THE IMPORTANCE OF THE ROOM THERMOSTAT FOR THE INDOOR CLIMATE AND THE ENERGY CONSUMPTION IN BUILDINGS

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ABSTRACT

Room thermostats for control of the indoor temperature are usually formed to react to changes of the air temperature. The time constant is normally high due to the considerable thermal capacity of the thermostat and the wall on which it may be fixed. Consequently the thermostat will respond more slowly than necessary to sudden changes of the heat load especially solar gain transferred to the room as radiation.

An investigation is reported in which a thermostat, recently developed at this laboratory, is compared with a traditional one under well-defined conditions. Also a long duration test in a low energy house is explained. The hot air heating plant has been operated alternately by the new thermostat and by the traditional one. The energy consumption as well as indoor climate fluctuations have been analysed in both cases.

KEYWORDS

Energy; Comfostat; Thermal Comfort; Low Energy Houses; Thermostat.

INTRODUCTION

The energy crisis of 1973 led to a substantial intensification of research into alternative and lasting sources of energy. Today, seven years later, most people would probably concede that it is going to take a very long time before these new sources of energy are able to make a significant impact on the energy consumption of modern society. The solution to the problem of energy consumption restraint will lie to a far greater extent with the optimization for minimum energy demand of current practices.

The energy consumption for heating of buildings represents a significant proportion of the total energy consumption in many countries - in Denmark it is approximately 45% - it makes very good sense to seek methods of reducing this proportion, preferably in ways which make minimal demands on resources and do not influence thermal comfort adversely.

This paper introduces a new kind of room thermostat - the Comfostat - which preliminary measurements indicate meets the very criteria mentioned.

CONTROL OF HEATING PLANT

In the last years, control systems for space-heating and air-conditioning installations have become steadily more advanced, except in respect to the room thermostat. The room thermostats used today closely resemble those that were new twenty years ago. Their thermal time-constants are long. The construction of room thermostats is such that they react to changes mainly in the air temperature.

Because of these two features, a sudden increase in the free heat in a room controlled by a conventional thermostat will result in a corresponding reduction in the output of the heating system only after a time interval. Conversely, the increased heat input from the system following an increased heat-loss from the room will be delayed. In both cases there will be a periodical change in the level of thermal comfort. This is particularly unfortunate if the thermostat in order to save energy has been set so that the occupants of the room are kept in the lower part of the comfort zone ($-1<PMV<0$).

