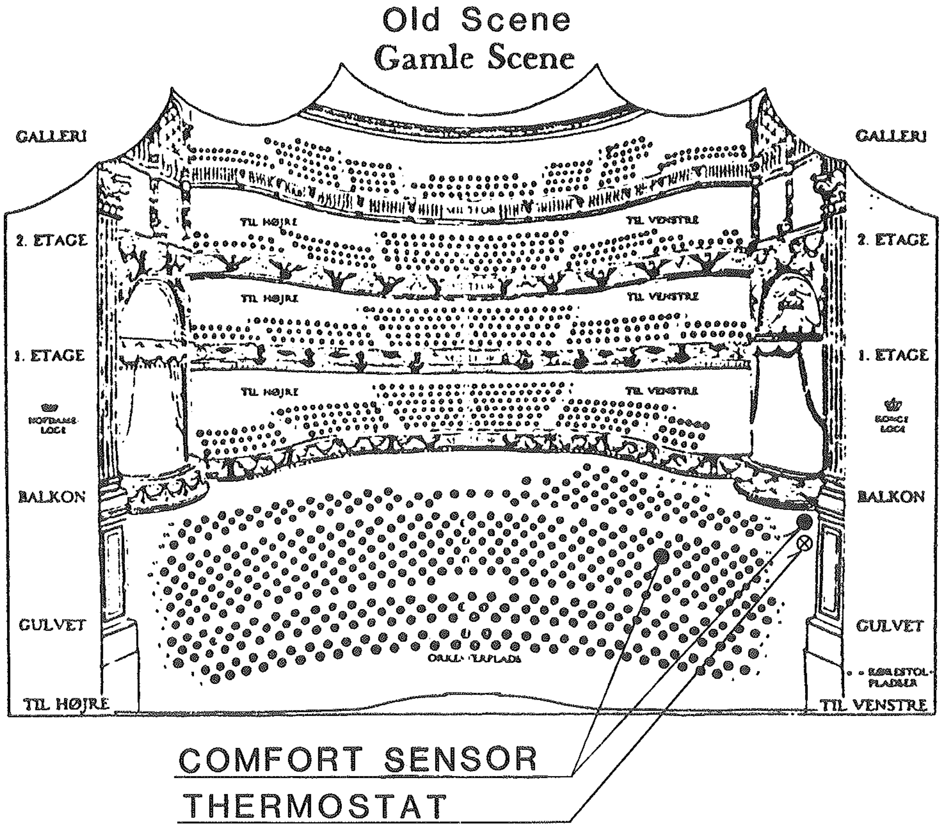
How Important is the Location of the Room Thermostate

T. L. Madsen, T.P. Schmidt and Uno Helk



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ABSTRACT

This paper describes a test performed in two rooms, one thermally light and the other thermally heavy, in order to investigate the influence of the thermostat location on thermal comfort and on energy consumption.

The ability of three thermostat types to maintain a constant equivalent temperature was tested for two different thermostat locations, one traditional location on the wall and the other in the living space close to the center of the room. During each test period, the free heat (light and artificial persons) was varied after a preset and repeatable schedule. At two points, close to each of the two thermostat locations, the equivalent temperature was recorded. After each test, the maximal variation of the equivalent temperature was calculated.

The main result was that the temperature variation in the living space can be reduced when the room thermostat is removed from a wall position to a location in the living space.

The laboratory test was supplied with a field test in the Danish Parliament and in the Royal Theater, chosen as two big rooms where the locations of room thermostats are decided for architectural, rather than engineering, reasons.

INTRODUCTION

The usual location of a room thermostat is on a wall, where the disturbance of the furnishings and the visual impression on the room are negligible. This means that the degree of thermal comfort in the living area is controlled by a temperature that is something like the average between the wall and the air temperature where the thermostat is mounted.

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From a comfort point of view, it would be more appropriate to mount the thermostat in the center of the living area. The sensor would then measure the temperature it is expected to control.

During the last 15 years there has been an increasing interest in the reduction of the energy used for space conditioning of buildings. It is, however, even more important to optimize the degree of thermal comfort. This important aspect is discussed in Haines (1988) and the conclusion is that if a worker's productivity can be increased one percent by a better thermal environment, then the entire annual utility cost can be offset. In this paper, only winter conditions (heating) will be discussed.

