Construction Technology in Europe

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Adaptive thermal comfort for buildings in Portugal

Expectations regarding the thermal comfort of indoor environments in buildings have significantly changed as a result of the generalised use of air conditioning (AC) in both work and public spaces and, from the modification, either justified or not, of the required comfort standards.

Figure 1 Field Surveys

Existing conventional comfort standards, that are largely responsible for the use of AC, are based on complex equations resultant from laboratory research. By the very nature of the laboratory derivation of these conventional standards, adaptive processes found in the real world have been limited or eliminated.

Alternate comfort criteria have been proposed using models based on the so-called adaptive theory of thermal comfort. Adaptive models assume indoor temperature variations which are dependent on outdoor temperatures to stimulate and to enable adaptive opportunities and actions. The final (desirable) results could be the users´ well-being and a reduction of energy consumption without compromising thermal comfort. Nowadays, adaptive models are already incorporated in some international thermal comfort standards. Nevertheless, the implementation of this alternate comfort criterion is dependent upon contextual factors specific to each region.

Like many other countries, indoor thermal reference conditions are defined in Portuguese thermal and energy regulations in a static way: indoor air temperature of 20ºC (heating season) or 25ºC (cooling season).

In this context a study was carried out at LNEC with two main goals:

(1) To evaluate the conditions, both environmental (objective) and psychosocial (subjective), of thermal comfort in indoor environments

(2) To develop an adaptive model for characterising and defining the thermal comfort conditions applicable to buildings in Portugal.

For this purpose, field surveys (Fig. 1) were performed on service buildings (office and educational buildings) and residential buildings (conventional and homes for the elderly). The information was gathered from the measurement of the environmental parameters (indoor and outdoor) and the completion of questionnaires (with the support of social scientists); during summer, mid-season and winter (Table 1).

The study has shown that in Portugal 'ideal' reference temperatures are unrealistic, and in fact people can feel comfortable in a much broader range of temperatures, depending on the local climate and building type construction, thus confirming the results from adaptive

Table 1 Sample building and field survey distribution

Building type		Surveys			Questionnaires
		summer	mid-season	winter	
Service	Office (9)	52	26	52	690
	Educational (6)	7	9	22	945
Residential	Conventional (4)	—	—	32	34
	Elderly homes (21)	34	15	36	698
Total (40)		93	50	142	2367

Continued on page 2 . . .

In brief

EU Greenhouse gas emission decrease
Greenhouse gas emissions continue to decrease in the EU, according to the Annual European Union Greenhouse Gas Inventory 1990-2008 and Inventory Report 2010 published by the European Environment Agency. The report finds that the EU-27 reduced their emissions by 11.3% compared with 1990, the Kyoto Protocol base year. The EU-15 posted a 6.5% cut in their GHG discharges in the same period. These reductions represent an emissions cut of 627 million tonnes CO_2 equivalents for the EU-27 and 274 million tonnes for the EU-15.

The report notes that 'The overall EU GHG emission trend is dominated by the two largest emitters, the UK and Germany, accounting for about one third of total EU-27 GHG emissions. These two Member States have achieved total GHG emission reductions of 417 million tonnes CO_2-equivalents compared to 1990.'

The report can be found in full on the EEA website at **http://eea.europa.eu/**.

Home buyers remain unconvinced by energy-efficient homes
Results from new EU research show that home buyers are unwilling to buy new, energy-efficient houses. Poor communication between builders and buyers is a big part of the problem say researchers studying the behavioral barriers to better acceptance of energy efficiency. The results are part of the CREATE ACCEPTANCE and CHANGING BEHAVIOUR projects. In the projects, a competition was organised inviting housing manufacturers to produce energy-efficient homes. Potential buyers were involved in stages of the competition and included as members of the competition jury.

House sales generated by the competition were disappointingly low. Some buyers wanted to make modifications that would render the houses no longer energy-efficient, others did not trust the information supplied to them or simply remained unconvinced of the need to be energy-efficient.

For more see CREATE ACCEPTANCE on: **http://www.createacceptance.net/home/** and CHANGING BEHAVIOUR on: **http://www.energychange.info/**

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Adaptive thermal comfort for buildings in Portugal

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Figure 2 Samples of the 'adaptive opportunities' used by occupants to reach thermal comfort

theory research. Human capacity of adaption, either from interacting with the building and its systems, or from those resulting from social and cultural habits, are essential to reach the thermal comfort conditions (Fig. 2).