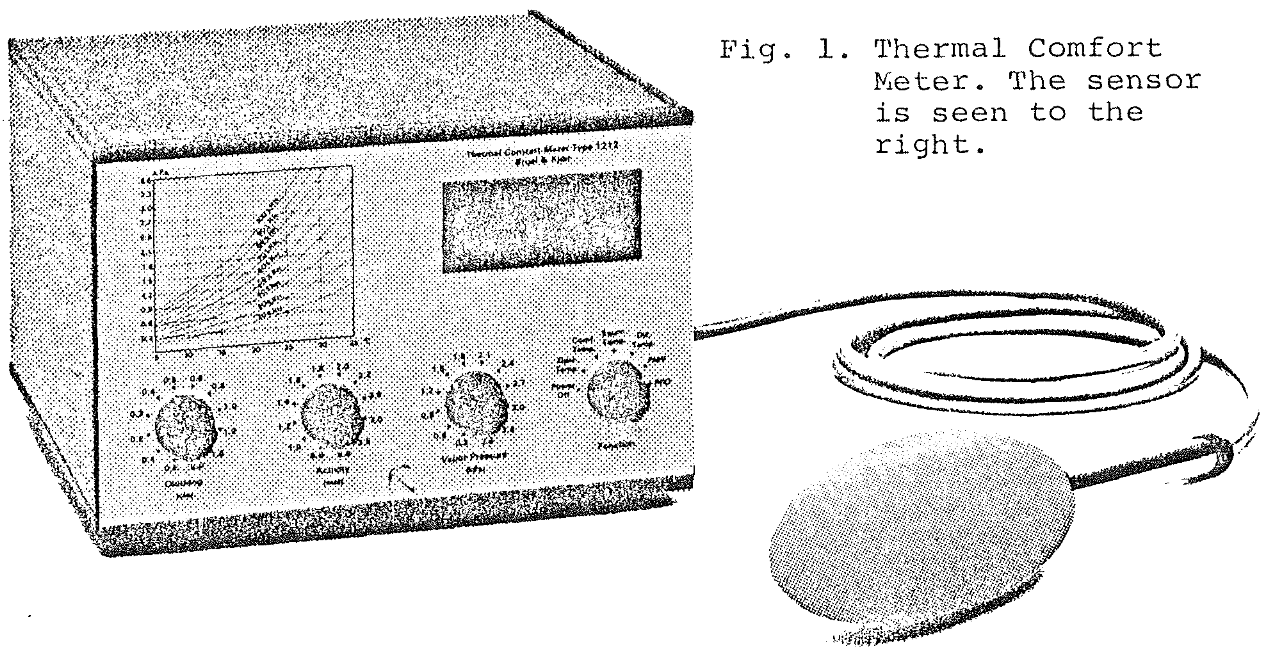

Fig. 1. Thermal Comfort Meter. The sensor is seen to the right.

THE COMFOSTAT - A NEW ROOM THERMOSTAT

At the Thermal Insulation Laboratory a new Thermal Comfort Meter has recently been developed. A very important part of this instrument is a new sensor which is able to measure continuously the combined influence of the air temperature, the air velocity and the mean radiant temperature on the room occupants' heat loss to the actual environment and thus on their thermal comfort. The sensor, Fig. 1, which is described in detail in [1] and [2], is constructed so as to simulate a person's heat exchange with his surroundings by radiation and convection. This is achieved by the choice of size, shape, radiation characteristics and surface temperature of the sensor. The sensor is heated, and has a mass which is small in relation to its surface area. Because of these two characteristics, it has a short time-constant. Furthermore the time-constant is the same for changes in either the air temperature or the mean radiation temperature.

As the function of a room thermostat is to regulate the output of a heating installation so as to maintain the thermal comfort of the occupants of a building, this sensor must be very suitable for use as a room thermostat. It can be connected to the control system in such a way that it attempts to maintain a constant emission of heat from the sensor, and thereby to maintain a constant level of thermal comfort for persons occupying the same thermal environment.

LABORATORY MEASUREMENTS

In order to evaluate the capacity of a particular thermostat for maintaining thermal conditions in a room constant, the following properties of the device must be determined:

- The temperature characteristics;
- The hysteresis;
- The time-constant;

For both a conventional thermostat and the new device, Fig. 2. the first two properties are derived from measurements in a highly insulated room at the laboratory. This room has a constant heat loss through a pair of double-glazed windows (glass area 2 x 1 m^2) to another room with a constant temperature of $-10^{o}C$. Heating of the test room is by an electric radiator under the windows. The heat input to the room from this radiator is controlled by each of the two thermostats in turn. Both thermostats are located on the light weight concrete wall 1.4 m above floor level. Characteristics for the Comfostat and a Fischbach TR40 thermostat are shown in Fig. 3.

