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Building and Environment, Vol. 28, No. 2, pp. 115–126, 1993.
Printed in Great Britain.

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The PASSYS Method for Testing Passive Solar Components

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One of the major goals of the CEC PASSYS research project (1986–1992) *is the development of common test procedures for the thermal and solar characterization of building components tested in the PASSYS outdoor test cells.*

Comparison of different test evaluation techniques led to the choice of parameter identification as the most promising approach. For the application of this technique on the test results a software package has been developed. A set of common test procedures has been developed which is suited for different climates and types of components. Both the parameter identification software and the test procedures are currently being evaluated.

Preliminary results are presented.

TERMS AND SYMBOLS

A: area (m^2)
C: overall heat capacity (J/K)
G: incident solar radiation intensity (W/m^2)
H: overall conductance (W/K)
g: total solar energy transmittance (—)
P: power (W)
q: heat flux (W)
R: heat resistance (m^{2}K/W)
U: heat transmission coefficient (W/m^{2}K)

Indices
cal : calibration wall
calc : calculated
co : cooling
e : external
he : heating
meas : measured
sr : service room
tr : test room
s,e : external test room surface
PSC : test component

Terms and symbols related to the test cells
Calibration wall : a thick opaque insulation panel replacing the component, for calibration of the test cell;
Test component : a construction element placed in the test cell opening;
$(UA)_{tr,e}$ sum of steady state overall thermal transmission coefficients between test room and *outdoor surfaces* of roof, floor, East and West wall of the test room; including edge effect at the connection of the calibration wall to the cell. (W/K)
$(UA)_{tr,sr}$ steady state overall thermal transmission coefficient of the partition between the test room and the service room. (W/K)
$(UA)_{psc}$ steady state overall thermal transmission coefficient of the test component. (W/K)
NB: in general a (computationally estimated) correction will be needed for the difference in edge effect between the test room with calibration wall and the test room with test component.
$(gA)_{psc}$ steady state overall solar transmittance, or total solar heat gain factor of the test component; definition: ratio of heat entering the test cell caused by solar radiation on the component, divided by the intensity of incident solar radiation on the component. (m^2)
CI_{tr} internal test room heat capacity: the amount of heat which goes into the test room envelope as a result of a change from one steady state situation to the same steady state situation except for the indoor temperature being raised by 1 K. (MJ/K)
CE_{tr} external test room heat capacity: the amount of heat which goes into the test room-envelope as a result of a change from one steady state situation to the same steady state situation except for the outdoor temperature being raised by 1 K. (MJ/K)
CI_{psc} internal component heat capacity: the amount of heat which goes into the component as a result of a change from one steady state situation to the same steady state situation except for the indoor temperature being raised by 1 K. (MJ/K)
CE_{psc} idem, external. (MJ/K)
$CI_{tr,sr}$ similarly for the partition to service room. (MJ/K)
$CE_{tr,sr}$ (MJ/K)
$etha_G$ gain utilization factor; that part of the long term average (e.g. monthly) solar and internal heat gains which results in a reduction of heating power. (—)

1. INTRODUCTION

THE European Commission started the PASSYS research project in 1986 with the aim of developing com-

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mon passive solar testing and calculation procedures. More extensive information on the PASSYS project can be found in the article by Wouters [1].

The development of a test method for obtaining the thermal and solar properties of building components is one of the major aims of the PASSYS research project. Within PASSYS, highly standardized test cells are used to provide a realistic but readily controllable configurable test environment. A description of the test cells and the common PASSYS equipment and instrumentation is given in [1]. The development of a coherent and affordable set of common European test procedures is the responsibility of the Subgroup Test Methodologies (TME), currently led by TNO.

This paper gives an introduction to the aims and main topics of research carried out by the participants in this Subgroup. The paper starts with an introduction of the passive solar characteristics and the points of attention involved (section 2). This chapter is followed by a description of the development and comparison of different types of test methods and the choice of a common approach: parameter identification (section 3). The chapter continues with a discussion of the development and choice of mathematical models and software tools. Section 4 deals with the test control strategy; the strategy is aimed to obtain a maximum of reliable information in a minimum of test duration. A selection of preliminary results is shown in section 5: an example of the calibration of the test cells, a test on a common reference wall for inter-laboratory comparison and a test on a wall with translucent insulation (TIM-wall). Also an example is shown from the category of "special tests", in this case an experiment aimed to identify properties at a subcomponent level. The evaluation of results is however still in progress, which means that an update in the results is to be expected before the end of the project, March 1992.

2. PASSIVE SOLAR CHARACTERISTICS

The main characteristics of a passive solar component are the heat loss coefficient (UA) and the total solar heat gain factor or solar transmittance (gA). Also important are the heat accumulation in the component, e.g. expressed as some thermal capacity (C) and the thermal coupling with the indoor environment.

Unfortunately the determination of these parameters is a nontrivial task. One could say that the simplicity of a passive solar system is compensated by the complexity of the thermal processes involved: access to some of the key heat transfer mechanisms, such as free convection and transmission of solar radiation, is difficult. Moreover, its performance will depend on the relative area, the orientation and position, the building's thermal mass, the presence of competing heat sources, and so on. The principal task in any experiment is to isolate these factors and to understand both the performance of the component alone and its interaction with the building and its occupancy.

In particular it is the intention of PASSYS to determine parameters which can be associated with standardized definitions in the building industry and ingredients for simplified design tools. The possible variability of the characteristics is one of the topics of the investigations in this respect. For instance solar transmittance being a function of solar angle and heat transmission being a function of temperature.

The time integrated effect of the dynamic interaction between the South wall component and the room behind may be represented by the gain utilization factor, $etha_G$. This factor is an indication for the part of the sum of the free gains which is utilized to diminish the heat demand. However, $etha_G$ has only practical meaning if defined for realistic indoor (and outdoor) temperature and heat flow patterns. Later on (section 3.3) a procedure for obtaining so-called 'gain utilization curves' is described.