An adaptive model was developed based on the results obtained. This model characterises, the acceptable thermal comfort conditions for buildings in Portugal, by taking into account the climate, as well as social and cultural characteristics of the Portuguese population.

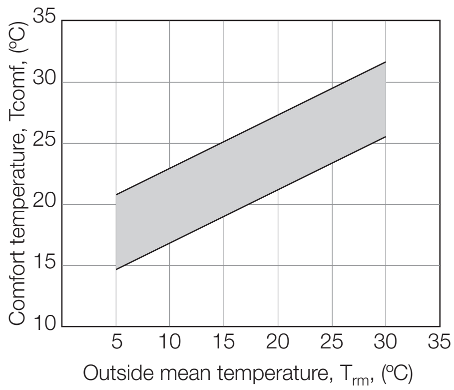

Figure 3 Proposed adaptive model

The proposed adaptive model intends to estimate the comfort temperature, T_{comf}, against the outside mean temperature, T_{rm}, as defined by the exponentially weighted running mean of the daily mean outdoor temperature over seven days (Fig. 3).

More detailed analysis and new surveys are required, mainly in the residential sector, to support the development of a more consolidated adaptive approach oriented to the definition of indoor thermal comfort requirements applicable to Portuguese buildings.

In the near future, this model is expected to contribute to the development of sustainable energy regulations better suited to Portugal.

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Perfection: Towards key performance indicators for the indoor environment

Perfection stands for a European Coordination Action on performance indicators for health, comfort and safety of the indoor environment. The goal of this FP7 coordination action is to help enable the application of new design and technologies that improve the impact of the indoor built environment on health, comfort, the feeling of safety, and positive stimulation. In order to monitor and report on the performance of the indoor environment a set of key performance indicators is a necessity.

perfection

The project concept consists of the following components:

(i) Construct an inventory of standards, regulations, technologies, research activities and policies related to the indoor environment.

(ii) Analyse current indoor performance indicators and their applicability within a generic framework, Identification of areas where new indicators for health and safety should be developed.

(iii) Collect experiences from case studies of building design and technologies exploiting the indicators in different building types.

(iv) Identification of incentives and barriers for the wide use of performance indicators.

(v) Develop a roadmap and recommendations for building design and technologies and support for appropriate policies.

(vi) Disseminate findings widely through an extensive expert network.

The project was introduced in the FP7-ENV 2007-1 call. Work started on 1st January 2009 and the project will run for 3 years. Two open workshops have been organised; a third one is scheduled for November 2010.

More information on the project and events is available on the project website **http://www.ca-perfection.eu**.

Work in progress

A Europe-wide network of experts and stakeholders has been set up, enabling an extensive knowledge base of European and national practices related to the indoor environment. The inventory work has been completed and a database holding standards, regulations, policies and research activities from more than 27 countries has been created. Two state-of-the art reports, one on comfort and health, the other on accessibility, feeling of safety and positive stimulation, have been finalised.

The consortium is currently defining an indicator framework and toolbox in an iterative process involving a limited number of case studies. The framework and toolbox will become the basis on which a web-enabled prototype decision support tool will be developed in the 2nd half of the project. Themes covered by the framework are indoor air quality, thermal, visual and acoustic comfort, water quality, feeling of safety and security, positive stimulation, adaptability, serviceability, and usability (including accessibility).

Policy-related work started with the first workshop held in Krakau in December 2009. This should lead initially to the identification of barriers to and incentives for the uptake of indicators, technologies and designs by the end of 2010. Furthermore, a user engagement report has been prepared. Besides a theoretical basis for the engagement process, the report focuses on ways to involve and interact with users in the development and operation of the Perfection tool and portal. A number of case studies referring to building industry, building users and policy makers have been developed in detail.

In the second half of 2010 the indicator framework will be optimised by an intensive interaction with users and stakeholders amongst others through a questionnaire and a workshop. Case study work and the prototype tool development are also scheduled for this period.

Contact information

The project is being coordinated by the Belgian Building Research Institute and involves 10 members (VTT, Apintech, CTU, ARMINES, Kornadt, ICTAF, SITI, TUE, ASM and BRE). It is linked to an extensive network of 33 experts representing industry, academia and research from all over Europe.

