INFLUENCE OF DIFFERENTLY ORIENTATED CONSERVATORIES ON THE HEAT ENERGY CONSUMPTION OF ONE-FAMILY-HOUSES - COMPARATIVE MEASUREMENTS WITH TWIN-HOUSES UNDER NATURAL CLIMATIC CONDITIONS -

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ABSTRACT

Since active measures to utilize solar energy for heating purposes proved to be uneconomical, hopes are banked on the passive utilization of solar radiation. U.S.-American experiences with solar houses are not directly transferable to European applications, firstly because of different climatic conditions and secondly because different construction traditions have to be considered. Hence there is the necessity to adjust the passive solar architecture to European demands.

In order to investigate the construction physical bases and demands of conservatories (greenhouses) under defined boundary conditions, two conservatories have been attached to the south and the north side of one of the two flexible testhouses - so called twin-houses, which are placed on the test ground of the Fraunhofer-Institut für Bauphysik. Comparative measurements of the energetic effects of conservatories were thus carried out under natural climatic conditions.

The results show that 10-25% of the heat energy of a usual German one-family-house can be saved by an attached conservatory according to its size, construction type, temporary insulation and utilization of its heated air.
INTRODUCTION

Since active measures to use solar energy for heating purposes proved to be unprofitable in Central Europe, new hopes have been placed more on passive solar heat gain for about three years. European architects inspired by futuristic examples in the USA reacted with enthusiasm to passive solar heat gain measures, in order to provide man with "new" and natural housing conditions. Especially constructors and users of one-family-houses are strongly attracted by the so-called conservatories.

Despite the fact that passive solar heat gain measures have been used in practice for a couple of years, only few scientific examinations have taken place to determine the energetic effects of attached conservatories in connection with traditional construction types in Germany.

In order to obtain scientific foundations of conservatories and their behaviour under defined boundary conditions, two identical one-family-houses were set up on the test area of the Fraunhofer-Institut für Bauphysik. Thus comparative measurements of the energetic and thermal effects of differently orientated conservatories were carried out under natural climatic conditions.

The first results of this project which is supported by the Bundesministerium für Forschung und Technologie and the glass producing industry are given below.

SUBJECT OF MEASUREMENTS - DESCRIPTION OF THE TWIN-HOUSES

In order to examine the effects of adjacent conservatories on the heat consumption of a traditional German one-family-house under German climatic conditions, the so-called twin-measurement-method was employed which ensures that the following influences are largely equal during the experiment:

- construction body
- heating system
- heating operation
- climatic conditions.
The construction of both houses allows a comparatively easy exchange of the vertical building parts, like exterior and interior walls. Since massive building types are dominant in Germany, brick walls were used for this experiment. The external walls are 30 cm thick light-weight-brick walls with an u-value of 0.78 W/m²K. This comparatively high u-value in connection with a heat insulation of the roof (u_roof = 0.26 W/m²K) complies with the German legal requirements for the heat insulation of a one-family-house.

The thermal data of the two houses are listed in table 1 and their dimension is shown in figure 1. Only to one of the two buildings - the so-called test house - conservatories (sometimes three at a time) were attached, which can be seen in figure 1. They are named "South 1" (in front of a wall with a small window), "South 2" (in front of a large window) and "North" (Like "South 1" but orientated to the north).

The two buildings were heated electrically with the aid of hot-water-radiators which were controlled by thermostats. The desired temperature was 20°C. No sunshading measurements were taken to avoid overheating of the building, due to direct insolation, because there was no reason to do so during the examination period (November - April). The maximum room temperatures didn't exceed 24°C even during very sunny days, due to the heavy construction type of the houses.

The thermal and energetic comparative measurements were carried out during a winter period of six months. The hourly mean values of about 250 data (temperature, heatflux, heat energy) were registered with the aid of a measurement data collection unit and stored on a magnetic data carrier for evaluation purposes in order to refer the thermal and energetic data to the meteorological data of the measurement period. Additionally to the winter measurements some temperatures were recorded in the buildings and the adjacent conservatories during August in order to determine their thermal behaviour without heating under typical summery conditions. The thermal and energetic behaviour of the two test houses is reported below. The house without conservatory is called reference house, the house with conservatory simply test house.

THERMAL BEHAVIOUR

With the aid of figure 2-4 the thermal behaviour in the conservatories and the adjacent rooms is explained.