It can be concluded that in the development of suitable test procedures for passive solar energy systems both the experimental conditions ("hardware") and the evaluation of the test results ("software") are of equal importance.

3. DEVELOPMENT OF A COMMON TEST METHOD

3.1 *Choice between different test methods*

During PASSYS phase I (1986–1990) different test evaluation methods were tried and compared [2] on the basis of preliminary tests and a series of simulated tests. The methods ranged from simple steady state methods to more sophisticated transient parameter identification techniques. The methods can be categorized as:

A. Integrated absolute method

The integrated values of the measured quantities over a long period give the ingredients for solving the steady state heat balance equations:

$$-(UA)_{psc}\cdot(T_{tr}-T_e)+(gA)_{psc}\cdot G_{psc} = +(UA)_{tr,e}\cdot(T_{tr}-T_{s,e})+(UA)_{tr,sr}\cdot(T_{tr}-T_{sr})-P_{he}+P_{co}. \quad (1)$$

If $(UA)_{tr,e}$ and $(UA)_{tr,sr}$ are obtained by calibration, equation (1) yields the values for $(UA)_{psc}$ and $(gA)_{psc}$, provided that two or more measuring points are available with sufficiently different conditions. The advantage of this approach is, that it is straightforward. The disadvantage is that per measuring point a time-integration is required which is to be extended over a sufficiently long period to avoid the disturbing influence of transient effects. One should realize that the test cells have a time constant of the order of two days, due to the high insulation level; but also heavy weight and heavily insulated components may have this kind of high inertia. Another obvious disadvantage is, that this method only yields the steady state characteristics.

B. Integrated absolute method, with first order correction

In this variant a first order thermal capacity is added to the steady state equations as a first order correction for transient effects: this means a term like:

$$C\cdot(T(t)-T(t-\mathrm{d}t))/\mathrm{d}t$$

is added to the equation (1) with C a first order approximation of the heat capacity. The quantity $\mathrm{d}t$ stands for the time period of integration (time step) between two successive measuring points. Once on this track, however, the temptation is strong to add new terms to the equations in order to further reduce the necessary period of integration; it is then only a small step to a full dynamic parameter identification method, see further on.

C. Transient comparative method

This method requires two test cells: an identical second cell (reference cell) with 'adiabatic' component is run in parallel with the cell containing the actual component under test; the indoor temperature in the reference cell is kept equal to the temperature inside the other cell by controlled cooling and heating. In this way the heat fluxes through the test cell envelopes are equal at all instances. The transient heat flow through the test component is now simply the difference in power between the cells. This is a very elegant principle; the obvious drawback is, that it requires two identical cells. The other major drawback is: that the accuracy may be questionable: (a) which is "the" indoor temperature that is to be kept equal: the (somehow) weighted mean of air and surface temperatures; (b) how accurately can the power difference be measured, in particular in the case of combined heating and cooling. The direct result of the comparative method is still only a transient heat flow through the component; this still has to be processed by an integrated method or parameter identification in order to give the required (transient and) steady state properties. For instance with an integrated method:

$$-(UA)_{\mathrm{psc}}\cdot(T_{\mathrm{tr}}-T_{\mathrm{e}})+(gA)_{\mathrm{psc}}\cdot G_{\mathrm{psc}} = -(P_{\mathrm{he}}-P_{\mathrm{he,ref}})+(P_{\mathrm{co}}-P_{\mathrm{co,ref}}) \quad (2)$$

with the variables integrated over a sufficiently long period.

D. Transient absolute method: parameter identification

With the parameter identification approach a transient mathematical model of the test cell and component is assumed; in an iterative process, with the aid of computer techniques, the set of parameter values for the model is found (identified), which gives the best agreement between measurements and model calculations (see Fig. 1); the parameters comprise the steady state and dynamic test cell and component characteristics. The parameter identification technique has characteristics in common with linear regression analysis. In regression analysis, however, the set of parameters (coefficients) of the model (equation) is found by an analytical calculation procedure. If the model is more complex or non-linear the parameters can only be obtained by an iterative process as illustrated in Fig. 1. The method is particularly suited to operate under dynamic test conditions, which is a great advantage, because of the varying outdoor conditions and the large inertia of the test cell and many components (e.g. mass walls).

At the beginning of PASSYS phase II (1990–1992) the parameter identification principle has been chosen as the test principle which is the most promising with regard to accuracy, application range and cost effectiveness.

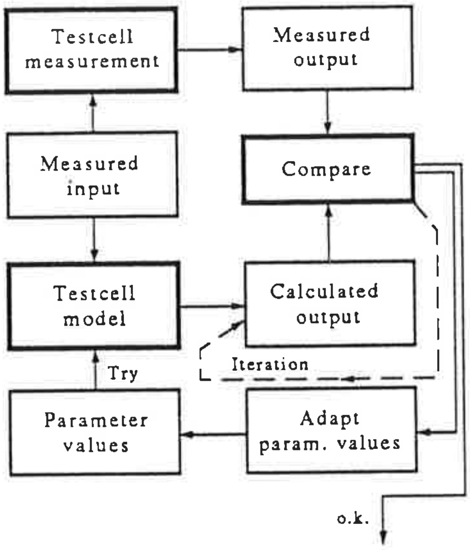

Fig. 1. The parameter identification principle.

3.2 *Parameter identification*

3.2.1 *Introduction.* After the choice of the parameter identification principle the investigations began to focus on the choice of a suitable model, identification software tool and necessary post processing routines ([4]).

3.2.2 *Model of test cell and component.* The choice of an adequate dynamic mathematical model of test cell and component is one of the major points of attention. The main requirements are:

- the model should contain identifiable parameters which can be translated into the required transient and steady state thermal characteristics, like *U*-value, *g*-value, time constants; the result must be sufficiently accurate and precise;
- the model should be capable of reproducing the dynamic behaviour of the system with sufficient accuracy.

