IEA ANNEX 30 "BRINGING SIMULATION TO APPLICATION". PRESENTATION OF SUBTASK 1: MODEL QUALIFICATION

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1. INTRODUCTION.

When trying to bring simulation to application in the current practice (consulting offices), the scientist and the engineer have to agree on the level of quality of the models that are to be used in the simulation process. Simulation programs are made of a collection of models representing the different physical processes occuring in the real world but the information about the quality of the models is very often lacking as if the implementation of a given model in a program offered a sufficient garantee concerning the ability of the model to adequately translate the behaviour of the real world. Before offering those models, embedded in ready-to-run packages, to the practice, a certification or qualification procedure should take place in order to allow the use of the model in some circumstances, clearly defined by the procedure.

The overall objective of the Subtask 1 of the Annex 30 "Bring simulation to application", is to define, develop, test and implement this qualification procedure using, as examples, the general material provided by the Annex 30 Case Studies. The application of this procedure aims at making the use of the models "safer" and at providing the user with garantees about the results obtained by the use of the models.

As it is shown later, a direct connection exists between Subtask 1 and the other Subtasks of the Annex. These connections point out the global approach considered in the Annex, which is the only feasible approach in order to achieve the general objective of the Annex 30: To Bring Simulation to (real) Application.

2. SUBTASK 1 DESCRIPTION.

In order to achieve the general objective of Subtask 1, the following actions were identified:

2.1. Review of the available models in the field of building and HVAC simulation.

Before attempting to develop a qualification procedure for a given model, it is necessary to have a general view of the existing models, their characteristics and their differences. Consequently, a review of the available models has to be performed, mainly based on existing material and information sources.

In order to limit the amount of work, a selection of typical components of a building/HVAC simulation was performed. The selection ended up with the following models:

- air handling units, including coils, fans, and humidifiers
- chilller plants, including storage systems and cooling towers
- thermal zones

The following sources of information were identified:

- the TRNSYS library [1]
- the HVACSim+ library [2]
- the ASHRAE Primary Toolkit [3]
- the ASHRAE Secondary Toolkit [4]
- the IEA/ECBCS Annex 10 databank [5]
- the IEA/ECBCS Annex 17 components [6]
- general purpose simulation softwares like BLAST [7], ESP [8], etc

These items are the most comprehensive sources of information available concerning building and HVAC simulation. They will be scanned and the corresponding relevant material will be extracted.

2.2. Review of available data sets.

The availability of data is very often a problem when attempting to perform a simulation. Building and HVAC simulation usually require a huge amount of data concerning the components to be modelled and concerning the internal and external excitations to be applied to the models. The following information requirements were identified:

- external sollicitations: meteorological data
- internal sollicitations: internal gains
- components: building material and elements; HVAC technical data.

For these information requirements, typical sources of information were identified: the EC produced a database of typical meteorological data (the "Test Reference Year" or TRY[9] format) to be used in simulations. The CEN is working on a standardization of the internal

gains value to be considered in a building simulation. The national building codes are very often associated with databases of building material and elements properties. Finally, HVAC manufacturers more and more propose their catalogs on computer media (CD-ROMs for instance) or make them available on-line through the Internet. A general HVAC components database was developed during the course of the COMBINE project by VTT [10]. It was designed to be compliant with the STEP standard.

Again, those sources of information will be scanned and the relevant material will be extracted.

2.3. Identification of models requirements at the different life-cycle phases.

A building and its connected HVAC equipment is a "living" concept which is characterized by an evolution generally divided in several phases (fig. 1):

- analysis
- concept
- planning
- construction design
- commissioning
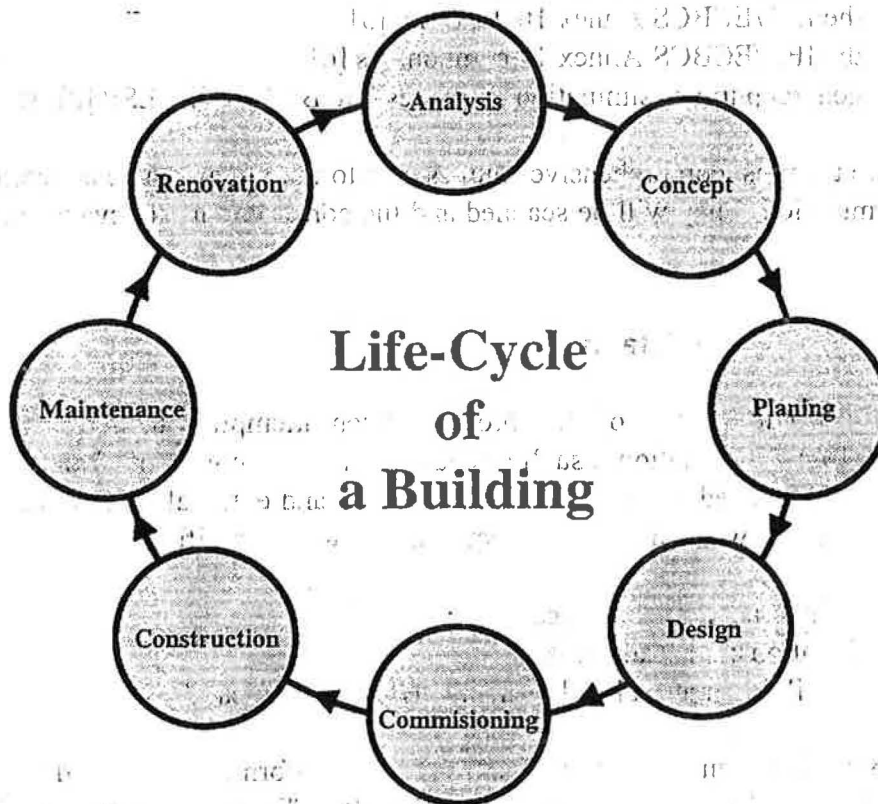- construction
- maintenance
- renovation

Fig. 1: The building life-cycle.