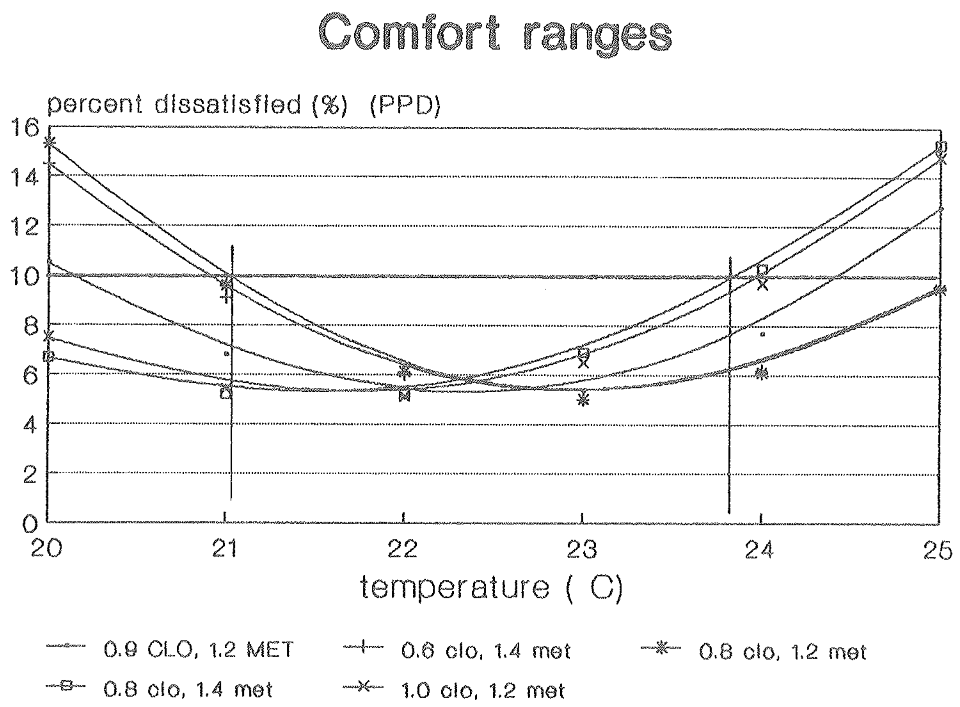

Figure 1. Correlation between room temperature and percent thermal dissatisfied (PPD) for typical combinations of clothing and activity.

Figure 1 shows comfort ranges for different combinations of clothing (clo) and activity (met) typical for the indoor environment. If as much as 10% dissatisfied is acceptable (ISO 7730), then the temperature range is 21 - 24°C. This narrow temperature range indicates that an accurate temperature control must be closely related to the thermal situation in the living area.

In earlier investigations (Madsen 1983; Nørgaard and Madsen 1985) we found that the time constant and hysteresis have an influence on comfort as well as on energy consumption, especially in well-insulated low-energy buildings where the free heat from solar gain, electric lights, and people constitutes the major part of the total energy for heating.

The purpose for this investigation has been to measure what, if any, increase of thermal comfort can be obtained by movement of the room thermostat from the usual wall location to a central location in the living space.

MEASUREMENTS

Measurements were performed in two different spaces, one thermally light and the other thermally heavy. The temperature variations close to the usual thermostat location on a wall were recorded during a varying thermal load, and the results were compared with simultaneous temperature measurements in the living space. This comparison was repeated with the thermostat placed in the living space instead of on the wall, but with the same variation of the thermal load figure 2. Three different types of thermostats were tested, all with the same electrical heating system. This basic investigation was supplied with field measurements in the Danish Parliament and at the Royal Theater in Copenhagen, where only measurements with the thermostat at the usual location on the wall were possible.