Sufficient accuracy means that the discrepancy between measurement and calculation (the so-called residual) should only consist of noise originating from measurement errors: the contribution by "noise" resulting from an inadequate model should be negligible.

A lumped parameter model is chosen as a type of model which is capable of fulfilling these requirements. Figure 2 shows—as an RC-network—the currently used configuration of the model: the upper string represents the test room envelope; the middle string the partition with service room; the bottom string represents the component.

One should realize that the identification of the large number of parameters shown in the model does not mean that each individual parameter necessarily has a physical meaning. The parts of the RC-network between the measured outdoor and measured indoor environments are actually 'black box' models. The individual values are only needed to obtain an adequate dynamic behaviour; see also 3.3.

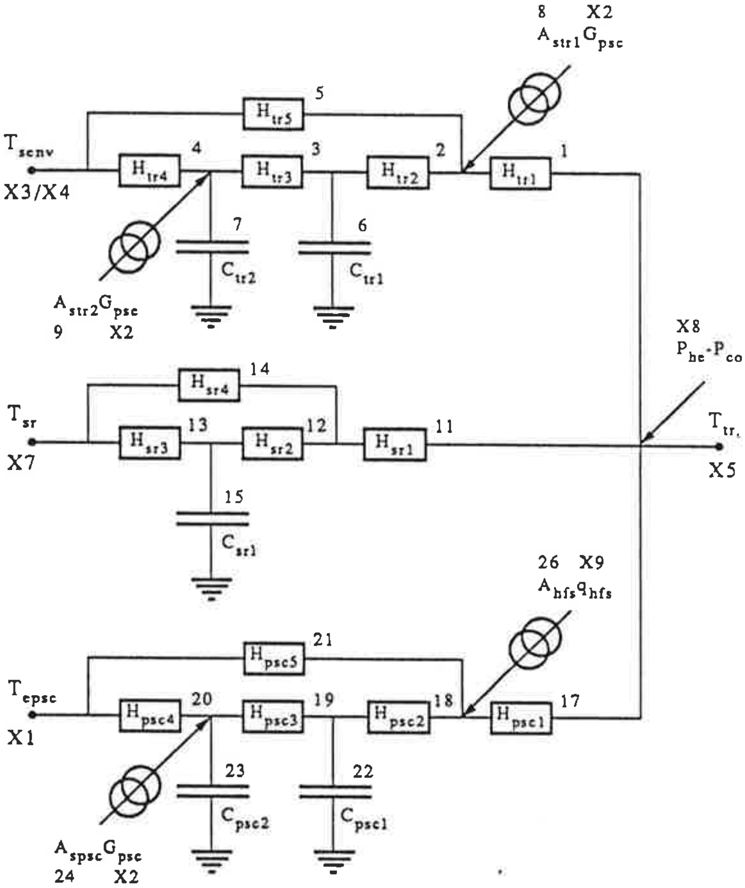

Fig. 2. The currently used lumped parameter model of test cell and component.

Also other types of models are being considered, in the category of more general (less tailor-made) mathematical descriptions. These may have advantages with respect to "efficiency": smaller number of parameters or 'nodes' in the model, and/or with respect to "flexibility": being capable of dealing with a wide variety of components. On the other hand: with a less tailor-made model it will be more difficult to anticipate in the model the expected occurrence of specific non-linear effects.

An example of the iteration process is given in Fig. 3; the output variable is the indoor temperature. This figure shows how the initially guessed temperature (marked with IT1) is strongly deviating from the measured one; the curves marked with IT2 and IT3 show the gradual improvement after a number of iteration steps. In this example, by the way, the curve IT3 is the 'best fit' curve. The figure clearly reveals that there is still room for improvement in the model.

3.2.3 *Multi-output and the modelling of the indoor environment.* The test room temperature is usually appointed as output variable; but—if available—other variables may also be chosen, like the output of a heat flux sensor applied on a homogeneous wall; input variables are outdoor temperture, solar radiation, heating power, etcetera.

One of the options which is used to optimize the accuracy of the test results is to utilize more of the information contained in the test results. For instance by using both the indoor air and the indoor mean surface temperatures as two output variables; this means that the identification process aims to obtain a minimum deviation for both output variables simultaneously.

Moreover. if the indoor temperature is defined as the mean *air* temperature a systematic error is made. A small portion of the heat losses and gains occur outside the scope of the heat balance around the indoor *air* temperature. A full explanation can be found in [3].

These errors can be largely reduced by adopting the surface temperatures as explicit elements in the heat balance.

3.2.4 *Software tools for parameter identification.* Parameter identification requires not only a model of the system, but also a software tool which carries out the iterative identification process to produce the set of parameters and the statistical information on the reliability.

The computer code MRQT, developed at TNO. has been preliminarily selected as a common identification tool. This makes it possible for all participating countries "to speak the same language" while the research continues.

With MRQT it is very easy to identify the parameters of various types of models, by simply linking them to the main parameter identification program. This makes it easier to compare the benefits and disadvantages of either

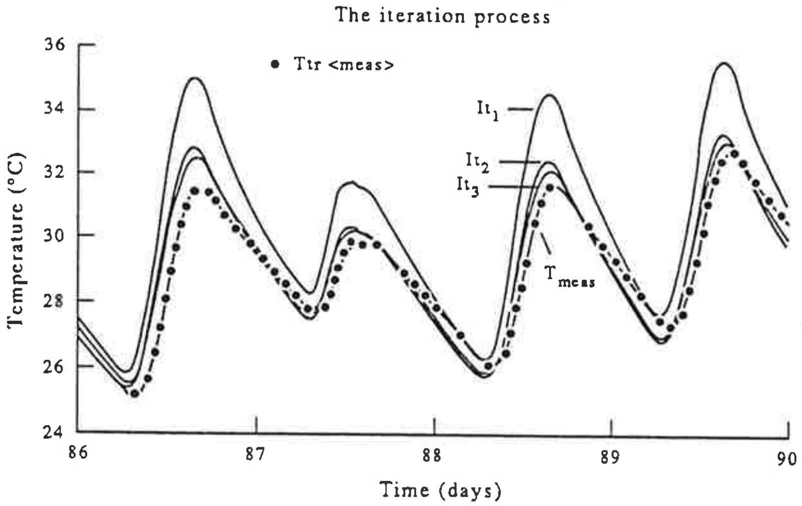

Fig. 3. Illustration of the parameter identification process.

a lumped parameter model of the test cell and component, or a more general mathematical description, within the same software environment. Within PASSYS the package is being further improved.