The succession of these phases defines the life-cycle analysis of a building project. The deep analysis of this building life-cycle is the specific activity of Subtask 2 of Annex 30 [11]. But strong connections appear between Subtask 2 and Subtask 1 because it is totally useless to examine the quality of a model without referring to the requirements from the design practice: a model is never "good" or "bad"; it is relevant for a given purpose or not. The assessment of the capability of a model to support the activity of the engineer at a given stage of the building life-cycle is an essential feature of the qualification procedure. Consequently, before defining and testing the qualification procedure, the requirements from the practice have to be clearly identified. As the design practice varies from one country to the other (although the key phases remain the same), this analysis is likely to be country-dependent.

2.4. Model qualification procedure.

The first three actions were aimed at collecting and providing the basic material in order to allow the model qualification procedure to take place. The present action, by far the most essential part of the Subtask, is concerned with the definition of the qualification procedure and its application to Case Studies.

First, a "qualification procedure" could be defined as *a standardized quality assessment procedure to be passed by a model before its implementation in a given simulation program and that certifies the quality of the model for a given purpose*.

The qualification certification could finally appear as a paper, optionally partly computerized, containing the following topics:

- Model documentation.

Model documentation appears as essential in order to make the engineer aware of the capabilities of the models he intends to use. A proposal of model documentation has been published during the course of the Annex . Others can be tested, for instance the building simulation models documentation expert system "MIS" [14] (for Management of Information System) developed in the frame of the project IEA-ECBCS Annex 21 "Calculation of Energy and Environmental Performances of Buildings". The CaseStudies will indicate whether this is relevant and comprehensive. Case Studies will point out what is really required as documentation. A standardized format is likely to be required.

The documentation sheet associated with a given model will include the following chapters:

- General description of the model
- Modelling assumptions and input/output characteristics
- Nomenclature of all the variables and symbols appearing in the model formulation
- Detailed mathematical representation of the model
- Typical input files
- Sample results
- optionally, source code of the model (if public domain).

Some examples, developed in the frame of the Annex, are proposed in [12] and [13].

- Parameter identification.

The "distance" between the scientific world and the engineer's domain very often makes the parameters of the models used in building and HVAC simulation not directly correspond to technical data of manufacturers. A "bridge" is consequently required between both worlds through the application of "identification procedures". A model can no longer be imagined without its own identification procedure that allows an efficient translation of the technical data. CaseStudies will "force" the development or use of some parameter identification procedures. The feedback of these tests will be useful to complete the qualification of a given model.

Depending upon the model type, different identification methods can be associated with a model. Most of the HVAC components models appear as static models. In some cases, an identification of the parameters of these models can consequently be obtained by a reverse use of the model (express the model in terms of the unknown parameters with respect to the known variables originating from manufacturers data or laboratory tests for instance).Or some basic statistical methods like linear regression can also be used to determine the relationship between unknown parameters and measured variables. Some examples of this elementary type of identification are provided in [12] and [13].

Some HVAC components models and most of the models representing the building appear as fully dynamic models. Consequently, the parameters of these models can no longer be estimated by elementary methods. Special methods, developed in the field of automatic control ("system identification methods") appear as relevant for this purpose. Some examples showing the use of such methods for the identification of building zone simplified models parameters are proposed in [18]. These methods can even be used in real time in order to help the control and management of the system.

- Examples of use.

When a model is provided to the engineer, it has to be illustrated with examples. Case Studies will provide real examples to work on. As they are concerning different stages in the life-cycle (see table below), execution of the Case Studies will indicate whether a given model is relevant for a given purpose or stage.

Annex 30 actually involves work on five Case Studies:

1. A fictitious offcie building located in Germany
2. A residential appartment building in Poland
3. A passive solar office building in the UK
4. The HVAC plant of a big office building in Brussels (Belgium)
5. The HVAC plant of an office building in Hong-Kong

Table 1 shows the life-cycle phases for which the use of each case study appear as relevant.

CS/Stage	Concept	Planning	Design	Construction/ commissioning	Maintenance	Renovation
1 - Germany	x	x	x			
2 - Poland					x	x
3 - UK		x	x	x	(x)	(x)
4 - Belgium				x	x	x
5 -HongKong				x	x	x

Table 1: Identification of the life-cycle phase corresponding to each Case Study.

- Validation.

This item will provide information about successful applications of the models in other circumstances than the test-benches: real life applications, test cell comparisons, etc. The realization of another validation exercise itself will not be part of the Annex. Although it does not seem feasible to make use of a non-validated model, this operation requires indeed efforts and man power that are largely beyond the availability in the Annex. Consequently, validation of building zone models will not be dealt with. Instead, reference to existing (IEA 21C/12 [19], PASSYS [20]) and on-going (IEA SHAC 22) work will be highlighted. For the other models, at least some comparison of simulation results with real monitored data should be performed in the Case Studies where this might be possible.

- Integration in the Data Exchange Process.

The Subtask 4 of the Annex 30 is concerned with the assessment of efficient data exchange procedures all along the course of the design process. A connection also exists with Subtask 1 as the use of a model can not be considered as isolated from the overall design activity. The capability of a model to successfully "pass" a data exchange process should be part of the qualification procedure. Because of the specificity and scope of this part of the work, only reference to existing and on-going work concerning the integration of the models under study in an available Data Exchange System will be mentioned.

3. TWO EXAMPLES OF QUALIFICATION PROCEDURE.

In order to illustrate the concept of model qualification procedure, two examples will be presented concerning first a cooling coil model and then a thermal zone model. For each of these examples, the following topics will successively be presented:

- review of available models
- detailed presentation of one model

These examples are aimed at illustrating the qualification procedure. As the development of these procedures is still on-going, some chapters of the procedure are still at a preliminary draft stage.

