NEW EPBD RELATED EUROPEAN STANDARDS AND THEIR RELATION TO BUILDING AND HVAC SYSTEM SIMULATION

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ABSTRACT
In reaction to the European Energy Performance of Buildings Directive (EPBD), existing and newly launched standard developments by CEN (European Committee for Standardization) were harmonized and synchronized, resulting in a set of about 50 standards addressing different aspects of the EPBD and the implementation of an overall building energy performance calculation method. A few of them address simulation issues:
An overview of these is given, focusing on one standard covering system related aspects for buildings with cooling, humidification or dehumidification. It allows for any calculation method, including hourly simulations, as long as the general requirements are fulfilled. In the HVAC domain the variety of systems is very large and there is no general method able to cover this. Simplified calculations may cover certain areas, and the standard gives indications when this is acceptable. Validation aspects are addressed in a very preliminary way, since this is an area for more research.

KEYWORDS
Standard; Cooling; Humidification; System Simulation; Validation

INTRODUCTION
For the implementation of the European Energy Performance of Buildings Directive (EPBD, 2002), the different European countries follow different philosophies in respect of requirements to the requested overall building energy performance calculation method. Simplicity is one of the most important requirements. However, it is recognized that several areas cannot be covered by simplified approaches and require hourly time step simulation approaches.
Among the set of standards developed in CEN (European Committee for Standardization) addressing the aspects of the EPBD, there are a few which address simulation related issues:
• prEN ISO 13790 Calculation of energy use for space heating and cooling
• EN ISO 13791: Calculation of Internal Temperatures of a Room in Summer without Mechanical Cooling – General Criteria and Validation Procedures
• EN ISO 13792: Calculation of Internal Temperatures of a Room in Summer without Mechanical Cooling – Simplified Methods
• prEN 15255 Sensible room cooling load calculation – General criteria and validation procedures
• prEN 15265 Calculation of energy use for space heating and cooling – General criteria and validation procedures
• prEN 15241 Calculation methods for energy losses due to ventilation and infiltration in buildings

† Corresponding Author: E-mail address: gzweifel@hta.fhz.ch
- prEN 15242 Calculation methods for the determination of air flow rates in buildings including infiltration
- prEN 15243 Calculation of room temperatures and of load and energy for buildings with room conditioning systems

prEN ISO 13790 covers the building related calculation of energy use for space heating and cooling. It allows 3 types of calculation methods (monthly, simple hourly and detailed simulation methods). This was described in detail in (van Dijk et. al. 2005).

VALIDATION STANDARDS FOR BUILDING SIMULATION METHODS

For the detailed simulation method prEN ISO 13790 refers to prEN 15265. This document belongs to a group of very closely related documents including prEN ISO 13791, prEN ISO 13792 and prEN 15255. These documents do not impose any particular method, although in some areas modeling assumptions to be used are fixed.

The contents of the standards are organized in two parts: the first part defines all assumptions, boundary conditions and simplifications which are mandatory (e.g. surface heat transfer coefficients, factors to split the solar gains), the second part defines a set of validation tests that must be performed by any calculation method or computer code in order to comply with the standard. Some standards have an informative annex giving an example of a solution method which satisfies the general criteria and validation tests given in the normative part of the standard. By this approach it is almost possible for any existing or new method and calculation tool to be used, provided that it fulfills the assumptions and boundary conditions given in the standard and passes all the validation tests and the criteria of accuracy, which are given in different classes. See table 1 and also (Frank et. al. 2007) for content details.

The test room for the validation cases is common to all 4 standards. It is shown in figure 1.

VENTILATION RELATED STANDARDS

The exceptions in the row of standards, which explicitly give calculation methods, are prEN 15241 and prEN 15242. They are both related to ventilation, the first giving the method for the calculation of the energy losses of ventilation systems, the second the calculation of air flow rates. Both methods can be applied to hourly simulations as well as other types of calculations.
### Table 1 Overview of the test parameters used in the validation process for the different standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Test Parameter</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EN ISO 13791 and 13792</td>
<td><strong>Room air temperatures in summer without mechanical cooling</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Building components</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Heat conduction through opaque elements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Internal long-wave radiation exchanges</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Shading by overhangs and side fins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reference test room (west exposure)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Fixed internal heat gain profile (50% convective / 50% radiative)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Window size (large / small)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Glazing quality (single pane / double pane)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Thermal mass (low / high)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Roof element (with / without)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Ventilation (fixed low / high, night ventilation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Summer cyclic outdoor climate conditions (Latitude 40°N and 52°N)</td>
<td></td>
</tr>
<tr>
<td>EN 15255</td>
<td><strong>Sensible room cooling load</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reference test room (west exposure, large window)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Internal heat gains (20 W/m² convective, 30 W/m² radiative)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Thermal mass (low / high)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Double pane glazing (with / without shading device)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- System control (air temperature / operative temperature)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- System operation (continuous / intermittent)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Ventilation (with / without night ventilation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Maximum cooling power (fixed / unlimited)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- With / without cooled surface system (floor or ceiling)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Summer cyclic outdoor climate conditions (Latitude 52°N)</td>
<td></td>
</tr>
<tr>
<td>EN 15265</td>
<td><strong>Energy needs for space heating and cooling</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reference test room (west exposure, large window)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Internal heat gains (20 W/m²)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Window shading device (with / without)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Roof element (with / without)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Set point for heating 20°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Set point for cooling (26°C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- System operation (continuous / intermittent)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Maximum heating and cooling power (fixed / unlimited)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Outdoor climate conditions (Full year data set Latitude 49°N, 2°E)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Classification of calculation methods in prEN 15255