Great attention is paid to error analysis, particularly the statistical and physical evaluation of the reliability of the test data and the characteristics derived from the test. With the help of simulated and real test series it is investigated whether an already available, more advanced computer package, CTLSM from the University of Denmark, would lead to better results in terms of accuracy or reliability. This package is capable of identifying noise terms in the model (stochastic instead of deterministic model).

In the selection of the most appropriate software package secondary criteria are the user friendliness, required computer run time, memory size and machine dependency.

Post processing software routines have been developed by CIEMAT (Spain) and the University of Denmark for the statistical evaluation of the so-called residuals, the discrepancies between the measurement and model output after identification of the optimum set of parameters.

The aim is to find 'objective' criteria to decide about the adequacy of the chosen model and/or test data.

These techniques are being tried out at the time of writing this article.

3.3 *Evaluation of test results*

The derivation of the physical characteristics from the identified parameters of the model is a straightforward procedure, as far as the steady state thermal and solar properties are concerned: the (UA)-values are derived from the sum of resistances of the three strings; the (gA)-values from the steady state calculation of the distribution of absorbed solar heat in the network. Similarly the (CI)- and (CE)-values are easily obtained by writing out the steady state equations which are represented by the RC-network.

Together with the test cell/component model, a special routine is linked to MRQT which contains these derivations. MRQT then provides the values of and the correlation between the physical quantities.

As mentioned in section 2, the gain utilization factor, $etha_G$, is a special characteristic, because this quantity has only practical meaning if defined for realistic indoor (and outdoor) temperature and heat flow patterns. The gain utilization factor is commonly characterized as a function of the inertia of the room and the ratio between sum of gains and the thermal load (heat losses). An example is shown in Fig. 4. Such gain utilization curve can be obtained by using the model with identified parameters in a simulation on standard weather conditions and indoor conditions which are typical for a real situation in a building, as illustrated in Fig. 5.

A special point of attention in this respect is: how to extrapolate to other types of rooms; in other words: how to separate the transient characteristics of the component and the characteristics of the test room.

3.4 *Other types of tests*

TNO developed and built the movable cold box (see Fig. 6) as an additional provision to the test facility in

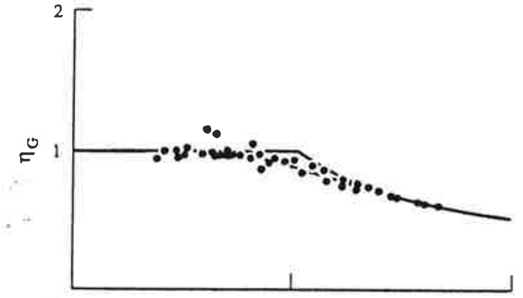

Fig. 4. Example of a gain utilization curve as function of the gain-load ratio (GLR) of a room.

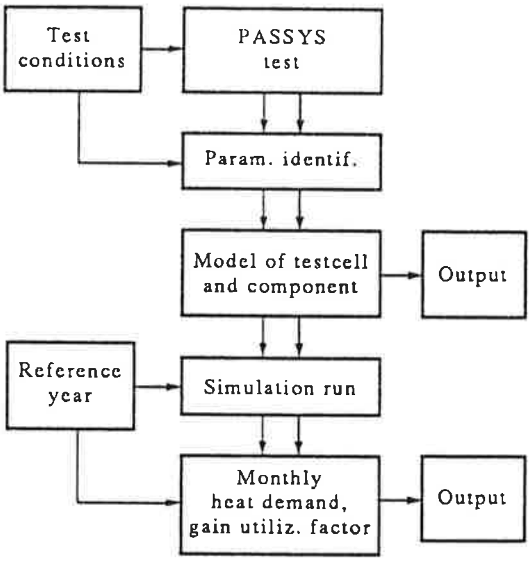

Fig. 5. Possible procedure to derive gain utilization curves from a test, using the identified model of test cell and component.

The Netherlands. This cold box can (temporarily) be placed over the outdoor facing side of the component to obtain dark outdoor conditions (low temperature, constant wind speed) to measure the thermal transmission properties of the component like the (UA)-value. This addition thus converts the cell into a flexible 'hot box' arrangement. Experimental results on components tested within PASSYS will be available by the end of 1991. Other participants experiment with the use of shading screens to obtain a larger variation in incident solar radiation. Moreover, experiments are under preparation to use the test cells for providing information on items like internal and surface condensation under real outdoor conditions, thermal bridges, etcetera.

4. TEST CONTROL STRATEGY

4.1 *Requirements*

Parameter identification allows the test to be carried out under dynamic conditions. For the steady state properties the main requirement is that there is sufficient temperature variation in the lowest frequency range. 'Lowest frequency range' means slower than a few times the largest time constant of the cell and component. 'Sufficient' means that a temperature difference should occur that is much larger than the uncertainty in indoor and outdoor temperature. This uncertainty consists not only of the *measurement error* (of the order of 0.1 K), but also of what could be called a *model error*. The model assumes a uniform indoor and outdoor environmental temperature, while the real physical outdoor and indoor temperatures are usually more complex: the outdoor temperature which governs the heat loss through the component is a mixture of sky, ground and (local . . .) air temperature; the indoor temperature which governs the transmission heat loss is a mixture of surface and air temperatures. The model error can easily be of the order of 1 K.