3.1. Cooling coil model

3.1.1. Review of cooling coil models.

A number of cooling coil models were identified within the sources listed above. The following software packages provide such a model:

- TRNSYS (version 14.2) [1]

Two different cooling coil models are available. They have different levels of complexity.

1. Type 32.

   The purpose of this Type is to separate the cooling input into sensible and latent effects. It is based upon empirical relationships published by ASHRAE [21]. They involve parameters such as the number of rows deep, the number of parallel cooling coil circuits, the coil face area and the inside tube diameter.

2. Type 52.

   This type is based upon the effectiveness concept [22]. The user must specify the geometry of the cooling coil and air duct (annular fins or continuous flat plate fins may be specified). Two levels of analysis are provided: detailed (separate analysis of the dry and wet portion of the coil in partially wet/dry conditions) or simple (the coil is assumed to be either fully dry or fully wet). This more refined model involves a larger number of parameters.

- HVACSim+ [2]

   HVACSim+ offers one cooling (or dehumidifying) coil model (Type 12). It is based upon the work of Elmahady and Mitalas [23]. It is worthwhile to notice that this model is a dynamic one. The coil is modelled as a classical counterflow heat exchanger. Three different cases can be handled by the model: all wet, partially wet, all dry. It involves a still larger number of parameters than TRNSYS Type 52.

- IEA Annex 10.

   A cooling coil model was also investigated in the frame of the Annex 10 project "System Simulation in Buildings" [24]. This model was proposed by Holmes [25]. It supposes that a fraction of air bypasses the coil and that the fraction entering the coil is saturated at the outlet of the coil. The total heat transfer is computed, assuming the air side heat transfer coefficient is enhanced by the sensible heat ratio, so that only dry bulb temperatures are considered. It is worthwhile to notice that the same model applies to

both heating and cooling coils and that some dynamics is taken into account through the definition of the coil time constants.

- IEA Annex 17 [26]

    A first order dynamic model was developed based upon the lumped thermal mass method. A fictitious mean temperature of the coil is used, which is assumed equal to the surface temperature of the coil [27]. This model is conceptually the same as that documented by Bourdouxhe [28] in the frame of the Annex 30.

- ASHRAE Secondary toolkit. [4]

    A cooling coil is also available in the Secondary Toolkit produced by ASHRAE. It is also based upon ASHRAE methods and the work of Elmahady and Mitalas [23]. Basically, this model is the same as that of HVACSim+.

- DOE2.1 program

    The model available in the DOE2.1 software calculates the performance of a DX cooling coil using default correlations. The routine determines the total capacity, sensible heat ratio and coefficient of performance for a coil given the rated performance, entering air temperature and humidity ratio, outdoor temperature and the ratio of evaporator airflow rate to rated airflow. The correlations do not account for indoor fan energy effects.

- ROM-HX Model [29]

    This is a very simple model in which the state of the coil is determined from the nominal point delivered by the vendor. The new working point is calculated with the changed state of the incoming air and water using the method of Bosnjakovic. For dry regimes, this approximation is close to reality.

    For the wet regime calculation, a by-pass factor is introduced, which describes the ratio between the air at the temperature of the coil and air not influenced by it. The mean surface temperature can be calculated from the rib efficiency. (η_R=0.85 for most air cooling coils).

3.1.2. Presentation of one model: the University of Liège (Ulg) model. [28]

A. Model documentation: general description and hypotheses of the model.

This routine was developed as a TRNSYS Type [1] and its purpose is to simulate a cooling and dehumidifying coil. The inputs, parameters and the outputs of the model are defined by fig. 2.

This static model of the coil assumes that only two extreme regimes can occur: fully dry or fully wet. The regime giving the highest heat flow rate from air stream is considered as the nearest to the exact solution [22]. Then the coil is modelled as a classical counterlow heat exchanger characterized by its global heat transfer coefficient.
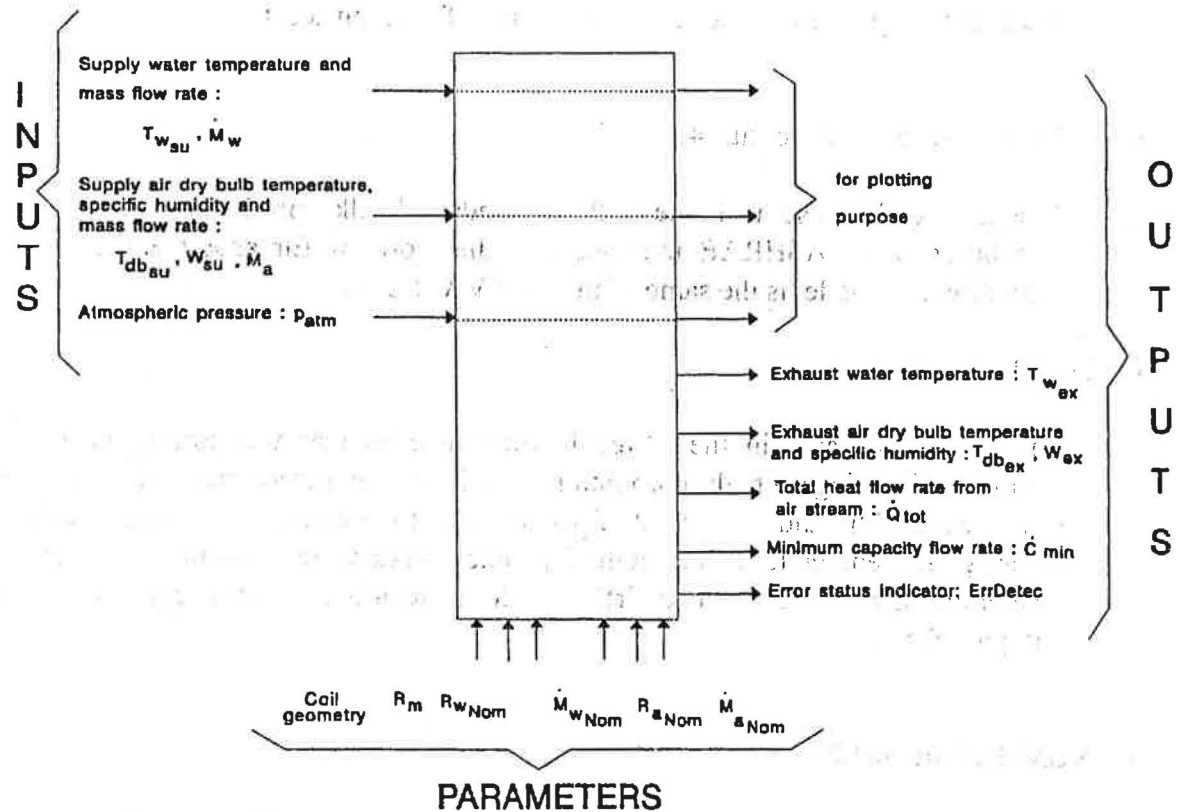

