is delimited by the $MODEL and $ENDMODEL keywords, the insertion of sub-models is a natural feature of the language. This kind of definition is fully explicit.

Example of an inline definition of a sub-model

```
$MODEL MEX
   $MODEL MARSIS

   # Here is all the definition of model MARSIS

   $ENDMODEL
# Here is all the definition of model MEX
$ENDMODEL
```

Integration with $EXTERNAL

The $EXTERNAL function can be used to define a sub-model contained in a separate file and change its name. This is useful when the sub-model is a generic modeling that must be used several times.
The name specified by the $EXTERNAL instruction refers to a file that should be located in the same working directory, with a classical suffix (*.DCK or *.d), if applicable.

Example of $EXTERNAL use

```
$MODEL ANIK
$MODEL BATTERY1
$EXTERNAL BATT_LITH
$ENDMODEL
$MODEL BATTERY2
$EXTERNAL BATT_LITH
$ENDMODEL
$ENDMODEL
```

Inclusion with $ELEMENTS

A sub-model included with the $ELEMENTS function is a parametric sub-model, which means that several parameters can be set by their father. This can be useful to build generic sub-models that can be used several times with some specific changes.
The name specified by the $ELEMENTS instruction refers to a file that should be located in the same working directory, with a classical suffix (*.DCK or *.d), if applicable.
The sub-model definition contains parameters written between the '%' symbols, i.e. %PARAM%, which means that the translator will detect that the value of PARAM is not specified in the sub-model but in his father.
Such parametric symbols can be used in any declaration or definition block as well as in any Mortran instruction of the execution blocks.
The father specifies the parameters after the $ELEMENTS instruction, in a $SUBSTITUTIONS paragraph. In addition, some parameters can have default values specified in the sub-model, in a $DEFAULTS paragraph.

Example of $ELEMENTS use

```
$MODEL E3000
$MODEL LHP1
$ELEMENTS LHPMODEL
$SUBSTITUTIONS
NBNODES = 170
POWER = 200
$ENDMODEL
...
...
$ENDMODEL
```

In this example, the sub-model LHPMODEL is defined this way:

Example of $ELEMENTS model

```
$MODEL LHPMODEL
$DEFAULTS
NBNODES = 16
$NODES
FOR INODE = 1 TO %NBNODES%
D INODE = 'tubing', T = 0, C = 15.5;
END FOR
```

```
D10000 = 'Incoming power', T = 0, QI - %POWER%;
...
...
$ENDMODEL
```

Library Functions and Subroutines

Solver library content

The solver library contains a large number of functions and subroutines, which can be accessed by the user in the execution paragraphs. The library can be classified into several families of functions:

- ***Solutions routines***

Calculation of the node temperatures for steady-state or transient problems. These routines are usually called in the $EXECUTION paragraph.
For more details on these routines, see chapter 4 about theoretical background.

- ***Heat transfer routines***

Calculation of flux exchanges between different families of nodes or between different sub-models.

- ***Interpolation routines***

Various interpolation functions to allow access to user arrays or tables.

- ***Nodal network management routines***

Activation, deactivation or status changing of nodes, couplings or sub-models.

- ***Mathematical routines***

Various basic mathematical functions.

- ***Data output routines***

Various routines for results or data output.

- ***Other routines***

Collection of various other functions.

Data output routines

Data output routines

Sorted ENTITIES definition for output routines

For the output data routines exporting a list of values for specified entities, it is also possible to sort the results in increasing or decreasing order of one of the entity.
To specify that a list shall be sorted, the attribute –DEC or –INC can be added next to the entity that should be used to sort the list. This entity is not necessary displayed unless it is explicitly specified.
If no sorted entity is specified, then it assumed to be sorted by increasing node numbering.

Example of sorted entities

```
'T,QS,QA,QE,T-INC'
'QS,QA,QE,T-DEC'
'GL,GL-DEC'
```

	*In the first example, the temperature, solar, Albedo and IR powers will be displayed sorted by increasing values of the temperatures.* *In the second example, only the powers will be displayed but will however sorted by decreasing temperatures.* *The third example shows that it is also possible to sort couplings when it makes sense (ordering by coupling values the temperatures is for example not possible).*

SUBROUTINE **PRNDTB** ***(ZNODES,ENTITIES,MODEL)***

- ***Input:***
- *ZNODES: Character string describing the nodes concerned*
- *ENTITIES: Character string describing the node entities to be printed*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the entities of all the nodes described in NODES in the model described by MODEL.

The node entities are described by the ENTITIES string, and can be: label, T, QS, QA, QE, QI, QR or any nodal entity defined by the $ENTITIES block.

The node number and status are systematically printed.

Example of a PRNDTB subroutine calls

```
CALL PRNDTB('#100', 'T,C', SATEM)
CALL PRNDTB('#100-400', 'QS,QA,ENT', CURRENT)    # where ENT is a nodal entity defined in $ENTITIES
CALL PRNDTB('#100,200,300', 'QI,QR', CURRENT)
CALL PRNDTB('#100,200,1000-3000,5000', 'T,C', SATEM)
CALL PRNDTB(' ', 'T,C,QS,QA,QE,QI', SATEM)
```

SUBROUTINE **PRHEAD**

- ***Input:*** *none*
- ***Output:*** *none*

- ***Description:***

***SUBROUTINE* PRHEAD**

This subroutine prints the header of the PRNDTB output subroutine, showing the name of the current solution routine, the current time step, and some key convergence parameters.

Example of a PRHEAD subroutine call

```
CALL PRHEAD
```

SUBROUTINE* PRNDBL *(ZNODES,DATA,MODEL)

- ***Input:***
- *NODES: Character string describing the nodes concerned*
- *DATA: Character string describing the data to be printed*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the data described by the DATA string, related to all the nodes described by the NODES string in the model described by MODEL. The data can be:

- **Node entities**: T, QS, QA, QE, QI, QR or any real nodal entity defined by the user in the file USRNOD.DAT.
- **Couplings**: GL, GR or GF.

Example of a PRNDBL subroutine calls

```
CALL PRNDBL(' ','T,QS,QI',CURRENT)
CALL PRNDBL('#1000,3000-3101','QI,QR',CURRENT)
CALL PRNDBL(' ','GL',CURRENT)
CALL PRNDBL('#1000,3000-3101','GR',CURRENT)
CALL PRNDBL(' ','T,QS,QI',SATEM)
CALL PRNDBL('#1000,3000-3101','QI,QR',SATEM:TELESCOPE)
```

SUBROUTINE* PTSINK *(ZNODE1,CNAME1,ZNODE2,CNAME2,TYPE)

- ***Input:***
- *ZNODE1: Thermal group*
- *CNAME1: Submodel name for thermal group*
- *ZNODE2: Environment group*
- *CNAME2: Submodel name for environment group*
- *TYPE: Integer type of sink temperature required*
- ***Output:*** *none*

SUBROUTINE PTSINK *(ZNODE1,CNAME1,ZNODE2,CNAME2,TYPE)*

- ***Description:***

This subroutine prints the sink temperature of all the nodes described in NODES, in the model described by MODEL (see function TSINK).

This function can be used for systems with wavelength dependent thermo-optical properties.

Example of a PTSINK subroutine calls

```
CALL PTSINK('#102-103', CURRENT, '#104-105', CURRENT, 4)
```

SUBROUTINE PTSINKN *(ZNODES,MODEL)*

- ***Input:***
- *NODES: Character string describing the nodes concerned*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the sink temperature of all the nodes described in NODES, in the model described by MODEL (see function TSINKN).

This function can be used for systems with wavelength dependent thermo-optical properties.

Example of a PTSINKN subroutine calls

```
CALL PTSINKN('#100', SATEM)
CALL PTSINKN('#100-400', CURRENT)
CALL PTSINKN('#100,200,300', CURRENT)
CALL PTSINKN('#100,200,1000-3000,5000',SATEM)
CALL PTSINKN(' ',SATEM)
```

SUBROUTINE QRATES *(ZNODES,MODEL)*

- ***Input:***
- *NODES: Character string describing the nodes concerned*
- *MODEL: Name of the model concerned*

SUBROUTINE **QRATES** ***(ZNODES,MODEL)***

- ***Output:*** *none*

- ***Description:***

This subroutine prints the heat exchanges of all the nodes described in NODES, in the model described by MODEL.

Example of a QRATES subroutine calls

```
CALL QRATES('#100',SATEM)
CALL QRATES('#100-400',CURRENT)
CALL QRATES('#100,200,300',CURRENT)
CALL QRATES('#100,200,1000-3000,5000',SATEM)
CALL QRATES(' ',SATEM)
```

SUBROUTINE **PRQBAL** ***(ZNODES,MODEL)***

- ***Input:***
- *NODES: Character string describing the nodes concerned*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the heat balance of all the nodes described in NODES, in the model described by MODEL.

Example of a PRQBAL subroutine calls

```
CALL PRQBAL('#100',SATEM)
CALL PRQBAL('#100-400',CURRENT)
CALL PRQBAL('#100,200,300',CURRENT)
CALL PRQBAL('#100,200,1000-3000,5000',SATEM)
CALL PRQBAL(' ',SATEM)
```

SUBROUTINE **PRQBOU** ***(MODEL)***

SUBROUTINE **PRQBOU** ***(MODEL)***

- ***Input:***
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the heat flows along all conductors in submodel MODEL which cross the submodel boundary.

A positive flux means the flux goes from the group of nodes specified by MODEL to the rest of the model.

Example of a PRQBOU subroutine calls

```
CALL PRQBOU(SATEM)
CALL PRQBOU(CURRENT)
```

SUBROUTINE **PRQNOD** ***(ZNODES, MODEL)***

- ***Input:***
- *NODES: Character string describing the nodes concerned*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the heat flows along all conductors of the group of nodes described by NODES in submodel MODEL which cross the boundary of the group of nodes.

A positive flux means the flux goes from the group of nodes to the rest of the model.

Example of a PRQNOD subroutine calls

```
CALL PRQNOD('#100,200,1000-3000,5000',SATEM)
CALL PRQNOD(' ',CURRENT)
```

SUBROUTINE **PRTTMD** ***(ZNODES,MODEL)***

- ***Input:***
- *NODES: Character string describing the nodes concerned*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

SUBROUTINE **PRTTMD** ***(ZNODES,MODEL)***

- ***Description:***

This subroutine prints the maximum temperature difference between the nodes described in NODES in the model described by MODEL, and prints the 2 nodes for which the maximum difference is observed.

Example of a PRTTMD subroutine calls

```
CALL PRTTMD('#100',SATEM) CALL PRTTMD('#100-400',CURRENT)
CALL PRTTMD('#100,200,300',CURRENT)
CALL PRTTMD('#100,200,1000-3000,5000',SATEM)
CALL PRTTMD(' ',SATEM)
```

SUBROUTINE **DMPTHM** ***(FILE)***

- ***Input:***
- *FILE: Character string – basename for output files*
- ***Output:*** *none*

- ***Description:***

This subroutine produces a set of CSV files containing nodal data in vector form (temperature, capacitance, and total heat load, one row per node) and conductance matrices (separately linear, radiative and fluidic). The latter are complete NxN matrices (N being the number of nodes in the model), with a zero entry wherever there is no conductor defined between the row and column nodes. This format is designed to be amenable to loading into numeric computation tools such as MATLAB®. There is also a list of nodes in the same row/column order, giving node type, number, label and model name.

FILE is used as the first part of each file name, unless it is blank in which case the model name is used.

The files produced are as follows:

- *FILE.nl.csv – Node list: number, type, label, model*
- *FILE.nd.csv – Node data: temperature, capacitance, total heat load (vectors)*
- *FILE.gl.csv – Linear conductances (matrix)*
- *FILE.gr.csv – Radiative conductances (matrix)*
- *FILE.gf.csv – Fluidic conductances (matrix)*

Example of a DMPTHM subroutine calls

```
CALL DMPTHM('export')
CALL DMPTHM(' ')
```

SUBROUTINE* PRNCSV *(ZNODES,ENTITIES,MODEL,ORDER,FILE)

- ***Input:***
- *ZNODES: Character string describing the nodes concerned*
- *ENTITIES: Character string describing the entities to be output*
- *MODEL: Name of the model concerned*
- *ORDER: Character string defining the ordering of the values.*
- *FILE: Character string for the output file name*
- ***Output:*** *none*

- ***Description:***

This subroutine prints the entities specified in ENTITIES for the group of nodes ZNODES. The data are sorted according to the ORDER specified. Column header are written, and the data are output as a comma-separated value list, appropriate for import into a post-processing tool such as a spreadsheet.

Example of a PRNCSV subroutine calls

CALL PRNCSV(' ','T',CURRENT, 'NODE', 'temperatures.csv')

CALL PRNCSV('#100-300', 'GL,GR', SUB1, 'ENTITY', 'conductors.csv')

SUBROUTINE* PRTTMD *(ZNODES,MODEL)

- ***Input:***
- *ZNODES: Character string describing the nodes concerned*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

Prints the maximum temperature difference between nodes of ZNODES within the MODEL specified.

Example of a PRTTMD subroutine call

```
CALL PRTTMD(' ',SUBMOD:ONLY)
```

SUBROUTINE* PRTNSM *(ZNODES,ENTITIES,MODEL)

- ***Input:***
- *ZNODES: Character string describing the nodes concerned*
- *ENTITIES: Character string describing the entities*
- *MODEL: Name of the model concerned*

SUBROUTINE* PRTNSM *(ZNODES,ENTITIES,MODEL)

- ***Output:*** *none*

- ***Description:***

Prints the sums of the entities for all the nodes specified

Example of a PRTNSM subroutine call

```
CALL PRTNSM('SCOPE','A, Damage', CURRENT:ONLY)
```

Output the sums of the area (A) and the user nodal entity called Damage for all the nodes in the current model only (excluding its submodels) having 'SCOPE' as a substring of their labels.

SUBROUTINE* PRTNAV *(ZNODES,ENTITIES,MODEL)

- ***Input:***
- *ZNODES: Character string describing the nodes concerned*
- *ENTITIES: Character string describing the entities*
- *MODEL: Name of the model concerned*
- ***Output:*** *none*

- ***Description:***

Prints the average of the entities for all the nodes specified

Example of a PRTNAV subroutine call

```
CALL PRTNAV('SCOPE','A, Damage', CURRENT:ONLY)
```

H5 output

Overview

Introduction

Posther is the name of the post-processing management of Thermisol. It includes the generation of the output file in the HDF5 format and analysis tools.
The advantage of this new data storage and post-processing tools is that it is based on the powerful HDF5 format which is already a standard. Free software applications can be used to manage this type of file, like HDF5 explorer, etc.
The file stored in this format (.h5 file) contains general data (program version, user name, start date and time of the simulation…), convergence data (number of iterative loops, evolution of the convergence criteria…), simulation

data (nodes identification and models identification, number of couplings), model properties (areas, capacitance, couplings…), thermal results (temperature, external fluxes…) and analysis data (minmax analyses, flux budgets…).

What is HDF5

The Hierarchical Data Format (HDF) implements a model for managing and storing data. It is compatible with any hardware platform and lets the user manage its data easily. Moreover, the low-level organization of the file is such that the accesses are much faster than with a standard scan of a file.
The structure of the HDF5 format is mostly divided into 3 kinds of objects:

- ***The Groups*** *are similar to folders. They are used to organize the data into different named categories.*
- ***The Datasets*** *are the data themselves.They are identified by a name and contain the values of the entity stored.*
- ***The Attributes*** *are single values which qualify a group or a dataset. They can be used to give the name of the axis definition of an array or to give additional data.*

Generation of the H5 file

Control variables

- ***H5_FREQ*** *This variable control the frequency of the data storage in the h5 file*

The default value is 4. This variable can be modified at any time during the simulation.

	*Negative times are systematically not stored in the H5 files.*

- ***H5_RES0*** *This variable specifies the data that only need to be stored once, at the initialization of the h5 file. The default value is 'NS,A,C,ALP,EPS,GL,GR,GF'. This value cannot be updated during the simulation.*
- ***H5_RES1*** *This variable specifies the time-dependant data that will be stored during the simulation at the frequency given by H5_FREQ. The default value is 'T,QS,QA,QE,QI,QR' . This value cannot be updated during the simulation.*

Note that it is possible to export any real or integer user entity in the h5 file at the initialization or at the frequency given by H5_FREQ by adding their name in the H5_RES0 or H5_RES1 variable. You can also export all the real and integer variables defined in the $VARIABLES block by adding 'VAR' in the H5_RES0 or H5_RES1 variable.

Example of H5 export setting

```
H5_FREQ = 2
H5_RES0  = 'NS,A,C,ALP,EPS,GL,GR,GF,ON_DISSIP,CSGNode';
H5_RES1  = 'T,QS,QA,QE,QI,QR,CSGNode,VAR';

In this example, the user entity ON_DISSIP (previously defined in the $ENTITIES
block) is stored in h5 file once at the initialization, in addition to the other
entities stored by default (NS,A,C,ALP,EPS,GL,GR and GF).
The user entity CSGNode is stored during the whole simulation at the H5_FREQ
frequency (i.e. every 2 time steps), in addition to the other entities stored by
default (T,QS,QA,QE,QI and QR).
Finally, all the real and integer variables defined in the $VARIABLES block are
stored during the whole simulation at the H5_FREQ frequency.
```

Storage functions

- ***H5_INIT(' ')***

Create a default result file and store the entity of ***H5_RES0*** *A filename can be specified as an argument.*

- ***H5_DUMP***

Store the results if the current iteration of the call corresponds to the storage frequency H5_FREQ (the iteration numbers are automatically reset at each start of a solution routine – last time of solution call is also stored independently of the frequency).

- ***H5_CLOSE***

Close the current h5 file

Storage behavior

If the initialization function H5_INIT is not specified in the input dck file, an hdf5 output will be automatically generated with a default name. In batch command the option "-no_auto_h5" deactivate the automatic generation of the h5 output.
The automatic generation of the h5 file is made for the entire simulation.
If the user wants to creates several h5 result files and/or if it is required to specify when to initialize and close one file, writing explicitly the command H5_INIT and H5_CLOSE will deactivate the automatic generation of the h5 file and the solver will switch to a manual control.
If the manual control is activated, the store of the results is not automatic and the use of the function H5_DUMP in the $VRESULT paragraph is required to control the dump.

Heat transfer routines

DOUBLE PRECISION **HEATBAL** ***(D1)***

- ***Input:***
- *NODE D1: Node designation*
- ***Output:***
- *DOUBLE PRECISION HEATBAL: Absolute heat balance of the node.*

- ***Description:***

This function computes the heat balance of the node by integrating its entire environment.

Example of a HEATBAL function call

```
BALANCE = HEATBAL(N100)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

DOUBLE PRECISION **FLUXL** ***(J1,J2,K1,K2)***

- ***Input:***
- *INTEGER J1: Node number of the first node of group J*
- *INTEGER J2: Node number of the last node of group J*
- *INTEGER K1: Node number of the first node of group K*

DOUBLE PRECISION **FLUXL** ***(J1,J2,K1,K2)***

- *INTEGER K2: Node number of the last node of group K*
- ***Output:***
- *DOUBLE PRECISION FLUXL: Conductive flux exchanged between group J and group K*

- ***Description:***

This function computes the power exchanged conductively between two groups of nodes. Two node numbers describe each group, involving all nodes having a number greater or less than the two specified numbers. The following quantity is returned: $FLUXL = \sum GL_{j,k}(T_k - T_j) \quad (J1 \le j \le J2 \; ; \; K1 \le k \le K2)$

Example of a FLUXL function call

```
CONDPOW = FLUXL(N100,N150,N20000,N21000)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

DOUBLE PRECISION **FLUXR** ***(J1,J2,K1,K2)***

- ***Input:***
- *INTEGER J1: Node number of the first node of group J*
- *INTEGER J2: Node number of the last node of group J*
- *INTEGER K1: Node number of the first node of group K*
- *INTEGER K2: Node number of the last node of group K*
- ***Output:***
- *DOUBLE PRECISION FLUXR: Radiative flux exchanged between group J and group K*

- ***Description:***

This function computes the power exchanged radiatively between two groups of nodes. Two node numbers describe each group, involving all nodes having a number greater or less than the two specified numbers. The following quantity is returned:

$$FLUXR = \sum \sigma \, GR_{j,k}(T_k^4 - T_j^4) \quad (J1 \le j \le J2 \; ; \; K1 \le k \le K2)$$

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantity is returned:

$$FLUXR = \sigma \sum_{j=j_1,j_2} \sum_{k=k_1,k_2} \left(\sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_k, \lambda_m, \lambda_{m+1}) \right) T_k^4 - \sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1}) \right) T_j^4 \right)$$

where $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

Example of a FLUXR function call

```
RADPOW = FLUXR(N100,N150,N20000,N21000)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

DOUBLE PRECISION **FLUXF** ***(J1,J2,K1,K2)***

- ***Input:***
- *INTEGER J1: Node number of the first node of group J*
- *INTEGER J2: Node number of the last node of group J*
- *INTEGER K1: Node number of the first node of group K*
- *INTEGER K2: Node number of the last node of group K*
- ***Output:***
- *DOUBLE PRECISION FLUXF: Convective flux exchanged between group J and group K*

- ***Description:***

This function computes the power exchanged through one-way linear couplings between two groups of nodes. Two node numbers describe each group, involving all nodes having a number greater or less than the two specified numbers. The following quantity is returned: $FLUXF = \sum GF_{j,k}(T_k - T_j) \quad (J1 \le j \le J2 \; ; \; K1 \le k \le K2)$

Example of a FLUXF function call

```
ONEWAYPOW = FLUXF(N100,N150,N20000,N21000)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

DOUBLE PRECISION **FLUXT** ***(J1,J2,K1,K2)***

- ***Input:***
- *INTEGER J1: Node number of the first node of group J*
- *INTEGER J2: Node number of the last node of group J*
- *INTEGER K1: Node number of the first node of group K*
- *INTEGER K2: Node number of the last node of group K*
- ***Output:***
- *DOUBLE PRECISION FLUXT: Totalflux exchanged between group J and group K*

- ***Description:***

This function computes the power exchanged in all possible ways (conductive, radiative and linear one-way) between two groups of nodes. Two node numbers describe each group, involving all nodes having a number higher or below the two numbers specified. The following quantity is returned:

$$FLUXT = \sum \left(GL_{j,k}(T_k - T_j) + \sigma \, GR_{j,k}(T_k^4 - T_j^4) + GF_{j,k}(T_k - T_j) \right) \quad (J1 \le j \le J2 \; ; \; K1 \le k \le K2)$$