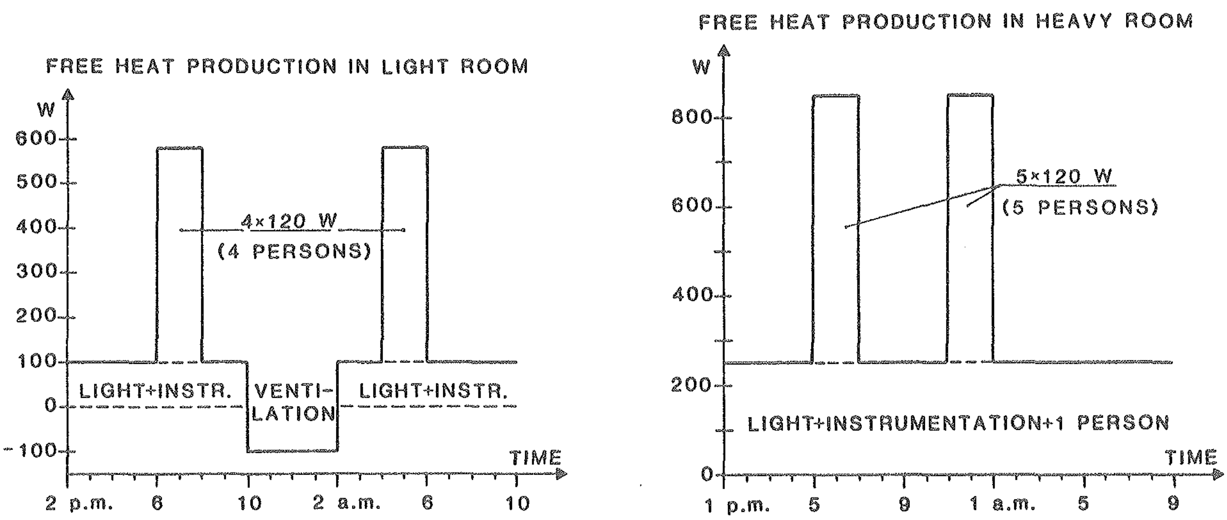

Figure 2. Variation of free heat in the two test rooms. Because of the increased infiltration from the cold box (ventiation) the free heat in this room is negative between 10 pm and 2 am.

LIGHT TEST ROOM

The test setup is shown in Figure 3. There is a constant heat loss through one "outer wall" with a window against a cold space at a constant temperature at -12°C. This heat loss is increased when a small fan in the "outer wall" is started. The free heat consists of four cylindrical heaters at 120 W each, simulating four occupants in the room. The heating system consists of two electrical radiators with a total effect of 1400 W, placed against the "outer wall" under the window. The radiators are controlled by a room thermostat placed on the wall (A) or in the living space (B). The equivalent temperature is registered using two comfort meters, one close to the thermostat and the other in the center of the living area. The variation of free heat is shown in Figure 2. Three different thermostats were tested, an on-off bimetallic thermostat, an electronic modulating thermostat (modulating I), and a new electronic system (modulating II), which uses the same thermal comfort sensor as the thermal comfort meter (ASHRAE 1985). The main results of the measurements are given in Table 1.

The difference between the maximum and minimum value of the recorded equivalent temperature (Δt_{eq}) during a measuring periode (24 h) was found in all tests to be smaller at point A close to the wall than at point B in the air close to the center of the room. When the thermostat location is changed from a position on the wall (A) to a central location (B), then Δt_{eq} is seen to be reduced in the living space but also, with one exeption (the modulating II thermostat), close to the wall (A). This indicates that the temperature variations in the space will be reduced in the heating season if the thermostat is given a more central location.

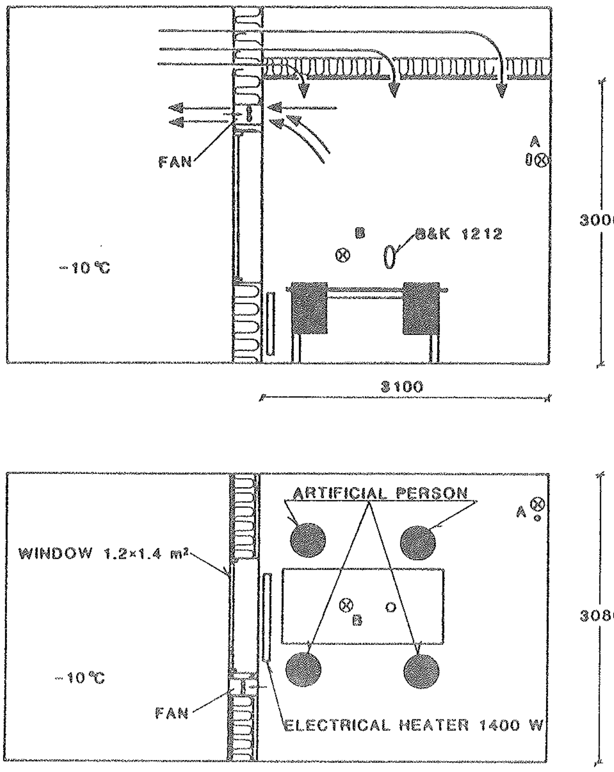

Figure 3. Light test room. A and B indicate the position of thermostat and comfort sensor, on the wall and in the living space on a table surrounded by four artificial persons.