Fig. 2: Inputs/outputs characteristics of the ULg cooling coil model.

In dry regime, the total heat flow rate is calculated by:

$$\dot{Q}_{TOT_{dry}} = \dot{C}_{min} \, \varepsilon (T_{db_{su}} - T_{w_{su}})$$

with:

$\dot{C}_{min}$ =   minimum capacity flow rate

ε =   heat exchanger effectiveness

$T_{db_{su}}$ =   dry bulb tempeature of supply air

$T'_{w_{su}}$ =   supply water temperature

In wet regime, the air wet-bulb temperatures are used as driving potentials instead of air enthalpies. The total heat flow rate is calculated by replacing the air by a fictitious ideal gas characterized by the air wet-bulb temperature (T_{wb}) and a fictitious capacity flow-rate C_{af}:

$$\dot{C}_{a_f} = \dot{M}_a c_{p_f}$$

where c_{p_f} is a fictitious specific heat:

$$c_{p_f} = \frac{h_{a_{ex}} - h_{a_{su}}}{T_{wb_{ex}} - T_{wb_{su}}}$$

where $h_{a_{ex}}$ and $h_{a_{su}}$ represent the enthalpy of the exhaust and supply air, respectively, and $t_{wb_{ex}}$ and $t_{wb_{su}}$ represent the wet bulb temperature of exhaust and supply air, respectively.

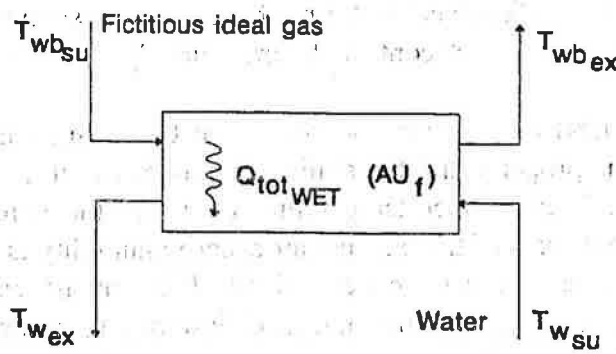The fictitious heat exchanger can be represented by the conceptual scheme of fig. 3:

Fig. 3: Conceptual schema of the cooling and dehumidifying coil in wet regime.

This fictitious heat exchanger is characterized by its global heat transfer coefficient AU_f. This coefficient is a function of the thermal resistance on water side (R_w), on fictitious fluid side (R_{af}) and of the coil metal (R_m). The thermal resistance on the fictitious fluid side is given by the following equation:

$$R_{a_f} = R_a \frac{c_{p_m}}{c_{p_f}}$$

where R_a is the actual thermal resistance on air side (assumed to remain the same in dry and wet regimes for the same air flow rate).

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c_{p_m} is the moist air specific heat.

The total heat flow rate is calculated as in dry regime:

$$\dot{Q}_{TOT_{wet}} = \dot{C}_{min}\varepsilon_f(T_{wb_{su}} - T_{w_{su}})$$

where:

$\dot{C}_{min}$ = minimum capacity flow rate

ε_f = fictitious heat exchanger effectiveness

$T_{wb_{su}}$ = wet bulb tempeature of supply air

$T_{w_{su}}$ = supply water temperature

Furthermore, in wet regime, the air dry-bulb temperature at the coil outlet is calculated on the basis of the "contact" factor method: the air is supposed to be in contact with an isothermal surface at the "contact" temperature T_c.

The effectivness of this semi-isothermal heat exchanger is the same in dry and wet regimes. This property and the similarity between heat and mass transfers allows the calculation of the contact temperature (T_c) and the exhaust air specific humidity (W_{ex}). On the basis of the exhaust air specific humidity and enthalpy, the exhaust air dry-bulb temperature can be determined. The exhaust water temperature is finally calculated on the basis of the total heat flow rate from air stream and on the energy stored in the condensed water.

In [28], Bourdouxhe provides some additional information about the calculation method.

C. Parameters identification.

From the model described above, a parameter identification procedure can be developed which simply consists of a reverse use of the model, starting from the following inputs:

1. The number of working points to be considered. The first working point is assumed to be the nominal working point.

2. For each working point:

    - the water mass flow rate, the water temperature at the coil inlet and outlet

- the air mass flow rate, the air dry bulb temperature and air specific humidity at the coil inlet and outlet as well as the atmospheric pressure.