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantity is returned:

$$FLUXT = \sum_{j=j_1,j_2} \sum_{k=k_1,k_2} \left(\sigma \sum_{m=1,NWLBANDS} \left(GR_{i,j,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1}) \right) T_j^4 - \sigma \sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1}) \right) T_j^4 + GL_{j,k}(T_k - T_j) + GF_{j,k}(T_k - T_j) \right)$$

where $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

DOUBLE PRECISION **FLUXT** ***(J1,J2,K1,K2)***

Example of a FLUXT function call

```
TOTPOW = FLUXT(N100,N150,N20000,N21000)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

DOUBLE PRECISION **FLUXGL** ***(ZNODE1,MDL1,ZNODE2,MDL2)***

- ***Input:***
- *ZNODE1 : string describing the first group of node*
- *MDL1 : starting model for the ZNODE1 specification*
- *ZNODE2 : string describing the second group of node*
- *MDL2 : starting model for the ZNODE2 specification*
- ***Output:***
- *DOUBLE PRECISION FLUXGL: Conductive flux exchanged between the two groups of nodes*

- ***Description:***

This function computes the power exchanged conductively between two groups of nodes The following quantity is returned:

$$FLUXGL = \sum GL_{j,k} \left(T_k - T_j\right) \qquad \left(J \in G1,\ K \in G2\right)$$

Example of a FLUXGL function call

```
CONDPOW = FLUXGL('#100-200',CURRENT,'RADIATORS',CURRENT)
```

DOUBLE PRECISION **FLUXGR** ***(ZNODE1,MDL1,ZNODE2,MDL2)***

- ***Input:***
- *ZNODE1 : string describing the first group of node*
- *MDL1 : starting model for the ZNODE1 specification*
- *ZNODE2 : string describing the second group of node*
- *MDL2 : starting model for the ZNODE2 specification*
- ***Output:***
- *DOUBLE PRECISION FLUXGR: Radiative flux exchanged between the two groups of nodes*

- ***Description:***

This function computes the power exchanged radiatively between two groups of nodes. Two node numbers describe each group, involving all nodes having a number greater or less than the two specified numbers. The following quantity is returned:

$$FLUXGR = \sum \sigma\, GR_{j,k} \left(T_k^4 - T_j^4\right) \qquad \left(J \in G1,\ K \in G2\right)$$

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantity is returned:

$$FLUXGR = \sigma \sum_{j=J_1,J_2} \sum_{k=k_1,k_2} \left(\sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_k, \lambda_m, \lambda_{m+1})\right) T_k^4 - \sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1})\right) T_j^4 \right)$$

where $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

DOUBLE PRECISION **FLUXGR** ***(ZNODE1,MDL1,ZNODE2,MDL2)***

Example of a FLUXGR function call

```
RADPOW = FLUXGR('#100-200',CURRENT,'RADIATORS',CURRENT)
```

DOUBLE PRECISION **FLUXGF** ***(ZNODE1,MDL1,ZNODE2,MDL2)***

- ***Input:***
- *ZNODE1 : string describing the first group of node*
- *MDL1 : starting model for the ZNODE1 specification*
- *ZNODE2 : string describing the second group of node*
- *MDL2 : starting model for the ZNODE2 specification*
- ***Output:***
- *DOUBLE PRECISION FLUXGF: Convective flux exchanged between the two groups of nodes*

- ***Description:***

This function computes the power exchanged through one-way linear couplings between two groups of nodes. Two node numbers describe each group, involving all nodes having a number greater or less than the two specified numbers. The following quantity is returned:

$$FLUXGF = \sum GF_{j,k} \left(T_k - T_j\right) \qquad \left(J \in G1,\ K \in G2\right)$$

Example of a FLUXGF function call

```
CONVPOW = FLUXGF('#100-200',CURRENT,'RADIATORS',CURRENT)
```

DOUBLE PRECISION **FLUXGT** ***(ZNODE1,MDL1,ZNODE2,MDL2)***

- ***Input:***
- *ZNODE1 : string describing the first group of node*
- *MDL1 : starting model for the ZNODE1 specification*
- *ZNODE2 : string describing the second group of node*
- *MDL2 : starting model for the ZNODE2 specification*
- ***Output:***
- *DOUBLE PRECISION FLUXGT: Total flux exchanged between the two groups of nodes*

- ***Description:***

This function computes the power exchanged in all possible ways (conductive, radiative and linear one-way) between two groups of nodes. Two node numbers describe each group, involving all nodes having a number higher or below the two numbers specified. The following quantity is returned:

$$FLUXGT = \sum \left(GL_{j,k}\left(T_k - T_j\right) + \sigma\, GR_{j,k}\left(T_k^4 - T_j^4\right) + GF_{j,k}\left(T_k - T_j\right)\right) \quad \left(J \in G1, K \in G2\right)$$

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantity is returned:

DOUBLE PRECISION **FLUXGT** ***(ZNODE1,MDL1,ZNODE2,MDL2)***

$$FLUXGT = \sum_{j=j_1,j_2} \sum_{k=k_1,k_2} \left(\sigma \sum_{m=1,NWLBANDS} \left(GR_{i,j,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1}) \right) T_j^4 - \sigma \sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1}) \right) T_j^4 + GL_{j,k}(T_k - T_j) + GF_{j,k}(T_k - T_j) \right)$$

where $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

Example of a FLUXGT function call

```
TOTPOW= FLUXGT('#100-200',CURRENT,'RADIATORS',CURRENT)
```

DOUBLE PRECISION **FLUXML** ***(M1,M2)***

- ***Input:***
- *MODEL NAME M1: First model*
- *MODEL NAME M2: Second model*
- ***Output:***
- *DOUBLE PRECISION FLUXML: Conductive flux exchanged between model M1 and model M2*

- ***Description:***

This function computes the power exchanged conductively between two models or sub-models. The following quantity is returned:

$$FLUXML = \sum GL_{j,k}(T_k - T_j) \quad (j \in M1 \; ; \; k \in M2)$$

Example of FLUXML function call

```
CONDPOW = FLUXML(BATTERY,MARSIS:PLATE)
```

DOUBLE PRECISION **FLUXMR** ***(M1,M2)***

- ***Input:***
- *MODEL NAME M1: First model*
- *MODEL NAME M2: Second model*
- ***Output:***
- *DOUBLE PRECISION FLUXMR: Radiative flux exchanged between model M1 and model M2*

- ***Description:***

This function computes the power exchanged radiatively between two models or sub-models. The following quantity is returned:

$$FLUXMR = \sum \sigma GR_{j,k}(T_k^4 - T_j^4) \quad (j \in M1 \; ; \; k \in M2)$$

DOUBLE PRECISION FLUXMR *(M1,M2)*

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantity is returned:

$$FLUXMR = \sigma \sum_{j=j_1,j_2} \sum_{k=k_1,k_2} \left(\sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_k, \lambda_m, \lambda_{m+1}) \right) T_k^4 - \sum_{m=1,NWLBANDS} \left(GR_{j,k,m} \times FBAND(T_j, \lambda_m, \lambda_{m+1}) \right) T_j^4 \right)$$

where $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

Example of FLUXMR function call

```
RADPOW = FLUXMR(BATTERY,MARSIS:PLATE)
```

DOUBLE PRECISION FLUXMF *(M1,M2)*

- ***Input:***
- *MODEL NAME M1: First model*
- *MODEL NAME M2: Second model*
- ***Output:***
- *DOUBLE PRECISION FLUXMF: Convective flux exchanged between model M1 and model M2*

- ***Description:***

This function computes the power exchanged through one-way linear couplings between two models or sub-models. The following quantity is returned:

$$FLUXMF = \sum GF_{j,k}(T_k - T_j) \quad (j \in M1 \; ; \; k \in M2)$$

Example of FLUXMF function call

```
CONVPOW = FLUXMF(BATTERY,MARSIS:PLATE)
```

DOUBLE PRECISION TSINK *(ZNODE1,CNAME1,ZNODE2,CNAME2,TYPE,ERR)*

- ***Input:***
- *ZNODE1: Thermal group*
- *CNAME1: Submodel name for thermal group*
- *ZNODE2: Environment group*
- *CNAME2: Submodel name for environment group*
- *TYPE: Integer type of sink temperature required*
- *ERR: error code (integer)*
- ***Output:***
- *DOUBLE PRECISION TSINK: Sink temperature of thermal group*

DOUBLE PRECISION **TSINK** ***(ZNODE1,CNAME1,ZNODE2,CNAME2,TYPE,ERR)***

Description:

This function returns the sink temperature between a group of node (thermal group) and an environment. TYPE will define which kind of sink temperature calculation is to be used. It has to be one of the following integers:

1. *Black body radiation sink temperature*

$$T_{Sink,BBR} = \sqrt[4]{\frac{\sum_i \left(\sum_j \left(\sigma GR_{i,j} \left(T_j^4 - T_i^4 \right) \right) + QS_i + QA_i + QE_i + \sigma \varepsilon_i A_i T_i^4 \right)}{\sum_i \sigma \varepsilon_i A_i}}$$

2. *Grey body radiation sink temperature*

$$T_{Sink,GBR} = \sqrt[4]{\frac{\sum_i \left(\sum_j \left(\sigma GR_{i,j} T_j^4 \right) + QS_i + QA_i + QE_i \right)}{\sum_i \sum_j \sigma GR_{ij}}}$$

3. *Radiative sink temperature*

$$T_{Sink,R} = \sqrt[4]{\frac{\sum_i \left(\sum_j \left(GR_{i,j} T_j^4 \right) \right)}{\sum_i \sum_j GR_{ij}}}$$

4. *Linear sink temperature*

$$T_{Sink,L} = \frac{\sum_i \left(\sum_j GL_{i,j} T_j \right)}{\sum_i \sum_j GL_{ij}}$$

The ERR parameter must be defined as an INTEGER. The returned error is non-zero if the denominator is equal to 0:

- *If the type is 4, the error is 6.*
- *For other types, the error is 5.*

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantities are returned:

1. *Black body radiation sink temperature*

$$T_{Sink,BBR} = \sqrt[4]{\frac{\sum_i \left(\sum_j \left(\sum_m \left(GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right) \right) T_j^4 - \sum_m \left(GR_{i,j,m} \times FBAND\left(T_i, \lambda_m, \lambda_{m+1}\right) \right) T_i^4 \right) + \frac{1}{\sigma} \left(QS_i + QA_i + QE_i \right) + \varepsilon_i A_i T_i^4 \right)}{\sum_i \varepsilon_i A_i}}$$

2. *Grey body radiation sink temperature*

DOUBLE PRECISION **TSINK** ***(ZNODE1,CNAME1,ZNODE2,CNAME2,TYPE,ERR)***

$$T_{Sink,GBR} = \sqrt[4]{\frac{\sum_i \left(\sum_j \left(\sum_m \left(GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right)\right) T_j^4\right)\right) + \frac{1}{\sigma}(QS_i + QA_i + QE_i)}{\sum_i \sum_j \sum_m \left(GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right)\right)}}$$

3. *Radiative sink temperature*

$$T_{Sink,R} = \sqrt[4]{\frac{\sum_i \left(\sum_j \left(\sum_m \left(GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right)\right) T_j^4\right)\right)}{\sum_i \sum_j \sum_m \left(GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right)\right)}}$$

4. *Linear sink temperature*

$$T_{Sink,L} = \frac{\sum_i \left(\sum_j GL_{i,j}\ T_j\right)}{\sum_i \sum_j GL_{ij}}$$

where $\sum_m$ *means* $\sum_{m=1,NWLBANDS}$ *and* $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

Example of a TSINK function call

```
TS = TSINK('#10-20',CURRENT, '#50-60', CURRENT, 3, ERR)
```

DOUBLE PRECISION **TSINKN** ***(NODE,ERR)***

- ***Input:***
- *NODE: Node concerned*
- *INTEGER ERR: error code*
- ***Output:***
- *DOUBLE PRECISION TSINKN: Sink temperature of NODE*

This function returns the sink temperature of a node. The sink temperature is used to explain in a different way the thermal environment of a node: it is the temperature of a "virtual" node, which radiatively exchanges the same energy as the total energy exchanged by the node with its complex environment (including internal powers):

$$\sigma \sum_j GRi_j \left(TSINK^4 - T_i^4\right) = \Phi_i$$

where Φ_i *is the power exchanged between the node and its environment:*

$$\Phi_i = \sum_j \left(GL_{i,j}(T_j - T_i) + \sigma\, GR_{i,j}\left(T_j^4 - T_i^4\right) + GF_{i,j}(T_j - T_i)\right) + QS + QA + QE + QL + QR$$

Hence, the following quantity returned:

$$TSINK = \sqrt[4]{T_i^4 + \frac{\Phi_i}{\sigma \sum_j GR_{i,j}}}$$

DOUBLE PRECISION **TSINKN** ***(NODE,ERR)***

The ERR parameter must be defined as an INTEGER. The returned error is 1 if the sum of the GR is zero. It is 0 otherwise.

This function can be used for systems with wavelength dependent thermo-optical properties. In that case, the following quantity is returned:

$$T_{Sink} = \sqrt[4]{T_i^4 + \frac{\phi_i}{\sum_j \sum_m \left(\sigma GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right)\right)}}$$

where

$$\phi_i = \sum_j \left(\sum_{m=1,NWLBANDS} \left(\sigma GR_{i,j,m} \times FBAND\left(T_j, \lambda_m, \lambda_{m+1}\right)\right) T_j^4 - \sum_m \left(\sigma GR_{i,j,m} \times FBAND\left(T_i, \lambda_m, \lambda_{m+1}\right)\right) T_i^4 + GL_{i,j}\left(T_j - T_i\right) + GF_{i,j}\left(T_j - T_i\right) \right) + \left(QS_i + QA_i + QE_i + QI_i + QR_i\right)$$

and $FBAND(T, \lambda_1, \lambda_2)$ *gives the fraction of energy radiated between* λ_1 *and* λ_2 *for a blackbody at temperature T.*

Example of a TSINKN function call

```
TS = TSINKN(N100, ERR)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

WARNING:

This function was previously known as TSINK but due to ESATAN incompatible definitions, this function has been renamed TSINKN.

However for the compatibility with previous version, THERMISOL automatically recognizes this function even if written at TSINK by checking the number of arguments.

DOUBLE PRECISION **GETCSG*(N1)***

- ***Input:***
- *NODE N1: Node designation*
- ***Output:***
- *DOUBLE PRECISION GETCSG: CSG value of the node.*

- ***Description:***

This function returns the CSG value of a node.

Example of a GETCSG function call

```
CSG = GETCSG(N100)
```

Older syntax 'D100', 'B100' or 'X100' can be used instead of the normalized one 'N100'

Interpolation routines

DOUBLE PRECISION **INTRP1** ***(X,ARR,N)***

- ***Input:***
- *DOUBLE PRECISION X: Independent variable*
- *ARR: User array of size (2,n) (DOUBLE PRECISION values)*
- *INTEGER N: interpolation order*
- ***Output:***
- *DOUBLE PRECISION INTRP1: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user array. The array must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type), and must have 2 columns (size 2,n).
The independent variable X is used to scan the 1st column of the ARR array. The interpolation order N may be 0 (constant result over the interval), 1 (for linear interpolation) or 2 (for quadratic interpolation).

Example of a INTRP1 function call

```
QS100 = INTRP1(120.0D0, SOL100, 1)
```

In this example, the solar flux of node 100 (QS100) is the result of the interpolation in the SOL100 user array for the time 120s. The first column of SOL100 contains some time steps and the second column contains the corresponding values for solar flux.

DOUBLE PRECISION **INTRP2** ***(X,Y,TAB,N)***

- ***Input:***
- *DOUBLE PRECISION X,Y: Independent variables*
- *TAB: User Table array with 2 independent variables*
- *INTEGER N: interpolation order*
- ***Output:***
- *DOUBLE PRECISION INTRP2: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user table array. The table array must be defined in the $TABLES definition paragraph, with 2 independent variables.
The independent variables X and Y are used to scan the 1st and 2nd columns respectively of the TAB table.
The interpolation order N may be 0 or 1. The order 0 is however not recommended on tables not defined as matrix.
The second order is not supported.

Example of a INTRP2 function call

```
C100 = INTRP2(TIMEN, T100, CAPTAB100, 1)
```

In this example, the capacitance of node 100 (C100) is the result of the interpolation in the CAPTAB100 user table which describes a capacitance depending on temperature (T100) and time (TIMEN).

DOUBLE PRECISION* INTRP3 *(X,Y,Z,TAB,N)

- ***Input:***
- *DOUBLE PRECISION X,Y,Z: Independent variables*
- *TAB: User Table array with 3 independent variables*
- *INTEGER N: interpolation order*
- ***Output:***
- *DOUBLE PRECISION INTRP3: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user table array. The table array must be defined in the $TABLES definition paragraph, with 3 independent variables. The independent variables X, Y and Z are used to scan the 1st, 2nd and 3rd columns respectively of the TAB table. The interpolation order N may be 0 or 1. The order 0 is however not recommended on tables not defined as matrix. The second order is not supported.

Example of a INTRP3 function call

```
V = INTRP3(X, Y, Z, TAB, 1)
```

DOUBLE PRECISION* INTERP *(X,ARRX,ARRY,N)

- ***Input:***
- *DOUBLE PRECISION X: Independent variable*
- *ARRX: User array of size (1,n) (DOUBLE PRECISION values)*
- *ARRY: User array of size (1,n) (DOUBLE PRECISION values)*
- *INTEGER N: interpolation order*
- ***Output:***
- *DOUBLE PRECISION INTERP: Result of the interpolation*

- ***Description:***

This function performs a linear interpolation over an ARRY user array. The ARRX and ARRY arrays must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type), and must have 1 column (size 1,n) and the same size. The independent variable X is used to scan the ARRX array, while the interpolation is performed into ARRY to return the output value. The interpolation order N may be 0 (constant result over the interval), 1 (for linear interpolation) or 2 (for quadratic interpolation).

Example of an INTERP function call

```
QS100 = INTERP(TIMEN, TIMEARRAY, SOLFLX100ARRAY, 1)
```

In this example, the solar flux of node 100 (QS100) is the result of the interpolation in the SOLFLX100ARRAY user array for the TIMEN time. The TIMEARRAY contains a list of time values, and SOLFLX100ARRAY contains the values of solar flux for node 100 for the same time values.
This function is useful for big models where the user can store the time steps in only one array and all the fluxes in separate arrays without redundant copies of all the time steps (on the contrary, the INTRP1 function requires that all the times and values be stored in the same array).

DOUBLE PRECISION **INTRPA** ***(X,ARR,N)***

- ***Input:***
- *DOUBLE PRECISION X: Independent variable*
- *ARR: User array of size (1,n) (DOUBLE PRECISION values)*
- *INTEGER N: interpolation order*
- ***Output:***
- *DOUBLE PRECISION INTRPA: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user array. The array must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type) and must have 1 column (size 1,n). The ARR array must have a special format: xstart, deltax, y1, y2, … , yend. The first two values (xstart and deltax) describe the way the independent variale X must be used to scan the array ARR: y1 corresponds to xstart, y2 corresponds to (xstart+deltax), y3 corresponds to (xstart+2deltax), … This allow to obtain a result more rapidly than in the other interpolation routines. The independent variable X is used to scan the array ARR from its 3rd value. Only the 0 and 1 interpolation order N are supported by this function.

Example of an INTRPA function call

```
GL(100,200) = INTRPA((T100+T200)/2.0D0, COUPL, 1)
```

In this example, the conductive coupling between nodes 100 and 200 is interpolated from the COUPL table containing coupling values for temperatures starting from –20°C with a 5°C step. The independent variable input to the routine is the mean temperature of the two nodes.

DOUBLE PRECISION **INTCY1** ***(X,ARR,N,PERIOD,SHIFT)***

- ***Input:***
- *DOUBLE PRECISION X: Independent variable*
- *ARR: User array of size (2,n) (DOUBLE PRECISION values)*
- *INTEGER N: interpolation order*
- *DOUBLE PRECISION PERIOD, SHIFT: period and shift concerning the independent variable X*
- ***Output:***
- *DOUBLE PRECISION INTCY1: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user array, assuming a periodic problem concerning the independent variable X. The array must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type), and must have 2 columns (size 2,n). The independent variable X is used to scan the 1st column of the array ARR. This variable is shifted and reduced to a value within one period, i.e. the interpolation is performed considering MOD(X+SHIFT,PERIOD) as an input. The PERIOD and SHIFT parameters must be defined as REAL to be taken into account. The interpolation order N may be 0 (constant result over the interval), 1 (for linear interpolation) or 2 (for quadratic interpolation). It is worth mentioning that, for a steady analysis, the INTCY1 function returns an average value of the second column of the array ARR.

Example of an INTCY1 function call

```
QS100 = INTCY1(80000.0D0, SOL100, 1, 14400.0D0, 0D0)
```

DOUBLE PRECISION **INTCY1** ***(X,ARR,N,PERIOD,SHIFT)***

In this example, the solar flux of node 100 (QS100) is the result of the interpolation in the user array SOL100 for the time 80000s. The solar fluxes are known only for a 14400s = 4 hour orbital period. A periodic interpolation will therefore be performed. The first column of SOL100 contains time steps and the second column contains the corresponding values for solar flux.

DOUBLE PRECISION **INTCY2** ***(X,Y,TAB,N,PERIOD,SHIFT)***

- ***Input:***
- *DOUBLE PRECISION X,Y: Independent variables*
- *TAB: User Table array with 2 independent variables*
- *INTEGER N: interpolation order*
- *DOUBLE PRECISION PERIOD, SHIFT: period and shift concerning the independent variable X*
- ***Output:***
- *DOUBLE PRECISION INTCY2: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user table array, assuming a periodic problem concerning the independent variable X. The table array must be defined in the $TABLES definition paragraph, with 2 independent variables. The time must be the first variable of the table. The independent variables X and Y are used to scan the 1^{st} and 2^{nd} columns respectively of the TAB table. The variable X is shifted and reduced to a value within one period, i.e. the interpolation is performed considering MOD(X+SHIFT,PERIOD) as an input. The PERIOD and SHIFT parameters must be defined as REAL to be taken into account. The interpolation order N may be 0 or 1. The order 0 is however not recommended on tables not defined as matrix. The second order is not supported.

Example of an INTCY2 function call

```
C100 = INTCY2(TIMEN, T100, CAPTAB100, 1, PERIO1, 0FFST)
```

In this example, the capacitance of node 100 (C100) is the result of the interpolation in the CAPTAB100 user table which describes a capacitance depending on temperature (T100) and time (TIMEN). This concerns the modeling of a periodic time-dependent problem with a period PERIO1. The CAPTAB100 table is thus periodic with respect to time.

