Energy Savings in Blocs of Flats Due to Individual Heat Metering

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SUMMARY

The installation of thermostatic valves and cost allocators represents the main modernization measure of the heating installation. In this study we determined theoretically and experimentally their effects upon the energy savings. Their adaptive behavior to the dynamic climatic conditions leads to 15% energy savings. Further on, the people reduce the indoor temperature in order to reduce the price of the energy. This effect represents another 9%, leading to a total of 24% energy savings. The north apartments need 15% more thermal energy than the south oriented apartments. The installation of these devices raise un other problem, the measures to correlate the heat production to the heat need.

INTRODUCTION

The modernization of the heating and hot water installations from blocs of flats in Romania is an operation that has started in 2000. The main operations consists in the installation of heat meters on the branch pipes of the two installations, the installation of individual water meters in bathrooms and kitchens and the installation of thermostatic valves with cost allocators for each radiator. These modernization measures offered the consumers the possibility to deal with the thermal consumptions as goods.

The paper presents a comparison, both theoretically and experimentally, of the heat consumption of a bloc of flats before and after the installation of thermostatic valves. The paper also presents o comparison between the heat consumptions of the north oriented apartments and the south oriented ones. The objective of the paper is to identify the consequences of this modernization measure.

The paper presents the description of the building, the theoretical model, the experimental protocol, the results, discussions of the results and the implications upon the actual district heating.

METHODS

Building description

The analysis was carried out on a bloc of flats (basement, ground floor and 10 more levels) composed of four stairwells with four apartments on each floor of a stairwell, in Bucharest Romania. The front wall of the building is north oriented, meaning that 80 apartments are north oriented and other 80 apartments are south oriented. The central heating installation of the building was gradually modernized:

- heat meters were installed on branch pipes of heating and hot water installations, in 1999,
- individual water meters were installed, in 2004,
- thermostatic valves and cost allocators were installed in the 2005 summer.

Both the theoretical and the experimental analysis were carried out during the cold season, considered from October till April.

**Theoretical approach**

Theoretic evaluation of the heat consumption was carried out in two situations: with and without thermostatic valves installed. In the first case, we considered that the set point of the thermostatic valves was 20°C. The outdoor climatic database for Bucharest (temperature and solar radiation) corresponds to an average intensity of the cold season. The database was composed of 30 similar days for each month, but different from one month to another (Figure 1).

![Figure 1. Variation of climatic parameters: a) temperature, b) Solar radiation](image)

The evaluation of the heat loss of the building represents the sum between the transmission heat loss through building envelope elements and the heat loss due to outdoor air infiltration.

In the second situation (no thermostatic valves), the unsuited temperature of the hot water in the heating installations generate a raise of the indoor temperature. The dynamic heat transfer calculus was based on the hypothesis of constant temperature inside the walls. The thermal behavior modeling of the radiators was achieved by means of stationary relations. We considered that the global thermal transfer coefficient of the radiator depends on the hot water temperature entering the radiator. Thus the temperature of the hot water at the end of the radiators is the result of the complex thermal transfer phenomenon building – heating installation.

The outdoor temperature used for the calculus cumulates both convective and solar radiation heat transfer phenomena (Equation 1 for heat transfer through walls and Equation 2 for heat transfer through windows).

\[
t_{EO} = \frac{\alpha_o}{\alpha_a} \cdot I + t_o \quad (1)
\]

\[
t_{EO} = \frac{\alpha_o \cdot \tau}{\alpha_a} \cdot I + t_o \quad (2)
\]
where \( t_{EO} \) is the equivalent outdoor temperature, \( t_o \) is the outdoor temperature, \( \alpha_o \) is the outside convective thermal transfer coefficient, \( \alpha_a \) is the absorption coefficient of the outside wall surface, \((\alpha_a \cdot \tau)\) is the absorption-transparency coefficient and \( I \) is the solar radiation.