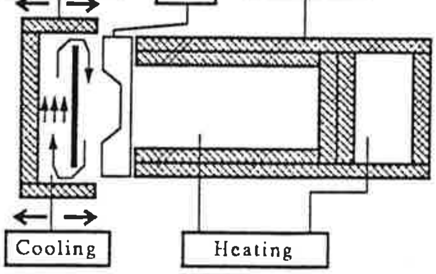

Fig. 6. The movable coldbox developed at TNO in front of one of the cells.

Furthermore, correlation between temperature and solar radiation should be minimized: if the indoor-outdoor temperature difference and the incident solar radiation are correlated, it is not possible to get a clear separation between the heat loss, governed by the temperature difference and the solar gain, governed by the radiation intensity. Both requirements can be met at the same time by a test which contains a sufficiently long period (few days) with high power in the test room and a period of similar length with low power, with power levels chosen to yield a temperature variation of the order of 20 K.

For the dynamic characteristics it is required that variations cover the range of frequencies corresponding with the range of characteristic times of the system. In the case of the test cell and component: for instance from 20 minutes to 50 hours (see 4.4).

Finally, because we want to isolate the component characteristics from the heat balance in the test cell, it is necessary to carry out a calibration test on the test cell without component (see 4.2).

The article by Wouters *et al.* [1], contains a full description of the measured variables.

4.2 *Calibration*

The actual tests are preceded by a calibration of the test cell, using an opaque insulation in the test cell opening. With this wall, a full test sequence of heating or cooling (see under 'Test control strategy') is carried out. Parameter identification applied on a model of the test room yields the parameters of the test room envelope and partition to service room. The calibration wall is eliminated from the model by replacing this part of the model by the output from a heat flux sensor on the indoor facing surface of the calibration wall.

During the evaluation of the actual test the parameters in the model representing the test room envelope and the partition to service room are held constant.

One of the topics which requires careful consideration when analysing test results is whether the interaction between component and test room may complicate the evaluation.

4.3 *Power or temperature setpoints*

Different power levels are needed to obtain the intended effect on the test room temperature. There is a

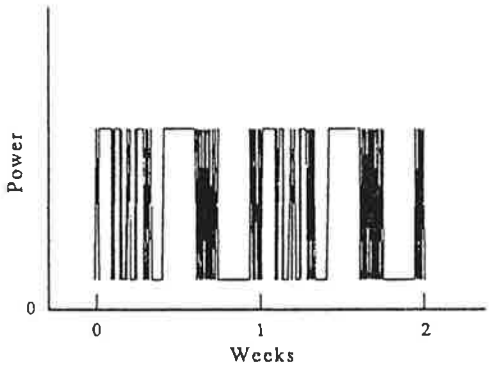

Fig. 7. The dynamic part of the control strategy.

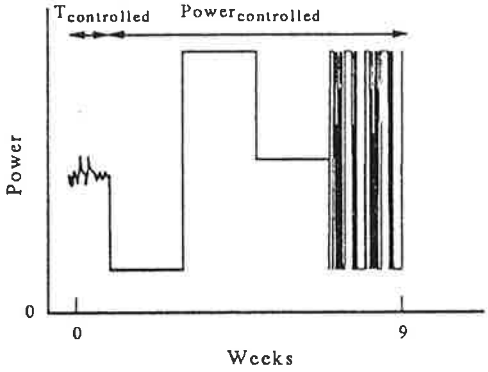

Fig. 8. Schematic view on the common research test control strategy.

choice between power or temperature setpoints. In case of power setpoints, changes in the setpoint lead to less rapid response of the system than in case of temperature setpoints.

On the other hand, a thermostat control may lead to a biased identification of the dynamic characteristics, due to the interaction (feedback) of the dynamics of the heating or cooling system and test cell/component dynamics.

For this reason power control instead of temperature control is chosen whenever possible, despite a number of control disadvantages.

4.4 *Dynamic part: ROLBS scheme*

The identification of the dynamic characteristics benefits from a dynamic power control in the test room. The dynamic power sequence is an 'on/off' sequence organized in such a way that it covers the whole band of relevant frequencies; to this extent the lengths of the 'on' and 'off' periods are chosen at (logarithmically) equal intervals and shuffled in a quasi random order (ROLBS sequence: randomly ordered log. distributed binary sequence, see Fig. 7).

4.5 *Specifications for the test sequence*

All elements mentioned above have been combined into the test sequence, described below.

The test consists of 4 parts with total length 8 weeks preceded by one week initialization. A schematic view on the procedure is given in Fig. 8. Successively the following parts can be defined:

part 0, 1 week, initialization at constant test room temperature;
part 1, 2 weeks, minimum power;
part 2, 2 weeks, high power;
part 3, 2 weeks, moderate power;
part 4, 2 weeks, dynamic power.

In this research phase of the project the long test duration is accepted, to get a maximum of information from the test. Each part and each change from one part to the other adds new information, such as on the heat loss characteristics, heat gain, heat accumulation, temperature effects (characteristics at different temperature levels), temperature decay, etcetera.

When more test experience is available, in a later stage, the length of the test will be reconsidered, in particular for more commercial types of testing.

5. SOME PRELIMINARY RESULTS

5.1 *Introduction*

After periods with experimental tests, aimed at developing the test strategy and trying out different test evaluation methods, results are now being acquired which can be used for detailed quantitative analysis.

The results of these tests have not yet been analysed in full detail; for instance, they require more refined 'postprocessing' actions like pre-filtering of data, component edge corrections, identification with a better 'tuned' model. statistical analysis of the reliability of the identified parameters and residual analysis. Therefore the results should be regarded as preliminary only.

5.2 *Example of calibration*

Figure 9 shows the result of a calibration test (test cell 2. TNO). Clearly visible are deviations between the measured test room temperature and the best fit model result. This test is now being analysed in more detail as an example of a test which requires careful postprocessing before the result can be accepted.