DOUBLE PRECISION **INTCY3** ***(X,Y,Z,TAB,N,PERIOD,SHIFT)***

- ***Input:***
- *DOUBLE PRECISION X,Y,Z: Independent variables*
- *TAB: User Table array with 3 independent variables*
- *INTEGER N: interpolation order*
- *DOUBLE PRECISION PERIOD, SHIFT: period and shift concerning the independent variable X*
- ***Output:***
- *DOUBLE PRECISION INTCY3: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user table array, assuming a periodic problem concerning the independent variable X. The table array must be defined in the $TABLES definition paragraph, with 3 independent variables. The time must be the first variable of the table. The independent variables X, Y and Z are used to scan the

DOUBLE PRECISION **INTCY3** ***(X,Y,Z,TAB,N,PERIOD,SHIFT)***

1st, 2nd and 3rd columns respectively of the TAB table. The variable X is shifted and reduced to a value within one period, i.e. the interpolation is performed considering MOD(X+SHIFT,PERIOD) as an input. The PERIOD and SHIFT parameters must be defined as REAL to be taken into account. The interpolation order N may be 0 or 1. The order 0 is however not recommended on tables not defined as matrix. The second order is not supported.

Example of an INTCY3 function call

```
V = INTCY3(TIMEN, Y, Z, TAB, 1, PERIO1, 0FFST)
```

DOUBLE PRECISION **INTCYC** ***(X,ARRX,ARRY,N,PERIOD,SHIFT)***

- ***Input:***
- *DOUBLE PRECISION X: Independent variable*
- *ARRX: User array of size (1,n) (DOUBLE PRECISION values)*
- *ARRY: User array of size (1,n) (DOUBLE PRECISION values)*
- *INTEGER N: interpolation order*
- *DOUBLE PRECISION PERIOD, SHIFT: period and shift concerning the independent variable X*
- ***Output:***
- *DOUBLE PRECISION INTCYC: Interpolation result.*

- ***Description:***

This function performs a linear interpolation over a user array ARRY, assuming a periodic problem concerning the independent variable X. The ARRX and ARRY arrays must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type), must have 1 column (size 1,n) and must have the same size. The independent variable X is used to scan the ARRX array, while the interpolation is performed into ARRY to return the output value. The variable X is shifted and reduced to a value within one period, i.e. the interpolation is performed considering MOD(X+SHIFT,PERIOD) as an input. The PERIOD and SHIFT parameters must be defined as REAL to be taken into account. The interpolation order N may be 0 (constant result over the interval), 1 (for linear interpolation) or 2 (for quadratic interpolation). It is worth mentioning that, for a steady analysis, the INTCYC function returns an average value of the array ARRY.

Example of an INTCYC function call

```
QS100 = INTCYC(TIMEN, TIMEARR, SOLFLX100ARR, 1, 14400.0D0, 0D0)
```

In this example, the solar flux of node 100 (QS100) is the result of the interpolation in the SOLFLX100ARR user array for the time TIMEN. The TIMEARR array contains a list of time values, and the array SOLFLX100ARR contains the values of solar flux for node 100 for the same time values. The problem is periodic, with a 14400s period.

DOUBLE PRECISION **NODFNC** ***(TYPE, ANAME|USRFNC[,N])***

- ***Input:***

DOUBLE PRECISION **NODFNC** ***(TYPE, ANAME|USRFNC[,N])***

- *TYPE: Integer (1: Lagrangian interpolation; 2: Function evaluation)*
- *ANAME: ARRAY name (if TYPE=1)*
- *USRFNC: Double Precision user function*
- *N: interpolation order (if TYPE=1)*
- ***Output:***
- *DOUBLE PRECISION NODFNC: Interpolation result.*

- ***Description:***

NODFNC provides a shorthand way of defining nodal entities which depend on temperature, such as capacitance or emissivity. This function removes the need for the user to supply the nodal temperature reference explicitly. It is not actually a function in its own right, but a reference to it in the $NODES block its translated by the pre-processor into a call to an appropriate underlying function. If TYPE=1 (interpolation mode), ANAME may be either a 2xN real array or a table array with one independent variable, containing (temperature, property) pairs. If TYPE=2 (function mode), USRFNC may be defined in the $SUBROUTINES block or may be contained in an external library. In either case the function must take a double precision input (temperature).

Example of an NODFNC function call

```
$NODES
D23, T=26.65, C=RHOX*NODFNC(1, SPECHT, 1);
D24, T=26.65, C=RHOX*NODFNC(2, MYFUNC);
```

Those declarations are equivalent to:
D23, T=26.65, C=RHOX*INTRP1(T23, SPECHT, 1);
D24, T=26.65, C=RHOX*MYFUNC(T24);

DOUBLE PRECISION **CNDFNC** ***(TYPE, ANAME|USRFNC[,N])***

- ***Input:***
- *TYPE: Integer (1: Lagrangian interpolation; 2: Function evaluation;3: Trapezoidal interpolation)*
- *ANAME: ARRAY name (if TYPE=1,3)*
- *USRFNC: Double Precision user function (if TYPE=2)*
- *N: interpolation order (if TYPE=1)*
- ***Output:***
- *DOUBLE PRECISION CNDFNC: Interpolation result.*

- ***Description:***

CNDFNC provides a shorthand way of defining couplings which depend on the average temperature of the two nodes. This function removes the need for the user to supply the nodal temperature reference explicitly.
It is not actually a function in its own right is translated by the pre-processor into a call to an appropriate underlying function.
If TYPE=1 or 3 (interpolation mode), ANAME may be either a 2xN real array or a table array with one independent variable, containing (temperature, property) pairs.
If TYPE=2 (function mode), USRFNC may be defined in the $SUBROUTINES block or may be contained in an external library. In either case the function must take a double precision input (temperature)

Example of an CNDFNC function call

DOUBLE PRECISION **CNDFNC** ***(TYPE, ANAME|USRFNC[,N])***

```
$CONDUCTORS
GL(2,3) = CNDFNC(1,CONDX,1)*CSA/DX;
GL(2,3) = CNDFNC(2,MYFUNC)*CSA/DX;
GL(2,3) = CNDFNC(3,MYARR)*CSA/DX;
```

Those declarations are equivalent to:
GL(2,3) = INTRP1((T2+T3)/2.0,CONDX,1)*CSA/DX;
GL(2,3) = MYFUNC((T2+T3)/2.0)*CSA/DX;
GL(2,3) = (INTGL1(T2,T3,MYARR)/(T3-T2))*CSA/DX;

Mathematical routines

DOUBLE PRECISION INTGL1(X1,X2,ARR)

- ***Input:***
- *DOUBLE PRECISION X1, X2: Limits of integration interval*
- *ARR: User array of size (2,n) (DOUBLE PRECISION values)*
- ***Output:***
- *DOUBLE PRECISION INTGL1: Integration result*
- ***Description:***

This function performs an integration over a user array. The array must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type), and must have 2 columns (size 2,n). The independent variable used for the integration from X1 to X2 corresponds to the 1st column of the ARR array.
Example of an INTGL1 function call
TPS = INTGL1(0.0D0, 120.0D0, SOLARR)

In this example, the TPS variable is used to store the result of the integration from 0 to 120 in the SOLARR user array.

DOUBLE PRECISION INTEGL(X1,X2,XARR,YARR)

- ***Input:***
- *DOUBLE PRECISION X1, X2: Limits of integration interval*
- *XARR, YARR: User array of size (1,n) (DOUBLE PRECISION values)*
- ***Output:***
- *DOUBLE PRECISION INTGL: Integration result*
- ***Description:***

This function performs an integration over a user array. The arrays must be defined in the $ARRAYS definition paragraph (in a $REAL sub-paragraph to specify the DOUBLE PRECISION type), and must each have 1 column (size 1,n). The independent variable used for the integration from X1 to X2 corresponds to the 1st array XARR while the values of the function are in the 2nd array YARR.
Example of an INTGL1function call
TPS = INTEGL(0.0D0, 120.0D0, TIMES, SOLARR)

SUBROUTINE THRMST(T,THIGH,TLOW,STATUS)

- ***Input:***

- *DOUBLE PRECISION T: Temperature*
- *DOUBLE PRECISION THIGH: High temperature threshold*
- *DOUBLE PRECISION TLOW: Low temperature threshold*
- ***Output:***
- *INTEGER STATUS: Thermostat status*
- ***Description:***

This subroutine simulates a basic thermostat:

- STATUS is set to 1 if T <= TLOW
- STATUS is set to 0 if T >= THIGH
- STATUS is unchanged if TLOW < T < THIGH

Example of a THRMST subroutine call

CALL THRMST(T100,25.0D0,0.0D0,STAT)

The THRMST subroutine should be called in the $VRESULT paragraph.

DOUBLE PRECISION THSTAT(INODE,THIGH,TLOW,POWER)

- ***Input:***
- *NODE ID INODE: Node reference to control and apply the thermostat dissipation*
- *DOUBLE PRECISION THIGH: High temperature threshold*
- *DOUBLE PRECISION TLOW: Low temperature threshold*
- *DOUBLE PRECISION POWER: Thermostat dissipation*
- ***Output:***
- *DOUBLE PRECISION THSTAT: Current thermostat dissipation*
- ***Description:***

This subroutine simulates a thermostat like the THRMST function exept that it is suitable for steady-state and transient cases.

It may return a value ON or OFF (dissipation equal to zero or to POWER) but also an intermediate value in steady-state cases corresponding to the duty cycle of the heater so to maintain the average temperature of the heater.

This routine can only be used with an identical control and dissipative node (use the version THSTAT2 in other cases).

This routine can be used with only one control node (use the version THSTAT3 for 3 control nodes).

Example of a THSTAT subroutine call

QR100 = THSTAT(N100,25.0D0,0.0D0,50.0D0)

The THSTAT subroutine should be called in the $VTEMPERATURE paragraph.

A basic example below shows the interest of the THSTAT routine compared to the THRMST function. Let's consider the following basic model:

$NODES

B 100 = ' ', T= 10.000, A= 0.000E+000, C= 0.0000E+000, ALP= 0.0000E+000, EPS= 0.0000E+000;

D 200 = ' ', T= 25.000, A= 0.000E+000, C= 1.0000E+000, ALP= 0.0000E+000, EPS= 0.0000E+000;

$CONDUCTORS

GL(100,200)= 1.D0;

Node 100 is a boundary node with a fixed temperature set to 10°C. Node 200 is a diffusive node with an initial temperature set to 25°C. These two nodes are linked by a conductive coupling. A transient analysis of this model shows that the temperature of node 200 tends to 10°C. It is possible to add a thermostat applied on node 200 to

impose a temperature value between 20°C and 25°C. This can be done using the THRMST routine or the THSTAT routine:

$VARIABLES

INTEGER* THSTS = 0;

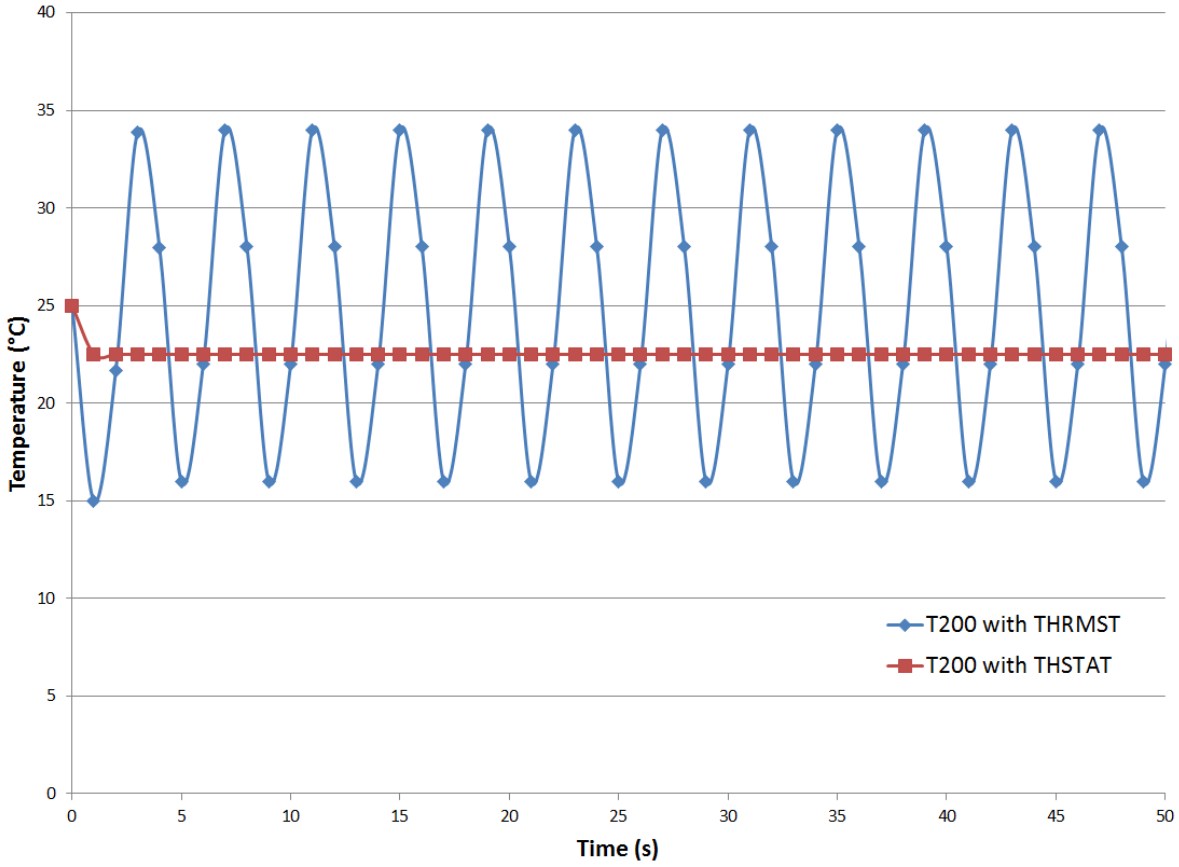
REAL* THPOW = 30.0;

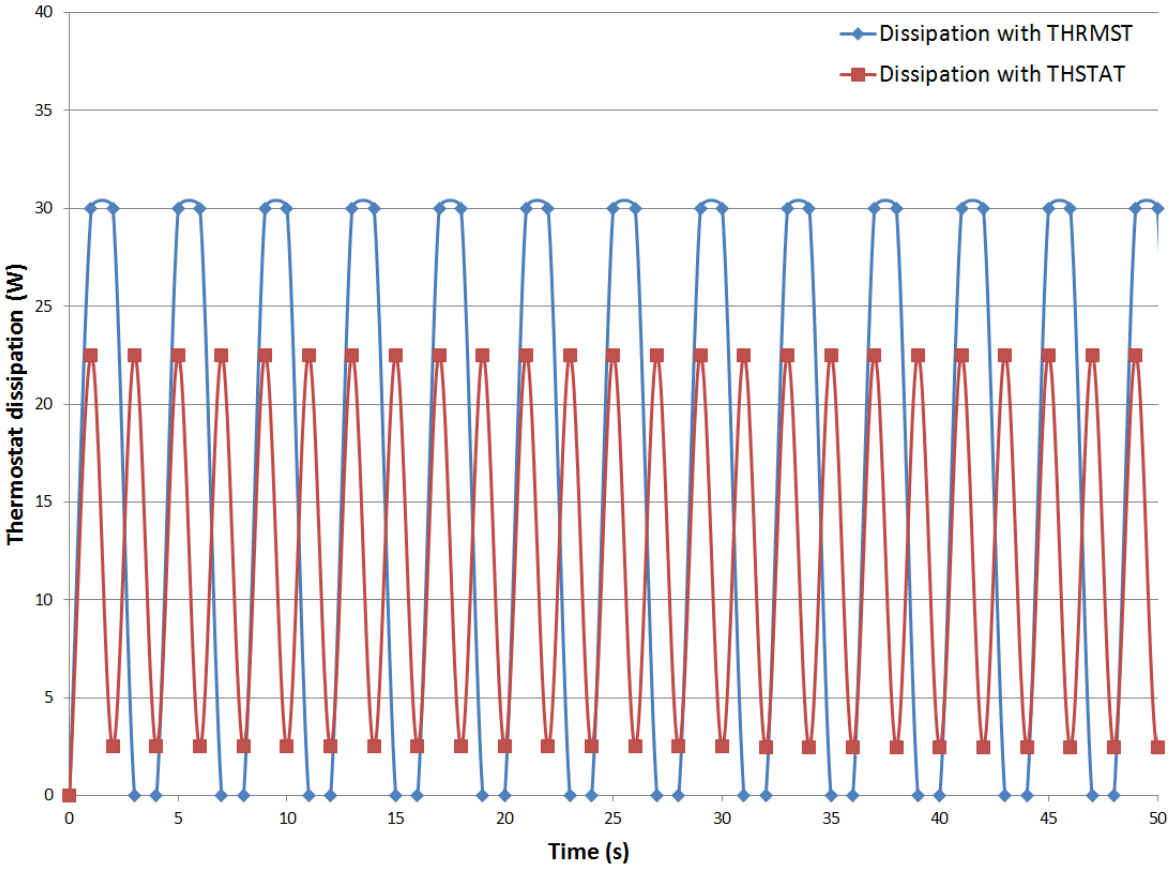
REAL* THMIN = 20.0;

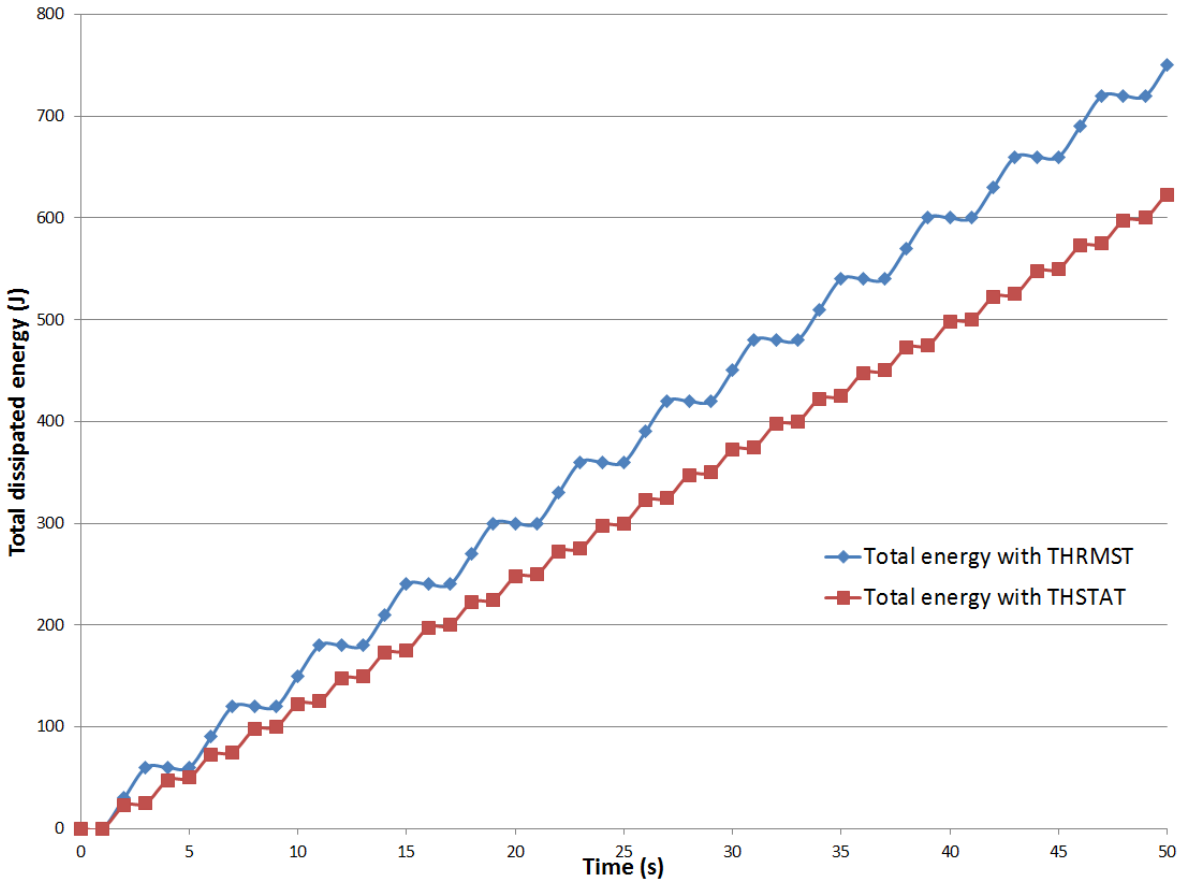
REAL* THMAX = 25.0;

THRMST routine	**THSTAT routine**
$VRESULTS CALL THRMST(T200, THMAX, THMIN, THSTS) QR200 = THSTS * THPOW	$VTEMPERATURES QR200 = THSTAT(N200, THMAX, THMIN, THPOW)

The results obtained after a transient analysis are given in the figures below. We can see that the THSTAT routine allows to better reach the target temperature value with less dissipated power. The THRMST routine overestimates the power needed to reach the target value.







DOUBLE PRECISION THSTAT2(INODE,THIGH,TLOW,POWER,QR)

- ***Input:***
- *NODE ID INODE: Node reference to control the thermostat*
- *DOUBLE PRECISION THIGH: High temperature threshold*
- *DOUBLE PRECISION TLOW: Low temperature threshold*
- *DOUBLE PRECISION POWER: Thermostat dissipation*
- *DOUBLE PRECISION QR: Dissipation currently applied*
- ***Output:***
- *DOUBLE PRECISION THSTAT2: Current thermostat dissipation*
- ***Description:***

This subroutine simulates a thermostat like the THRMST function exept that it is suitable for steady-state and transient cases.

It may return a value ON or OFF (dissipation equal to zero or to POWER) but also an intermediate value in steady-state cases corresponding to the duty cycle of the heater so to maintain the average temperature of the heater.

This routine can be used with only one control node (use the version THSTAT3 for 3 control nodes).

Examples of a THSTAT2 subroutine call

HPOW = THSTAT2(N100,25.0D0,0.0D0,50.0D0, QR110)

QR110 = THSTAT2(N100,25.0D0,0.0D0,50.0D0, QR110)

Please note that the two example are different. The first example only give the information of what should be the dissipation to applied on node 110 (only post-processing) whereas the dissipation is effectively applied on node 110 in the second example.

The THSTAT2 subroutine should be called in the $VTEMPERATURE paragraph.

DOUBLE PRECISION THSTAT3(INODE1,INODE2,INODE3,THIGH,TLOW,POWER,QR)

- ***Input:***
- *NODE ID INODE1, INODE2, INODE3: Node reference to control the thermostat*
- *DOUBLE PRECISION THIGH: High temperature threshold*
- *DOUBLE PRECISION TLOW: Low temperature threshold*
- *DOUBLE PRECISION POWER: Thermostat dissipation*
- *DOUBLE PRECISION QR: Dissipation currently applied*
- ***Output:***
- *DOUBLE PRECISION THSTAT3: Current thermostat dissipation*
- ***Description:***

This subroutine identifies the node (INODE1, INODE2 or INODE3) corresponding to the median temperature value and calls the THSTAT2 subroutine with the median node as input.