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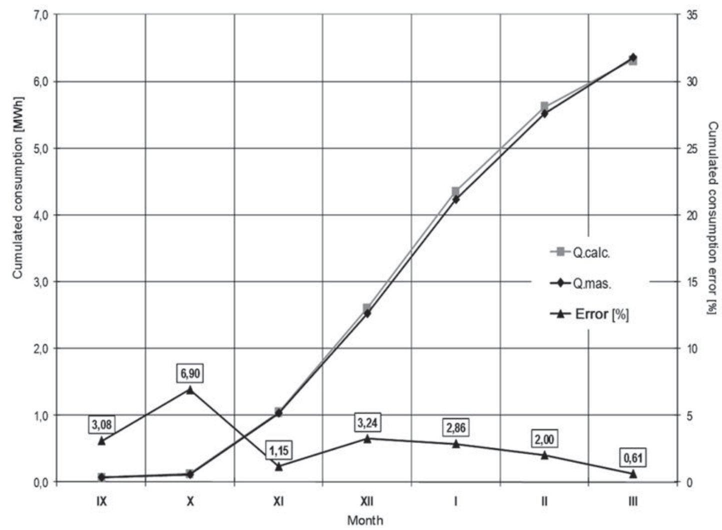
Large scale experimental and numerical validation of EPB national calculation methods*

In the period 2003-2009 an experimental building was built at INCERC Bucharest, aimed to experimentally validate the calculation models specific to the EPB estimation and to testing the innovative technologies. The building is equipped with systems of air-conditioning and measured data processing, including wireless transmission of the measured data to the dynamic simulation system of the Department for Buildings Energy Efficiency. Tests were also performed on Bucharest (1996-2000) and Cluj (1997) condominiums. This article presents some results of the theoretical and experimental activity in CE INCERC Bucharest in the period 2008-2009.

The measurements performed on CE INCERC provided the thermodynamic parameters necessary in checking the heat/cold sensitive and latent load and consumption calculation methods included in the codes concerning buildings energy assessment. The operation of the air-conditioning systems is automatically controlled within the experimental programs during the whole year. The program, more intensive in 2008-2009, was focused on the validation of EPB calculation methods in terms of EN 13790, EN 13791 and EN 13792 European standards taken over as national standards and substantiating the existing national methodology, Mc001-2006 and on the calculation methods developed by INCERC since 1993 (INVAR-1993, NP 048-2000, PCV-2008).



Cumulated energy consumptions - INCERC Bucharest CE heating - 2008-2009 cold season and comparison between measured and calculated values (NP 048-2000)

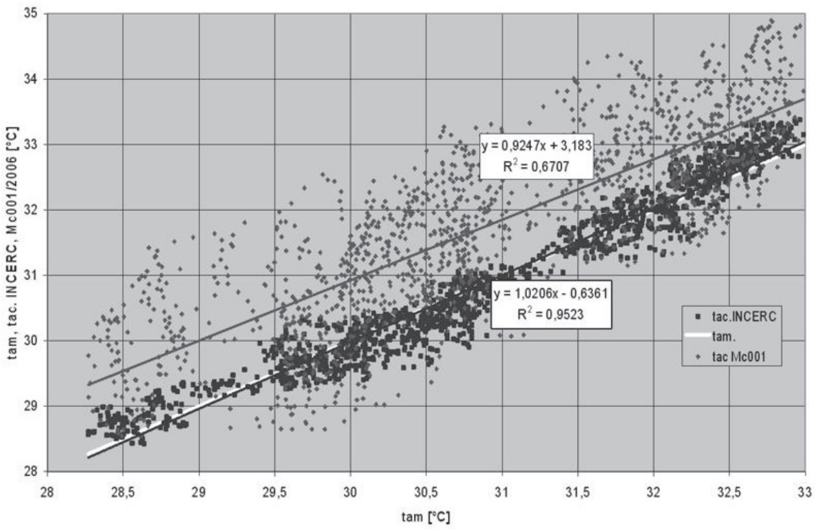
Space heating was examined in the 2007-2008 and 2008-2009 cold seasons. During the experiment, the indoor conditions are controlled, the indoor temperature is constant. The result in the form of cumulated curves of the two heat consumptions ($Q_{măsurat}$ şi $Q_{calcul\ NP\ 048}$) attests the NP 048-2000 calculation procedure accuracy. The 2008-2009 heating season error is 0.61%. A case-study, subject of cold season, performed on a condominium and on an office building by simultaneously using the seasonal calculation method (Mc 001/2006, based on EN 13790, EN 13791, 13792) and the INCERC methods (NP048-2000, monthly time-step method and hourly time-step methods based on INVAR, PCV validated in CE INCERC) attests the accurate use of NP 048-2000 monthly calculation model (3.3% error compared to the transient model), but unacceptable deviations of the seasonal model (Mc 001/2006) compared to the INCERC models (transient) (33% for heated spaces, 41.7% for the connection to the heat source) for the condominium, and an error of 0.5% compared to transient if NP 048-2000 is used, namely unacceptable deviations of Mc 001/2006 model compared to the INCERC transient one (24%, 31.5%) for the office building.