The application of this identification procedure yields the following outputs:

1. The nominal thermal resistance on air side and the nominal air mass flow rate;
2. The thermal resistance of the coil metal;
3. The nominal thermal resistance on water side and the nominal water mass flow rate (this flow rate is deduced from the energy balances associated with the nominal working point).
4. The relative error on the total heat flow rate from air stream (in this case, all the working points are considered).

Furthermore, the identification procedure produces additional and secondary outputs: error status indicator, comparion between the data from the laboratory test results and the results of the simulation of the working points and the comparison between the water mass flow rates a sinputs and the water mass flow rates deduced from the energy balances.

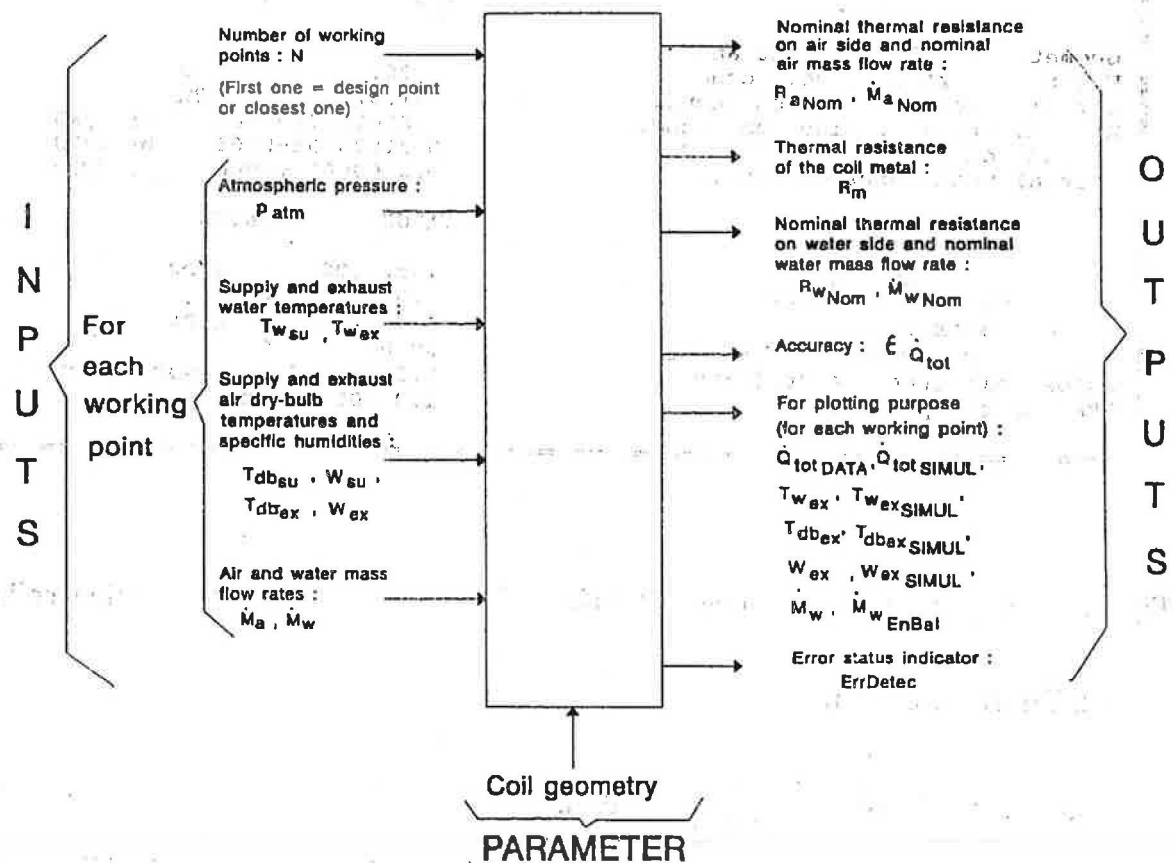This can be schematically repersented by the information flow diagram of fig.4.

Fig.4: Information flow diagram of the coil parameters identification routine.

Again, in [28], Bourdouxhe provides some additional information about the calculation method. This can be summarized as follows:

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1. The procedure calculates the global heat transfer coefficient characterizing each working point.

2. Once the global heat transfer coefficient are known, the procedure determines the thermal resistances on air and water sides as well as the thermal resistance of the coil metal. Each working point is then simulated on the basis of the identified thermal resistances.

3. The procedure outputs the value of the thermal resistances as well as the results of the simulation of each working point.

D. Example of use

Fig. 5, extracted from [28] shows the parameters and inputs and the output produced by the simulation of one working point.

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=[·]==================== C:\TRNEDCOI\TYPE21.TRD ========================

     *****  TYPE 21 SIMULATION COOLING AND DEHUMIDIFYING COIL  *****

        PARAMETERS                       VALUE        UNITS

  Geometry of the heat exchanger         1
  Water flow rate in nom. cond.          7790.40        kg/hr
  Dry air flow rate in nom. cond.        26125.00       kg/hr
  Resist. on water side Nom. cond.       3.8162000E-0005     hr-C/kJ
  Resist. on air side Nom. cond.         5.7107000E-0005     hr-C/kJ
  Thermal resistance of metal            0.0000000E+0000     hr-C/kJ