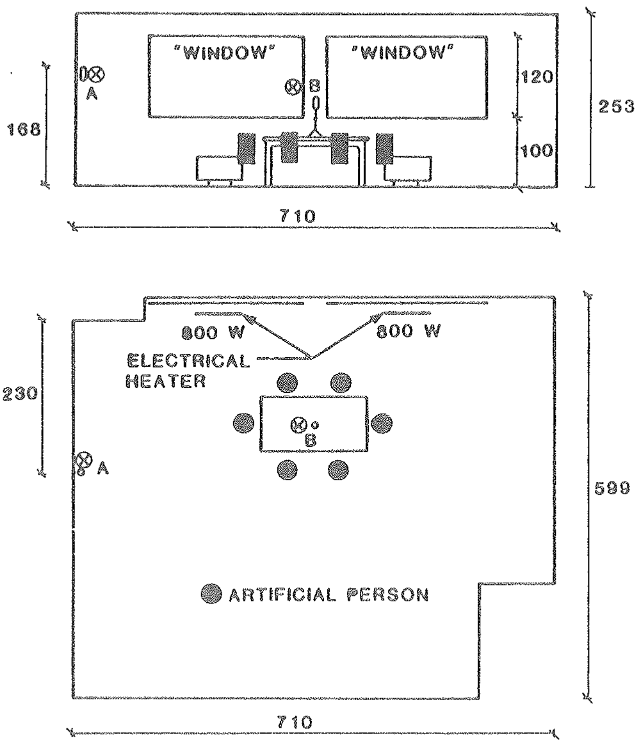

Figure 4. Heavy test room. A and B indicate the position of thermostat and comfort sensor on the wall and in the living space on a table surrounded by six artificial persons.

HEAVY TEST ROOM

This test setup is shown in Figure 4. Floor and ceiling are made of concrete, and all four walls are brickwall. All six surfaces are insulated with 100 mm mineral wool between the concrete/brickwork and the outer parts of the building. The heat loss from this space is established by two plane cooling elements with a total surface area of 11.5 m². These elements simulate two windows in a wall. The free heat varies between 250 W and 850 W as seen on Figur 2. The heat source is two electric radiators, 800 W each, placed under the cooling elements close to the wall. Both radiators are controlled from the same thermostat placed on the wall 170 cm above floor level (A) or in the center of the living space at the same height over the floor (B). The three thermostats used in this room are the same as used in the thermally light room, except for the on-off thermostat, which in this case is a comfort sensor, also on-off but a fast-responding measuring element. The main results from the measurements are given in Table 1.

TABLE 1

Variation of the equivalent temperature Δt_{eq} in the living space (B) and close to the wall (A) for different types of thermostat placed on the wall (A) or in the living space.

		Difference between max. and min. value of equivalent temperature during test periode (Δt_{eq})				Reduction of Δt_{eq} after removal of thermostat from wall to living space			
Measuring point location		wall A	space B	wall A	space B	wall A	space B	wall A	space B
Thermostat type	Timeconstant (min)	Thermostat location on wall A		Thermostat location in living space B		Reduction of Δt_{eq} in K.		Reduction of Δt_{eq} in %	
Light room									
On/off bimetallic	8	2.3	3.3	2.1	2.9	0.2	0.4	9	12
Modulating I	5	1.4	2.0	1.1	1.1	0.3	0.9	21	45
Modulating II	1	0.7	1.7	1.4	1.3	-0.7	0.4	-100	23
Mean		1.5	2.3	1.5	1.8	0	0.5	0	27
Heavy room									
On/off comfostat	1	0.6	1.9	0.5	1.4	0.1	0.5	17	26
Modulating I	5	0.6	1.5	0.4	1.2	0.2	0.3	33	20
Modulating II	1	0.5	1.1	0.4	0.8	0.1	0.3	20	27
Mean		0.6	1.5	0.4	1.1	0.1	0.4	23	24

Δt_{eq} express the difference between highest and lowest recorded value of the equivalent temperature during each measuring period (24 h). The last four columns give the reduction of Δt_{eq} after removal of thermostat from wall to living space. The measured time constant for each of the thermostats when placed on the wall is also given.

The Δt_{eq} is shown again to be reduced in the living space when the thermostat location is changed from a wall position to a central position in the living space. A smaller but positive reduction is recorded close to the wall. In this heavy room, the temperature variation (Δt_{eq}) is smaller than in the light room and consequently the reduction, after removal of the thermostat, is also smaller.