In the 2008 and 2009 hot seasons, data were collected on the building thermal conditions with no operating air-conditioning systems and no energy management measures. The official calculation method – the object of Mc 001/2006 (taken over by the SR EN 13792/2005) was used in assessing inside air temperature $t_{ac\ Mc\ 001/2006}(\tau)$. Theoretical $t_{ac\ INCERC}(\tau)$ hourly variation temperature was also assessed, resulting from the dynamic calculation method developed by INCERC Bucharest, as the method used in validating the software products used

* Acknowledgement: The research program was supported by Ministry for Regional Development and Tourism–General Technical Department for Construction and National Authority for Science and Research (Program no.1/2008 and ANVINTEX project no. 31-055/2007).

Experimental INCERC house – CE INCERC Bucharest

in assessing EPB of new and existing buildings (PCV). The linear regression equation and the correlation degree between $t_{ac\ INCERC}(\tau)$ and $t_{ac\ Mc\ 001/2006}(\tau)$, simulated hourly values, with $t_{am}(t)$, hourly measured values, prove the inconsistency of the calculation method recommended by Mc 001/2006 and the accuracy of INCERC (PCV) software. The experiment was completed in summer 2009 by the building thermal conditions follow-up and simulation, based on night-time cooling and controlled mechanical ventilation. The ventilation rate average hourly values range between $n_{a\ min}$ and $n_{a\ max}$ ($0{,}5\ h^{-1} \div 10\ h^{-1}$). The average deviation of indoor air temperature hourly values calculated by Mc 001/2006 (25.9°C) compared to the measured values and those calculated by PCV INCERC (both 24.3°C) is unacceptable (ε=1.6°C).



Correlation of calculated temperatures hourly values, INCERC (PCV), Mc001/2006 (SR EN 13792/2005) of air in CE INCERC Bucharest with corresponding measured values - free running temperatures

The building was artificially cooled in the period 20.07.2009-05.08.2009. The cooling system operation alternated with the controlled night-time mechanical ventilation in order to achieve thermal comfort with minimum power consumption. The results attest an acceptable closeness of the measured cold demand cumulated values (-211.1 kWh) and the PCV calculated cold demand (-219.5 kWh). The calculated values error compared to those measured is only 3.98%. The mean square deviation index is also acceptable, 0.0125. The similar analysis based on the Mc 001/2006 (EN 13791, EN 13792) method provides a cumulated value (-284.8 kWh), deviated by 20.7% from the experimental value.

The extending of the analysis to the whole year emphasises the capacity of the INCERC (PCV), hourly simulation software of accurately proving the heat/cold load and demand and temperature hourly variation which makes it proper for use as a standard software in validating alternative calculation methods and in new buildings energy design. In 2010 the EPB Mc 001/2006 calculation method will be updated and corrected based on these results.

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Standards for Earthen Building Products

– A new perspective for an old material

Earth is one of the oldest materials used for construction. Between one quarter to one third of the world's population live in houses built with earth. What is often a material of necessity due to its availability and easy processing in the Developing World has almost been forgotten in developed countries where other materials have replaced earth.

BAM
Federal Institute for Materials Research and Testing

Figure 1 A range of readymade industrial earthen building products

In Germany earthen building products have been increasingly used for indoor and outdoor construction purposes for the last 25 years. This is partly due to their outstanding climatic properties as well as their very low primary energy consumption during production and application. This makes the material highly attractive for eco-friendly housing projects. The production of earthen materials has developed into an SME dominated sector with a variety of readymade products ranging from earth blocks, earth mortars and plasters, earthen panels as well as earthen insulation materials (Fig. 1). Over the last 20 years this sector is constantly expanding and production levels have increased not only for the domestic market but also for export.