Wintery Conditions

Figure 2 shows the air temperatures in the southerly and northerly orientated conservatories (diagram in the middle) and in the adjacent rooms of the test house (below) during a period of seven days in February with outside air temperatures between -10°C and +5°C and southerly solar radiation up to 1150 W/m² during the first few days. During the first two days with comparatively high solar radiation and comparatively low outside air
measures, the air temperature in the southerly orientated conservatory measured, without additional shading or ventilation, measures about 50°C in the afternoon. In the early morning hours with about -7°C outside air temperatures, the lowest temperatures (about 4°C) of the southerly orientated conservatory were measured. It should be mentioned that the conservatories had a double glazing insulation with an u-value of 3.0 W/m²K. The air temperatures of the northerly conservatory, also without temporary heat insulation measures, fell about 4 degrees below zero. During the daytime, however, the temperature in the northerly conservatory reached more than 10°C, largely independent from the direct solar radiation. The air temperatures of the adjacent rooms were, due to the small window areas, only to a minor extend influenced by the temperature in the two conservatories, as can be seen from figure 2 below.

Summary Conditions

Figure 4 shows the meteorological data under summery conditions (above), the air temperatures of the two southerly conservatories ("South 1" and "South 2") which were measured two meters above the ground (figure 3 in the middle) and of the adjacent rooms (room 3 and 4). While sunshading in the conservatories was achieved with white internal blinds attached to the roof plane, no additional sunshading measures were taken in the rooms. The windows of the conservatories were open to grant a good ventilation. The fact that a southerly orientated conservatory can offer also summery insulation (protection from high room temperatures), can be seen from figure 4.

Energetic Behaviour

In order to determine the energetic behaviour of the two buildings with and without conservatory the heat consumption of all rooms was registered continuously.

Effects of Southerly Orientated Conservatories

Figure 5 shows the daily heat energy consumption of both houses measured over a period of about three months in dependence of the outside air temperature. Since the dispersion of the data points is comparatively high, due to different solar radiation intensities and heat storage effects, the regression was calculated which is shown in the right diagram. The average heat energy savings as a result of the effects of the two southerly conservatories amounted to 13% with an average day temperature of 2.9°C and an average radiation intensity of $I_{\text{Global}}=3.1 \text{ kWh/m}^2\text{d}$ and $I_{\text{South}}=2.9 \text{ kWh/m}^2\text{d}$.

A more detailed evaluation of the heat consumption during defined meteorological periods (very cold and high solar radiation - "clear sky") is shown in figure 6. There the average heat consumption during a period of two weeks each, of the building with conservatory (south) is compared to that of the building without conservatory. It is remarkable that the difference of the heat consumption with and without conservatory is lower during a clear sky period than the one of a covered sky period.
This can be explained by the higher direct insolation gains through the window of the house without conservatory during a period with high solar radiation. This effect can be seen more clearly in figure 7 (diagram below) where the heat consumption of the rooms with large windows (room 3) is outlined. Here the consumption during the daytime of the room without adjacent conservatory is lower than the consumption of the room with conservatory. Less extreme are the differences of the heat consumption of the rooms "behind wall" (room 4, diagram in the middle of figure 7).

Effects Of Northerly Orientated Conservatories

The comparison of the effects of a northerly and a southerly orientated conservatory on the heat consumption of the adjacent rooms is shown in figure 8. There the average consumption of room 4 and room 6 is outlined for a period of three weeks in January. The left diagram shows the comparison with and without southerly orientated conservatory and the right diagram the comparison with and without northerly orientated conservatory. The in both cases identical meteorological boundary conditions are listed below (figure 8). The absolute energy savings, which can be calculated from the difference of the consumption with and without conservatories, of the northerly orientated conservatory amount to about 84% (74/88·100%) of the energy savings of the southerly orientated conservatory. Under completely covered sky conditions the heat gain of the different conservatories is almost equal.

A typical course of the heat consumption of room 4 and room 6 with and without conservatory is shown in figure 9. During the first days with high solar radiation intensities, the heat consumption of the southerly rooms with and without conservatories decreases considerably (diagram in the middle), with slightly higher solar heat gains of the room without conservatory, due to direct insolation. On the contrary the heat consumption of the northerly room without conservatory is always higher than the consumption in the same room with conservatory (diagramm below).

CONCLUSIONS

The simulation calculations based on the experimental results show that 10-25% of the heat energy of a usual German one-family-house can be saved by an attached conservatory according to its size, construction type, temporary insulation and utilization of its heated air.

Due to the higher efficiency it is more favourable to place the conservatories in front of non-transparent wall parts.

Northerly orientated conservatories are also energetically effective. The heat gain during days with covered sky is equally high as with respective southerly orientated conservatories. As a place of residence the northerly orientated conservatory is not suitable, due to its susceptibility to condensation water during the winter months. During the summer, however, it can be quite useful because its maximum air temperatures are rather low.
SUMMARY

The thermal and energetic behaviour of differently orientated conservatories is determined with the aid of experimental comparative examinations at the example of two identical test houses - so-called twinhouses - with dimensions of one-family-houses. By figures it is shown which temperatures and heat consumptions of the conservatories and the adjacent rooms can be expected during typical climatic periods.