5.3 *Example of a component test: a TIM-wall*

In contrast with this, Fig. 10 shows a result obtained from a test on a transparently insulated wall (TIM-wall) in which the directly measured heat flux was taken as the output variable for identification ([5], [6]). The agreement between test and model output is very good here: the curves can be distinguished only at incidental moments. A more detailed finite difference model was used then the model given by the lower part shown on Fig. 3. Unfortunately the wall performance in terms of U- and g-values was less than expected, due to flaws in the wall's construction.

5.4 *Example of identification on a sub-component level*

Figure 11 shows the result of a different application of the parameter identification technique. In this case local

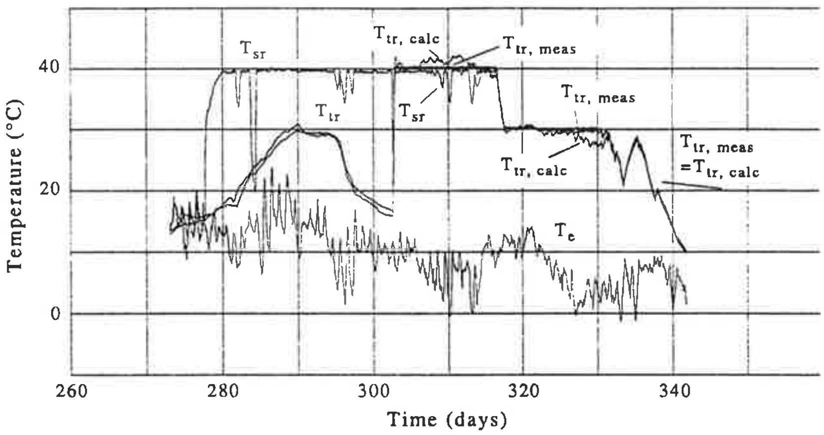

Fig. 9. Example of a calibration result.

surface heat flux and surface plus internal temperature measurements on the opaque part of the lightweight reference wall (test site: WTCB, Belgium) have been used as inputs and output for the identification. The aim was to try to identify the transient and steady state thermal properties of the construction (conductivity and capacity).

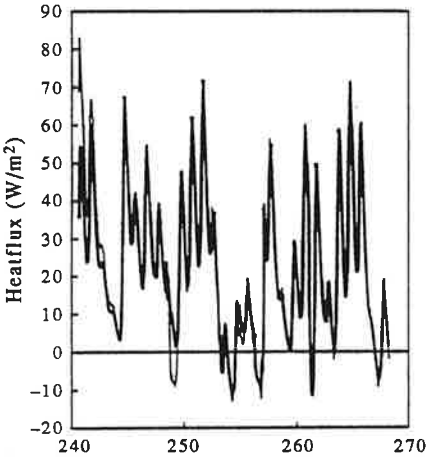

Fig. 10. Example of measured and calculated heat flux through a TIM-wall.

The identified characteristics were very close to the theoretical values.

Figure 11 shows the measured internal and external surface temperatures. In Fig. 12 the measured and calculated temperature at a position behind a 13 mm plywood cover are presented; the calculated value is the result of identification with the internal surface temperature and heat flux as input variables. Again the good agreement leads to coinciding curves in the figure. The identified plywood characteristics, compared with the theoretical values, are:

	identified:	theory:	
conductivity:	0.10	0.1	W/mK
internal capacity:	0.011	0.0091	MJ/K

5.5 *Example of a reference wall test*

Finally, Figs 13–18 show preliminary results from a test on the so-called PASSYS lightweight reference wall, a wall with double glazed window which is used as reference for all the test sites; see [1]. This test on identical components at different sites under different climate conditions will provide a unique possibility for investigating

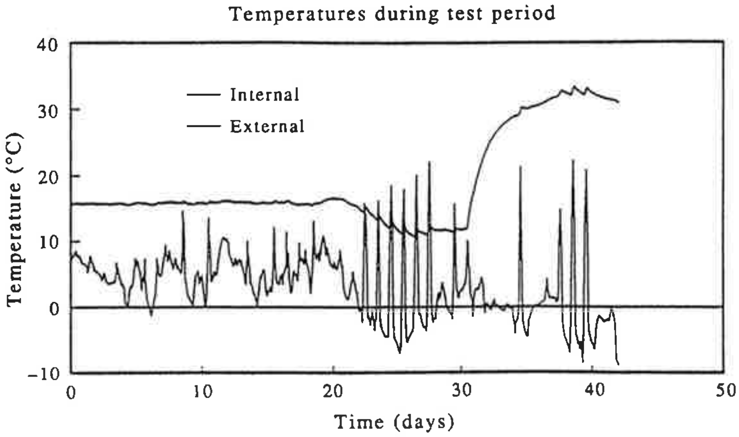

Fig. 11. Example of identification on a (sub-)component level; measured internal and external surface temperatures on the opaque part of the reference wall.

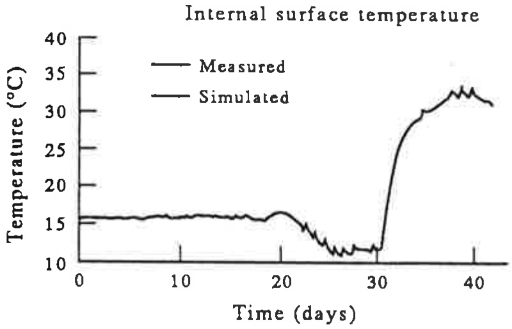

Fig. 12. Example of identification on a (sub-)component level; example of measured and calculated output, in this case the temperature behind 13 mm plywood.

the possible variability of the characteristics, for instance solar transmittance being a function of solar angle and heat transmission being a function of temperature. Figures 13–15 show the main measured variables. The identification has been carried out with indoor air and mean surface temperature as simultaneous output variables.

