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

Gerhard Zweifel

Lucerne School of Engineering and Architecture (HTA)
University of Applied Sciences of Central Switzerland
6048 Horw, Switzerland

ABSTRACT

In reaction to the European Energy Performance of Buildings Directive (EPBD), existing and newly lanced 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

CEN (European Committee for Standardization) is in charge of the development of standards for European countries including the EU and EFTA. In several Technical Committees (TC), building and HVAC system related standards are developed. In reaction to the European Energy Performance of Buildings Directive (EPBD, 2002) which is in force since January 2006, an EU/EFTA funded project was carried out, in which existing and newly lanced standard developments were harmonized and synchronized, resulting in a set of about 50 standards addressing different aspects of the EPBD and its main core requirement, the implementation of an overall building energy performance calculation method. The different countries follow different philosophies in respect to the requirements to the 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 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
- 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 fulfils 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.

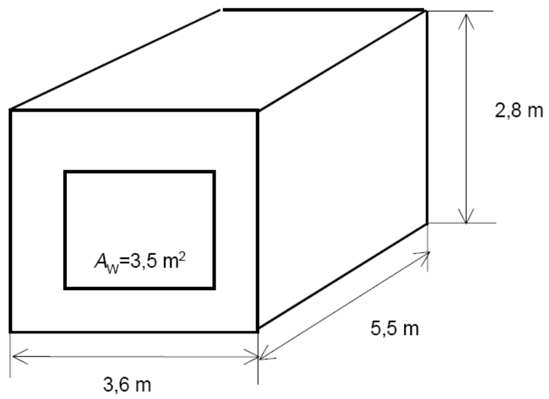

Figure 1 Test room for validation

The heating and cooling load related standard prEN 15255 classifies the calculation methods depending on the intended application. Tables 2 and 3 show the classes.

Table 1 Overview of the test parameters used in the validation process for the different standards

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

Table 2 Classification of calculation methods in prEN 15255

COOLING SYSTEMS WITHIN CAPABILITY OF METHOD		CLASS OF CALCULATION METHOD			
		1	2	3	4
Pure convective system	Infinite cooling capacity, continuous operation	v	v	v	v
	Infinite cooling capacity, continuous or intermittent operation		v	v	v
	Limited cooling capacity + moveable shading			v	v
Surface + convective system					v

Table 3 Sub-classification of calculation methods

CONTROL TYPE WITHIN CAPABILITY OF METHOD	SUB-CLASS	
	a	b
Air temperature	v	v
Operative temperature		v

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.

PREN 15243

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.

Table 4 Classification of Building versus System calculation methods

		SYSTEM CALCULATION	
		Hourly	Monthly seasonal annual
BUILDING CALCULATION	Hourly	BhSh	BhSm
	Monthly seasonal	BmSh	BmSm

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.

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 calculation 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.