Example of a THSTAT3 subroutine call

HPOW = THSTAT3(N100,N101,N102,25.0D0,0.0D0,50.0D0, QR110)

The THSTAT3 subroutine should be called in the $VTEMPERATURE paragraph.

DOUBLE PRECISION STEADYQR(INODETM,INODETH,TOBJ,TLOW,POWER,RELAX)

- ***Input:***
- *NODE ID INODETM: Node reference to control and apply the dissipation*
- *NODE ID INODETH: Node reference to thermostat*
- *DOUBLE PRECISION TOBJ: Objective temperature*
- *DOUBLE PRECISION TLOW: Low temperature threshold*
- *DOUBLE PRECISION POWER: Thermostat dissipation*
- *DOUBLE PRECISION RELAX: Relaxation criteria*
- ***Output:***
- *DOUBLE PRECISION STEADYQR: Current thermostat dissipation*
- ***Description:***

This subroutine simulates a thermostat like the THRMST function except that it is suitable for steady-state cases.

Note: POWER must be a high value to achieve the objective temperature

It will return an intermediate value corresponding to the duty cycle of the heater so to maintain the average temperature of the heater.

Example of a *STEADYQR* subroutine call

QR110 = STEADYQR(N100, N110, 12.5D0, 0.0D0, 1000.0D0, 0.0001D0)

The STEADYQR subroutine should be called in the $VTEMPERATURE paragraph.

INTEGER ADIM(ARRAY)

- ***Input:***
- *ARRAY: User array name*
- ***Output:***
- *INTEGER ADIM: User array dimension*
- ***Description:***

This function returns the dimension of a user array: 1 or 2 dimensions.

Example of an ADIM function call

DIMENSION = ADIM(MYARRAY)

INTEGER ADIMVL(ARRAY,N)

- ***Input:***
- *ARRAY: User array name*
- *INTEGER N: Dimension for which the size is requested*
- ***Output:***
- *INTEGER ADIMVL: Size of the Nth dimension of the array*
- ***Description:***

This function returns the size of the Nth dimension for a user array.
Example of an ADIMVL function call
DIMENSION = ADIM(MYARRAY,2)

NTEGER ASIZE(ARRAY)

- ***Input:***
- *ARRAY: User array name*
- ***Output:***
- *INTEGER ASIER: User array size*
- ***Description:***

This function returns the size of the user array: total number of elements.
Example of an ASIZE function call
SIZE = ASIZE(MYARRAY)

SUBROUTINE ACONST(ARRAY,VALUE)

- ***Input:***
- *ARRAY: User array name (integer or double precision)*
- *VALUE: Value to be set (integer or double precision)*
- ***Output:***
- *ARRAY: Updated user array*
- ***Description:***

This subroutine sets all the elements of ARRAY to VALUE.
Example of an ACONST subroutine call
CALL ACONST(MYARRAY, 23.2D0)

SUBROUTINE AELCPY(ARRAY1,ARRAY2)

- ***Input:***
- *ARRAY1: User array name (integer or double precision)*
- ***Output:***
- *ARRAY2: Name of the resulting user array (integer or double precision)*
- ***Description:***

This subroutine copies all the elements of ARRAY1 to ARRAY2.
Example of an AELCPY subroutine call
CALL AELCPY(MYARRAY1, MYARRAY2)

SUBROUTINE AELADD(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the addition ARRAY3 = ARRAY1 + ARRAY2, element by element.
Example of an AELADD subroutine call
CALL AELADD(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELSUB(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the difference ARRAY3 = ARRAY1 - ARRAY2, element by element.
Example of an AELSUB subroutine call
CALL AELSUB(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELMLT(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the multiplication ARRAY3 = ARRAY1 × ARRAY2, element by element. This is not a classical matrix product.
Example of an AELMLT subroutine call
CALL AELMLT(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELDIV(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the division ARRAY3 = ARRAY1/ARRAY2, element by element. This has nothing to do with the classical matrix inversion.
Example of an AELDIV subroutine call
CALL AELDIV(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELINV(ARRAY1,ARRAY2)

- ***Input:***
- *ARRAY1: Name of the user array (double precision)*
- ***Output:***
- *ARRAY2: Name of the user array storing the result (double precision)*
- ***Description:***

This subroutine performs the inversion ARRAY2 = 1/ARRAY1, element by element. This has nothing to do with the classical matrix inversion.

Example of an AELINV subroutine call

CALL AELINV(MYARRAY1, MYARRAY2)

SUBROUTINE AELGT(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the logical comparison ARRAY1 > ARRAY2, element by element. If the logical comparison returns TRUE, the value of the element of ARRAY3 is set to the corresponding element of ARRAY1; if FALSE is returned, the element of ARRAY3 is set to 0.

Example of an AELGT subroutine call

CALL AELGT(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELGE(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the logical comparison ARRAY1 ≥ ARRAY2, element by element. If the logical comparison returns TRUE, the value of the element of ARRAY3 is set to the corresponding element of ARRAY1; if FALSE is returned, the element of ARRAY3 is set to 0.

Example of an AELGE subroutine call

CALL AELGE(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELLT(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the logical comparison ARRAY1 < ARRAY2, element by element. If the logical comparison returns TRUE, the value of the element of ARRAY3 is set to the corresponding element of ARRAY1; if FALSE is returned, the element of ARRAY3 is set to 0.

Example of an AELLT subroutine call

CALL AELLT(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELLE(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the logical comparison ARRAY1 ≤ ARRAY2, element by element. If the logical comparison returns TRUE, the value of the element of ARRAY3 is set to the corresponding element of ARRAY1; if FALSE is returned, the element of ARRAY3 is set to 0.

Example of an AELLE subroutine call

CALL AELLE(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELEQ(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the logical test ARRAY1 = ARRAY2, element by element. If the logical test returns TRUE, the value of the element of ARRAY3 is set to the corresponding element of ARRAY1; if FALSE is returned, the element of ARRAY3 is set to 0.

Example of an AELEQ subroutine call

CALL AELGT(MYARRAY1, MYARRAY2, MYARRAY3)

SUBROUTINE AELNE(ARRAY1,ARRAY2,ARRAY3)

- ***Input:***
- *ARRAY1: Name of the first user array (integer or double precision)*
- *ARRAY2: Name of the second user array (integer or double precision)*
- ***Output:***
- *ARRAY3: Name of the user array storing the result (integer or double precision)*
- ***Description:***

This subroutine performs the logical test ARRAY1 ≠ ARRAY2, element by element. If the logical test returns TRUE, the value of the element of ARRAY3 is set to the corresponding element of ARRAY1; if FALSE is returned, the element of ARRAY3 is set to 0.

Example of an AELNE subroutine call

CALL AELNE(MYARRAY1, MYARRAY2, MYARRAY3)

Nodal network management routines

SUBROUTINE STATST(ENTITY,STATUS)

- ***Input:***
- *ENTITY: Node or conductor*
- *STATUS: Status to apply to the node or conductor*
- ***Description:***

This subroutine is used to change the status of a node or a conductor. The possible statuses for a node are: 'B' (boundary), 'D' (diffusive) or 'X' (inactive). The possible statuses for a conductor are: 'ON' (active) or 'OFF' (inactive).

Example of a STATST subroutine call

```
CALL STATST('N300','X')
CALL STATST(GL(200,1000),'OFF')
```

Since version 4.3.1 the STATST routine can be replaced by a direct Mortran syntax:

```
NS 300 = 'X' GLS(200,1000) = 'X'
```

For couplings, the values are 'A' for active and 'X' for inactive.

CHARACTER*3 STATRP(ENTITY)

- ***Input:***
- *ENTITY: Node, conductor or model*
- ***Output:***
- *CHARACTER*3 STATRP: Entity status*
- ***Description:***

This function returns the status of a node, a conductor or a model. The possible statuses for a node are: 'B' (boundary), 'D' (diffusive) or 'X' (inactive). The possible statuses for a conductor are: 'ON' (active) or 'OFF' (inactive). The possible statuses for a model are: 'ON' (active) or 'OFF' (inactive).

Example of a STATRP function call

```
ST = STATRP('D300')
 WRITE(*,*) 'Coupling status = ', STATRP(GL(200,1000))
```

Since version 4.3.1 the STATRP routine can be replaced by a direct Mortran syntax:

```
NS 300 GLS(200,1000)
```

For couplings, the values are 'A' for active and 'X' for inactive (and not 'ON' or 'OFF')

SUBROUTINE MDLON(MODEL)

- ***Input:***
- *MODEL: Model to be activated*
- ***Output:*** *none*
- ***Description:***

This subroutine is used to activate a model, by changing the status of the model to 'ON'. The status of the nodes in this model is not changed: the boundary/diffusive/inactive nodes remain the same.

Example of a MDLON subroutine call

```
CALL MDLON(BATERRY)
```

SUBROUTINE MDLOFF(MODEL)

- ***Input:***

- *MODEL: Model to be deactivated*
- ***Output:*** *none*
- ***Description:***

This subroutine is used to deactivate a model, by changing the status of the model to 'OFF'. The status of the nodes in this model is not changed: the boundary/diffusive/inactive nodes remain the same.

Example of a MDLOFF subroutine call

```
CALL MDLOFF(LAUNCHER)
```

SUBROUTINE SAVET(MODEL)

- ***Input:***
- *MODEL: Model concerned*
- ***Output:*** *none*
- ***Description:***

This subroutine is used to save the temperature of all the nodes in MODEL, in a binary file. This file is named by the solver as: MODEL.UNF, and will be loaded later by the FETCHT subroutine, possibly during another execution of the solver.

Example of a SAVET subroutine call

```
CALL SAVET(SATEM)
CALL SAVET(SATEM:TELESCOPE)
CALL SAVET(CURRENT)
```

SUBROUTINE FETCHT(MODEL)

- ***Input:***
- *MODEL: Model concerned*
- ***Output:*** *none*
- ***Description:***

This subroutine is used to load the temperature of all the nodes in MODEL from a binary file. This file is saved by the solver as: MODEL.UNF, and has been already created, possibly during a previous execution of the solver.

Example of a FETCHT subroutine call

```
CALL FETCHT(SATEM)
CALL FETCHT(SATEM:TELESCOPE)
CALL FETCHT(CURRENT)
```

SUBROUTINE TINIT5(H5NAME, TIME)

- ***Input:***
- H5NAME: Character string to specify the name of the H5 file
- DOUBLE PRECISION TIME: time at which values will be retrieved
- ***Output:*** none
- ***Description:***

This subroutine is used to initialize the temperatures from an H5 file generated by thermisol during a previous calculation. TIME=-1 is used to get the temperature values at the last point of the h5 file. This function should be called in the $INITIAL paragraph.

Example of a TINIT5 subroutine call

```
CALL TINIT5('Process.temp.h5', -1.0)
CALL TINIT5('NewModel.temp.h5', 1286.0)
```

INTEGER INTNOD(MODEL,NODE)

- ***Input:***
- *MODEL: Model concerned*
- *INTEGER NODE: User node number*
- ***Output:***
- *INTEGER INTNOD: Internal node number*
- ***Description:***

This function returns the internal node number associated with the node which has a user node number NUMBER in MODEL.

Example of an INTNOD function call

N = INTNOD(CURRENT, 102)
N = INTNOD(SATEM:TELESCOPE, 1000)

This routine becomes now obsolete in MORTRAN codes with the syntax "N: [MODEL_PATH:] NODE" Which is strictly equivalent to "INTNOD(MODEL_PATH,NODE)" However, with the extended MORTRAN language proposed by THERMISOL, the knowledge of the internal numbering should never be required.

INTEGER NODNUM(N)

- ***Input:***
- *INTEGER N: Internal node number*
- ***Output:***
- *INTEGER NODNUM: User node number*
- ***Description:***

This function returns the user node number associated with the node which has an internal number N.

Example of a NODNUM function call

TN = NODNUM(3)

CHARACTER*256 SUBMDN(N,NAMETYPE)

- ***Input:***
- *INTEGER N: Internal node number*
- *NAMETYPE: Character string to specify the name format*
- ***Output:***
- *CHARACTER*256 SUBMDN: Model name*
- ***Description:***

This function returns the name of the model or submodel to which the node N belongs (N is an internal node number). The character string NAMETYPE can have the following values:

- **'ALL':** The model name will be returned as a full name (e.g: 'SATEM:PLATFORM:TELESCOPE')
- **'ALL-NOMAIN':** The model name will be returned as a full name but without the main model name (e.g: 'PLATFORM:TELESCOPE')
- **'ROOT':** The name returned is the full name of the father model (e.g: 'SATEM:PLATFORM')
- **'ROOT-NOMAIN':** The name returned is the full name of the father model without the main model name (e.g: 'PLATFORM')
- **'SUBMODEL':** The name returned is the model name, without his fathers (e.g: 'TELESCOPE')

Example of a SUBMDN function call

NAME = SUBMDN(3, 'ALL')
NAME = SUBMDN(30, 'ROOT')
NAME = SUBMDN(30, 'SUBMODEL')

NAME = SUBMDN(3, 'ALL-NOMAIN')
NAME = SUBMDN(30, 'ROOT-NOMAIN')

CHARACTER*256 SUBMOD(NAMETYPE)

- ***Input:***
- *NAMETYPE: Character string to specify the name format*
- ***Output:***
- *CHARACTER*256 SUBMOD: Model name*
- ***Description:***

This function returns the name of the current model. The current model is the model to which the calling subroutine belongs.
The character string NAMETYPE can have the following values:

- **'ALL':** The model name will be returned as a full name (e.g: 'SATEM:PLATFORM:TELESCOPE')
- **'ALL-NOMAIN':** The model name will be returned as a full name but without the main model name (e.g: 'PLATFORM:TELESCOPE')
- **'ROOT':** The name returned is the full name of the father model (e.g: 'SATEM:PLATFORM')
- **'ROOT-NOMAIN':** The name returned is the full name of the father model without the main model name (e.g: 'PLATFORM')
- **'SUBMODEL':** The name returned is the model name, without his fathers (e.g: 'TELESCOPE')

Example of a SUBMOD function call
NAME = SUBMOD('ALL')
NAME = SUBMOD('ROOT')
NAME = SUBMOD('SUBMODEL')
NAME = SUBMOD('ALL-NOMAIN')
NAME = SUBMOD('ROOT-NOMAIN')

INTEGER INTGL(MODEL1,NODE1,MODEL2,NODE2,INDEX)

- ***Input:***
- *INTEGER MODEL1: Model of first node*
- *INTEGER NODE1: User first node number*
- *INTEGER MODEL2: Model of second node*
- *INTEGER NODE2: User second node number*
- *INTEGER INDEX: Index of the coupling*
- ***Output:***
- *INTEGER INTGL: Internal number of the GL coupling*
- ***Description:***

This function returns the internal coupling number between the two nodes. If a coupling has been multi-defined, the index is used to select the coupling index to be returned by the function
Example of an INTGL function call
N = INTGL(CURRENT, 102, CURRENT, 103, 1)
N = INTGL(SATEM:TELESCOPE, 1000, CURRENT, 102, 1)

INTEGER INTGR(MODEL1,NODE1,MODEL2,NODE2,INDEX)

- ***Input:***

- *INTEGER MODEL1: Model of first node*
- *INTEGER NODE1: User first node number*
- *INTEGER MODEL2: Model of second node*
- *INTEGER NODE2: User second node number*
- *INTEGER INDEX: Index of the coupling*
- ***Output:***
- *INTEGER INTGR: Internal number of the GR coupling*
- ***Description:***

This function returns the internal coupling number between the two nodes. If a coupling has been multi-defined, the index is used to select the coupling index to be returned by the function

Example of an INTGR function call

N = INTGR(CURRENT, 102, CURRENT, 103, 1)
N = INTGR(SATEM:TELESCOPE, 1000, CURRENT, 102, 1)

INTEGER INTGF(MODEL1,NODE1,MODEL2,NODE2,INDEX)

- ***Input:***
- *INTEGER MODEL1: Model of first node*
- *INTEGER NODE1: User first node number*
- *INTEGER MODEL2: Model of second node*
- *INTEGER NODE2: User second node number*
- *INTEGER INDEX: Index of the coupling*
- ***Output:***
- *INTEGER INTGF: Internal number of the GF coupling*
- ***Description:***

This function returns the internal coupling number between the two nodes. If a coupling has been multi-defined, the index is used to select the coupling index to be returned by the function

Example of an INTGF function call

N = INTGF(CURRENT, 102, CURRENT, 103, 1)
N = INTGF(SATEM:TELESCOPE, 1000, CURRENT, 102, 1)

INTEGER INTGV(MODEL1,NODE1,MODEL2,NODE2,INDEX)

- ***Input:***
- *INTEGER MODEL1: Model of first node*
- *INTEGER NODE1: User first node number*
- *INTEGER MODEL2: Model of second node*
- *INTEGER NODE2: User second node number*
- *INTEGER INDEX: Index of the coupling*
- ***Output:***
- *INTEGER INTGV: Internal number of the GV coupling*
- ***Description:***

This function returns the internal coupling number between the two nodes. If a coupling has been multi-defined, the index is used to select the coupling index to be returned by the function

Example of an INTGV function call

N = INTGV(CURRENT, 102, CURRENT, 103, 1)
N = INTGV(SATEM:TELESCOPE, 1000, CURRENT, 102, 1)

SETNDI(ZNODE,ENTITY,VALUE,MODEL)

- ***Input:***
- *ZNODE: Character string describing the nodes concerned*
- *ENTITY: Character string describing the nodal entity to be valued*
- *VALUE: Integer value to be affected*
- *MODEL: Model*
- ***Output:*** *none*
- ***Description:***

This function affects a value of a given nodal entity to all nodes specified by ZNODE from the model MODEL. Since no integer nodal entity exists by default the function can only be called on a user nodal entity.

Example of a SETNDI function call

```
CALL SETNDI('#300-399','STATUS',0,CURRENT)
```

This function has been developed only for compatibility matters with ESATAN.
The extended MORTRAN language of THERMISOL may be more convenient to use. The previous example can then be written:

```
STATUS:'#300-399' = 0
```

SETNDR(ZNODE,ENTITY,VALUE,MODEL)

- ***Input:***
- *ZNODE: Character string describing the nodes concerned*
- *ENTITY: Character string describing the nodal entity to be valued*
- *VALUE: Real value to be affected*
- *MODEL: Model*
- ***Output:*** *none*
- ***Description:***

This function affects a value of a given nodal entity to all nodes specified by ZNODE from the model MODEL. This may be applied to existing nodal entities or to user declared ones.

Example of a SETNDR function call

```
CALL SETNDR('#300-399','T',20.0D0,CURRENT)
```

This function has been developed only for compatibility matters with ESATAN.
The extended MORTRAN language of THERMISOL may be more convenient to use. The previous example can then be written:

```
T:'#300-399' = 20.0
```

SETNDZ(ZNODE,ENTITY,VALUE,MODEL)

- ***Input:***
- *ZNODE: Character string describing the nodes concerned*
- *ENTITY: Character string describing the nodal entity to be valued*
- *VALUE: String value to be affected*
- *MODEL: Model*
- ***Output:*** *none*
- ***Description:***

This function affects a value of a given nodal entity to all nodes specified by ZNODE from the model MODEL. Since no string nodal entity exists by default the function can only be called on a user nodal entity.

Example of a SETNDZ function call

```
CALL SETNDZ('#300-399','STATUS','OFF',CURRENT)
```

This function has been developed only for compatibility matters with ESATAN.
The extended MORTRAN language of THERMISOL may be more convenient to use. The previous example can then be written:
STATUS:'#300-399' = 'OFF'

STORMM(ENTITY,MIN,TMIN,MAX,TMAX)

- ***Input:***
- *ENTITY: Character string describing the nodal entity to be compared*
- *MIN: Character string of nodal entity to store minimums*
- *TMIN: Character string of nodal entity to store times of minimums*
- *MAX: Character string of nodal entity to store maximums*
- *TMAX: Character string of nodal entity to store times of maximums*
- ***Output:*** *none*
- ***Description:***

This function is used to store the minimums, maximums and their times of a nodal entity during a transient analysis. The nodal entity referenced by the MIN, TMIN, MAX and TMAX parameters shall be user nodal entities declared by the user
This function shall be called in the $VRESULTS (or $VARIABLES2) block.
Example of a STORMM function call

```
$ENTITIES
MIN;
TMIN;
MAX;
TMAX;
$NODES
…
…
$VRESULTS
CALL STORMM('T','MIN','TMIN','MAX,'TMAX')
```

DOUBLE PRECISION GRPMIN(ZNODE,ENTITY,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be compared*
- *MODEL: Model*
- ***Output:***
- *GRPMIN : Minimum value*
- ***Description:***

This function returns the minimum value of the nodal entity specified within the group of nodes described by ZNODE.
Example of a GRPMIN function call

```
TMIN = GRPMIN('#300-500','T',CURRENT)
```

DOUBLE PRECISION GRPMAX(ZNODE,ENTITY,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be compared*
- *MODEL: Model*

- ***Output:***
- *GRPMAX : Maximum value*
- ***Description:***

This function returns the maximum value of the nodal entity specified within the group of nodes described by ZNODE.
Example of a GRPMAX function call
TMAX = GRPMAX('#300-500','T',CURRENT)

DOUBLE PRECISION GRPSUM(ZNODE,ENTITY,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be sumed*
- *MODEL: Model*
- ***Output:***
- *GRPSUM : Sum value*
- ***Description:***

This function returns the sum of all values of the nodal entity specified within the group of nodes described by ZNODE.
Example of a GRPSUM function call
TOTAL_POWER = GRPSUM('#300-500','QR',CURRENT)

DOUBLE PRECISION GRPAVE(ZNODE,ENTITY,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be averaged*
- *MODEL: Model*
- ***Output:***
- *GRPAVE : Average value*
- ***Description:***

This function returns the arithmetic average value (sum divided by the number of elements) of the nodal entity specified within the group of nodes described by ZNODE.
Example of a GRPAVE function call
TAVE = GRPAVE('#300-500','T',CURRENT)

DOUBLE PRECISION GRPAVE2(ZNODE,ENTITY,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be averaged*
- *MODEL: Model*
- ***Output:***
- *GRPAVE2 : Quadratic average value*
- ***Description:***

This function returns the quadratic average value of the nodal entity specified within the group of nodes described by ZNODE.

Example of a GRPAVE2 function call

TAVE = GRPAVE2('#300-500','T',CURRENT)

DOUBLE PRECISION GRPAVE_W(ZNODE,ENTITY,ENTITY2,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be averaged*
- *ENTITY2: Character string describing the nodal entity to weight the average*
- *MODEL: Model*
- ***Output:***
- *GRPAVE_W : Weighted average value*
- ***Description:***

This function returns the arithmetic weighted average value of the nodal entity specified within the group of nodes described by ZNODE.