In Fig. 16 the measured and calculated indoor air temperatures are presented; the mean surface temperature follows a very similar course. Again the curves for the measured and calculated temperatures coincide due to the good agreement. The first few days are used for initialization; the identification process ignores this part of the test; for the actual test period the agreement is quite good; except for a few isolated periods, around

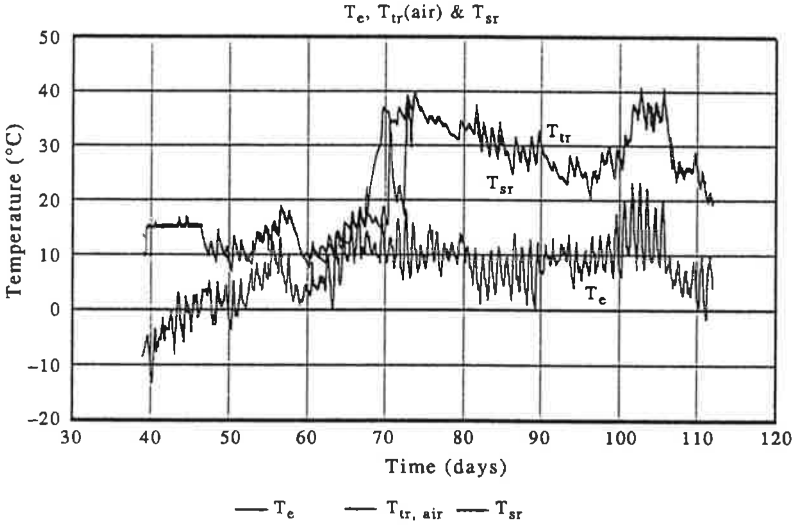

Fig. 13. Preliminary result from a test on the lightweight reference wall; measured outdoor, test room and service room temperatures.

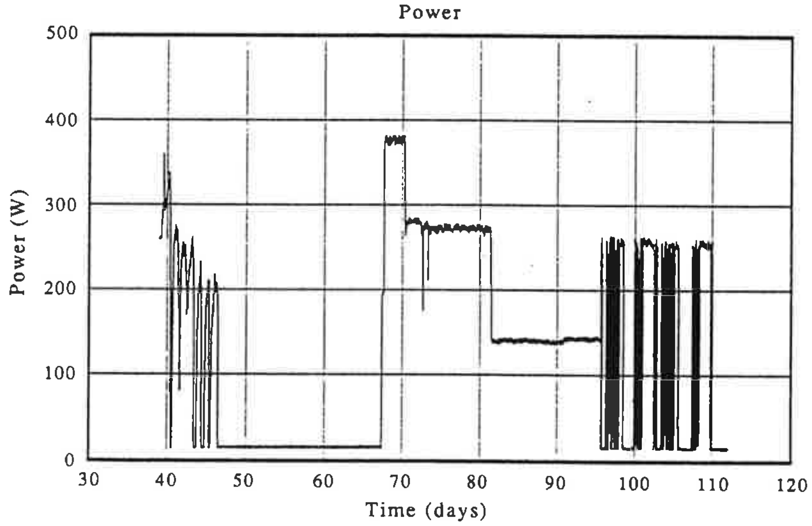

Fig. 14. Preliminary result from a test on the lightweight reference wall; heating power supplied to the test room.

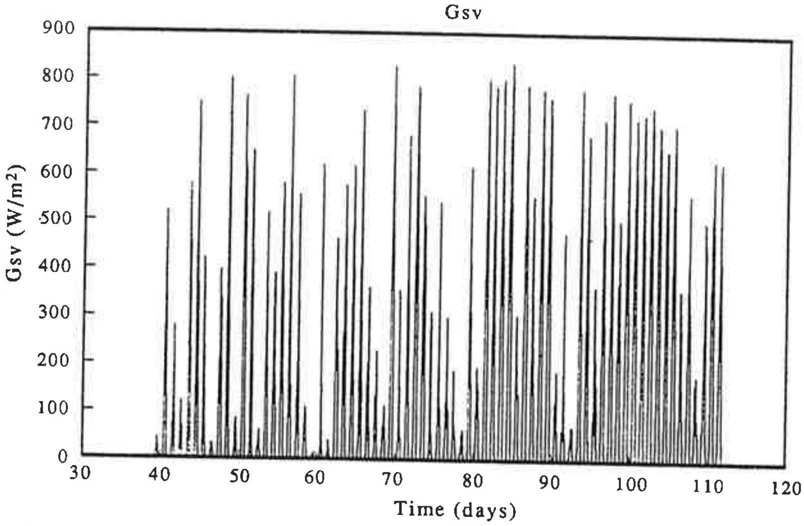

Fig. 15. Preliminary result from a test on the lightweight reference wall; measured incident solar radiation on the component.

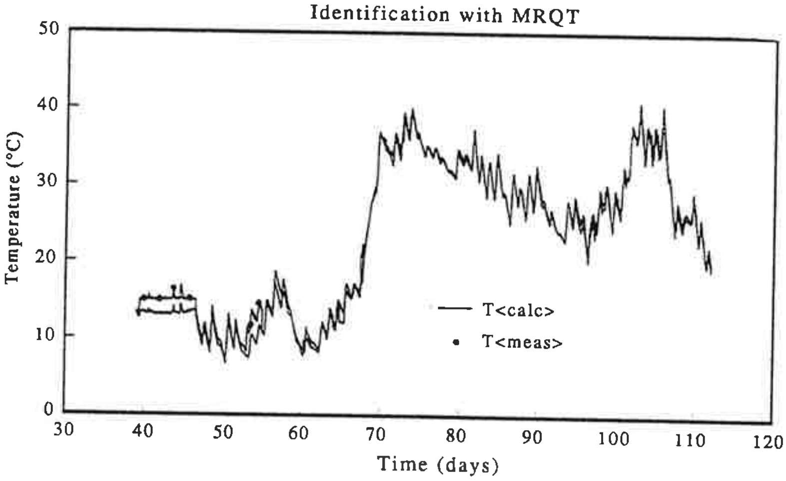

Fig. 16. Preliminary result from a test on the lightweight reference wall; measured and calculated indoor air temperature.