<table>
<thead>
<tr>
<th>Class of calculation method</th>
<th>Cooling systems within capability of method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Pure convective system</td>
<td>v</td>
</tr>
<tr>
<td>Limited cooling capacity + moveable shading</td>
<td>v</td>
</tr>
</tbody>
</table>

### Table 3 Sub-classification of calculation methods

<table>
<thead>
<tr>
<th>Control type within capability of method</th>
<th>Sub-class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control type within capability of method</td>
<td>a</td>
</tr>
<tr>
<td>Sub-class</td>
<td>b</td>
</tr>
</tbody>
</table>
prEN 15243 covers almost all system related aspects for buildings which are not only heated, but have cooling, humidification or dehumidification needs. For the ventilation part it refers to the above mentioned documents. For the building related temperature, load and energy values, it is based on the results provided by calculations according to the respective standards.

One of the key issues of this standard is, that it is generally possible to use any calculation method, especially including hourly simulations, as long as the general requirements given in the standard are fulfilled. The main driving force of this is the fact that in the HVAC domain the variety of systems is very large, and there is no general method able to cover all types of systems.

Simplified calculations may cover certain areas, and the standard gives indications when this is acceptable. There are several possibilities in combination of building and system calculation methods, as shown in table 4.

Table 4 Classification of building versus system calculation methods

<table>
<thead>
<tr>
<th>Building Calculation</th>
<th>System calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hourly</td>
</tr>
<tr>
<td></td>
<td>Monthly seasonal</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
</tr>
<tr>
<td>Hourly</td>
<td>BhSh</td>
</tr>
<tr>
<td></td>
<td>BhSm</td>
</tr>
<tr>
<td>Monthly seasonal</td>
<td>BmSh</td>
</tr>
<tr>
<td></td>
<td>BmSm</td>
</tr>
</tbody>
</table>

Type BhSh
This configuration makes it possible to take into account hourly interactions between building behavior and system behavior. It is the case for example for VAV system where the air flow depends on the cooling demand, or for latent load which are difficult to calculate on a monthly basis.

Type BmSh
In this case the system behavior is calculated based on hourly values before the building calculation is performed. This can be done when the system behavior is not dependent on the building behavior. It can be for example for systems reacting mainly to outdoor climate (for example combination of outdoor air temperature and humidity). Some assumptions can also be used e.g. relating for example indoor temperature to outdoor temperatures.

Type BmSm and BhSm
In this case the system behavior is calculated by averaged monthly, seasonal or annual values, using in general statistical analysis based on hourly calculations for typical climates, configurations etc. It can also be done directly if the system is simple enough to neglect the interaction with both outdoor climate and the building behavior.

A commonly used category of system calculation method is based on the frequency distribution of hourly outdoor air temperature and/or humidity. This can be combined with either hourly or monthly / seasonal building calculations thus belongs to category BhSh or BmSh.

General Structure and Requirements for System Calculation
The standard gives a general scheme of an overall heating and cooling system calculation, which is shown in figure 2.

The total system consists of subsystems, and all subsystem calculations must take into account the energy flows shown in figure 3. For the heat losses a distinction is made between the recoverable and
non recoverable part, the recovered portion of the first being taken into account in the building
calculation by iteration or by a fixed factor.

Figure 2 General HVAC system structure and energy flows

Figure 3 Subsystem energy flows

The general requirements for all calculations methods are:

- The energy flows according to figure 3 must be taken into account;
- The method shall address all the mechanisms that are relevant to the system types being
considered. The documentation accompanying each calculation method shall report how each
mechanism is represented.

In order to give an indication for the second requirement, a table of HVAC systems is given in the
standard (see table 5). A similar table, which is not presented here, is also given for ventilation systems.
Another elaborate table, an excerpt of which is represented in table 6, then allocates the important
technical features that affect the energy consumption to the different HVAC systems from table 5. Again,
another similar table is given for ventilation systems.

Different degrees of calculation complexity will be appropriate for different applications. An informative
annex contains recommendations for appropriate levels of treatment and refers to other relevant annexes and standards.