Example of a GRPAVE_W function call

```
 TAVE = GRPAVE_W('#300-500','T','A',CURRENT)
```

DOUBLE PRECISION GRPAVE2_W(ZNODE,ENTITY,MODEL)

- ***Input:***
- *ZNODE: Character string describing the group of nodes*
- *ENTITY: Character string describing the nodal entity to be averaged*
- *ENTITY2: Character string describing the nodal entity to weight the average*
- *MODEL: Model*
- ***Output:***
- *GRPAVE2_W : Quadratic weighted average value*
- ***Description:***

This function returns the quadratic weighted average value of the nodal entity specified within the group of nodes described by ZNODE.

Example of a GRPAVE2_W function call

```
 TAVE = GRPAVE2_W('#300-500','T','A',CURRENT)
```

DOUBLE PRECISION GETGL(MODEL,NODE1,NODE2)

- ***Input:***
- *MODEL: Model*
- *NODE1: Node number of the first node*
- *NODE2: Node number of the second node*
- ***Output:***
- *GETGL : Total conductive coupling between node 1 and node 2*
- ***Description:***

This function returns the value of the total conductive coupling between two nodes (that is, it sum over i the GL(node 1, node 2, i)). This function is especially useful for a multi-defined coupling.

Example of a GETGL function call

```
GLTOT = GETGL(CURRENT, N100, N200)
```

DOUBLE PRECISION GETGR(MODEL,NODE1,NODE2)

- ***Input:***
- *MODEL: Model*

- *NODE1: Node number of the first node*
- *NODE2: Node number of the second node*
- ***Output:***
- *GETGR : Total radiative coupling between node 1 and node 2*
- ***Description:***

This function returns the value of the total radiative coupling between two nodes (that is, it sum over i the GR(node 1, node 2, i)). This function is especially useful for a multi-defined coupling.

Example of a GETGR function call

```
GRTOT = GETGR(CURRENT, N100, N200)
```

DOUBLE PRECISION GETGF(MODEL,NODE1,NODE2)

- ***Input:***
- *MODEL: Model*
- *NODE1: Node number of the first node*
- *NODE2: Node number of the second node*
- ***Output:***
- *GETGF : Total convective coupling between node 1 and node 2*
- ***Description:***

This function returns the value of the total convective coupling between two nodes (that is, it sum over i the GF(node 1, node 2, i)). This function is especially useful for a multi-defined coupling.

Example of a GETGF function call

```
GFTOT = GETGF(CURRENT, N100, N200)
```

Other routines

CHARACTER*17 ZDAYDT()

- ***Input:*** *none*
- ***Output:***
- *CHARACTER*17 ZDAYDT: Current date*
- ***Description:***

This function returns the current date (information provided by the operating system).
Example of a ZDAYDT function call

```
DATE = ZDAYDT()
```

CHARACTER*8 ZDAYTM()

- ***Input:*** *none*
- ***Output:***
- *CHARACTER*8 ZDAYTM: Current time*
- ***Description:***

This function returns the current time (information provided by the operating system).
Example of a ZDAYTM function call

```
TIME = ZDAYTM()
```

Solution routines

Steady-State

SUBROUTINE SOLVIT

This subroutine computes the solution of a steady-state problem with the Newton Raphson algorithm as described in the Theoretical chapter.
Driving parameters:

- **RELXCA:** maximum temperature change for one node over one iteration.The criterion is: RELXCC < RELXCA.
- **NLOOP:** maximum number of iterations allowed. The criterion is: LOOPCT < NLOOP.
- **INBALA:** maximum power exchange between diffusive nodes and boundary nodes.The criterion is: ENBALA < INBALA.
- **INBALR:** maximum relative power exchange between diffusive nodes and boundary nodes. The criterion is: ENBALR < INBALR.
- **DAMPT:** damping factor to be applied to all the nodes at each iteration for temperature change ($T^{(n+1)} = T^{(n)} - DAMPT \cdot f / f'$).
  If DAMPT=1, the algorithm will apply some dynamic changes to ensure convergence.

Typical values are: NLOOP=1000, RELXCA=1e-4, INBALA=1e-3, INBALR=1e-5.
In a general way, do not specify any value for DAMPT (or just DAMPT=1 which is equivalent). However, you can try successive values (such as 0.9, 0.5 or 0.1) if no convergence occurs. In this case, please contact our services to enable us to improve the algorithm.

SUBROUTINE SOLVFM

This subroutine computes the solution of a steady-state problem with a Newton-Krylov algorithm as described in the Theoretical chapter.
Driving parameters:

- **RELXCA:** maximum temperature change for one node over one iteration. The criterion is: RELXCC < RELXCA.
- **NLOOP:** maximum number of iterations allowed. The criterion is: LOOPCT < NLOOP.
- **INBALA:** maximum power exchange between diffusive nodes and boundary nodes. The criterion is: ENBALA < INBALA.
- **INBALR:** maximum relative power exchange between diffusive nodes and boundary nodes. The criterion is: ENBALR < INBALR.
- **DAMPT:** damping factor to be applied to all the nodes at each iteration for temperature change ($T^{(n+1)} = T^{(n)} - DAMPT \cdot DeltaT$). If DAMPT=1, the algorithm will apply some dynamic changes to ensure convergence.

Typical values are: NLOOP=1000, RELXCA=1e-4 (INBALA=0.1 and INBALR=1e-4 may also be used).

In a general way, do not specify any value for DAMPT (or just DAMPT=1 which is equivalent). However, you can try successive values (such as 0.9, 0.5 or 0.1) if no convergence occurs. In this case, please contact our services to enable us to improve the algorithm.

Transient

SUBROUTINE SCRANK

This subroutine computes the solution of a transient problem with the Crank Nicholson algorithm as described in the Theoretical chapter.
Driving parameters:

- **TIMEO:** start date.
- **TIMEND:** end date.
- **DTIMEI:** time step.
- **RELXCA:** maximum temperature change for one node over an iteration, at a given time. The criterion is: RELXCC < RELXCA.
- **INBALT:** maximum power exchange by diffusive nodes, including capacitive power. This is a convergence criterion more physical than the RELXCA one. It has been introduced because the definition of the INBALA control variable is not suitable for transient cases. However, each diffusive node has to respect a balanced flux equation taking into account transient phenomena such as capacitive fluxes. The criterion is: ENBALT < INBALT.
- **NLOOP:** maximum number of iterations allowed, at a given time. The criterion is: LOOPCT < NLOOP.
- **DAMPT:** damping factor to be applied to all the nodes at each iteration of the implicit convergence. If DAMPT=1, the algorithm will apply some dynamic changes to ensure convergence.

The values for TIMEO, TIMEND and DTIMEI depend on the problem being modelled.
Other typical values are: RELXCA=1e-4, NLOOP=1000 (in general, only 5 to 50 iterations are sufficient).
In this routine, the DTMIN, DTMAX and DTPMAX variables are not used.

A special call of the function UPDATE_FLUX in $VRESULT allows to take into account a discontinuous phenomena that happens at a specific time by forcing the start flux of the next time-step to be recomputed and not equal to the end flux of the current time-step.

SUBROUTINE SCRANKAUTO

This subroutine computes the solution of a transient problem with the Crank Nicholson algorithm associated with an automatic time step as described in the Theoretical chapter.
Driving parameters:

- **Same as SCRANK:** TIMEO, TIMEND, RELXCA, INBLAT, NLOOP, DAMPT
- **DTIMEI:** initial time step.
- **ERRMIN:** if the maximum estimated relative error in the model is lower than ERRMIN, the time step will be increased.
- **ERRMAX:** if the maximum estimated relative error in the model is higher than ERRMAX, then the time step is decreased and the solution is recomputed.
- **DTMIN:** minimum time-step allowed.
- **DTMAX:** maximum time-step allowed.

The values for TIMEO, TIMEND and DTIMEI depend on the problem being modelled.
Other typical values are: RELXCA=1e-4, NLOOP=1000 (in general, only 5 to 50 iterations are sufficient), ERRMIN=1e-4, ERRMAX=1e-4 (these last two parameters can be equal – the solution will always be as close as possible, but lower, to the desired relative error value).

Cyclic Convergence Routines

SUBROUTINE SOLCYC(SOLNAM, CVTCA, CVDTCA, PERIOD, MAXCYC, ZNODE, OUTIML)

SOLCYC is a 'meta-solver', the purpose of which is to attain a steady cyclic solution.: i.e. successive cycles of a transient analysis giving the same thermal results to within user-specified criteria

- ***Inputs:***
  - SOLNAM : String – *transient solver to be used*
  - CVTCA: Double – *Cycle convergence criterion for temperature*
  - CVDTCA: Double - *Cycle convergence criterion for rate of change of temperature (not used)*
  - PERIOD: Double – *Period of cycle (seconds)*
  - MAXCYC: Integer – *Maximum number of cycles*
  - ZNODE: *Specifies nodes for which criteria shall be met*
  - OUTIML: String – *defines whether normal output is required ('NONE' or 'ALL')*

Example of a SOLCYC function call

```
$EXECUTION
```

1. Attain steady cycles
   ```
   CALL SOLCYC ('SCRANK', 0.01, 0.0, 6450.0, 10, '#100-200', 'NONE')
   ```

2. Run for one more cycle to get output
   ```
   CALL SCRANK
   ```

SUBROUTINE SCYCLE(SOLNAM, PERIOD, MAXCYC) + SUBROUTINE SCYCLE_ADDSPEC(ZNODE, CVTCA)

SCYCLE is a 'meta-solver', the purpose of which is to attain a steady cyclic solution.: i.e. successive cycles of a transient analysis giving the same thermal results to within user-specified criteria.

*This routine uses convergence criteria previously defined by one or several calls to the subroutine **SCYCLE_ADDSPEC** (limited to 32), allowing to specify different convergence levels for several group of nodes.*

Moreover, it automatically performs convergence cycles excluding calls to the $OUTPUTS block and storing the convergence results into a specific h5 file.

If the cyclic convergence has been successfully reached, a last cycle is performed including calls to $OUTPUTS and storing this last cycle results into the original h5 file.

A detail convergence repporting is written in the convergence control file (csv) plus a summary into the standard output file (out).

- ***Inputs: (SCYCLE)***
  - SOLNAM : String – *transient solver to be used*
  - PERIOD: Double – *Period of cycle (seconds)*
  - MAXCYC: Interger – *Maximum number of cycle*
- ***Inputs: (SCYCLE_ADDSPEC)***
  - ZNODE: *Specifies nodes for which criteria shall be met*

- CVTCA: Double – *Cycle convergence criterion for temperature*

Example of a SCYCLE function call

```
$EXECUTION
```

1. Specification of convergence criteria
   ```
   CALL SCYCLE_ADDSPEC('#100-200', 3.0)
   CALL SCYCLE_ADDSPEC('Equipments', 0.5)
   ```

2. Run for one more cycle to get output
   ```
   CALL SCYCLE ('SCRANKAUTO', 6450.0, 10)
   ```

Wavelength dependency management routines

DOUBLE PRECISION EPSWLBEF ()

- ***Input:***
- *none*
- ***Output:***
- *DOUBLE PRECISION EPSWLBEF: equivalent epsilon.*

- ***Description:***

This function computes the equivalent epsilon value according to the wavelength discretization and the temperature of the thermal node. The function shall be exclusively used at the nodal description level (the value of the EPS data will then be updated during the execution according to the GENMOR behaviour). The following quantity is returned:

$$EPSWLBEF_i = \sum_{m=1,NWLBANDS} FBAND(T_i, \lambda_m, \lambda_{m+1}).EPSWLB_i(m)$$

Example of a EPSWLBEF function call

```
D123='Radiator +X', T=20.0, ALP=0.22,
   EPS = EPSWLBEF(), EPSWLB=[0.22, 0.35, 0.45, 0.47, 0.44];
```

DOUBLE PRECISION* FBAND *(T,L1,L2)

- ***Input:***
- *DOUBLE PRECISION T: Temperature of thermal node*
- *DOUBLE PRECISION L1: Lower bound of the wavelength band*
- *DOUBLE PRECISION L2: Upper bound of the wavelength band*
- ***Output:***
- *DOUBLE PRECISION FBAND: fractional emissive power*

DOUBLE PRECISION **FBAND** ***(T,L1,L2)***

- ***Description:***

This function computes the fractional emissive power for a given wavelength band. It returns the weight factor of a given wavelength band according to the thermal node temperature. The value of the FBAND function is given by:

$$FBAND(T,\lambda_m,\lambda_{m+1}) = BBFN(\lambda_{m+1}.T_i) - BBFN(\lambda_m.T_i)$$

where the wavelength band m is defined by the two bounds λ_m, λ_{m+1} *and the BBFN function is given by*

Michael F.Modest, Radiative Heat Transfer - Second Edition, 2003, Academic Press, ISBN 0-120503163-7

Example of a FBAND function call

```
DO IW=1, NWLBANDS
   EQUIVEPS = EQUIVEPS
      + FBAND(T100,WLBANDS(WLB=IW),WLBANDS(WLB=IW+1))*EPSWLB100(WLB=IW)
ENDDO
```

This example computes the equivalent epsilon value of the node 100 which can be obtained with the function EPSWLBEF().

Theoretical Background

Mathematical Formulation of the Thermal Problem

THERMISOL deals with a specific class of mathematical equations related to thermal analysis, especially adapted for the modeling of conduction and radiation but extendable to more complex applications.
The mathematical formulation is a system of differential equations:

$$\left\{ C_i \frac{dT_i}{dt} = \sigma \sum_j^M GR_{ij}\left(T_j^4 - T_i^4\right) + \sum_j^M GL_{ij}\left(T_j - T_i\right) + \sum_j^M GF_{ij}\left(T_j - T_i\right) + QS_i + QA_i + QE_i + QI_i + QR_i \right.$$

where:

- ***Ti* is the temperature of node *i*, to be computed**
- ***t* is the time**
- ***Ci* is the capacitance (M.Cp) of node *i***
- ***GRij* is a symmetric radiative coupling between nodes *i* and *j***
- ***GLij* is a symmetric linear coupling between nodes *i* and *j***
- ***GFij* is a one-way linear coupling between nodes *i* and *j***
- ***QSi* is the solar power absorbed by node *i***
- ***QAi* is the planet albedo power absorbed by node *i***
- ***QEi* is the planet infra-red power absorbed by node *i***
- ***QIi* is an internal power absorbed by node *i***
- ***QRi* is an additional power absorbed by node *i*.**

At several moments (at each iteration or at each time step), the user can modify any of these data, using a Fortran-like language. This can be useful to integrate the variations of external fluxes, the activation of heaters or

dissipation of equipment, etc. It can also be used to simulate different classes of mathematical equations; e.g., linear couplings can be changed according to the temperature to model convective exchanges.

Numerical Methods for Steady-State Problems

Newton algorithm

The **Newton method** is a general method for solving non-linear systems written as the follow:

$$f(\vec{x}) = 0$$

Starting from an initial data x_0, the Newton method builds a series $\left(x^{(k)}\right)_{k\in\mathbb{N}}$ of approximations of $\bar{x}$.
Supposing that 2 successive approximations are close enough, the Taylor development of the function to the first order gives:

$$f\left(x^{(k+1)}\right) = f\left(x^{(k)}\right) + \nabla f\left(x^{(k)}\right)\left(x^{(k+1)} - x^{(k)}\right) + o\left(x^{(k+1)} - x^{(k)}\right)$$

We can then define the series $\left(x^{(k)}\right)_{k\in\mathbb{N}}$ as:

$$\begin{cases} x^{(0)} = x_0 \\ f\left(x^{(k)}\right) + \nabla f\left(x^{(k)}\right)\left(x^{(k+1)} - x^{(k)}\right) = 0 \end{cases}$$

The construction of this series stops when the convergence criterion is reached.

At each iteration k, the algorithm shall compute the following steps:

1. Compute the Jacobian matrix $A = \nabla f\left(x^{(k)}\right)$
2. Solve the system $As^{(k)} = -f\left(x^{(k)}\right)$ then deduce the new solution $x^{(k+1)} = x^{(k)} + s^{(k)}$
3. Evaluate $f\left(x^{(k+1)}\right)$

This method may be optimized by introducing a damping factor β in the evaluation of the new solution at the second step $x^{(k+1)} = x^{(k)} + \beta . s^{(k)}$ in order to accelerate the convergence.
In order to avoid the "over-solving", the iteration of the Newton method may be approximated with an increasing accuracy. It is also possible to simplify the Jacobian matrix.
As it has been presented, the Newton method consists to solve a non-linear problem by successive linear system that tends to the non-linear solution. This process of convergence requires then to solve linear systems. This may be done by different approaches:

The algorithms stop when the maximum temperature change during an iteration (RELXCC) is less than the specified criterion (RELXCA):

$$RELXCC^{(n)} = \max_i \left| T_i^{(n)} - T_i^{(n-1)} \right| \leq RELXCA$$

Then, the global equilibrium is verified, considering incoming and outgoing fluxes (due to internal powers and exchanges with boundary nodes). This difference is called "ENBALA" and has to be less than the "INBALA" user parameter. The relative balance "ENBALR" is also evaluated and compared with the user parameter "INBALR".

$$ENBALA = \left| \Phi_{in} - \Phi_{out} \right| \leq INBALA$$

$$ENBALR = \frac{ENBALA}{\max\left(\Phi_{in}, \Phi_{out}\right)} \leq INBALR$$

$$ENBALT = \sum f_i(T_i) \leq INBALT$$

In all cases, the algorithm will be stopped if the number of iterations (LOOPCT) has reached the maximum value

allowed by the user (NLOOP).
To deal with the convergence of the model with more information, the RELXCC, ENBALA and ENBALR outputs are signed.

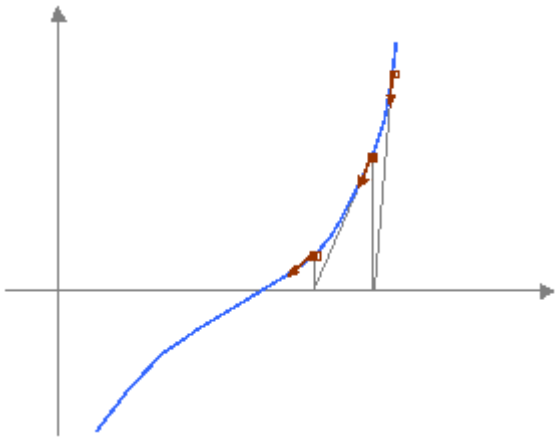
Newton Raphson algorithm (SOLVIT)

The iterative **Newton-Raphson** algorithm, implemented for thermal resolution under the THERMISOL function SOLVIT consist of solving for each line i of linear system matrix the solution $x_i^{(k+1)}$ according to the data $\left(x_j^{(k+1)}\right)_{j<i}$, $\left(x_j^{(k)}\right)_{j\geq i}$.
This method is very efficient for thermal problems since all temperature variables are widely coupled to each other with radiative links. However, for more sparse problems or purely linear problems, it becomes much less efficient than a matricial method.
For each iteration, the system of N equations is considered as N independent equations of 1 variable. For each equation (i), the unknown variable is Ti and all the Tj (ji) are considered as fixed values:

$$f(T_i) = \sum_j a_{ij}\left(T_j^4 - T_i^4\right) + \sum_j b_{ij}\left(T_j - T_i\right) + c_i = 0$$

Then, Ti is modified as per the Newton's method:

$$T_i^{(n+1)} = T_i^{(n)} - d\frac{f\left(T_i^{(n)}\right)}{f'\left(T_i^{(n)}\right)}$$



1. Graphical representation of the Newton Raphson algorithm

Where: *d* is a damping factor (DAMPT variable in the language).
If the user does not specify the value of DAMPT, the solver modifies it dynamically during the solution to allow a fast and robust convergence.
At the end of each iteration, when all $T_i^{(n)}$ have been computed, the solver calls the user subroutine $VTEMPERATURE (or $VARIABLES1) in which the *f* function can be updated (for couplings, fluxes or other data depending on the temperature).

Newton-Krylov algorithm (SOLVFM)

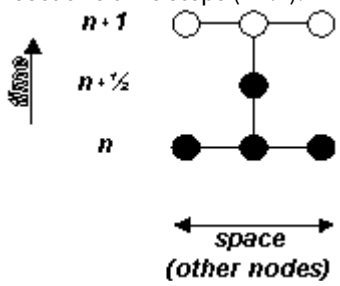
Originally, the SOLVFM routine was based on Cholesky decomposition. This matricial approach solves directly the linearized system.
In that case, the **inexact Newton method** allows replacing the Jacobian matrix A by a symmetric matrix $A' = \frac{1}{2}\left(A + A^T\right)$ in order to use a **Cholesky** factorization, less time-consuming than a **LU** factorization.
The **Krylov** methods work by forming a basis from a matrix A and a vector b $K_r(A,b) = \left\{b, Ab, A^2b, \ldots, A^{r-1}b\right\}$.
The approximations to the solution are then formed by minimizing the residual formed over the increasing subspace created.

This method is suitable for large sparse systems that are difficult to be handled by the Cholesky decomposition. Both generalized minimum residual (GMRES) and conjugate gradient (CG) have been tested. It resulted that CG gave better results in the context of thermal or electrical problems.
The **Newton-Krylov** method is the one now being implemented in the thermal resolution SOLVFM.
This method requires a pre-conditioner which is given by a partial sparse Cholesky decomposition. This pre-conditioner is updated not at each iteration but when necessary.
This decomposition has then became an incomplete decomposition used as a pre-conditioner for a conjugate gradient resolution.

Numerical Methods for Transient Problems

Crank Nicholson algorithm

The Crank Nicholson Algorithm is an implicit method based on the evaluation of the equations in the middle of two consecutive time steps (n+½).