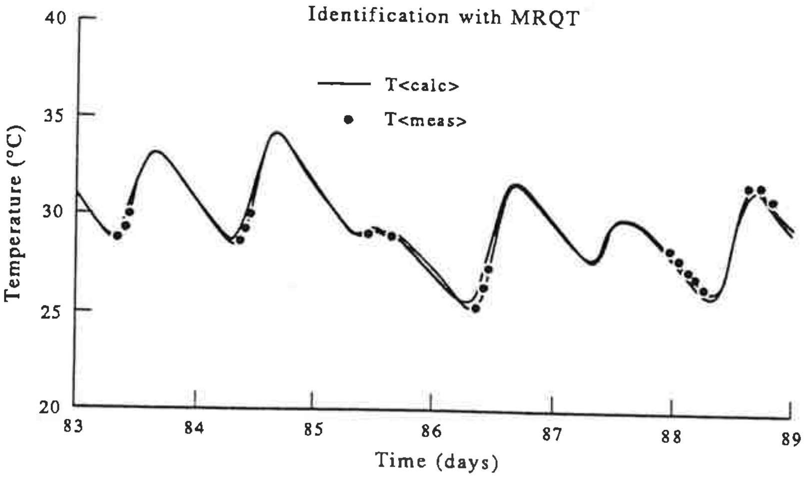

Fig. 17. Preliminary result from a test on the lightweight reference wall; measured and calculated indoor air temperature (detail).

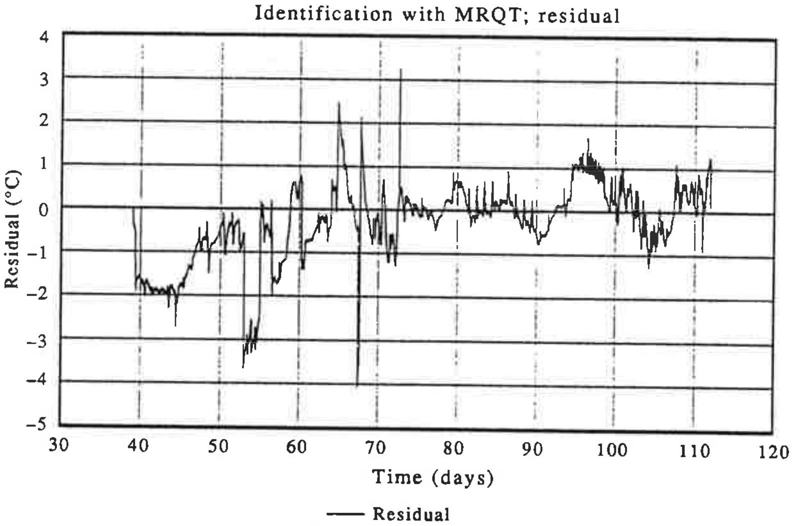

Fig. 18. Preliminary result from a test on the lightweight reference wall; residuals of the indoor air temperature.

day numbers 53 and 65 where a gap in the data has been filled by interpolation. In the identification process such periods are skipped. Figure 17 shows a detail of the same curves. Now it is clear that there is still a small but systematic deviation between measured and calculated temperature, which apparently could not be avoided by the current lumped parameter model. Figure 18 gives the residuals for the indoor air temperature, the discrepancy between calculated and measured output. Analysis of the frequency and auto-correlation characteristics of the residuals is the next step, to give a clear indication in which direction further improvements may be found.

Although more analysis is needed before the results can be fully trusted, the preliminarily obtained results are encouraging: the following characteristics have been identified:

	test cell	partition wall	test component (reference wall)	
(UA)	7.74	1.86	7.16	W/K
(gA)	—	—	0.96	m^2
CI	2.41	0.53	0.56	MJ/K

It should be emphasized that these are preliminary values without all the necessary corrections and checks. The theoretical steady state characteristics for the reference wall are: $(UA) = 5.2$ (W/K); $(gA) = 0.9$ (m^2); the theoretical (UA)-value, however, covers only the one-dimensional heat loss; thermal bridges are not yet taken into account.

6. CONCLUSIONS

One of the major goals of the CEC PASSYS research project is the development of common test procedures for the thermal and solar characterization of building components tested in the PASSYS outdoor test cells.

Comparison of different test evaluation techniques led to the choice of parameter identification as the most promising approach.

Both the parameter identification software and the developed common test procedures are currently being evaluated.

Preliminary results show that the CEC PASSYS test cells in combination with these advanced test evaluation techniques allow the extraction of the transient and steady state characteristics of passive solar components under real, dynamic outdoor conditions.

The facilities have proven to be capable of dealing with a variety of components as walls with solar blinds, translucent insulation, sunspaces, etcetera.

The level of reliability is the main topic of the current investigation. At short notice, for instance, results will become available from identical components tested at different PASSYS sites.

How to deal with possible climatic influences on the characteristics is another point of current attention.

The preliminary test results also show, that the full scale tests are very useful to detect shortcomings in innovative construction elements (e.g. TIM-walls), before application in occupied buildings.

Preliminary results also indicate, that the use of additional equipment and use of the test cells for other types of tests may benefit greatly from the uniform European test environment. For example: *U*-value measurements with cold box, investigation of condensation risk under dynamic conditions, etcetera.

The parameter identification technique is expected to be also a powerful tool for in situ measurements. This could be one of the 'spin off' results from PASSYS.

Acknowledgements—The author would like to acknowledge the joint efforts of all PASSYS participants in the development of a common European test method and the financial support from the CEC DG XII.

This contribution is one of three in this issue that reports the work of the PASSYS project. It was written in mid-1991. At that time, no final results were available, either on the identification of thermal performance parameters, or on the whole model validation experiments. At publication time, these anticipated results have become available and have been reported in a series of documents from the PASSYS project. An overview of the final products, as well as information on how to obtain them, is given in the last issue of the 'PASSYS Newsletter' which is available on request for no charge from the PASSYS Coordinator, BBRI, Violetstraat 21–23 1000 Brussels, Belgium.

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