The measurements are, however, not yet completely finished. The project was financed by the Bundesministerium für Forschung und Technologie of West-Germany and by the glass producing industry.

Table I: Geometrical and thermal data of the experimental houses (1982-1984) (without conservatory).

<table>
<thead>
<tr>
<th>Area</th>
<th>Area [m²]</th>
<th>U-value [W/m² d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside wall</td>
<td>141,7</td>
<td>0,78</td>
</tr>
<tr>
<td>Window</td>
<td>24,0</td>
<td>3,0</td>
</tr>
<tr>
<td>Outside doors</td>
<td>2,0</td>
<td>2,2</td>
</tr>
<tr>
<td>Saddlebag roof</td>
<td>113,7</td>
<td>0,26</td>
</tr>
<tr>
<td>Ceiling</td>
<td>101,0</td>
<td>0,53</td>
</tr>
<tr>
<td>Basement ceiling</td>
<td>101,0</td>
<td>0,45</td>
</tr>
<tr>
<td>Basement wall</td>
<td>110,5</td>
<td>3,67</td>
</tr>
<tr>
<td>Basement floor</td>
<td>101,0</td>
<td>0,86</td>
</tr>
<tr>
<td>Living area (data measuring level)</td>
<td>81,7</td>
<td>-</td>
</tr>
<tr>
<td>Medium u-value</td>
<td>-</td>
<td>0,64</td>
</tr>
</tbody>
</table>

area-/ volume proportion 1,08 m⁻¹
heat storing capacity (per m² living area) 170 Wh/m² d
heat requirement (t_out = -16°C) 5,5 kW
Table II: Areas of conservatories and window areas of both buildings.

<table>
<thead>
<tr>
<th>Window areas</th>
<th>Glass area [m²]</th>
<th>percentage of glass area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South (room 4)</td>
<td>8,24</td>
<td>South: 41</td>
</tr>
<tr>
<td>South (room 3)</td>
<td>1,23</td>
<td></td>
</tr>
<tr>
<td>West (room 3)</td>
<td>0,55</td>
<td>West: 12</td>
</tr>
<tr>
<td>West (room 2)</td>
<td>1,23</td>
<td></td>
</tr>
<tr>
<td>East (room 5)</td>
<td>0,55</td>
<td>East: 6</td>
</tr>
<tr>
<td>North (room 6)</td>
<td>1,23</td>
<td>North: 6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Glas areas of the conservatories</th>
<th>Glass area [m²]</th>
<th>percentage of glass area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservatory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;South 1&quot; and &quot;South 2&quot; &quot;roof area&quot;</td>
<td>8,53, 5,11, 11,78</td>
<td>76,4, 68,8, 81,4</td>
</tr>
<tr>
<td>&quot;North&quot; &quot;roof area&quot;</td>
<td>8,53, 5,11, 11,78</td>
<td>76,4, 68,8, 11,78</td>
</tr>
<tr>
<td>Total (per conservatory)</td>
<td>30,53</td>
<td>75,4</td>
</tr>
<tr>
<td>Floor area (per conserv.)</td>
<td>10,64</td>
<td>-</td>
</tr>
<tr>
<td>Fraction = floor area of one conservatory / total living area</td>
<td>13%</td>
<td></td>
</tr>
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</table>
Figure 1. Site plan of the twin-houses.
Figure 2. Air temperature in the southerly and northerly orientated conservatories as well as the adjacent rooms during a typical period in winter (20.2.84 - 26.2.84).

Figure 3. Air temperatures in southerly orientated conservatories and adjacent rooms during a period in summer (13.8.84 - 19.8.84).
Figure 4. Comparison of the temperatures in rooms behind wall and behind window during a summer period (without heating).
Figure 5a. Test values of the daily heating power of both houses with and without southerly orientated conservatory in dependence of the daily mean temperature.

Figure 5b. Linear regression and max. scatter of the test values of fig. 5a. The average saving amounted to 13.6%.
Figure 6. Comparison of the energetic effects of a southerly orientated conservatory during periods of high solar radiation (clear sky) and low solar radiation (covered sky).

Figure 7. Comparison of heating power in rooms behind wall and behind window with and without southerly orientated conservatories.
<table>
<thead>
<tr>
<th>Orientation of Conservatories</th>
<th>South</th>
<th>North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Air Temperature</td>
<td>0.6°C</td>
<td></td>
</tr>
<tr>
<td>Global Radiation</td>
<td>1.75 kWh/m²d</td>
<td></td>
</tr>
<tr>
<td>South Radiation</td>
<td>2.90 kWh/m²d</td>
<td></td>
</tr>
<tr>
<td>North Radiation</td>
<td>0.76 kWh/m²d</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 8.** Comparison of heating power in rooms with different orientated conservatories (3 weeks in January 1984).

**Figure 9.** Typical course of heating power in rooms with and without conservatories during a week in February.
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