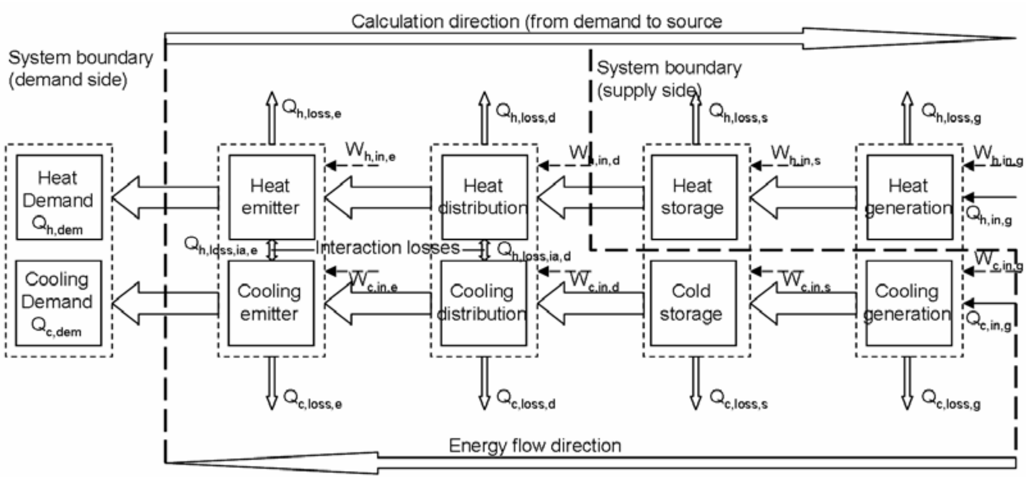

Figure 2 General HVAC system structure and energy flows

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.

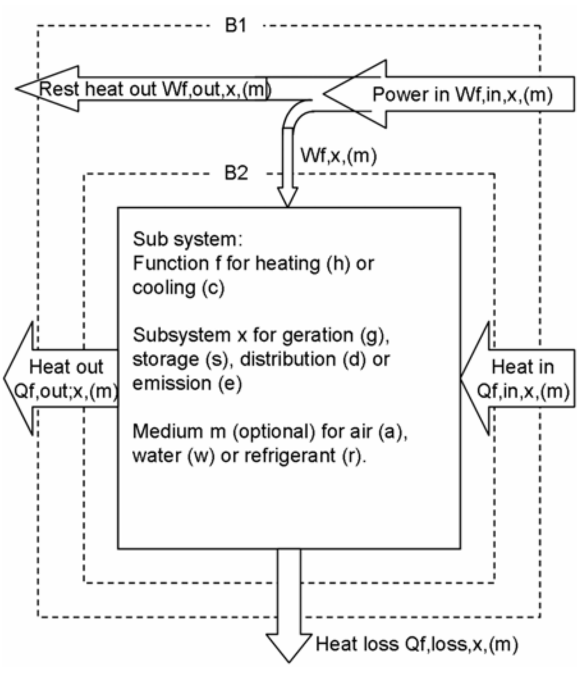

Figure 3 Subsystem energy flows

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.

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.

Step 1: Define required characteristics and check that the method appears to provide them

Step 2: Verification of calculation accuracy

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 main ones are shown in a table (table 7). 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.

Table 5 HVAC system overview from prEN 15243

CODE	SYSTEM NAME	DOES NOT ALWAYS INCLUDE HEATING PROVISION AND MAY BE USED WITH SEPARATE HEATING SYSTEM (INCLUDING ROOM HEATERS WHICH MAY BE WITHIN TERMINALS)	DOES NOT INCLUDE INTEGRAL PROVISION OF VENTILATION AND MAY BE USED WITH SEPARATE (COOLED) VENTILATION SYSTEM
A	All-air systems		
A1	Single duct system (including multi-zone)		
A2	Dual duct system		
A3	Single duct, Terminal reheat		
A4	Constant Volume (with separate heating)	✔	
A5	Variable Air Volume (with separate heating)	✔	
B	Water-based systems		
B1	Fan coil system, 2-pipe	✔	✔
B2	Fan coil system, 3-pipe		✔
B3	Fan coil system, 4-pipe		✔
B4	Induction system, 2-pipe non change over	✔	
B5	Induction system, 2-pipe change over		
B6	Induction system, 3-pipe		
B7	Induction system, 4-pipe		
B8	Two-pipe radiant cooling panels (including chilled ceilings and passive chilled beams)	✔	✔
B9	Four-pipe radiant cooling panels (including chilled ceilings and passive chilled beams)		✔
B10	Embedded cooling system (floors, walls or ceilings)		✔
B11	Active beam ceiling system	✔	✔
B12	Heat pump loop system	□	✔ □
C	Packaged Air Conditioning Units		
C1	Room units (including single duct units)	✔	✔
C2	Direct expansion single split system	✔	✔
C3	Direct expansion multi split system (including variable refrigerant flow systems)	✔	✔

Table 6 Important technical features that affect the energy consumption of different types of HVAC system (excerpt)