THE PARLIAMENT

This large room was chosen as an example of a new air-conditioning system in a heavy building without solar gain but with a varying amount of free heat from occupants. A high degree of thermal comfort is reported in this room. Figure 5 shows a sketch of the room with the two thermostats in their existing positions and with one measuring point close to one of them (A) and the other measuring point in the living area (B), kindly accepted by one of the Parliament members. The thermostats used consist of an NTC-resistor in a perforated brass tube. This tube (20^{Φ} x 80 mm^2) is placed in a horizontal position on the wall 1.5 m above the floor. The time constant is measured to be 18 min. This long time constant can explain the long delay of the correction of the air inlet temperature when many, but not all leave the room, for examples, after voting.
The equivalent temperature was recorded for three weeks (in an intensive political period), close to the existing thermostat and in the middle of the room (Figure 5). The main results are given in Table 2.
It shows that during each of the three measuring periods, the variation of Δt_{eq} is greater in the living space than close to the thermostat.

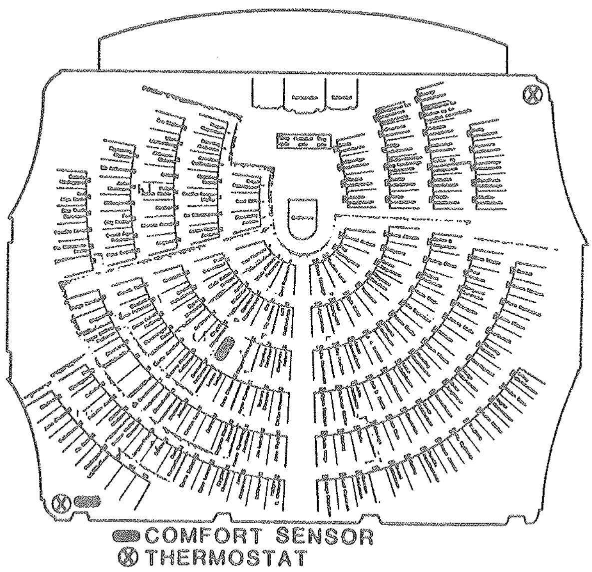

Figure 5. Thermostat position and measuring points in the Danish Parliament

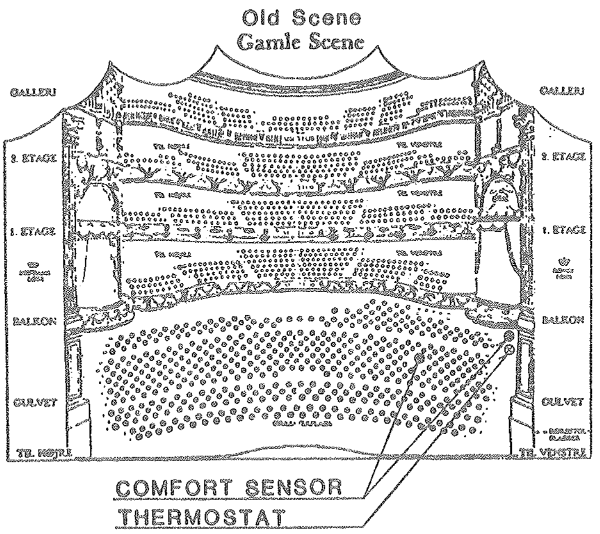

Figure 6. Thermostat position and measuring points in the Royal Theater, Old Scene.

THE ROYAL THEATER

The purpose of this investigation was to measure the increase of the equivalent temperature in a nearly full theater in the audience space and compare this measurement with simultaneus measurement of the equivalent temperature close to the thermostat. Figure 6 shows the position of the thermostat and one comfort sensor on the wall under a balcony and the other comfort sensor in a normal seat in the audience. The measurements were recorded during three performances and is shown are Table 2.
In this old theater, the temperature increases during a performance due to the free heat from the audience. This increase was, for all three measuring periods, greater in the audience than close to the thermostat.

TABLE 2

Difference between highest and lowest value of the equivalent temperature Δt_{eq}.