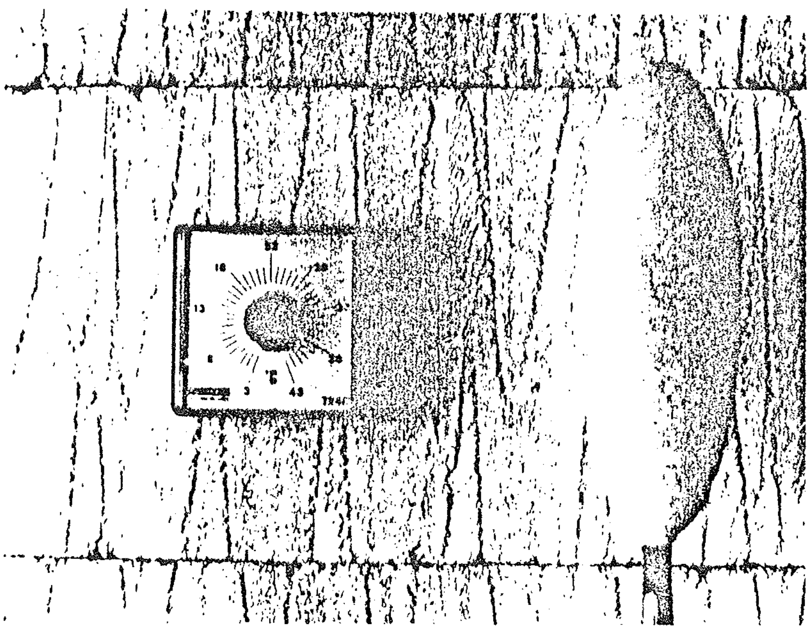

Fig. 2. Fischbach TR40 thermostat and Comfostat in test room.

The time-constants are obtained from a recording of the output of each thermostat when it is exposed to a momentary change in environmental conditions. This change is implemented by the use of a heated box constructed from 50 mm polystyrene foam, open on one side. This box is placed up against the light-weight concrete wall on which the thermostats are fixed (see Fig. 2). When both thermostats have reached thermal equilibrium, the box is removed and the cooling of each thermostat is recorded. The time-constants are determined from the resulting curves.

Fig. 4 shows the step-responses of the Fischbach TR40 and the Comfostat. The latter is identical to the comfort sensor and its electronic accessories; The Fischbach is constructed around a temperature-sensitive semiconductor circuit which delivers an electric voltage proportional to the room temperature. τ_C = 0.9 minutes and τ_F = 14.5 minutes are the time-constants measured respectively for the Comfostat and the Fischbach TR40. The long time-constant of the latter is due mainly to the relatively tight casing of the semiconductor circuit in a plastic housing with few ventilation holes.

PRACTICAL MEASUREMENTS

In order to gain an impression of how the new thermostat would function in a practical situation, it was substituted for the conventional thermostat controlling the central heating in one of the Laboratory's six Low-Energy Houses, for a trial period [3].