Mechanism	System type																			
	All-air systems					**Water-based systems**												**Packa-ged Air Condi-tioners**		
	A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**C1**	**C2**	**C3**
Within-room mechanisms																				
Room heat balance and temperature	Part of building demand calculation – not HVAC system calculation																			
Room moisture balance and moisture content	Part of building demand calculation – not HVAC system calculation																			
Definition of zones and ability to combine room demands into zonal demands	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔
Combination of room conditions into zonal return air state	✔	✔	✔	✔	✔				✔	✔	✔	✔								
Contribution to room demands from separate ventilation / base cooling system						✔	✔	✔					✔	✔	✔	✔	✔	✔	✔	✔
Contribution to room demands from heat gains or losses from pipes and ducts	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔				
Impact of proportional band on energy supplied	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Impact of dead band on energy suppplied	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Effect of open-loop control or averaging of sensors	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔
Effect of absence of interlock between heating and cooling					✔		✔		✔				✔		✔	✔		✔	✔	✔
Distribution: terminal issues																				
Energy penalties from hot/cold mixing or reheat systems	□	✔	✔		✔	✔		✔	✔		✔									
Terminal auxiliary energy.					✔	✔	✔	✔								✔	✔	✔	✔	✔
Effect of sensible heat ratio of terminal (and risk of condensation)						✔	✔	✔					✔	✔	✔	✔	✔	✔	✔	✔
Lack of local time control	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔				✔
Heat gains and losses from pipes and ducts Includes AHUs and other air-handling components	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			
Duct system air leakage Includes AHUs and other air-handling components	□	✔	✔	✔	✔				✔	✔	✔	✔								
Refrigerant pipework heat losses																	✔	✔	✔	✔
Fan and pump energy pickup	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			
Heat recovery provision	✔	✔	✔	✔	✔															
Distribution systems: operation																				
Latent demand calculation at central (zonal) plant (includes dewpoint control plus reheat)	✔	✔	✔	✔	✔															
Adiabatic spray cooling	✔	✔	✔	✔	✔															
Additional demands produced by hot deck:cold deck mixing systems	✔	✔																		

Table 7 Verification techniques

TECHNIQUE	METHOD	STRENGTHS	WEAKNESSES
Theory checking	Equations are checked	* Ensures that appropriate theory has been applied.	* Requires expert knowledge and judgement about appropriate theory
Code checking	Computer code is checked line by line	* Ensures that equations have been correctly implemented * Ensures that data are correctly processed	* Only possible by experts * Only possible for open programs *Slow and time consuming *Only practicable for simple algorithms
Analytic tests	Predictions for simple situations are compared with analytic solutions	* Tests correct processing by input interface, program, and output interface * Exact answer known, so absolute accuracy can be determined	* There are very few situations for which analytic solutions can be produced * Analytic solutions not possible for building-like spaces * May be difficult to isolate testable algorithms from program * Cannot test whole program
Inter-model comparisons	Prediction are compared with those from other methods supplied with equivalent data	* Relatively easy to undertake and, in principle, can cover any building situation * Can test whole program * By carefully sequencing tests, sensitivity to design changes can be compared	* Tests for consistency between models rather than for absolute accuracy. If one model is out of line with the remainder, this may indicate poor performance – alternatively, it may indicate more accurate modelling
Empirical validation	Prediction are compared to detailed measurements in real buildings (Predictions should be made without knowledge of actual performance – that is, blind)	* In principle, the most powerful validation technique as it compares prediction with reality	* Difficult to carry out convincingly because it is very difficult and time-consuming to obtain measurements of adequate accuracy. In practice, this means that data are from unoccupied simple buildings.
Statistical validation	Predictions for many buildings are compared to energy consumption measurements	* The most directly relevant verification for existing buildings	* There are many uncontrolled variables, especially in occupied buildings, so the verification is of a combination of calculation method and data set. * The results are specific to the combination of building type of the sample, * In practice, there are large variations that are not explained by the calculation method

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 singe 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.

CONCLUSION

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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