Despite the success in marketing these types of products further development in this sector is slow when compared with other building materials. This is due to the fact that the rules for the production of earth materials are still basic. In Germany there is one guideline for earth and its application, which is officially approved and legally acknowledged. However, the guideline does not include information for producers on how to control the quality of their products or test procedures and threshold values for independent testing institutes, values needed to define and declare the product properties.

This was the motivation to initiate the project StandardLehm, funded by the German Federal Ministry of Economics and Technology (BMWi). The topics of this project are:

- the development of testing procedures and quality control strategies
- the definition of sustainability aspects with life cycle analysis, and
- the formulation of declaration procedures.

The results will be used for the design of pre-normative guidelines as a basis for the future standardisation process. The project partners consist of an SME producer of earthen construction materials, a materials research institute (BAM) and the German national association for building in earth as associated partner. The consortium is in close contact with national authorities (DIBt, BMWi) and the German institute for standardization (DIN).

The three year project focuses on three earthen building products (earth blocks, earth mortars and earth plasters) and on the raw material, soil. The test procedures under development or modification are designed for the control of product quality and for defining the product properties for further declaration. These include mostly mechanical and physical properties.

In the case of plasters and earth blocks the adsorption of water vapour has been included into the test programme. Earthen materials have a particularly high capacity to adsorb and desorb water vapour from the air compared to other materials (Fig. 2). At the same time routines for the internal and external periodical quality control of the production are being developed together with the SME partner. Both components will be included as a requirement in the standards equal to that of other building products.

The development/modification of test procedures for the three earthen building products are almost complete. For earth blocks a draft pre-standard has already been formulated and is now under revision by independent experts. Further pre-standards will be formulated for earth mortars and plasters as well as soil. As soon as a national standardisation committee has been established it is planned, to publish the pre-standards in the form of draft standards for these four groups of materials.

In future many more earthen building products will need to be standardised. However, it will take time to create the actual products and standards for earthen building materials on a national level and even longer on a European scale. Nevertheless, these standards will help to integrate earthen materials as a highly sustainable alternative to other building products and increase the range of low energy materials for the construction of eco-efficient buildings.

Acknowledgments
We would like to thank our German Federal Ministry of Economics and Technology (BMWi) for funding the project under the umbrella of their funding instrument MNPQ.