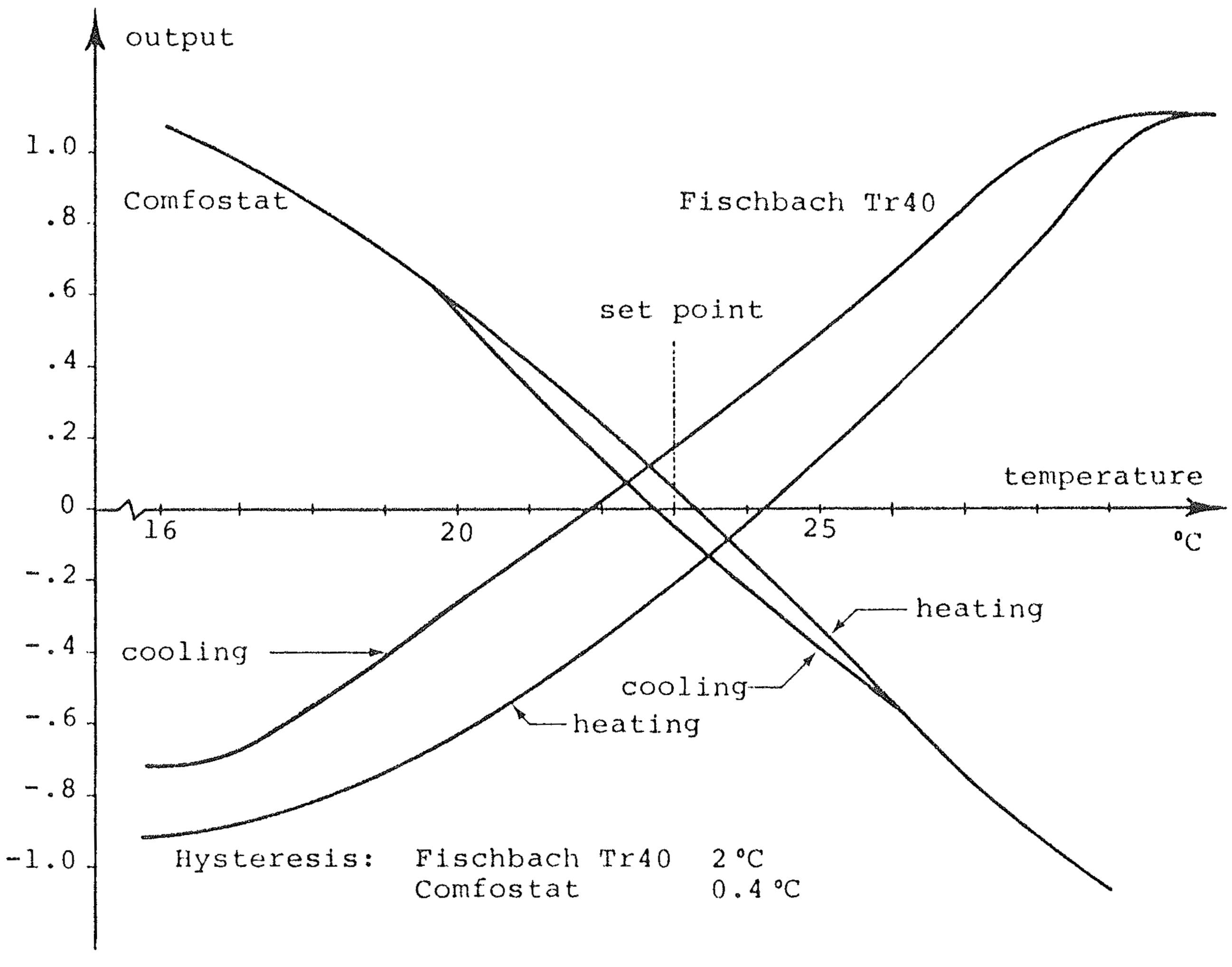

Fig. 3. Measured correlation between room-temperature and output from Fischbach TR40 and Comfostat.

