Energy Impact of Ventilation and Air Infiltration
14th AIVC Conference, Copenhagen, Denmark
21-23 September 1993

Thermography: Its Applications for Building Air Leakage Measurements

J W Roberts, I C Ward

University of Sheffield, UK

Thermography: Its applications for building air leakage measurements.

J. W. Roberts and I. C. Ward.
University of Sheffield

Synopsis

Preliminary work [1] has indicated that thermography can be used to determine air leakage pathways from or to buildings. Accurate measurements have now been taken using temperature controllable environmental chambers. These results reinforce the potential use of thermography for this application.

In conjunction with the physical measurements a simulation has been carried out using computational fluid dynamics. The two sets of results are found to be in good agreement with each other thus validating the computer model, and give further proof of the adaptability of thermography for building air leakage measurements.

1. Introduction

The work detailed in this paper is a direct continuation of the work presented at the 13th A. I. V. C. conference at Nice in 1992 [1]. Previous work had been concerned with whether or not a thermography camera could be used to measure the heat loss from buildings and also whether this heat flow could successfully be modelled using computer flow dynamics. If a reliable model is found then this could be used in conjunction with the thermography camera to give greater insight into the heat flow to and from buildings.

2. The Physical Measurement

The initial results had been obtained by using an environmental chamber which had dimensions of 2m x 2m x 2m on either side of a partition on which the cracks were mounted. One of the rooms was then heated up to 40°C to give a temperature differential of 20°C compared with normal room temperature. This temperature differential was chosen to simulate the difference between a heated room and outside during the winter months in England.

The main problem with this set-up was the control of a fixed 40°C temperature for the duration of the three hour experiment. To counter this a smaller box was constructed with dimensions 1m x 1m x 1m. and two cracks mounted on one side. The temperature in this size box proved far easier to control and the same cracks, as used in the initial experiment, were able to be mounted thus eliminating any inconsistencies in turbulence had different length cracks been used. Measurements were taken for the top crack made from hard wood and perspex, and are shown in figures 1a and 1b.

The emissivity of hard wood and perspex have been measured using the thermography camera and found to be both very close to a value of 0.90. This means that all properties responsible for the thermal image are the same for both the hard wood and the perspex cracks. It is this fact that is represented by the above curves being so similar in shape. The outlet curves are seen to rise in the first sixty to ninety minutes of the experiment and then to level off. There is a slight oscillation in the temperature over time but this is interpreted as a consequence of using a heater which is controlled by a thermostat which maintains the temperature of the box to 40±3°C.

3. The Theoretical Study Using Computer Fluid Dynamics

The computer fluid dynamics (CFD) package Flovent was chosen for the study because it has been especially developed by Flomerics Limited and The Building Services Research and Information Association (BSRIA) to model buildings. It was therefore hoped that this would give a more reliable model than a general CFD package such as Fluent which had been used in the past.

In the computer model the $1m^3$ box was joined to another $1m^3$ box by two cracks of 5cm length and 3mm width. For ease of explanation the left hand box is known as box 1 and the right hand box as box 2. The cracks are mounted 25cm from the top and bottom of the box. Various studies were made at different temperatures, e.g. 40°C and 20°C, the experimental situation, and 20°C and 0°C, the real-life winter situation. All the results were found to be consistent with each other. Therefore one temperature differential can be studied and then the results used in other situations were there is a 20°C temperature difference.

Two different methods of heating the boxes were studied; the first one dealt with a unit heater in one box that heated the air by 4°C every cycle. In the other method the temperature of the walls were set to constant temperatures and the convection was just buoyancy driven.

3.1 The Boxes Heated by a Unit Heater

The unit was placed on the wall opposite the cracks and had dimensions of 10cm x 45cm. It has a 5cm gap to the floor thus leaving a 50cm gap to the top of the box. The outlet of the heater is located on the top of the heater and the outlet velocity of the air set to $4ms^{-1}$.The inlet for the crack is set at the bottom of the heater on the side facing the cracks. The heater increases the temperature of the air passing through the heater by 4°C every cycle. This method of heating the box can produce very high temperatures very quickly. To compensate for this and to stop the box temperature becoming unrealistically high the thermal conductivity of all the walls was set to $100Wm^{-2}$. This mechanism of heating and cooling the boxes can be viewed as a crude form of thermostat.