           INPUTS                        VALUE        UNITS

  Water mass flow rate                   13579.00       kg/hr
  Supply water temperature               7.00           C
  Dry air mass flow rate                 -26125.00      kg/hr
  Supply air dry bulb temperature        30.00          C
  Supply air specific humidity           1.31E-0002     kgwat/kgair
  Atmospheric pressure                   1.00000        atm
```

Fig. 5: Inputs, parameters and output of the simulation of one working point. Cooling coil model.

3.2. Thermal zone model

3.1.1. Review of thermal zone models.

Thermal zone models are as numerous as the number of available building simulation programs. Consequently, it is neither possible nor very useful to draw an exaustive list of the available models. Instead, a kind of categorization can take place which ends up with a presentation of the different model families. This survey was performed in the

course of the Annex and a report was produced [30]. This report identifies two major characteristics of a thermal zone model:

- the calculation of the heat transfer through the walls
- the representation of the zone temperature.

For the former, the following methods are identified:

- finite differences
- nodal method
- state space analysis
- modal analysis
- transfer function (Laplace domain or z-transform)
- stochastic models

For the latter, the different models either handle air temperatures or aggregated concepts like "resultant" temperatures, "operative" temperatures, "comfort" temperature which involve the concept of "radiant" or "mean radiant" temperature.

Another very important level of classification for the thermal zone models is related to the "simplified" or "detailed" character of the model.

"Detailed" (or "comprehensive") models consider separately the different building elements (walls, windows, roofs,...) and the different heat fluxes that appear between those elements and with the ambient, the occupants and the HVAC system. "Simplified" models aggregate either building elements, or heat sources, or both and end up with a representation of a zone only characterized by a few state variables, a small number of parameters and a limited number of input variables. An example of such a simplified building model will be "submitted" below to the qualification procedure.

3.2.2. Presentation of one model: the Annex 10 zone model.

A. Model documentation: general description and hypotheses of the model.

The purpose of this model is to simulate a single zone building in dynamic regime using a simplified representation of the physical processes. This routine is developed for the modular simulation program TRNSYS [1]. The building model is originating from the work of Louis Laret [31].

The inputs of the model are:

1. The " sol-air " temperature which gathers the effect of ambient temperature and solar radiation in one single variable.
2. The heat flux coming from the HVAC system and the internal gains

The outputs of the model are:

1. The resultant temperature of the zone
2. The structure temperature of the zone.

The model does not include any control. The calculation of the energy (heating or cooling) required in order to maintain a given set point has to be performed outside the routine, using an adequate controller model.

The model of the building is based upon the assumption that the dynamics of the building can be classified in two ranges: the " slow " effects due to the heavy structures of the building and the " fast " effects linked with the behaviour of the zone air and the light structures of the building. Consequently, the building is represented by two time constants or two state variables and the model is made of a set of two coupled differential equations translating the energy balance of both state variables. Using the classical electrical analogy, the state variables are associated with a thermal capacitance and are linked to each other by a purely resistive connection. Boundary conditions can be given as potentials (Dirichlet conditions) or as fluxes (Neumann conditions). The first type is used to represent the external climate, by means of the so-called " sol-air " temperature concept; the second one is used to represent the internal inputs: HVAC system and internal gains. Again, purely resistive connections can be established between the external node and both state variables. All these features form the following electrical analogy diagram (fig. 6):