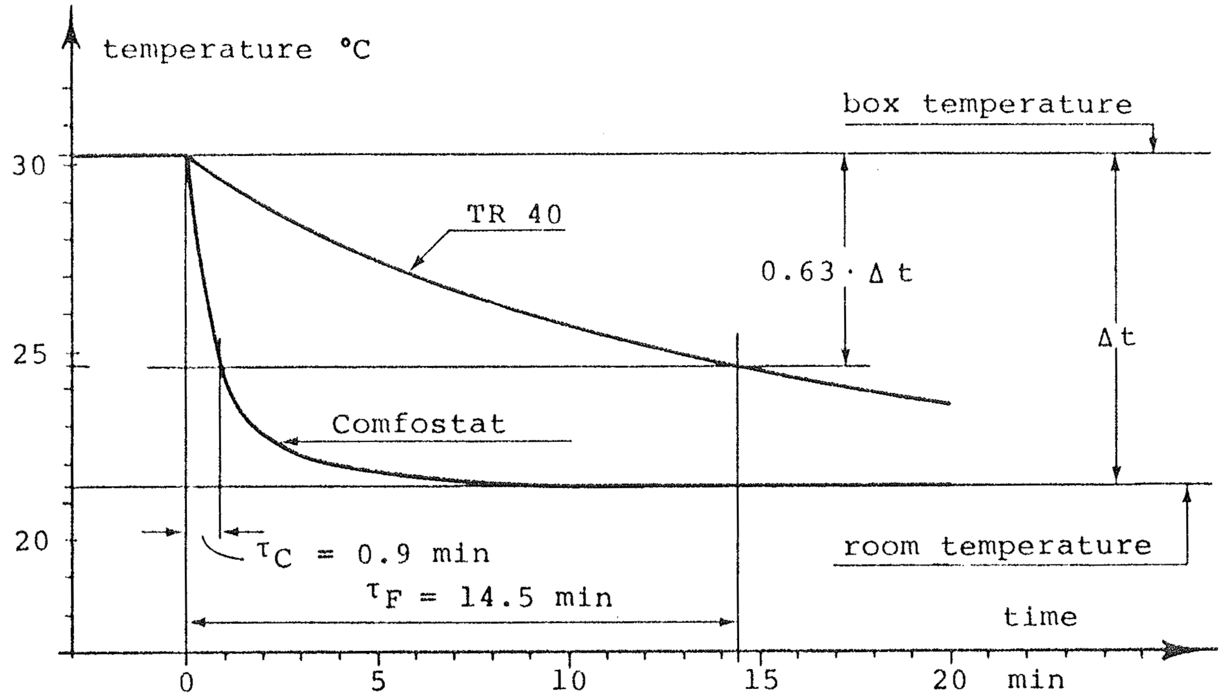

Fig. 4. Step response of Fischbach TR40 and Comfostat.

This particular house is a highly insulated structure built of light-weight concrete, with a ground area of 120 m^2, and glazed areas of 7.6 m^2 and 2.1 m^2 facing south and north respectively. The heating system in the house is a warm-air type with 100% recirculation, controlled by a Fischbach TR40 thermostat. This is capable of regulating the amount of hot air injected continuously between 0 and 100%. Moreover the house is provided with a fresh-air ventilation system incorporating heat-recovery, which functions continuously. The location of the thermostat will be apparent from Fig. 5. Its height above the floor is 2.2 m.

In order to obtain realistic figures for energy consumption, occupation of the house has been simulated. All household appliances, including television, lightning, refrigerator etc., have been operated as if a family of four adults lived in the house. The heat generated by four people living a normal family life is supplied to the house by person-simulators sited in all the habitable rooms. Hot water is run off in the kitchen and the bathroom (altogether about 250 litres per 24 hours) at the normal times for washing, bathing etc.

The circumstances described make it possible to analyse realistically the thermal environment and energy consumption in this house.

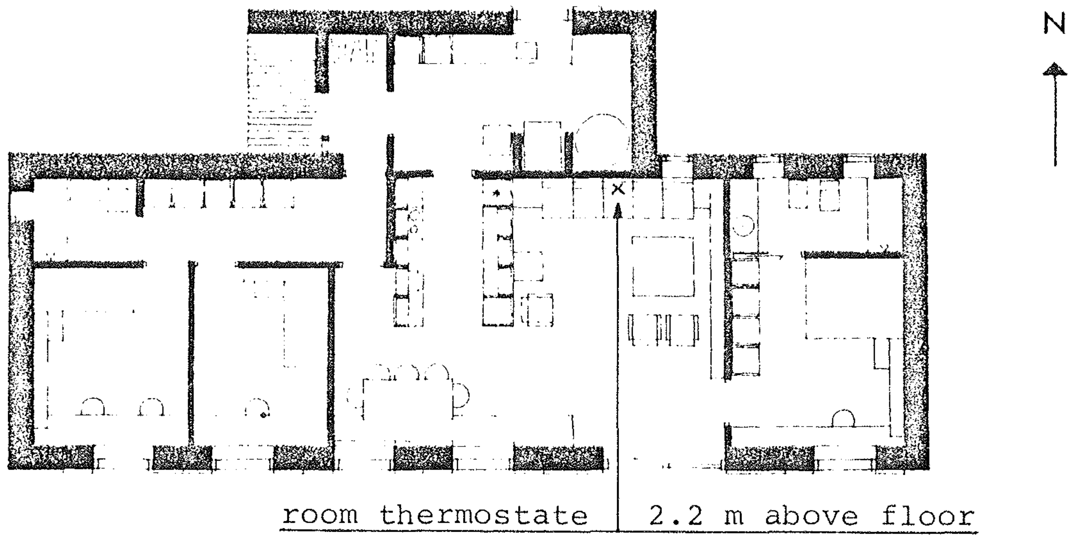

Fig. 5. Location of room thermostat in low-energy house.