At this time (n+½), the temperature derivative is given by a centered evaluation:

$$\left(\frac{dT}{dt}\right)^{(n+1/2)} \approx \frac{T^{(n+1)} - T^{(n)}}{t^{(n+1)} - t^{(n)}}$$

and the flux is evaluated by:

$$f^{(n+1/2)} \approx \frac{f^{(n+1)} + f^{(n)}}{2}$$

Thus, the thermal equation giving $T^{(n+1)}$ as a function of $T^{(n)}$, is the following implicit scheme:

$$\varphi_i = C_i \frac{T_i^{(n+1)} - T_i^{(n)}}{t^{(n+1)} - t^{(n)}} - \frac{f^{(n+1)}\left(T_i^{(n+1)}\right) + f^{(n)}\left(T_i^{(n)}\right)}{2} = 0$$

where:

$$f(T_i) = \sum_j a_{ij}\left(T_j^4 - T_i^4\right) + \sum_j b_{ij}\left(T_j - T_i\right) + c_i$$

Then, the solver computes all the $T_i^{(n+1)}$ values with a Newton Raphson algorithm, controlled by the NLOOP and RELXCA. These variables have the same meaning as in the steady-state problem.
Arithmetic nodes (without capacitance) are solved using the Newton-Raphson algorithm (see SOLVIT).
As for steady-state cases, a criterion based on diffusive nodes equilibrium has been set, INBALT, defined by:

$$ENBALT = \sum \varphi_i(T_i) \leq INBALT$$

Crank Nicholson with automatic time step

The time stepping can be automatically changed during the solution. Since the Crank Nicholson algorithm is a 2nd order scheme, the error can be accurately estimated by the 3rd term of the Taylor temperature development:

$$err \approx \max_i \frac{d^3 T_i}{dt^3} \frac{\Delta t^3}{6}$$

Two user variables, ERRMIN and ERRMAX, are used to modify the time step, leading to 3 different cases:

- *_ERRMIN err ERRMAX: the iteration is correct and the time step is not changed._*
- *_err ERRMIN: the iteration is correct but the time step is increased:_*

$$\Delta t^{n+1} = 1.1\,\Delta t^n \left(\frac{ERRMAX}{err}\right)^{\frac{1}{3}}.$$

- *_err ERRMAX: the iteration is cancelled and computed again with a smaller time step:_*

$$\Delta t^{n+1} = 0.9\,\Delta t^n \left(\frac{ERRMAX}{err}\right)^{\frac{1}{3}}.$$

The first time-step is initially adjusted to 0.5*CSGMIN, where CSGMIN is the minimum of all CSG coefficients.

Skeleton

THERMICA / THERMISOL link

The skeleton is mainly used to create a simple interface between THERMICA and THERMISOL. Its goal is to collect the network files coming from THERMICA and to include them into a standard skeleton of the input file dedicated to the THERMISOL temperature solver. The skeleton module can be used to create a skeleton of an input file for THERMISOL. The user specifies the options to be written, the values of the control variables and the resolution function to call. He also specifies the files to be included as reading instructions. In a second stage, the skeleton module expands the file in order to create a complete THERMISOL input.

Usage and interest

Interactive mode

In the interactive mode (i.e. into SYSTEMA), the skeleton module is used as a simple interface between THERMICA and THERMISOL giving the possibility to the user to add customized instructions from a file written by himself. The interest of such an interface is that the user can write common instructions into a single file that will be taken into account automatically in the successive calls of THERMICA/THERMISOL processes. It is only requested to select that file without needing to modify manually the THERMISOL input file.

Batch mode

The skeleton file is also very convenient to use when running the temperature solver in batch command. A standard skeleton wrote by the user can then be re-used to expand many different cases just by changing the references to the files containing the couplings or different instructions. An "easy batch" mode is also available to directly translate a ske file into a dck file. Read the batch mode section for more details.

Reading instructions

Reading instructions

Contextual expansion

To reference the different files, the skeleton uses special reading instructions. Those instructions will expand the content of a given block from the file to read where the reading instructions are placed.
There are 5 types of reading instructions:

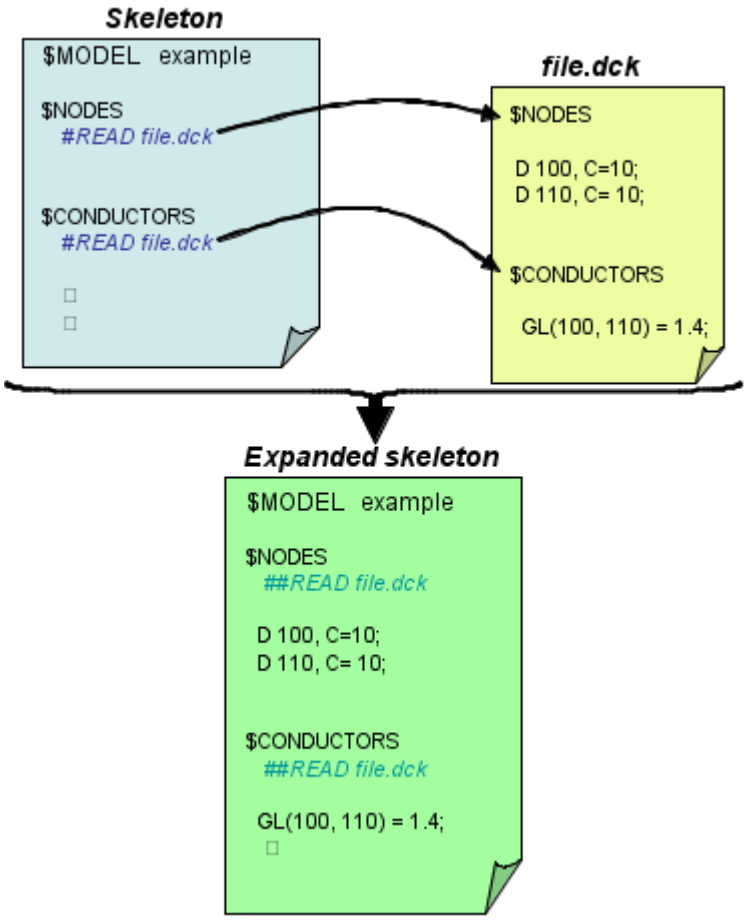
- *#READ*
- *#READ-MODELNAME*
- *#READ-SUBMODEL*
- *#USE*
- *#READ-n where n is an integer from the range 1 to 256*
- *#USE-n where n is an integer from the range 1 to 256*

Standard READ

The *#READ* is used to basically expand the content of one block. When this command is found under a specific block into the skeleton file, the expansion module will replace it by the content of that block from the file to be read.
If the file referenced by a #READ has no context (no blocks are written into the file), it is completely expanded at its call.

-

Example



If the file specified by the *#READ* does not contain any block, it is then supposed to be entirely expended where it is called.

Modelname READ

This type of READ instruction has to be exclusively used after a $MODEL in order to get the model name from a specific input file (usually the nodal description).

This feature was used by default with THERMICA-THERMISOL v4.5. Now the model name is usually directly set from the skeleton parameters and the nodal description does not contain the main model name anymore (which avoids the use of this option).

Sub-model READ

The sub-model READ instruction has to be placed under a $MODEL block.

Compared to a standard READ (or a USE function), it is specialized to expand sub-models with the possibility to select which blocks shall be included.

To select the blocks of a submodel expansion, the syntax is as follow:

#READ-SUBMODEL [$BLOCK1, $BLOCK2,…] *filename*

In case the model is structured with sub-models, it is recommended to expand each sub-model individually and to merge them into the main model by a submodel inclusion.

USE statement

The *#USE* command is a new helpful command to be specified at the beginning of the skeleton file.
It means that the file specified by the #USE instruction has to be extended in any block of the skeleton file if it matches a block of the file to be extended.
In fact, it replaces repetitions of the #READ instructions in the skeleton file by a single statement at its beginning.

The *#USE* command can be used in a recursive manner.

Parametric READ or USE

Batch mode with a parameter file only
The basic *#READ* or #*USE* instructions are followed by a filename. Rather than explicitly referencing a given file, it is possible to replace it by a file index between 1 and 256.
In order to re-use a skeleton for different cases, it can be necessary to change the reference of the files to be expanded. This change could be done directly in the skeleton file but it may be more convenient to specify the reference of the files at an upper level so the skeleton file never has to be changed.
To call a parametric READ, the instruction is given by *#READ-n* where *n* is an integer between 1 and 256.
The references shall then be given in the batch command parameter file using the keywords READ-n.

Skeleton Inputs Outputs

Inputs

SKE file

If the SKE file is specified in the Inputs (in the batch mode, it is considered as an input if the file exist, otherwise it is considered as an output), then the Skeleton program will use this skeleton file to create the input solver file (DCK file).
If no SKE file is specified (or if the SKE file specified in the batch mode does not exist), the Skeleton program will build a generic skeleton file.

NWK files

In the case of a skeleton generation, the nwk files specified as inputs will be added as reading instruction into the ske file.
A simple expansion of a ske file into a dck one does not require the nwk files to be specified in the inputs if they are in the result folder. Indeed, the batch mode does not usually need those files to be expressed as parameters.

However, the interactive process, which is executed into a deported result folder, needs those arguments to be specified.

Outputs

SKE file

If specified as an output, a generic skeleton file will be created (except if one is specified as an input).

DCK file

If specified, this file contains the expanded skeleton, i.e. the THERMISOL temperature solver input file.

Posther

Introduction

POSTHER is a tool used to export data and to perform some analysis. The results are exported to both a XLS file (to be read in Excel® or any other similar tool) and to a text file. The data requested by POSTHER are specified in the h5 result file from THERMISOL under a "POSTHER" group. The kind of analysis performed by POSTHER can be extended to any user's need thanks to an API (available for FORTRAN and C++).

Nodes specifications

Whenever the user can select a group of nodes, the general syntax is the same one than the 'ZNODES' used in some THERMISOL output routines:

- *ALL* to select all the nodes
- *@[model path]* to select the nodes of a given sub-model and its sub-models

- *#X* to select the node X
- *#[model path]:X* to select the node X in a specified submodel
- *#X-Y* to select the range of nodes between X and Y
- *#[model path]:X-Y* to select the range of nodes between X and Y from a specified submodel
- *#X, Y, [model path]:Z-T* to select nodes X, Y and nodes from Z to T of a sub-model
- *[label]* to select all the nodes with the given label in their name
- *[model path]:[label]* to select the nodes with a given label from a sub-model

A group can be the concatenation of many specification separated by ;

'#100-199; @Equipment' means all the nodes between 100 and 199 plus the nodes having 'Equipment' in their names.

If the character '!' is placed before one specification, then it is considered as exclusion:

'ALL;!#100-199' means all the nodes except the nodes between 100 and 199.

Analyses Modules

Extract

The « extract » module creates both xls and text reports on which it is possible to choose the data to be written. First, the user can select a group of nodes to be output as well as a time range.
The selected data will be classified in two tables: the first one for constant data (or data that have been stored as constant in the h5 file – using the H5_RES0 control parameter of THERMISOL), the second one for time dependant results.
The data that can be selected for the module are

- Areas
- Capacitances
- Emissivities (epsilon)
- Absorptivities (alpha)
- Temperatures
- Solar Fluxes
- Albedo Fluxes
- Planet IR Fluxes
- Internal Dissipations

- Residual Fluxes

If the number of column to write in the xls file is to large then this file may be split in different files. The option EXCEL_COL can be set to define the maximum number of columns of the files.
If a time occurs more than once (for example if a steady-state has been called before the transient resolution, time 0 may be stored twice in the 5h file), only the last one is exported and taken into account.

Node Min/Max

The « node min/max » analysis exports, for each time stored in the h5 file and for each entity selected:

- its minimum value, on which node it is found
- its maximum value, on which node it is found
- the mean value on the selected group of node

The mean temperature is computed using the area of the nodes if they are stored in the h5 file. The means on the fluxes (which are actually powers), as well as the temperature's mean in case no areas are found in the h5 file, are algebraic means (the sum divided by the number of summed values).

	A	B	C	D	E	F	G	H	I	J	K
1			Posther				Thermisol HDF5 result		T.temp.h5		
2			version 4.3.1				Thermisol version		V4.3.0		
3							Input DCK file		T		
4			Node Min/Max/Mean				Directory of run		/model/v4/T/T_Tdck		
5							Date of run		Ended on 23-Jun-2008 at 17:28:05		
6							Date of 1st time		0 Julian days		
7							Simulation time range		0-10 sec		
8	Nodal specification	#1001-1999									
9	Time range	0 - 10									
10											
11											

		Temperature				
		Minimum		Maximum		Mean
	Time	Node	Value	Node	Value	Value
15	0	1001	0	1001	0	0
16	0.02	1033	-7.42E-06	1003	0.00656703	0.000980754
17	0.04	1033	-0.0122387	1004	0.376832	0.0921504
18	0.06	1001	0	1004	2.63662	0.786872
19	0.08	1001	0	1004	5.41716	1.87218
20	0.1	1001	0	1004	8.16346	3.10344
21	0.12	1001	0	1004	10.7007	4.3342
22	0.14	1001	0	1004	12.9838	5.49221
23	0.16	1001	0	1004	15.0168	6.54902
24	0.18	1001	0	1004	16.8226	7.49942
25	0.2	1001	0	1004	18.4297	8.34938

1. Node Min/Max Excel sheet

```
POSTHER   -  Node Min/Max/Mean
  version 4.3.1

Thermisol HDF5 result : T.temp.h5
Thermisol version     : V4.3.0
Input DCK file        : T
Directory of run      : /model/v4/T/T_Tdck
Date of run           : Ended on  23-Jun-2008  at  17:28:05
1st simulation time   : 0 Julian days
Simulation time range : 0-10 sec
Nodal specification   : #1001-1999
Time range : 0 - 10


          ||                          T                        ||
          ||    Minimum          |      Maximum          |     Mean||
      Time||       Node|      Value|       Node|      Value|    Value||
         0||       1001|          0|       1001|          0|        0||
      0.02||       1033|-7.41825e-|       1003|0.00656703|0.00098075||
      0.04||       1033|-0.0122387|       1004|  0.376832| 0.0921504||
      0.06||       1001|          0|       1004|   2.63662|  0.786872||
      0.08||       1001|          0|       1004|   5.41716|   1.87218||
       0.1||       1001|          0|       1004|   8.16346|   3.10344||
      0.12||       1001|          0|       1004|   10.7007|    4.3342||
      0.14||       1001|          0|       1004|   12.9838|   5.49221||
      0.16||       1001|          0|       1004|   15.0168|   6.54902||
      0.18||       1001|          0|       1004|   16.8226|   7.49942||
       0.2||       1001|          0|       1004|   18.4297|   8.34938||
      0.22||       1001|          0|       1004|   19.8665|    9.1094||
      0.24||       1001|          0|       1004|   21.1584|   9.79109||
      0.26||       1001|          0|       1004|   22.3277|   10.4055||
      0.28||       1001|          0|       1004|   23.3929|   10.9626||
       0.3||       1001|          0|       1004|   24.3693|   11.4706||
```

1. Time Min/Max Text sheet

Time Min/Max

The « time min/max » analysis exports, for each selected node and for each entity selected:

- its minimum value, at which time it is found
- its maximum value, at which time it is found
- the mean value over the time range specified

The mean values are computed taking into account the time-steps variations.

	A	B	C	D	E	F	G	H	I	J	K
1			*Posther*				Thermisol HDF5 result		T.temp.h5		
2			version 4.3.1				Thermisol version		V4.3.0		
3							Input DCK file		T		
4			*Time Min/Max/Mean*				Directory of run		/model/v4/T/T_Tdck		
5							Date of run		Ended on 23-Jun-2008 at 17:28:05		
6							Date of 1st time		0 Julian days		
7							Simulation time range		0-10 sec		
8	Nodal specification	#1001-1999									
9	Time range	0 - 10									
10											
11											

		Temperature				
		Minimum		Maximum		Mean
12	Node	Time	Value	Time	Value	Value
13	1001	0	0	0	0	0
14	1002	0	0	10	12.5097	11.9601
15	1003	0	0	10	27.5215	26.3516
16	1004	0	0	10	42.5074	40.8031
17	1011	0	0	0	0	0
18	1012	0	0	10	12.5045	11.9549
19	1013	0.04	-0.00733389	10	27.5087	26.3386
20	1014	0	0	10	42.5032	40.7989
21	1021	0	0	0	0	0
22	1022	0	0	10	12.5006	11.951
23	1023	0.04	-0.0115917	10	27.5021	26.3319
24	1024	0	0	10	42.5005	40.7961
25	1031	0	0	0	0	0
26	1032	0.02	-3.02E-06	10	12.4992	11.9496
27	1033	0.04	-0.0122387	10	27.5001	26.33
28	1034	0	0	10	42.4996	40.7952

1. Time Min/Max Excel sheet

Flux Budget

Exchange Flux

The flux budget analyses all the fluxes across the frontiers between 2 groups of nodes noticed G1 and G2:

- Direct radiative flux through the radiative links between thermal nodes of each group
- Direct conductive flux through the conductive links between thermal nodes of each group
- Direct conductive flux through the common edges of the 2 goups
- Direct convective flux through the convectif links between thermal nodes of each group

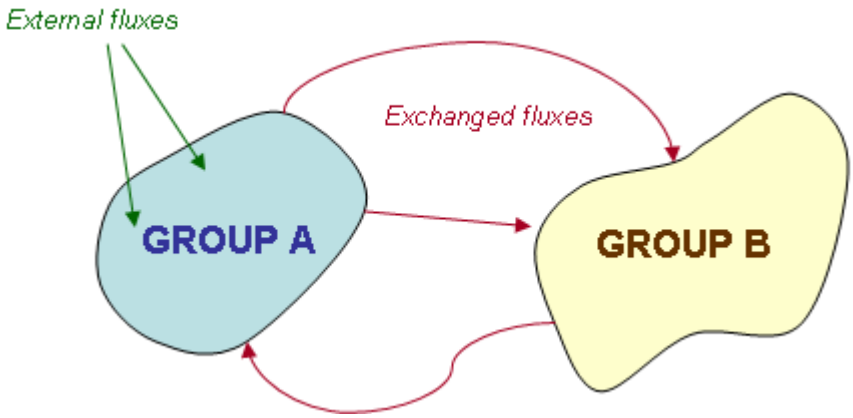
Each category is subdivided with:

- flux from G1 to G2 (with a negative sign)
- from G2 to G1 (with a positive sign)
- exchanged between the 2 groups (sum of the 2 previous, with a negative sign if the total radiative flux goes from G1 to G2 and a positive sign otherwise)

Except for the conductive flux through the edges for which the direct flux is physically known between the group and its frontier. In case a third group of nodes is also connected to the common frontier of G1 and G2, the third flux balancing the frontier is also given

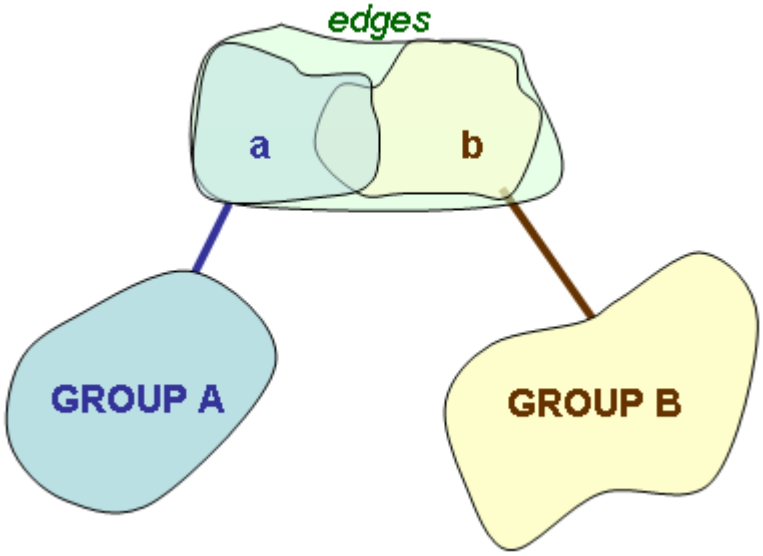
- flux from G1 to its frontier with G2 (with a negative sign)
- flux from the frontier to G2 (with a positive sign)
- flux from the frontier to the other connected nodes G0 (sum of the 2 previous)

Group definitions



1. Flux analyses: group definition

The two groups of nodes are exclusives. If the group B contains nodes already defined in group A, those are removed from group B.
When the model contains conductive interfaces (i.e. edge nodes), the group of nodes A and B are closed by the edges directly connected to the groups. The specification of the groups can so be done without taking into account the edge nodes belonging to a group. Another advantage of this specification is that it allows the two groups to overlap (some edges can be shared by the two groups).



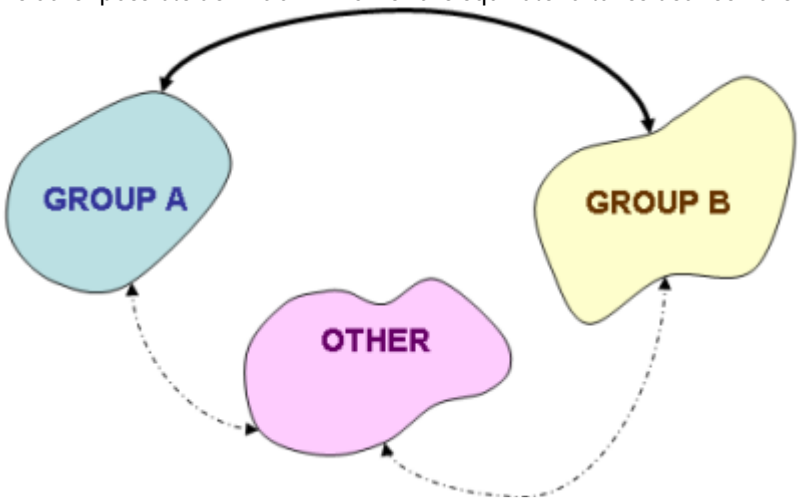
1. Flux analyses: edge nodes closure

In most case the group B is defined as "the model but group A (and edges if any)". This configuration leads to study all the fluxes going in or out from group A (closed by its edges).

Flux analyses between groups

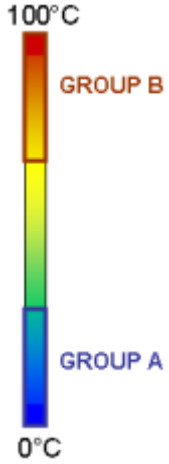
If the union of the two groups (closed by their edges) is not the entire model, then the definition of the fluxes between the groups is "**the fluxes exchanged by a direct link or a direct contact"**. This definition is different from

the other possible definition which is "the equivalent fluxes between the two groups".