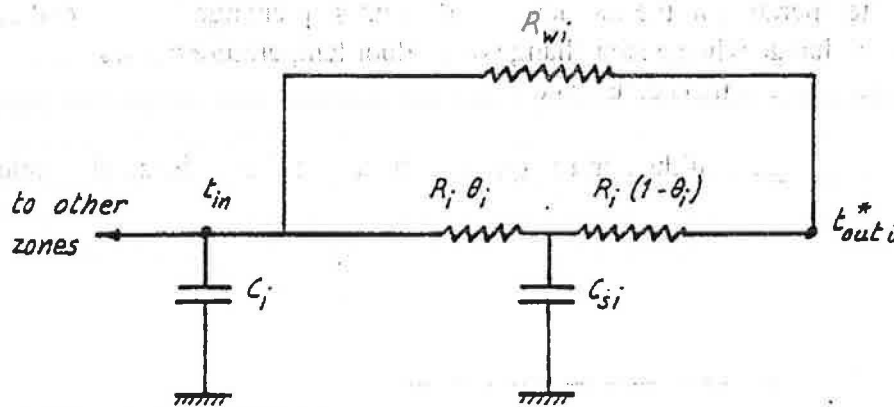

Fig. 6 Electrical analogy of the single zone model

with:

T_{si}, T_{in}:   state variables
R_i, $R_o = (1-\theta)R_i$, R_i, R_{wi}:   connection resistances
T_{out}^*, Q: boundary conditions

Based upon this representation, the energy balance of both nodes yields:

$$C_{si} \frac{dT_{si}}{dt} = \frac{T_{out}^* - T_{si}}{R_o} + \frac{Tn_i - T_{si}}{R_i} \tag{1}$$

$$C_i \frac{dT_{in}}{dt} = \frac{T_{si} - T_{in}}{R_i} + \frac{T_{out}^* - T_{in}}{R_{wi}} + Q \tag{2}$$

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The apparent simplification of the model is obtained at the price of the definition of very aggregated quantities: the sol-air temperature for the boundary conditions; the connection resistances and the thermal capacitances for the building structure. In this respect, the originality of the model is the method used to calculate the aggregated quantities.

The " sol-air " temperature can be defined as the equivalent temperature which produces the same heat flow between the ambient and the external surface of the building as the combination of ambient temperature, solar radiation and infrared temperature:

The parameters of the analog electrical model are calculated in order to meet the following criteria:

1. The overall heat loss factor of the building is conserved
2. The ratio of loss through light structures to the total losses is conserved
3. The characteristic responses to a step change are conserved: they are namely the sudden change of internal temperature at the moment when a unit step change in heat load is applied inside and a similar change when a step change of outdoor temperature occurs
4. The time constant of the zone is conserved

The information flow diagram of the simulation of a one zone building simplified model is given in figure 7
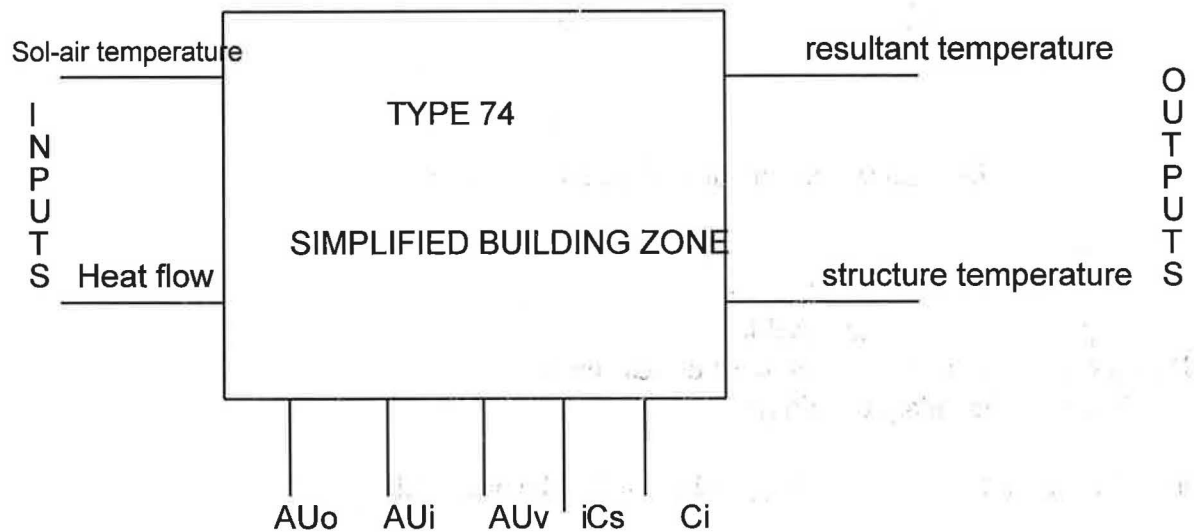

Fig. 7 Information flow diagram of routine Type 74

In [32], Laret et al provide some additional information about the calculation method.

C. Parameters identification.

As shown in [32], the calculation of the parameters of a building simplified model follows a tedious process. The apparent simplicity of the model is obtained at the price of a heavy preprocessing work which furthermore requires a lot of information: material properties,

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walls composition, room geometry. This information is not always fully available and, in many cases, can not be certified. In those cases where a preliminary calculation does not provide a reliable result, an alternative method would be to estimate the parameters of the building model from data monitored on real projects, using a process identification algorithm. Indeed, the building model presented above is a fully dynamic model and the parameters of the model can not be estimated on the basis of one working point in steady state regime. Methods suitable to identify dynamic processes are required.

In order to apply system identification techniques, the model is recast in the system analysis formalism. The equations of the model can be rewritten as:

$$\frac{d}{dt}\begin{pmatrix} T_{si} \\ T_{in} \end{pmatrix} = \underline{\underline{A}}\begin{pmatrix} T_{si} \\ T_{in} \end{pmatrix} + \underline{\underline{B}}\begin{pmatrix} T_{out}^* \\ Q \end{pmatrix} \tag{3}$$

where the matrices

$\underline{\underline{A}}$ and $\underline{\underline{B}}$ are related to the parameters of the model by a set of relations presented in [33].

This is the expression of a state space equation. An output equation can be associated with this state equation:

$$(T_{in}) = \underline{\underline{C}}\begin{pmatrix} T_{si} \\ T_{in} \end{pmatrix} + \underline{\underline{D}}\begin{pmatrix} T_{out}^* \\ Q \end{pmatrix} \tag{4}$$

with

$\underline{\underline{C}}$ and $\underline{\underline{D}}$ again related to the parameters of the model by a set of relations presented in [33].