MEASURING RESULTS

The analysis is derived from measurement of a number of parameters which were recorded on a datalogger every ten minutes throughout the trial period. Each type of thermostat controlled the central heating over a period of seven days, one a few days after the other, from the latter part of November till the beginning of December 1979. From the data collected, it is possible to compare differences in parameter fluctuations for each of the two thermostats used. On Fig. 6 is shown the progress over two twenty-four-hour periods - one for each thermostat - of some of the most important parameters measured.

As can be seen from the top diagram in Fig. 6 the TR40 has operated as a traditional on-off thermostat, switching between a maximum and a minimum air-flow across the heating surface. The lower diagram on the figure exhibits, however, a strongly modulated air-flow, emphasizing the ability of the Comfostat to match the heat supply to the current heat requirement quickly. Integration of each of the two air-flows over the seven-day period reveals that the 24-hour mean air-flow with Comfostat control is only 52% of the 24-hour mean air-flow with control by the TR40. Consequently a substantial reduction in energy consumption would be predicted for control by the Comfostat.

In order to evaluate the expected reduction in energy consumption more precisely an energy balance has been drawn up for the house. In the table is given the calculated heat loss as well as the amount of heat input from the different energy sources. Values are shown for both the seven days period and for the days with no solar radiation.

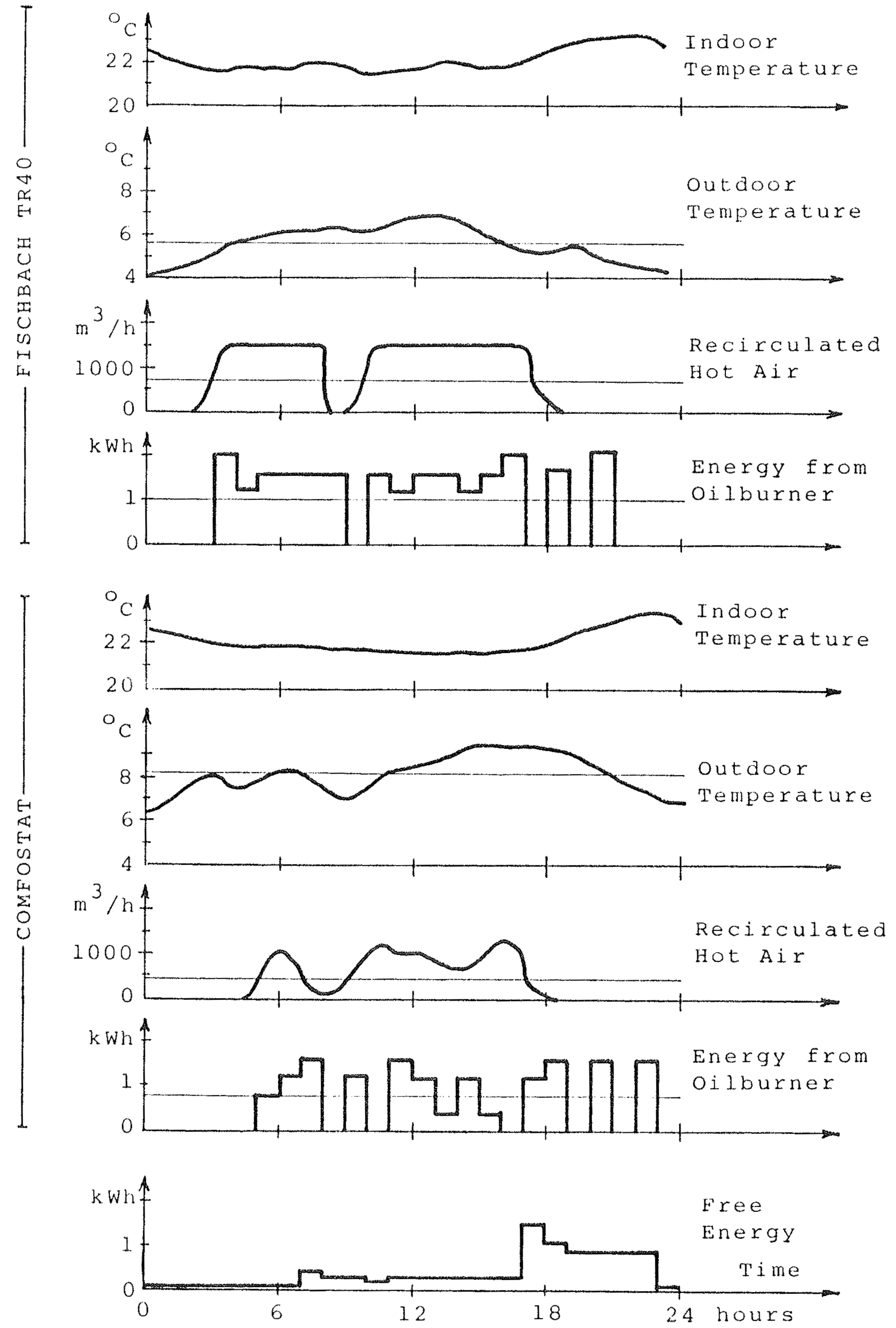

Fig.6 Fluctuation of some important parameters through a typical 24 hour period for each of the two thermostats. Energy from the oilburner includes energy used for heating hot domestic water. Bottom curve shows the amount of free energy produced from household appliances and person simulators.

		Fischbach TR40		Comfostat	
no.	time period 1979	12-18 Nov	15-16 Nov	29 Nov-5 Dec	29 Nov-3 Dec
	mean outdoor temp. °C	4.1	4.7	7.8	7.9