1. Flux analyses between two groups

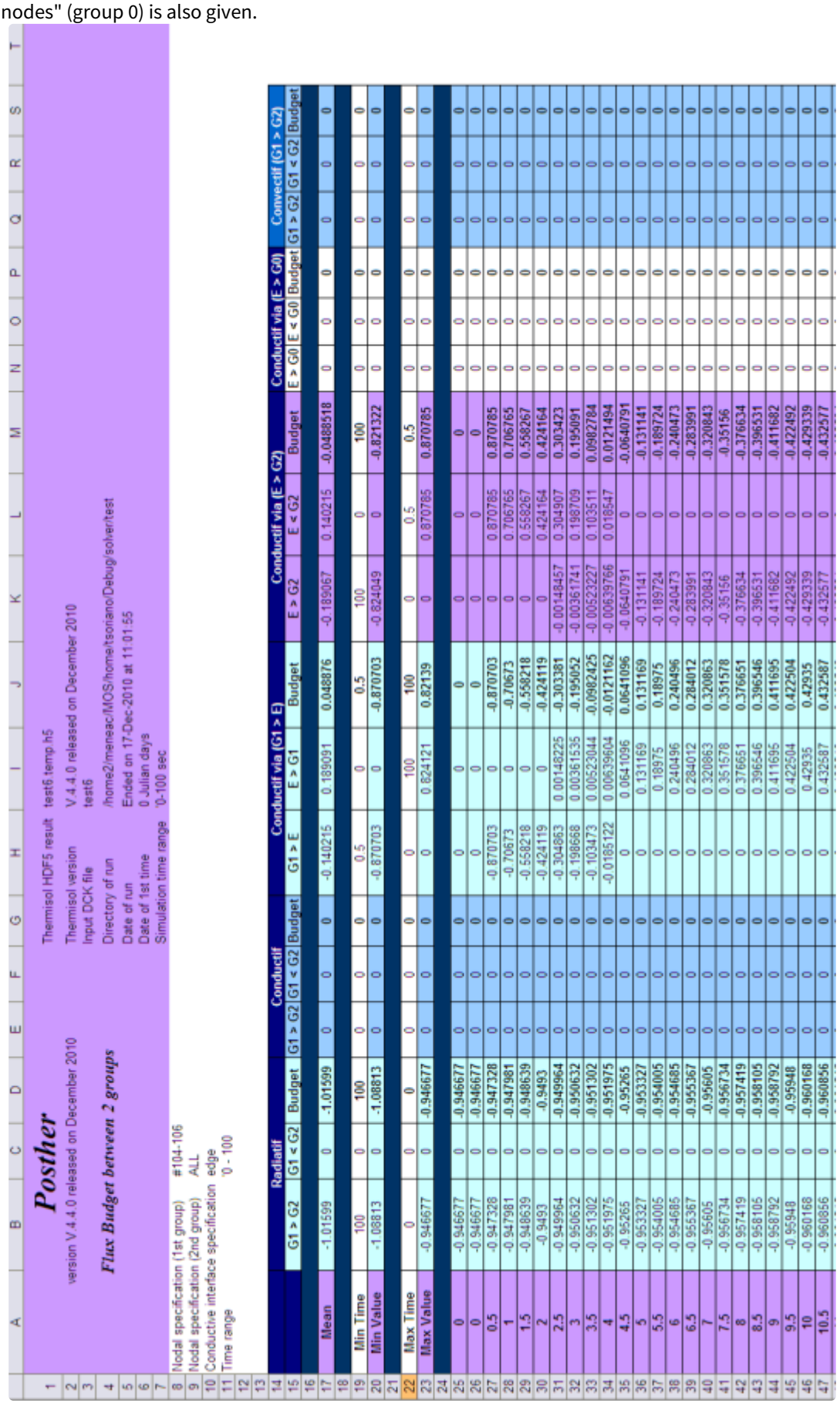
The user needs to be aware of that definition because in the following example, the interpretation of the fluxes should be considered carefully.



1. Flux analyses with groups: example of a bar

The results returned from this configuration will give zero conductive flux between the groups even if there is a temperature gradient and an obvious equivalent conductive coupling between A and B.
The conductive flux received by A is transmitted by the rest of the model and not the group B.
If groups A and B are interconnected with other nodes, the flux exchanged between A-B is the flux directly exchanged between the 2 groups. In this case, the interconnected nodes that do not belong to group A or B have an influence on this flux (in fact the fluxes have to be considered all together). In the report, the influence of the "other

nodes" (group 0) is also given.



Posther

version V.4.4.0 released on December 2010

Flux Budget between 2 groups

Thermisol HDF5 result test6.temp.h5
Thermisol version V.4.4.0 released on December 2010
Input DCK file test6
Directory of run /home2/meneac/MOS/home/tsoniano/Debug/solver/test
Date of run Ended on 17-Dec-2010 at 11:01:55
Date of 1st time 0 Julian days
Simulation time range '0-100 sec

Nodal specification (1st group) #104-106
Nodal specification (2nd group) ALL
Conductive interface specification edge
Time range '0 - 100

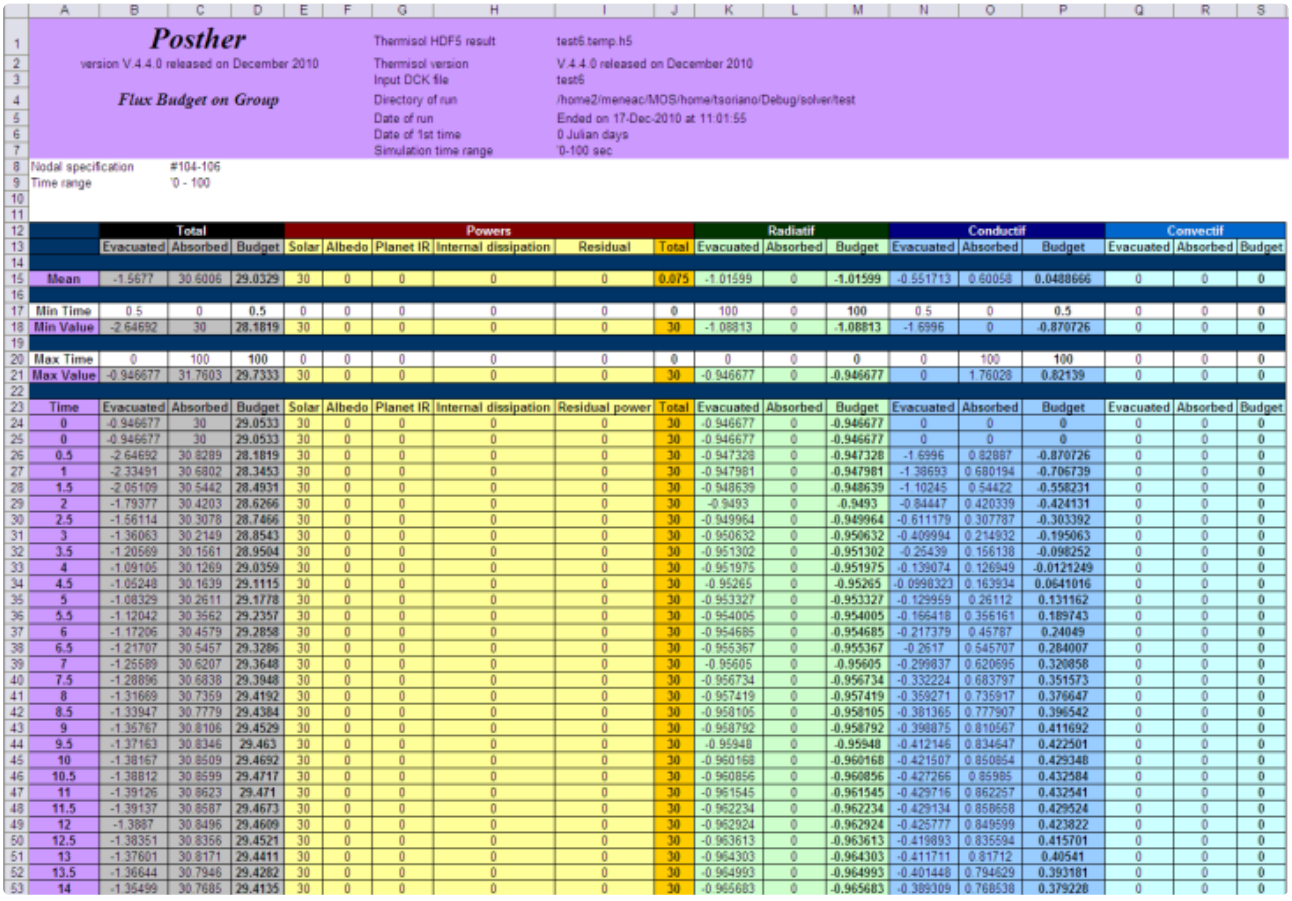
	Radiatif			Conductif			Conductif via (G1 > E)			Conductif via (E > G2)			Conductif via (E > G0)			Convectif (G1 > G2)		
	G1 > G2	G1 < G2	Budget	G1 > G2	G1 < G2	Budget	G1 > E	E > G1	Budget	E > G2	E < G2	Budget	E > G0	E < G0	Budget	G1 > G2	G1 < G2	Budget
Mean	-1.01599	0	-1.01599	0	0	0	-0.140215	0.189091	0.048876	-0.189067	0.140215	-0.0488518	0	0	0	0	0	0
Min Time	100	0	100	0	0	0	0.5	0	0.5	100	0	100	0	0	0	0	0	0
Min Value	-1.08813	0	-1.08813	0	0	0	-0.870703	0	-0.870703	-0.824049	0	-0.821322	0	0	0	0	0	0
Max Time	0	0	0	0	0	0	0	100	100	0	0.5	0.5	0	0	0	0	0	0
Max Value	-0.946677	0	-0.946677	0	0	0	0	0.824121	0.82139	0	0.870785	0.870785	0	0	0	0	0	0
0	-0.946677	0	-0.946677	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	-0.946677	0	-0.946677	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	-0.947328	0	-0.947328	0	0	0	-0.870703	0	-0.870703	0	0.870785	0.870785	0	0	0	0	0	0
1	-0.947981	0	-0.947981	0	0	0	-0.70673	0	-0.70673	0	0.706765	0.706765	0	0	0	0	0	0
1.5	-0.948639	0	-0.948639	0	0	0	-0.558218	0	-0.558218	0	0.558267	0.558267	0	0	0	0	0	0
2	-0.9493	0	-0.9493	0	0	0	-0.424119	0	-0.424119	0	0.424164	0.424164	0	0	0	0	0	0
2.5	-0.949964	0	-0.949964	0	0	0	-0.304863	0.00148225	-0.303381	-0.00148457	0.304907	0.303423	0	0	0	0	0	0
3	-0.950632	0	-0.950632	0	0	0	-0.198668	0.00361535	-0.195052	-0.00361741	0.198709	0.195091	0	0	0	0	0	0
3.5	-0.951302	0	-0.951302	0	0	0	-0.103473	0.00523044	-0.0982425	-0.00523227	0.103511	0.0982784	0	0	0	0	0	0
4	-0.951975	0	-0.951975	0	0	0	-0.0185122	0.00639604	-0.0121162	-0.00639766	0.018547	0.0121494	0	0	0	0	0	0
4.5	-0.95265	0	-0.95265	0	0	0	0	0.0641096	0.0641096	-0.0640791	0	-0.0640791	0	0	0	0	0	0
5	-0.953327	0	-0.953327	0	0	0	0	0.131169	0.131169	-0.131141	0	-0.131141	0	0	0	0	0	0
5.5	-0.954005	0	-0.954005	0	0	0	0	0.18975	0.18975	-0.189724	0	-0.189724	0	0	0	0	0	0
6	-0.954685	0	-0.954685	0	0	0	0	0.240496	0.240496	-0.240473	0	-0.240473	0	0	0	0	0	0
6.5	-0.955367	0	-0.955367	0	0	0	0	0.284012	0.284012	-0.283991	0	-0.283991	0	0	0	0	0	0
7	-0.95605	0	-0.95605	0	0	0	0	0.320863	0.320863	-0.320843	0	-0.320843	0	0	0	0	0	0
7.5	-0.956734	0	-0.956734	0	0	0	0	0.351578	0.351578	-0.35156	0	-0.35156	0	0	0	0	0	0
8	-0.957419	0	-0.957419	0	0	0	0	0.376651	0.376651	-0.376634	0	-0.376634	0	0	0	0	0	0
8.5	-0.958105	0	-0.958105	0	0	0	0	0.396546	0.396546	-0.396531	0	-0.396531	0	0	0	0	0	0
9	-0.958792	0	-0.958792	0	0	0	0	0.411695	0.411695	-0.411682	0	-0.411682	0	0	0	0	0	0
9.5	-0.95948	0	-0.95948	0	0	0	0	0.422504	0.422504	-0.422492	0	-0.422492	0	0	0	0	0	0
10	-0.960168	0	-0.960168	0	0	0	0	0.42935	0.42935	-0.429339	0	-0.429339	0	0	0	0	0	0
10.5	-0.960856	0	-0.960856	0	0	0	0	0.432587	0.432587	-0.432577	0	-0.432577	0	0	0	0	0	0

1. Flux Budget Excel sheet

Group Balance

The group balance export the budget of all powers related to that group (with eventually its enclosure in case a EDGE node group is specified).
Are then exported:

- *The total absorbed, evacuated powers*
- *The extern powers Solar, Albedo, Planet IR, Internal dissipation and Residual powers*
- *The absorbed and evacuated radiative powers*
- *The absorbed and evacuated conductive powers*
- *The absorbed and evacuated convective powers*



Posther
version V.4.4.0 released on December 2010

Flux Budget on Group

Thermisol HDF5 result	test6.temp.h5
Thermisol version	V.4.4.0 released on December 2010
Input DCK file	test6
Directory of run	/home2/meneac/MOS/home/tsoriano/Debug/solver/test
Date of run	Ended on 17-Dec-2010 at 11:01:55
Date of 1st time	0 Julian days
Simulation time range	'0-100 sec
Nodal specification	#104-106
Time range	'0 - 100

	Total			Powers						Radiatif			Conductif			Convectif		
	Evacuated	Absorbed	Budget	Solar	Albedo	Planet IR	Internal dissipation	Residual	Total	Evacuated	Absorbed	Budget	Evacuated	Absorbed	Budget	Evacuated	Absorbed	Budget
Mean	-1.5677	30.6006	29.0329	30	0	0	0	0	0.075	-1.01599	0	-1.01599	-0.551713	0.60058	0.0488666	0	0	0
Min Time	0.5	0	0.5	0	0	0	0	0	0	100	0	100	0.5	0	0.5	0	0	0
Min Value	-2.64692	30	28.1819	30	0	0	0	0	30	-1.08813	0	-1.08813	-1.6996	0	-0.870726	0	0	0
Max Time	0	100	100	0	0	0	0	0	0	0	0	0	0	100	100	0	0	0
Max Value	-0.946677	31.7603	29.7333	30	0	0	0	0	30	-0.946677	0	-0.946677	0	1.76028	0.82139	0	0	0

Time	Evacuated	Absorbed	Budget	Solar	Albedo	Planet IR	Internal dissipation	Residual power	Total	Evacuated	Absorbed	Budget	Evacuated	Absorbed	Budget	Evacuated	Absorbed	Budget
0	-0.946677	30	29.0533	30	0	0	0	0	30	-0.946677	0	-0.946677	0	0	0	0	0	0
0	-0.946677	30	29.0533	30	0	0	0	0	30	-0.946677	0	-0.946677	0	0	0	0	0	0
0.5	-2.64692	30.8289	28.1819	30	0	0	0	0	30	-0.947328	0	-0.947328	-1.6996	0.82887	-0.870726	0	0	0
1	-2.33491	30.6802	28.3453	30	0	0	0	0	30	-0.947981	0	-0.947981	-1.38693	0.680194	-0.706739	0	0	0
1.5	-2.05109	30.5442	28.4931	30	0	0	0	0	30	-0.948639	0	-0.948639	-1.10245	0.54422	-0.558231	0	0	0
2	-1.79377	30.4203	28.6266	30	0	0	0	0	30	-0.9493	0	-0.9493	-0.84447	0.420339	-0.424131	0	0	0
2.5	-1.56114	30.3078	28.7466	30	0	0	0	0	30	-0.949964	0	-0.949964	-0.611179	0.307787	-0.303392	0	0	0
3	-1.36063	30.2149	28.8543	30	0	0	0	0	30	-0.950632	0	-0.950632	-0.409994	0.214932	-0.195063	0	0	0
3.5	-1.20569	30.1561	28.9504	30	0	0	0	0	30	-0.951302	0	-0.951302	-0.25439	0.156138	-0.098252	0	0	0
4	-1.09105	30.1269	29.0359	30	0	0	0	0	30	-0.951975	0	-0.951975	-0.139074	0.126949	-0.0121249	0	0	0
4.5	-1.05248	30.1639	29.1115	30	0	0	0	0	30	-0.95265	0	-0.95265	-0.0998323	0.163934	0.0641016	0	0	0
5	-1.08329	30.2611	29.1778	30	0	0	0	0	30	-0.953327	0	-0.953327	-0.129959	0.26112	0.131162	0	0	0
5.5	-1.12042	30.3562	29.2357	30	0	0	0	0	30	-0.954005	0	-0.954005	-0.166418	0.356161	0.189743	0	0	0
6	-1.17206	30.4579	29.2858	30	0	0	0	0	30	-0.954685	0	-0.954685	-0.217379	0.45787	0.24049	0	0	0
6.5	-1.21707	30.5457	29.3286	30	0	0	0	0	30	-0.955367	0	-0.955367	-0.2617	0.545707	0.284007	0	0	0
7	-1.25589	30.6207	29.3648	30	0	0	0	0	30	-0.95605	0	-0.95605	-0.299837	0.620695	0.320858	0	0	0
7.5	-1.28896	30.6838	29.3948	30	0	0	0	0	30	-0.956734	0	-0.956734	-0.332224	0.683797	0.351573	0	0	0
8	-1.31669	30.7359	29.4192	30	0	0	0	0	30	-0.957419	0	-0.957419	-0.359271	0.735917	0.376647	0	0	0
8.5	-1.33947	30.7779	29.4384	30	0	0	0	0	30	-0.958105	0	-0.958105	-0.381365	0.777907	0.396542	0	0	0
9	-1.35767	30.8106	29.4529	30	0	0	0	0	30	-0.958792	0	-0.958792	-0.398875	0.810567	0.411692	0	0	0
9.5	-1.37163	30.8346	29.463	30	0	0	0	0	30	-0.95948	0	-0.95948	-0.412146	0.834647	0.422501	0	0	0
10	-1.38167	30.8509	29.4692	30	0	0	0	0	30	-0.960168	0	-0.960168	-0.421507	0.850854	0.429348	0	0	0
10.5	-1.38812	30.8599	29.4717	30	0	0	0	0	30	-0.960856	0	-0.960856	-0.427266	0.85985	0.432584	0	0	0
11	-1.39126	30.8623	29.471	30	0	0	0	0	30	-0.961545	0	-0.961545	-0.429716	0.862257	0.432541	0	0	0
11.5	-1.39137	30.8587	29.4673	30	0	0	0	0	30	-0.962234	0	-0.962234	-0.429134	0.858668	0.429524	0	0	0
12	-1.3887	30.8496	29.4609	30	0	0	0	0	30	-0.962924	0	-0.962924	-0.425777	0.849599	0.423822	0	0	0
12.5	-1.38351	30.8356	29.4521	30	0	0	0	0	30	-0.963613	0	-0.963613	-0.419893	0.835594	0.415701	0	0	0
13	-1.37601	30.8171	29.4411	30	0	0	0	0	30	-0.964303	0	-0.964303	-0.411711	0.81712	0.40541	0	0	0
13.5	-1.36644	30.7946	29.4282	30	0	0	0	0	30	-0.964993	0	-0.964993	-0.401448	0.794629	0.393181	0	0	0
14	-1.35499	30.7685	29.4135	30	0	0	0	0	30	-0.965683	0	-0.965683	-0.389309	0.768538	0.379228	0	0	0

1. Group Balance Excel sheet

Radiative Budget

The radiative budget exports for the specified group of nodes:

- *Area*

$$Area = \sum_i A_i$$

- *Equivalent Emissivity*

$$\bar{\varepsilon} = \frac{\sum_i A_i \varepsilon_i}{\sum_i A_i}$$

- *GR sum*

$$SGR = \sum_i \sum_j GR_{ij}$$

- *Linear Temperature*

$$\overline{T}_{lin} = \frac{\sum_i A_i T_i}{\sum_i A_i}$$

- *Quadratic Temperature*

$$\overline{T}_{quad} = \sqrt[4]{\frac{\sum_i A_i \varepsilon_i T_i^4}{\sum_i A_i \varepsilon_i}}$$

- *Black-Body Tsink (°C)*

$$T_{Sink} = \sqrt[4]{\left(\frac{\sum_i \left(\sum_j \left(\sigma GR_{i,j} \left(T_j^4 - T_i^4 \right) \right) + QS_i + QA_i + QE_i + \varepsilon_i A_i T_i^4 \right)}{\sum_i \sigma \varepsilon_i A_i} \right)}$$

- *Rejection Power (W)*

$$RP = \sum_i \left(\sum_j \left(\sigma GR_{i,j} \left(T_j^4 - T_i^4 \right) \right) + QS_i + QA_i + QE_i \right)$$

- _Rejection Flux (W/m²)_

$$RF = \frac{RP}{\sum_i A_i}$$

Posther

version V.4.4.0 released on December 2010

Radiative Budget

Thermisol HDF5 result	test6.temp.h5
Thermisol version	V.4.4.0 released on December 2010
Input DCK file	test6
Directory of run	/home2/meneac/MOS/home/tsoriano/Debug/solver/test
Date of run	Ended on 17-Dec-2010 at 11:01:55
Date of 1st time	0 Julian days
Simulation time range	'0-100 sec

Nodal specification #104-106
Time range '0 - 100

Time	Area	Equivalent emissivity	GR sum	Linear Temperature	Quadratic Temperature	Black-Body Tsink (°C)	Rejection Power (W)	Rejection Flux (W/m²)
Mean	0.03	0.1	0.003	4.82626	4.86804	374.934	29.984	966.134
0	0.03	0.1	0.003	2.20E-14	-8.88E-16	374.934	29.0533	968.444
0	0.03	0.1	0.003	2.20E-14	-8.88E-16	374.934	29.0533	968.444
0.5	0.03	0.1	0.003	0.0469105	0.0469105	374.934	29.0527	968.422
1	0.03	0.1	0.003	0.0940209	0.0940211	374.934	29.052	968.401
1.5	0.03	0.1	0.003	0.141395	0.141395	374.934	29.0514	968.379
2	0.03	0.1	0.003	0.189004	0.189004	374.934	29.0507	968.357
2.5	0.03	0.1	0.003	0.236824	0.236825	374.934	29.05	968.335
3	0.03	0.1	0.003	0.284834	0.284835	374.934	29.0494	968.312
3.5	0.03	0.1	0.003	0.333014	0.333014	374.934	29.0487	968.29
4	0.03	0.1	0.003	0.381344	0.381345	374.934	29.048	968.268
4.5	0.03	0.1	0.003	0.429809	0.429809	374.934	29.0474	968.245
5	0.03	0.1	0.003	0.478391	0.478392	374.934	29.0467	968.222
5.5	0.03	0.1	0.003	0.527077	0.527077	374.934	29.046	968.2
6	0.03	0.1	0.003	0.575852	0.575853	374.934	29.0453	968.177
6.5	0.03	0.1	0.003	0.624705	0.624706	374.934	29.0446	968.154
7	0.03	0.1	0.003	0.673624	0.673624	374.934	29.0439	968.132
7.5	0.03	0.1	0.003	0.722597	0.722597	374.934	29.0433	968.109
8	0.03	0.1	0.003	0.771615	0.771615	374.934	29.0426	968.086
8.5	0.03	0.1	0.003	0.82067	0.82067	374.934	29.0419	968.063
9	0.03	0.1	0.003	0.869752	0.869752	374.934	29.0412	968.04
9.5	0.03	0.1	0.003	0.918855	0.918855	374.934	29.0405	968.017
10	0.03	0.1	0.003	0.967971	0.967971	374.934	29.0398	967.994

1. Radiative Budget Excel sheet

Temperature Initialization

This mode is only available in batch mode. It exports the node temperatures into a file as a "$INITIAL" block to be integrate into a DCK file (directly or through the Skeleton module).