In figure 2 the boundary of the boxes is shown along with the airflow velocity vectors. As would be expected the maximum air velocity occurs above the outlet of the heater. This aids the natural convection ands gives rise to strong circulation of the air in box 1. The circulation of the air in box 2 is not as strong as that seen in box 1. The top crack acts as an outlet for box 1 and the bottom crack is seen to act as an inlet for box 1. This is in agreement with the actual measurements.

In figure 3 the temperature profile of a point in the middle of the top crack is plotted against time. This shows good agreement with the profile shown in figures 1a and 1b. The temperature in the outlet crack is seen to rise steadily with time and then become stable at approximately 48°C. The model is set up in a way so as the equations are said to be solved when steady state conditions have been attained.

Figure 4 shows the temperature contours of the two rooms when steady state conditions have been attained. It shows hotter air flowing from box 1 to box 2 through the top crack and cooler air flowing from box 2 to box 1 through the bottom crack.

3.2 The Walls of the Boxes set to a Constant Temperature

In this set-up the boxes were heated up by setting the walls of the boxes to stay at a constant temperature. The walls in box 1 were set to be 40°C and the walls in box 2 were set to be 20°C. Figure 5, shows the airflow velocity vectors for this situation. As can be seen there is a far more even circulation or air between the two boxes than in the previous case. This is because there is no forced convection and only buoyancy effects are causing the convection. There is a good exchange of hotter air through the top crack and cooler air through the lower crack. This is given added proof by looking at figure 6, the temperature contours.

The temperature profile of a point in the middle of the top crack plotted against time is shown in figure 7. The temperature is seen to rise steadily with time and then become steady at approximately 31°C. It shows good agreement with the plots shown in figures 1a and 1b.

4. Conclusions

This paper has been concerned with the continuing work into extending the applications of thermography. It has already proved itself to be a very adaptable tool for the measurement of the thermal profile of buildings. The results documented above are very consistent with each other and this gives us confidence both in the reliability of thermography as a building science tool and in the computer models predicted by the computer fluid dynamic package Flovent.

Future work will concentrate on two main areas in the near future. The first will use the thermal camera to study the hot air flow out of window apertures and the cold air flow into buildings through window apertures. The second will develop the Flovent calculations to model more complicated and practical applications.

References

1. An investigation of the potential use of thermography for building air leakage measurements.
   J. W. Roberts, S. Sharples and I. C. Ward.
   Proceedings of the 13th AIVC conference, Nice, France, September 1992 p 598.

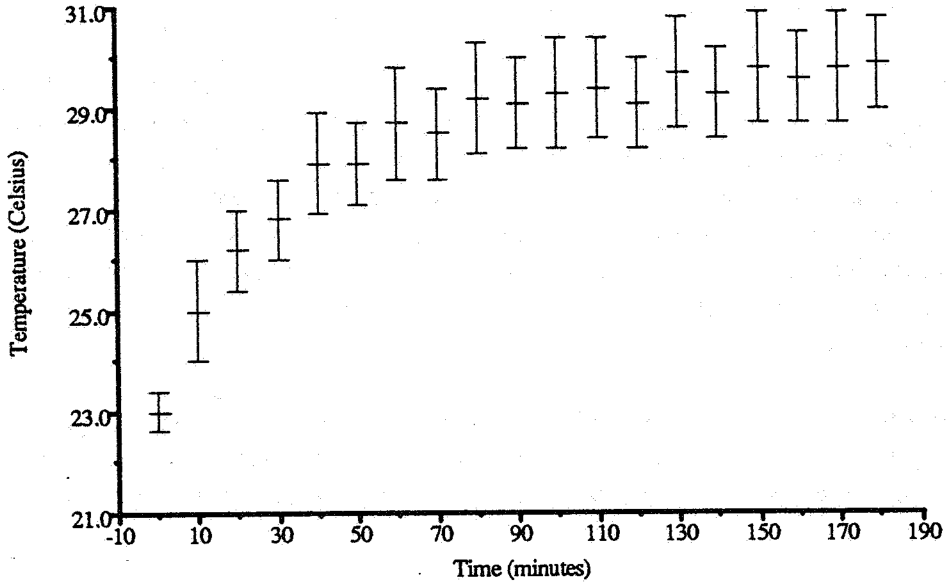

Figure 1a: Temperature of outlet crack made of hard wood plotted against time.