The heat consumption represents the time integration of the heat flux during the cold season. The heat consumption was calculated in both situations of the installation: with and without thermostatic valves.

**Experimental approach**

The first type of recordings is the heat consumption of the entire building, measured for several years on the branch pipes of the heating and hot water installations.

The second type of recordings is the individual heat consumption due to the installation of the thermostatic valves before winter 2005-2006. These heat consumptions were estimated by means of the monthly recordings of the cost allocators and the indoor temperatures.

**RESULTS**

**Theoretical approach**

The theoretical approach is based on the hypothesis that the occupants of the apartments do not modify the position of the thermostatic valves; thus the initial setting of the valves corresponding to a 20°C indoor temperature becomes permanent.

The heat consumption of the apartments with thermostatic valves is:
- similar to that of the apartments without thermostatic valves during evening and night period (20:00-07:00), whatever the orientation of the apartment,
- smaller than that of the apartments without thermostatic valves during morning and midday period (07:00-20:00), whatever the orientation of the apartment (Figure 2).

![Figure 2. Daily variation of the heat losses of the apartments on a) NORTH b) SOUTH side of the building, for an average day on JANUARY](image)

Comparing the heat loss of the north and south oriented apartments we note that:
- the simple valves do not adapt according to heat gains, and the heat losses is almost similar whatever the orientation,
- the thermostatic valves react to heat gains and lead to important energy savings (Figure 2).

The integration of heat losses during the winter season (October – April) lead to the values of the heat consumptions (Table 1).

Table 1. Specific heat consumption

<table>
<thead>
<tr>
<th>Orientation</th>
<th>with thermostatic valves (kWh/m².an)</th>
<th>without thermostatic valves (kWh/m².an)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH</td>
<td>105,176</td>
<td>127,561</td>
</tr>
<tr>
<td>NORTH</td>
<td>120,323</td>
<td>132,338</td>
</tr>
</tbody>
</table>

The following conclusions can be drawn from this analysis:
- In the case of simple valves, there is only a very small difference (3.7%) between the heat consumptions of north and south sides of the building. This value is due to different solar radiation between the two sides of the building.
- In the case of thermostatic valves, north oriented apartments present a 14,4% higher heat consumption than the south oriented apartments,
- In the case of south oriented apartments, the thermostatic valves generate a 21.3% energy saving compared to the simple valves,
- In the case of north oriented apartments, the thermostatic valves generate a 10% energy saving compared to the simple valves,

The same specific heat consumption index was calculated for the entire building in the two situations (with and without thermostatic valves). In the case of simple valves the heat consumption is 129.95 kWh/m².an, while in the case of thermostatic valves it is 112.75 kWh/m².an.

We conclude this analysis with the remark that this modernization measure (installation of thermostatic valves and cost allocators) lead to 15% energy savings.

**Experimental validation**

Before the installation of the thermostatic valves and cost allocators, the evaluation of the heat consumptions of the north and south oriented apartments is not possible, thus this paragraph presents only two aspects:
- a comparison of the heat consumptions of the north and south oriented apartments for the winter 2005-2006, and
- a comparison of the recorded heat consumptions of the same building between the winters 2004-2005 (the thermostatic valves were not yet installed) and 2005-2006 (the thermostatic valves were installed), in order to experimentally establish the effect of the thermostatic valves.

The recorded heat consumption of the north oriented apartments are, obviously, higher than for the south oriented apartments (Table 2). The recorded thermal energy savings of the north oriented apartments compared to the south apartments considering the entire cold season (14,74%) is almost equal to the theoretic result (14,4%). This represents a good validation of the theoretic model.
Table 2. Heat consumption comparison between north and south oriented apartments