The state space differential system (two coupled first order differential equations) can be transformed to a second order input-output differential equation, which can be written as:

$$a_2 \frac{d^2 T_i}{dt^2} + a_1 \frac{dT_i}{dt} + a_0 T_i = b_{11} \frac{dT_o^*}{dt} + b_{10} T_o^* + b_{21} \frac{dQ}{dt} + b_{20} Q$$

with the coefficients a_i and b_{ij} related to the original matrices parameters by a set of relations presented in [33]

The structure temperature has been eliminated in this equation. This formalism can be easily converted to a discrete time equation:

$$\alpha_2 T_i(k+2) + \alpha_1 T_i(k+1) + \alpha_0 T_i(k) = \beta_{11} T_o^*(k+1) + \beta_{10} T_o^*(K) + \beta_{21} Q(k+1) + \beta_{20} Q(k)$$

which suits the needs of a system identification algorithm. For instance, the ELS ("Extended Least Squares") algorithm can be used [34]. The application of this algorithm

leads to an estimation of the value of the α_i and β_{ij} parameters which are related to the "physical" parameters through a set of mathematical relations also presented in [33].

An example of the application of this method is given in [33].

D. Example of use

This simplified model was used for the simulation of the case Study nr 1 (german fictitious building). In that sense, it was compared to a detailed building model (the MBDSA building model or Type 46) for a number of cases:

- unconditioned building: february, september and hot wave period
- controlled building: february, september and hot wave period.

The detailed results are given in [35]. Only a few samples will be presented here.

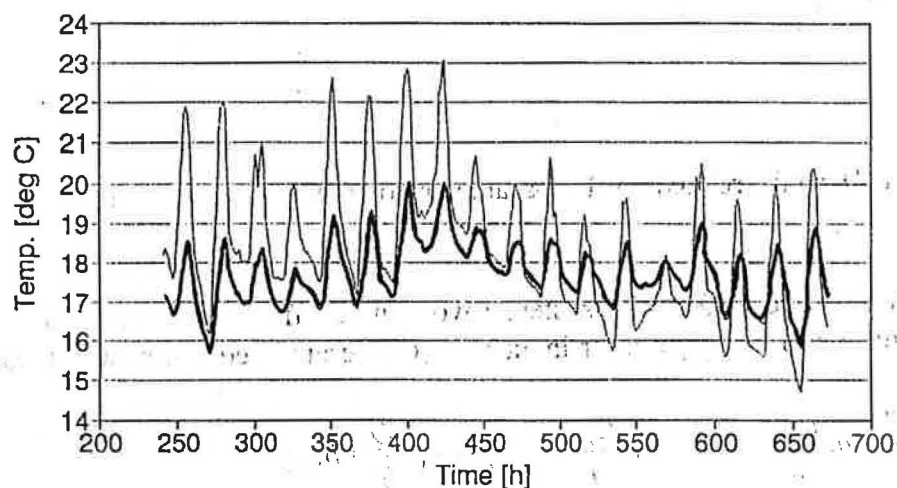Fig. 8 shows the compared evolution of the temperature for the september period in the unconditioned case.

Fig. 8: Compared temperature evolution. Unconditioned building, september.

Fig. 9 shows the compared evolution of the temperature for this period and fig. 10 shows the compared evolution of the cooling load.
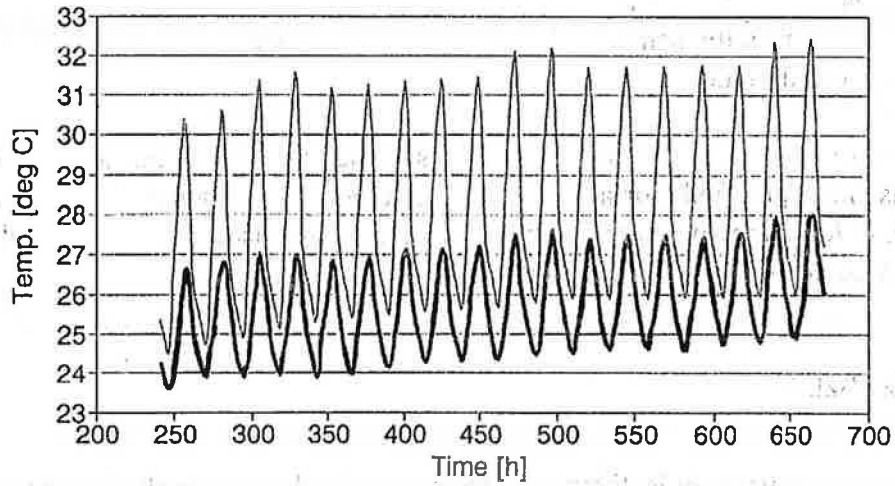
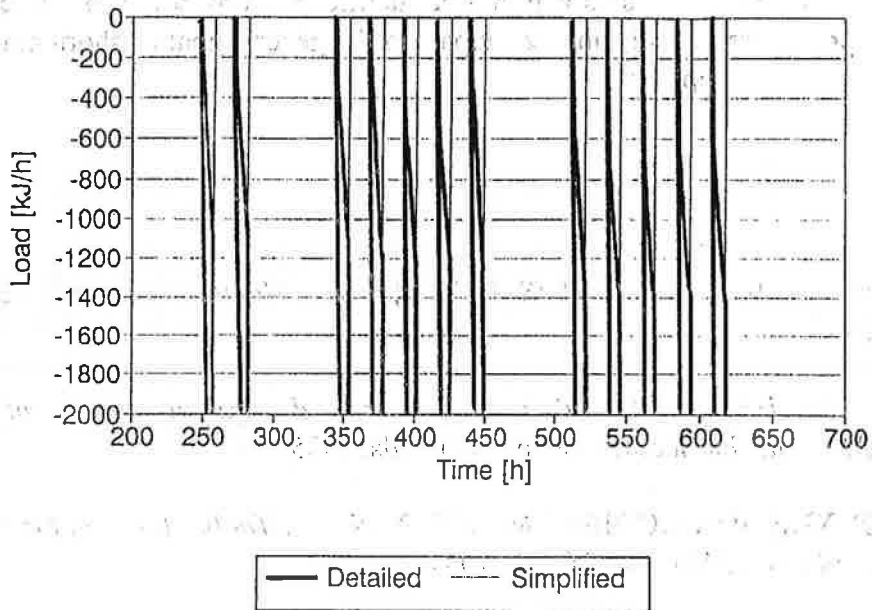Fig. 9: Compared temperature evolution. Controlled building, summer.

Fig. 10: Compared cooling load evolution. Controlled building, summer.

The different results presented point out the following conclusions:

- problems associated with the treatment of solar gains by the simplified model
- the control behaviour is similar for both models

- the heating load calculation yields similar results. This is not true for the cooling load.
- simulation speed is very similar
- basic information is the same for both models. A heavier preprocessing work is required for the simplified model.

As a conclusion of this qualification exercise, the simplified building model will be considered as "non qualified" for a set of building types which include high inertia buildings. Furthermore, calculation of overheating risk and cooling loads in case of high solar gains should not be carried on using this model.

4. CONCLUSIONS.

In this paper, the general objectives of Subtask 1 and the approach used to achieve these objectives are presented. As the other Subtasks of the Annex 30, to which it is intimately connnected, Subtask 1 will mainly rely on the material provided by the Case Studies. The development and application of model qualification procedures will be the main activity and output of Subtask 1. A number of topics were identified to be included in the procedure. A typical example was presented concerning the cooling coil models: after a quick review of the most common available models, the model in use at the University of Liège was presented with more details. Based upon this model, a qualification procedure is being set up providing test-benches and making them available to both potential users and model developers. A comparable procedure was developed for building zone models. These test-benches are heavily relying on Case Studies as applying a qualification procedure to real examples only can make this procedure realistic and participate to the general goal of shortening the distance between simulation and application.

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