	Difference betwen max. and min. value of equivalent temperature during one test periode Δt_{eq}		Difference between Δt_{eq} in living space and close to thermostat
Measuring point location	close to thermostat A	in living space B	B - A
Parliament, test period			
1. 3-6 Nov.1987 72 h. 2. 30 Nov.-2 Dec.1987 72 h. 3. 14-17 Dec.1987 72 h.	1.8 2.1 3.1	3.2 2.8 4.4	1.4 0.7 1.3
Mean	2.3	3.5	1.1
Royal Theater, test period			
1. Ballet 28.10.87 3 h. 2. Don Juan 10.11.87 3 h. 3. Nut-Cracker 12.12.87 3.h.	1.6 2.0 2.2	3.0 3.0 3.4	1.4 1.0 1.2
Mean	1.9	3.1	1.2

Recorded in the Danish Parliament and in the Royal Theater close to thermostat A and in the living space B during each measuring period.

DISCUSSION

The results from the two test rooms indicate that temperature variations are reduced when the room thermostat is moved from the wall to the air in the living area. This reduction is found in the living space (B), as well as, with one exception, close to the wall outside the living space.

The greatest fluctuation (3.3 K) is found in the light room, with a traditional on/off thermostat on the wall. The best result is obtained with the "modulating II" system in the living space, in the heavy room (Δt_{eq} = 0.8 K).

In both rooms, the influence of thermostat type is greater than the influence of thermostat position.

Climatic chamber tests (Lebrun and Marrat 1980; Sprague and McNall 1970) have shown that during winter conditions people will not set the thermostat in accordance with the mean temperature but in accordance with the minimum temperature. In Sprague and McNall the following equation is given:

$$t_{pref} = t_{comf} + 0.3\ A.$$

where: t_{comf} = the equivalent temperature for PMV = 0
A=peak to peak amplitude of the periodic temperature fluctuation.

If, for example, the modulating thermostat in the light room is moved from the wall to the living area, then the preferred temperature can be decreased:

$$\Delta t_{pref} = 0.3\ (2.0 - 1.1) = \underline{\underline{0.3°C}}$$

If the on/off thermostat in the light room is replaced with a modulating II system, still at the same place on the wall, then reduction of prefered room temperature is:

$$\Delta t_{pref} = 0.3\ (3.3 - 1.7) = \underline{\underline{0.5°K}}$$

In Nielsen (1978) is found that for climatic zones with 3000 degree-days a year, as in Denmark, a one degree (°C) increase in mean indoor temperature may cause a 10% to 15% increase in energy used for heating. This means that even small improvement of, for example, the room temperature control may have a significant positive influence on energy consumption.

In the Parliament building and in the Royal Theater, a removal of the thermostat from the wall to the living area was not possible during this pilot test. An evaluation of the influence on the thermal condition caused by this movement can only be made indirectly. It is possible to compare the temperature fluctuation close to the thermostat with the corresponding fluctuation in the living space. This comparision is done in Table 3. The difference between Δt_{eq} at the two locations (B - A) is greater in the Parliament and Theater than in the two test rooms. This indicates that also in the larger rooms, a reduction of Δt_{eq} can be expected after a movement of the room thermostat from A to B.

In Table 3, (B-A) is the difference between temperature fluctuation in the living space and close to the wall. In the two test rooms, this difference is smaller for a space location of the thermostat than for a wall location. This indicates that a space location of the room thermostat may give a more even temperature distribution in the room than a wall location. More investigations are needed with more measuring points before a final conclusion can be drawn.

TABLE 3

Comparison of temperature variation Δt_{eq} (K).

Thermostat location	On wall A			In living space B		
Measuring point location	wall A	space B	B - A	wall A	space B	B - A
Light test room	1.5	2.3	0.8	1.5	1.8	0.3
Heavy test room	0.6	1.5	0.9	0.4	1.1	0.7
Parliament	2.3	3.5	1.2	?	?	?
Royal Theater	1.9	3.1	1.2	?	?	?

From Table 1 and Table 2. B - A indicates the difference between temperature fluctuations at the two measuring points A and B. For the two test rooms B - A is given for both thermostat locations.

CONCLUSION

The laboratory test shows that temperature fluctuations in the living space are reduced when the room thermostat location is changed from a wall position to a central place in the room.

A central location of the room thermostat may create a more constant temperature, not only close to the thermostat, but also close to the wall outside the living space.

In the heating season, a more constant equivalent temperature may reduce energy consumption for heating, since the prefered temperature can be reduced proportionally to the reduction of the temperature fluctuations.

These first field tests in two large meeting rooms indicate that temperature control can be improved if the room thermostat is moved to a more central position in the space. More investigations are needed before a final conclusion can be drawn.

ACKNOWLEDGMENT

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