	mean indoor temp °C	22.9	22.8	22.8	22.8
1	calculated heat-loss kwh/24h	43.2	42.0	35.7	35.5
2	energy from oil burner -	28.1	31.8	21.0	20.9
3	transmitted solar energy -	6.3	0	1.7	0
4	free heat (persons, lightning etc.) -	20.6	20.6	20.6	20.6
5	energy for water heating -	10.1	10.1	10.1	10.1
6	2 + 3 + 4 - 5 -	44.9	42.3	33.2	31.4
	heat input - heat loss (6 - 1) -	1.7	0.3	-2.5	-4.1

From the data in the table it is possible to calculate the percentage of energy saving in the Comfostat period compared with the Fischbach period:

$$S_{7\ days} = \left(\frac{1.7}{28.1 - 10.1} - \frac{-2.5}{21.0 - 10.1}\right) \cdot 100 = \underline{32\%}$$

$$S_{no\ sun} = \left(\frac{0.3}{31.8 - 10.1} - \frac{-4.1}{20.9 - 10.1}\right) \cdot 100 = \underline{39\%}$$

It is important to point out that these few measurements are only to be taken as a pilot study and the found percentage of saving is more of qualitative than of quantitative nature. In other periods under different weather conditions, in houses of different design, or with other types of heating systems, the saving will be different.

CONCLUSION

This initial comparison between a typical traditional room thermostat and the new Comfostat indicate that it is possible to save fuel by using a more suitable design of the temperature-sensing element in the control circuit.

The laboratory measurements of the hysteresis and time-constants of the two sensors do suggest that because of its dynamic characteristics the Comfostat is better able to maintain conditions of constant thermal comfort in the face of fluctuating thermal influences in the room. This ensures a utilization of free heat which is almost optimum.

The use of this new kind of room thermostat can therefore be expected to improve on the performance of traditional types in respect of both fuel economy and maintenance of thermal comfort under all normal operating conditions. However, far more measurements are needed before a correct value can be given for the expected energy saving by use of this new Comfostat.

ACKNOWLEDGEMENTS

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