<table>
<thead>
<tr>
<th>Month</th>
<th>Heat consumption, %</th>
<th>Reduction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NORTH</td>
<td>SOUTH</td>
</tr>
<tr>
<td>nov. 05</td>
<td>53,74</td>
<td>46,26</td>
</tr>
<tr>
<td>dec. 05</td>
<td>53,25</td>
<td>46,75</td>
</tr>
<tr>
<td>jan. 06</td>
<td>52,71</td>
<td>47,29</td>
</tr>
<tr>
<td>feb. 06</td>
<td>53,23</td>
<td>46,77</td>
</tr>
<tr>
<td>mar. 06</td>
<td>53,15</td>
<td>46,85</td>
</tr>
<tr>
<td>apr. 06</td>
<td>56,04</td>
<td>43,96</td>
</tr>
<tr>
<td>cold season</td>
<td>53,69</td>
<td>46,31</td>
</tr>
</tbody>
</table>

In the case of the second analysis, we mention that the two cold seasons were characterized by different climatic conditions, leading to an improper comparison of the heat consumptions (Table 3).

Table 3. Temperatures and specific heat consumptions for winters 2004-2005 and 2005-2006

<table>
<thead>
<tr>
<th>Month</th>
<th>Winter 2004-2005 without thermostatic valves</th>
<th>Winter 2005-2006 with thermostatic valves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t_o, °C</td>
<td>t_{t-o}, °C</td>
</tr>
<tr>
<td>November</td>
<td>7.4</td>
<td>12.6</td>
</tr>
<tr>
<td>December</td>
<td>3.06</td>
<td>16.94</td>
</tr>
<tr>
<td>January</td>
<td>2.18</td>
<td>17.82</td>
</tr>
<tr>
<td>February</td>
<td>-0.4</td>
<td>20.37</td>
</tr>
<tr>
<td>March</td>
<td>5.3</td>
<td>14.7</td>
</tr>
</tbody>
</table>

In order to surpass this inconvenient, we compare the heat consumptions divided by the indoor-outdoor temperature difference (Figure 3).

The heat consumptions for the 2005-2006 winter are smaller then those of 2004-2005 winter with 12% (December) up to 33% (January). We can conclude that the installation of the thermostatic valves generate an average value of 24% thermal energy saving during the cold season. The difference between the experimental result (energy reduction of 24%) and the theoretic result (energy reduction of 15%) is probably due to human behavior; people tend to modify the indoor temperature in order to accord the thermal comfort to the desired cost.
DISCUSSION

The theoretical and experimental research followed two objectives. The first is to determine the effect of the thermostatic valves installations upon the thermal energy consumption. The theoretical simulation shows that there is a 15% energy savings while the experimental work showed a 24% energy savings. The 9% difference is probably due to the initial hypothesis for the theoretical model, that indoor temperature is constant 20°C, while in reality people tend to reduce the indoor temperature in order to reduce further more the expenses. The second objective is the comparison of the heat consumption of the apartments oriented north and those oriented south. The advantage of the thermostatic valves is that they can adapt the water flow and by consequently the heat consumption according to the heat gains. We obtained a 14.5% energy savings of the south oriented apartments compared to the north oriented apartments.

Both analyses show the advantages of this modernization of the heating installation, the installation of thermostatic valves and cost allocators. However, if they represent a very important and economic measure for the consumers, the thermostatic valves have a major impact upon the heat producer.

In today’s conditions of rising price of thermal energy, the lack of individual control of heat consumption leads to the impossibility of payment from the consumer. Many district heating company were obliged to stop the thermal energy delivery. Thus the installation of thermostatic valves becomes not only a modernization measure but also a necessity. Another influence of the thermostatic valves consists in the running strategy of the heat production. If before, there was a constant production of heat, and the entire district heating was functioning this way, now the thermostatic valves present a dynamic thermal energy need. The district heating company from Bucharest, RADET, is now confronted with this aspect of correlation between the heat production with the dynamic heat need. The national research project ENERGSYS was developed in order to find the suitable measures to adapt the heat production to the variable heat need.
ACKNOWLEDGEMENT

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REFERENCES