Table 5 HVAC system overview from prEN 15243

<table>
<thead>
<tr>
<th>Code</th>
<th>System name</th>
<th>Does not always include heating provision and may be used with separate heating system (including room heaters which may be within terminals)</th>
<th>Does not include integral provision of ventilation and may be used with separate (cooled) ventilation system</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>All-air systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>Single duct system (including multi-zone)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Dual duct system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>Single duct, Terminal reheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>Constant Volume (with separate heating)</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>A5</td>
<td>Variable Air Volume (with separate heating)</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B</td>
<td>Water-based systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>Fan coil system, 2-pipe</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B2</td>
<td>Fan coil system, 3-pipe</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B3</td>
<td>Fan coil system, 4-pipe</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B4</td>
<td>Induction system, 2-pipe non change over</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B5</td>
<td>Induction system, 2-pipe change over</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B6</td>
<td>Induction system, 3-pipe</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B7</td>
<td>Induction system, 4-pipe</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B8</td>
<td>Two-pipe radiant cooling panels (including chilled ceilings and passive chilled beams)</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B9</td>
<td>Four-pipe radiant cooling panels (including chilled ceilings and passive chilled beams)</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B10</td>
<td>Embedded cooling system (floors, walls or ceilings)</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B11</td>
<td>Active beam ceiling system</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>B12</td>
<td>Heat pump loop system</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>C</td>
<td>Packaged Air Conditioning Units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>Room units (including single duct units)</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>C2</td>
<td>Direct expansion single split system</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>C3</td>
<td>Direct expansion multi split system (including variable refrigerant flow systems)</td>
<td>☑</td>
<td>☑</td>
</tr>
</tbody>
</table>

Verification

In order to verify compliance with the above mentioned requirements, a two step verification approach is proposed. Key requirements are

- Credibility: The mechanisms should be technically sound and the results of the calculation must be plausible.
- Discrimination: The rating should be better for systems and buildings that are clearly more energy-efficient.
- Repeatability: Different users should get essentially the same results for the same building.
- Transparency: It should be straightforward to check the data used and the execution of the procedure.
Table 6 Important technical features that affect the energy consumption of different types of HVAC system (excerpt)

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>All-air systems</th>
<th>Water-based systems</th>
<th>Packaged Air Conditioners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within-room mechanisms</td>
<td>A1 A2 A3 A4 A5 A6</td>
<td>B1 B2 B3 B4 B5 B6 B7</td>
<td>C1 C2 C3 C4 C5 C6</td>
</tr>
<tr>
<td>Room heat balance and temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room moisture balance and moisture content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definition of zones and ability to combine room demands into zonal demands</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Combination of room conditions into zonal return air state</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contribution to room demands from separate ventilation / base cooling system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contribution to room demands from heat gains or losses from pipes and ducts</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Impact of proportional band on energy supplied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of dead band on energy supplied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect of open-loop control or averaging of sensors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect of absence of interlock between heating and cooling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution: terminal issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy penalties from hot/cold mixing or reheat systems</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Terminal auxiliary energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect of sensible heat ratio of terminal (and risk of condensation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of local time control</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Heat gains and losses from pipes and ducts Includes AHUs and other air-handling components</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Duct system - air leakage Includes AHUs and other air-handling components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigerant pipework heat losses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fan and pump energy pickup</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat recovery provision</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution systems: operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latent demand calculation at central (zonal) plant (includes dewpoint control plus reheat)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>
Mechanism System type

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>All-air systems</th>
<th>Water-based systems</th>
<th>Packaged Air Conditioners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adiabatic spray cooling</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Additional demands produced by hot deck: cold deck mixing systems</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

For the second step, reference is made to several techniques for verifying calculation methods, none of which can completely guarantee accuracy in all conditions. The application of verification techniques is decided on a national basis. If a verification technique is used, the results obtained shall be stated.

It is clear that in the HVAC system area there are only few validation tests available from research projects that are ready to use for an application in standards. First steps were made in (Neymark and Judkoff 2002) and in (Purdy and Beausoleil 2003). Due to the variety of systems, there is still a lot more research needed.

In an informative annex, the standard also refers to the Energy Diagnosis Reference (EDR), a Dutch methodology to verify the performance of calculation procedures. This methodology, still under development, is a systematic approach to verification of calculation methods, referring to different validation tools and standards.

Informative Annexes

For many specific aspects in system energy calculation, example methods are given in informative annexes. Due to the variety of calculation approaches in use in the different European countries, it would not have been possible at this time to define one single common method. Often, the building regulations refer to National standards, and even in consideration of possible improvements it would not have been possible for those countries to change. One or two more generations of standard revisions will be needed to get to a closer harmonization. This is a first step in this direction.

CONCLUSIONS

A set of European standards is being released for use in connection to the EPBD. Building and HVAC system simulation aspects are treated in several of them.

In the area of HVAC simulation, the requirements for the calculation methods remain rather general for two reasons: the big variety of system types, which makes the use of different calculation methods necessary, and the lack of available validation tests covering a sufficient part of the system range.

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REFERENCES