B-Plot

Introduction

B-Plot is a postscript document writer. It reads instruction from a file and export graphs into a ps document. As POSTHER, this module is a post-processing tool which is based on the h5 output of THERMISOL.

Principle

B-Plot is based on the following principles: a graph is described by instructions written in a text file called the B-Plot command file. Those instructions respect a language described in the next paragraph. A document is made of several graphs and each graph is made of several curves. A curve is given by a node specification and an entity (T, QS, QA, QE, QR or QI). It is possible to plot temperature and power curves into a same graphic. If this is the case, B-Plot will automatic display 2 y axes (one on the left and one on the right of the graph). The use of 1 y axe or 2 y axes can also be manually managed as well as the axes labels, factors, curve titles, graph titles… In this version of B-Plot, it is possible to choose between 2 page formats. The default format corresponds to 1 graph per page in landscape orientation. The other possibility is to specify 2 graphs per page in portrait orientation.

Limitations

B-Plot authorize the maximal number of declaration of:

- *5 input files (h5 results from THERMISOL Temperature Solver runs)*
- *10 curves per graph*

The numbers of graphs, the total number of nodes and the length of the time vector have no limit.

B-Plot command file

Keywords

Command	**Parameters**	**Description**
NUM	*n*	*First page number*
NGRAPH	*n*	*Number of graphs per page (1 or 2)*
F	*n , file*	*Input File (h5 format)*
T	*n [text]*	*Title (or case) given to a result file*
@	*text*	*New graph – graph title*
!	*n, Xn, [$nom]*	*New curve – curve specifications*

AXEX	*xmin, xmax* *[, xdelta [, xoffset]]*	X axe definition
XFACT	*real value*	X axe scale
XLABLE	*text*	*Label of the X axe*
AXEY (or AXEY1)	*ymin, ymax [, ydelta]*	Y1 axe definition
YFACT (or Y1FACT)	*real value*	Y1 axe scale
YLABLE (or Y1LABLE)	*text*	*Label of the Y1 axe*
AXEY2	*ymin, ymax*	Y2 axe definition
Y2FACT	*real value*	Y2 axe scale
Y2LABLE	*text*	*Label of the Y2 axe*

Command sequences

Here is an example of a B-Plot command sequence.

1. comment: a B-Plot command sequence
2. Input data
   F1 …
   T1 …
   F2 …
   T2 …
   … …
3. General definitions
   NGRAPH…
   NUM…
   XLABEL …
   XFACT…
4. Graph 1:
   @…
   AXEX…
   AXEY…
   YLABLE…
   AXEY2…
5. Curve 1 (of graph 1)
   !…
6. Curve 2
   !…
   …
7. Graph 2:
   @…
   …
   …

Keywords definitions

AXEX
AXEX *xmin*, *xmax* [, *xdelta* [, *xoffset*]]

OPTIONAL
Set the minimum and maximum values of the X axis
Default values
The range is set to the minimum and maximum values of the time reference
The offset is set to zero

Déclaration *:*

- *Into the general definition (before any @ command). Set the default values to apply to each graph*
- *Into one graph definition (after a @ command). Locally overload the default value.|*

Limitation *: no*

Parameter	***Values***	***Description***
xmin	*Real*	*Minimum value of X to plot*
xmax	*Real*	*Maximum value of X to plot*
xdelta	*Real*	*Grid spacing*
xoffset	*Real*	*Offset of X values*

AXEY / AXEY1 / AXEY2
AXEY / AXEY1 / AXEY2 *ymin*, *ymax*

OPTIONAL
Set the minimum and maximum values of the Y axis
Default values
The range is set to the minimum and maximum values of the curves relative to that axis

Déclaration *:*

- *Into the general definition (before any @ command). Set the default values to apply to each graph*
- *Into one graph definition (after a @ command). Locally overload the default value.|*

Limitation *: no*

Parameter	***Values***	***Description***
ymin	*Real*	*Minimum value of Y to plot*
ymax	*Real*	*Maximum value of Y to plot*

F
F *n file*

Input file declaration
Déclaration *:*

- *Into the general definition (before any @ command).* |

Limitation *: The input file has to be a h5 output from THERMISOL* *5 files maximum can be declared*

Parameter	***Values***	***Description***
n	_1 Integer 5_	*File number*
file	*String*	*Filename (with its relative path)*

NUM
NUM *n*

OPTIONAL *First page number* ***Defaul value*** *The first page starts with number 1*
Déclaration *:*

- *Into the general definition (before any @ command).* |

Limitation *: The input file has to be a h5 output from THERMISOL* *5 files maximum can be declared*

Parameter	***Values***	***Description***
n	*Integer*	*First page number*

NGRAPH
NGRAPH *n*

OPTIONAL *Number of graphs per page* ***Defaul value*** *One graph per page (LANDSCAPE format)*
Déclaration *:*

- *Into the general definition (before any @ command).* |

Limitation *: There can be only 1 or 2 graphs per page*		
Parameter	***Values***	***Description***
n	_1 Integer 2_	*Number of graphs per page*

T
T *n text*

Set the title of an input file to be reported into the curve legends
Déclaration *:*

- *Just after a* ***F*** *command |*

Limitation *: See the F command*		
Parameter	***Values***	***Description***
n	_1 Integer 5_	*File number*
text	*String*	*Title of the file*

XFACT / YFACT / Y1FACT / Y2FACT
XFACT / YFACT / Y1FACT / Y2FACT *val*

OPTIONAL *Apply a factor to the values displayed from the values stored in the result file* ***Default value*** *1.0*
Déclaration *:*

- *Into the general definition (before any @ command). Set the default values to apply to each graph*
- *Into one graph definition (after a @ command). Locally overload the default value.|*

Limitation *: None*		
Parameter	***Values***	***Description***
val	*Real*	*Factor to be applied on the axis*

Remark
The time is output in seconds if XFACT is set to 1.
To convert the time into minutes, XFACT shall be set to 1.6667e-2
hours, 2.7778e-4
days, 1.1574e-5
The other default units (corresponding to a factor of 1.0) are
Temperatures Degre Celsius
Power Watt

XLABLE / YLABLE / Y1LABLE / Y2LABLE
XLABLE / YLABLE/ Y1LABLE / Y2LABLE *text*

OPTIONAL *Set a title for the axis* ***Default value*** *X axis Time (seconds)* *Y1 axis Temperature (Celsius) or Power (W) depending on the entities plotted* *Y2 axis Power (W) if both temperatures and powers are displayed in one graph*
Déclaration *:*

- *Into the general definition (before any @ command). Set the default values to apply to each graph*
- *Into one graph definition (after a @ command). Locally overload the default value.*|

Limitation *: None*

Parameter	***Values***	***Description***
text	*String*	*Title of the axis*

!
! *n, X node, $label*

Define a curve
Déclaration *:*

- *Into one graph definition (after a @ command).* |

Limitation *: Only 10 curves per graph can be plotted*

Parameter	***Values***	***Description***
n	_1 Integer 5_	*File number of the data*

X	_T	QS	QA	QE	QR	QI_	*Entitytoplot*
node	[*submodel path :*] *Node number*	*Node reference*					
label	String	*Curve label*					

@
@ *text*

New graph definition
Déclaration *:*

- *After general definitions*
- *After a previous graph*

Limitation *: None*		
Paramètre	***Valeurs***	***Description***
text	*String*	*Graph title*

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Batch Mode

Introduction

THERMISOL is package of applications which is convenient to call directly from batch command. This batch mode should allow the user to completely define all the required computations. It should be easy to use and all the options should not necessarily be defined if they are not different from the common default values.
The batch program will execute each paragraph defined in the command file.
A paragraph is defined by the keyword "$" followed by the name of the module to be executed.
There are 4 modules in THERMISOL which are:

- $SKELETON
- $SOLVER
- $POSTHER
- $BPLOT

A command file can include as many occurrences of those modules.

Expansion of a skeleton file

Another use of the skeleton module is to expand a skeleton file into a THERMISOL input file (usually written with dck extension).
This operation may be a simple expansion not requiring any extra parameters or may use specific options which shall be describe in a parameter file.

Direct expansion

The direct expansion can be call with the following syntax:
[path] ThermisolLNX –e file.ske *on Linux systems*

Or[path] ThermisolWIN.exe –e file.ske *on Windows systems*
It will automatically create the THERMISOL input file.dck.

Expansion with parameters

In case the user needs more advanced options, it is possible to use a parameter file.
In the parameter file, it is then possible to assign file names to the parametric #READ-n instructions.
The call is then:
[path] ThermisolLNX parameters.txt *on Linux systems*
Or[path] ThermisolWIN.exe parameters.txt *on Windows systems*

Name	Type	Default value			Description
# Inputs					
SKE	String	NEEDED			Name of the skeleton file
READ-*n*	String	" "			File reference for parametric expansion (n = 1 to 256)

USE-*n*	String	" "			File reference for parametric expansion (n = 1 to 256)
# Outputs					
DCK	String	NEEDED			Name of the DCK file

It is also possible to complete this command with the following options:
–ske_inputs_dir [directory]
This option allows specifying a directory where the files to be expanded are located.
–dck_outputs_dir [directory]
This option specifies where to create the dck file. If the parameter file contains a second block of instructions $SOLVER to execute the temperature solver, it will be automatically executed in that directory. If the path specified does not exist, it will be automatically created.

Module paragraph "SOLVER"

Name	Type	Default value	Description
# Inputs			
DCK	String	NEEDED	Name of the DCK file
# Outputs			
OUT	String	" "	Name of the text result file
HDF	String	" "	Name of the h5 result file
CSV	String	" "	Name of the convergence file
LOG	String	" "	Name of the log file
# Options			
TASK	Integer	0	Specifies the tasks to be achieved: 0 – All 1 – Translate Mortran 2 – Compile Fortran 3 – Link with the solver library 4 – Execute resolution
DEBUG	Flag	No	Creates extra data for debugging
IMPLICIT_NONE	Flag	No	Specifies Fortran routines to be "IMPLICIT NONE"

			(Default is "IMPLICIT DOUBLE PRECISION A-H L-Z")

Direct batch call to the solver

As for the expansion, it is possible to call directly the solver module without specifying a parameter file. Use the following syntax;
ThermisolXXX –d example.dck

Module paragraph "POSTHER"

Name	Type	Default value	Description
# Inputs			
INPUT	String	NEEDED	Name of the temperature results (h5 format)
# Outputs			
OUTPUT	String	"- "	Name of the output file
# Options			
TYPE	String	"EXTRACT"	Specifies the type of post-processing: "Extract" "Tinit" "NodeMinMax" "TimeMinMax" "Flux" "Balance" "RadBudget"
NODE_SPEC	String	"ALL"	Nodal specification
NODE_SPEC2	String	"ALL"	Nodal specification of 2nd group (for "Flux" analyses only)
INTERFACE_SPEC	String	"EDGE"	Nodal specification of conductive interface group (usually it is the EDGE submodel) (for "Flux" analyses only)

TIME1	Real	-1	Minimum time range specification (-1 goes automatically to the zero of the simulation)
TIME2	Real	-1	Maximum time range specification (-1 goes automatically to the end of the simulation)
TIME	Real	-1	Time for Tinit output (-1 goes to the end time of the simulation)
A	Flag	No	To output the Areas
C	Flag	No	To output the Capacitances
T	Flag	Yes	To output the Temperatures
QS	Flag	No	To output the Solar Fluxes
QA	Flag	No	To output the Albedo Fluxes
QE	Flag	No	To output the IR planet Fluxes
QI	Flag	No	To output the Internal Dissipations
QR	Flag	No	To output the Residual Fluxes
RADIATIF	Flag	No	To output a detail radiative "Flux" budget
CONDUCTIF	Flag	No	To output a detail conductive "Flux" budget
CONVECTIF	Flag	No	To output a detail convective "Flux" budget

Module paragraph "BPlot"

Using the sequential batch mode

Under the keyword "$BPLOT", the commands for executing B-Plot are as described in the B-Plot chapter.

Using a direct call to B-Plot

Type the command
ThermisolXXX –b bplot.dat
where bplot.dat is a parameter file conform to the specifications described int B-Plot chapter.

Example

Here is an example of THERMISOL batch sequence that was used for THERMICA validation procedures on industrial cases:
The goal of this sequence was to compare results between THERMICA v3 and v4. Let's suppose that THERMICA files for THERMISOL has been already computed
THERMICA files :

- V3 Results:
  - Example99N.TAN *Nodal Description*
  - Example99R.TAN *Radiative Couplings*
  - Example99H.TAN *External Fluxes*
- V4 Results:
  - Example.nod.nwk *Nodal Description*
  - Example.gr.nwk *Radiative Couplings*
  - Example.fsa.nwk *Solar Fluxes*
  - Example.fpa.nwk *Planet Fluxes*

In order to compare those results, let's compute the steady-state and transient temperatures in both case and plot some curves to have a graphical check.
First of all, we need a generic skeleton using parametric file references that we are going to use for both cases.
Skeleton.ske

```
#---------------------------------#
# Generic Skeleton for Thermisol #
#---------------------------------#
#
# Parametric files description:
#
# File 1: Nodal Description
# File 2: Radiative Couplings
# File 3: Planet Fluxes (v4) or External Fluxes (v3)
# File 4: Solar Fluxes (v4) or OFF (v3)

$INFOS

#READ-1
#READ-2
#READ-3
#READ-4

$MODEL #READ-1


$NODES

#READ-1


$CONDUCTORS
```

```
#READ-2


$LOCALS

INTEGER* NBORBIT = 2;

# inclusion of local constants defined in input files
#READ-2
#READ-3
#READ-4

$ARRAYS

#READ-2
#READ-3
#READ-4


$CONTROL

# simulation time definition
#READ-2
#READ-3
TIMEO = 0;
TIMEND = NBORBIT * PERIOD;

DTIMEI = 10;
OUTINT = PERIOD / 20;

# csv output
CSV_FREQ = 10;

# h5 output definition
```

1. initial data storage

```
   H5_RES0 = 'NS,A,C,ALP,EPS,GL,GR,GF';
   # frequency data storage
   H5_FREQ = 4;
   H5_RES1 = 'T,QS,QA,QE,QI,QR';


   $SUBROUTINES

   #READ-2
   #READ-3
   #READ-4


   $INITIAL

   # initialisation to average time-dependant values
   #READ-2
   #READ-3
   #READ-4

   # Storage in h5 file
   CALL H5_INIT(' ')
```

```
$VTIME

# update of time-dependant radiative couplings and fluxes
#READ-2
#READ-3
#READ-4


$VRESULT

# Storage in h5 file
CALL H5_DUMP


$OUTPUTS

CALL PRNDTB(' ','L,C,T,QS,QA,QE,QI,QR',CURRENT)


$EXECUTION

# Steady-State case
CALL SOLVIT

# Saving to CSV files initial values
CALL DMPTHM(' ')

# Transient case
CALL SCRANK


$ENDMODEL
```

Now, let's define the instruction sequence into a parameter file:
Sequence.txt

```
#
# THERMISOL Script for results comparison
#



# V3 Expansion and Execution
$SKELETON

# Input: Skeleton
SKE Skeleton.ske

# Output: DCK – THERMISOL input file
DCK v3.dck

# Parametric reading file
READ-1 Example99N.TAN
READ-2 Example99R.TAN
READ-3 Example99H.TAN
READ-4 OFF
```

$SOLVER

 # Input: DCK
DCK v3.dck

 # V4 Expansion and Execution
$SKELETON

 # Input: Skeleton
SKE Skeleton.ske

 # Output: DCK – THERMISOL input file
DCK v4.dck

 # Parametric reading file
READ-1 Example.nod.nwk
READ-2 Example.gr.nwk
READ-3 Example.fsa.nwk
READ-4 Example.fpa.nwk

$SOLVER

 # Input: DCK
DCK v4.dck

 # Curve Plotting
$BPLOT

 # Output: Post-Script file
OUTPUT v3-v4.ps

 # Input result files
F1 v3.temp.h5
T1 v3.2.31_3

F2 v4.temp.h5
T2 v4.3.3

 # X label Definition (Time)
Xlabel Seconds

 # Graph 1:
@Temperatures of nodes 51 & 314
!1,T51,$Baseplate
!2,T51,$Baseplate
!1,T314,$Radiator
!2,T314,$Radiator

 # Graph 2:
@Cylindrical structure
!1,T476,$Cycl7-Temperature
!2,T476,$Cycl7-Temperature
!1,QS476,$Cycl7-Solar Flux
!2,QS476,$Cycl7-Solar Flux

```
!1,QA476,$Cycl7-Albedo Flux
!2,QA476,$Cycl7-Albedo Flux
!1,QE476,$Cycl7-IR Flux
!2,QE476,$Cycl7-IR Flux
```

The following command will then perform all the tasks requested:
ThermisolXXX Sequence.txt

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DCK to STEP-TAS converter

The STEP-TAS converter processing is used to export data from the thermal mathematical model (TMM) into a STEP-TAS file. The exported data are:

- node properties:
  - node name
  - capacitance
  - internal dissipation
  - initial temperature
- radiative couplings
- conductive couplings

In order to proceed, this converter needs 2 inputs.

- the GMM (geometrical model) in the STEP-TAS format. ⚠ The STEP-TAS geometrical model is not available in the processing tab. Hence, the user has to manually export the meshing using "Save As/STEP-TAS file" and complete this GMM input before the run.
- the DCK, the Thermisol mathematical model in dck format (Skeleton module output)

It will output the newly created TMM file in the STEP-TAS format, which is the result of the completion of the input GMM with TMM data from Thermisol.

⚠ Conduction couplings must be outputted in a standard format to be exported using this module. This means the user has to use the "Simplified RCN" in the Conduction module (default value) and not the "RCN".

Command line use

The use of the DCK to STEP-TAS converter in command line is is done through the following command:

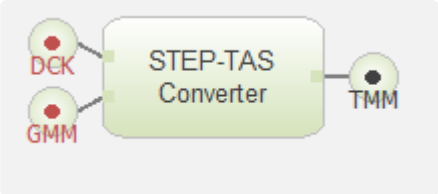
```
Dck2Steptas[WIN.exe] -gmm <your_gmm_STEP_file> -dck <your_dck_tmm_file> -out
<output_tmm_STEP_file>
```

> *Please note that both DCK and GMM files have to be related. Especially, the DCK file must be generated from processings based upon the GMM meshing.*

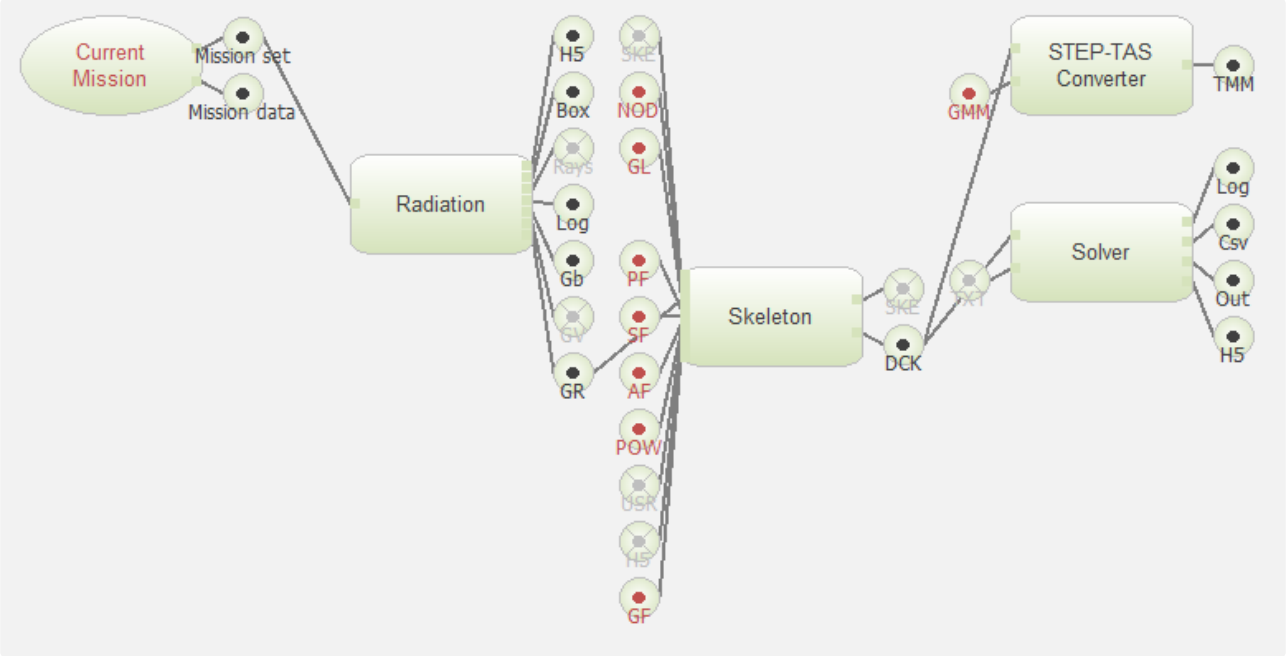
HMI process tab use

Systema also provides the DCK to STEP-TAS conversion from the processing tab.

This processing is available under the Thermisol section and is displayed as:



The parameters are exactly the same as the command line use. The dck input can however be the result of other processing boxes like bellow.



It is possible to use the resulting STEP-TAS file with the TASVerter tool from ESA. In order to have a compatible file, please modify the following line

NRF_TOOL_OR_FACILITY('TMMverter','Systema vs STEP-TAS converter',$);

into

NRF_TOOL_OR_FACILITY('TMMverter','ESATAN vs STEP-TAS converter',$);

Troubleshooting

Compilation issues with user subroutines on Windows (since version 4.9.2)

Starting from version 4.9.2, you may encounter compilation issues on Windows when using user subroutines written in previous versions. This is due to a change in the compilation process:

- **Since version 4.9.2**, the **libsolver** library is compiled in **64-bit** on Windows (it has been 64-bit on Linux since version 4.6.1).
- To support this transition, the compiler has changed from **g77 (32-bit) to gfortran (64-bit)**.

Although there are no major differences between these compilers, some user subroutines may be **incompatible** and require minor adjustments.

If your Fortran code has compatibility issues, errors **may not appear in the Systema run window**. Instead, you may experience:

- an "**error at link**" message
- a **crash** of the zz executable

To diagnose these issues, it is recommended to run **Thermisol in bacth mode**, which provides **detailed compilation error messages**.