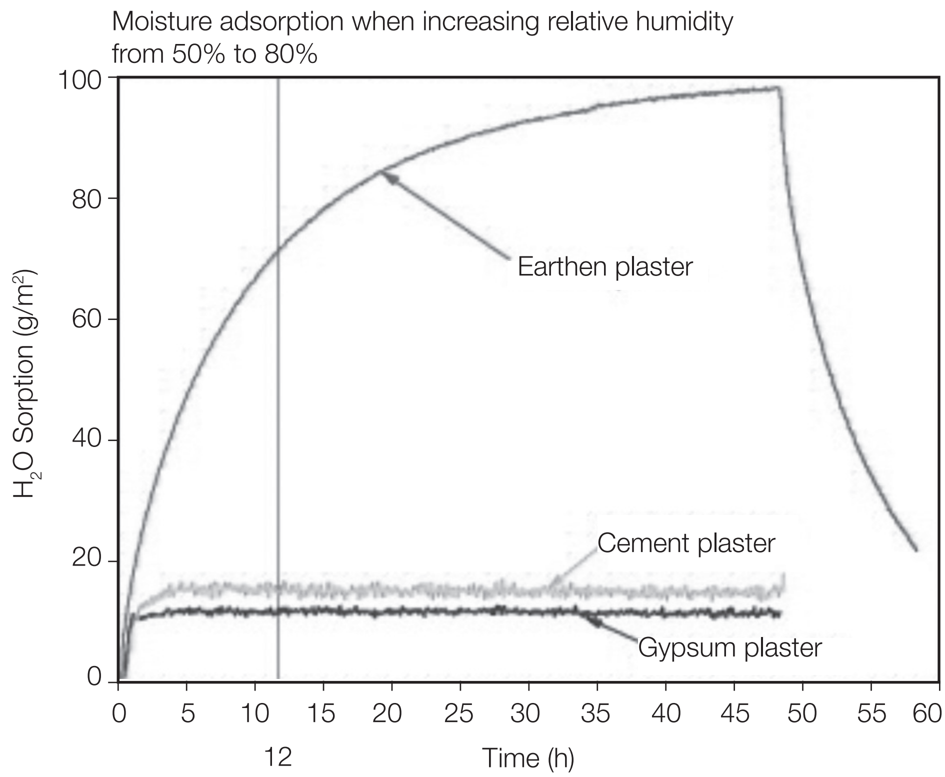

Figure 2 Water vapour adsorption curves for an earth, gypsum and cement plaster at constant temperature (23°C)

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Evaluation of heat pumps: combination of virtual and real

CSTB has developed an experimental geothermal platform within the ENR (Renewable Energies) cluster in Sophia Antipolis. More precisely, it has developed a semi-virtual laboratory through which manufacturers, industrialists and institutions (such as the French Environment and Energy Management Agency ADEME) can evaluate products, particularly heat pumps, under almost real conditions.

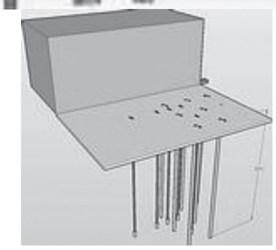
Explanations and test methodology

The geothermal platform

The platform is a genuine field of geothermal boreholes, arranged in a double U and at a depth of 20 metres. The equipment can extract energy from the ground or inject energy into the ground. This borehole field is connected to CSTB's semi-virtual laboratory, PEPSY (Platform for the Evaluation of Performances of dynamic SYstems). These two platforms can be used to evaluate the behaviour and performance of the global system of a geothermal heat pump. Geothermal boreholes can be connected to a virtual heat pump and a virtual building, or they can be coupled to a real heat pump itself connected to the hydraulic network of a virtual building. In this instance, part of the system to be tested (heat pump, storage tank, pumps, regulation, etc.) is actually installed in the laboratory, while the building or the house (with its distribution and heat emissions, occupants, equipment, climate and geothermal exchangers) is simulated numerically. The boundary between the 'real' and 'virtual' parts can be freely determined as a function of the product to be tested.

Adaptability at the service of a complete system

This adaptability is the main advantage of this experimental platform; the



behaviour and performance of the heat pump are evaluated on a complete system combining geothermal boreholes, heat pumps and buildings. Unlike conventional tests, performances are annual or seasonal rather than nominal. For example for heating, the COP (Coefficient of Performance) is an annual or seasonal COP and is not a nominal COP. The robustness of product control is also tested at the same time. This is not the case currently with standard tests. Therefore data from the heat source, emission, heat pump and auxiliaries are included with that data characterising the inertia of the global system, building regulation, etc. The result is an analysis and a global performance calculation including all relevant parameters i.e. equipment, climate, typology, building use, etc. It offers a genuine advantage for manufacturers who wish to optimise their industrial products or improve prototypes. Only a short period and a few tests are necessary to optimise a particular heat pump for a set of climates, buildings or different soil types, while guaranteeing results close to reality.

Saving time and money

This is a priceless advantage because it is well known that genuine monitoring is normally essential to evaluate the performances of a geothermal heat pump installation. This 'real' monitoring often needs several years, including at least one heating season and one cooling season, thus respecting the natural rhythm of the seasons. Such monitoring is not only long but is extremely expensive.

CSTB has developed a unique methodology that goes beyond these constraints. It uses a 12-day test sequence based on climatic data. A calculation automatically determines the appropriate test sequence. In this test (in which each day of the test corresponds to the average day of one month), the heat pump outlet temperatures (at the evaporator and at the condenser side) and the corresponding flows are measured and sent to the virtual environment at each time step of the test (namely every 5 seconds). In return, the simulated environment calculates the conditions of fluid to be controlled at the inlet of the heat pump (realised using charge and discharge loops). Temperature sensors, for example to determine the temperature in the zone or the outside temperature, are replaced by variable resistance boxes exactly reproducing the temperatures of the virtual system, so that the heat pump and the regulation act as they would in a real building.

Peter Riederer, CSTB geothermal laboratory, concludes: "12 days instead of 365 is obviously attractive! We could even reduce this time further for some of the systems. In any case, we are working on it …"

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