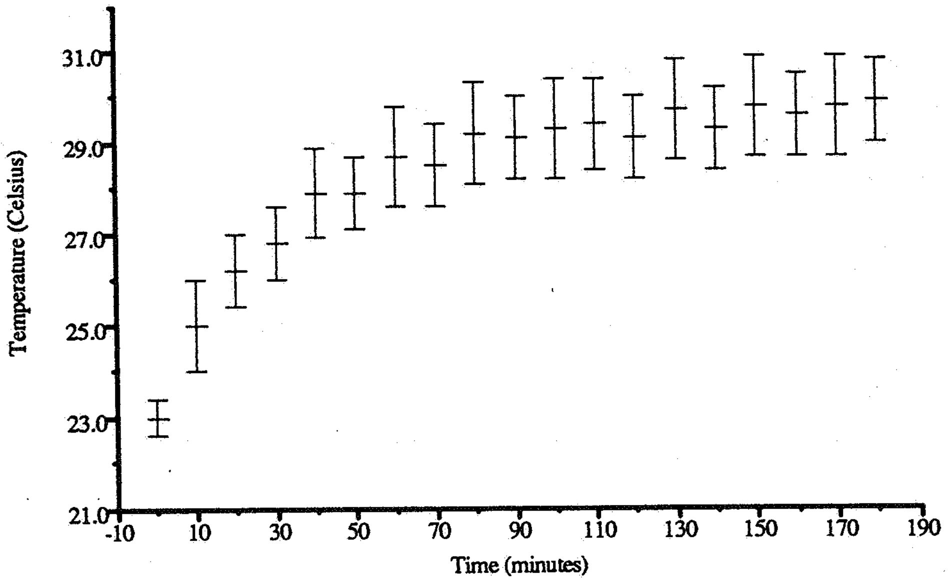

Figure 1b: Temperature of outlet crack made of perspex plotted against time.

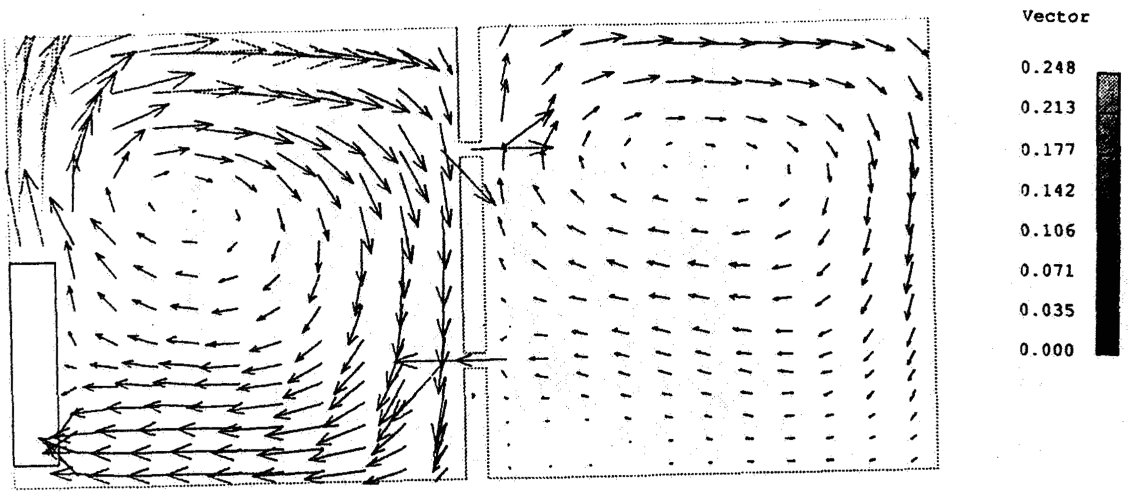

Figure 2: Flovent output showing airflow velocity vectors for the boxes heated by a unit heater. The heater is shown to the left of box 1.

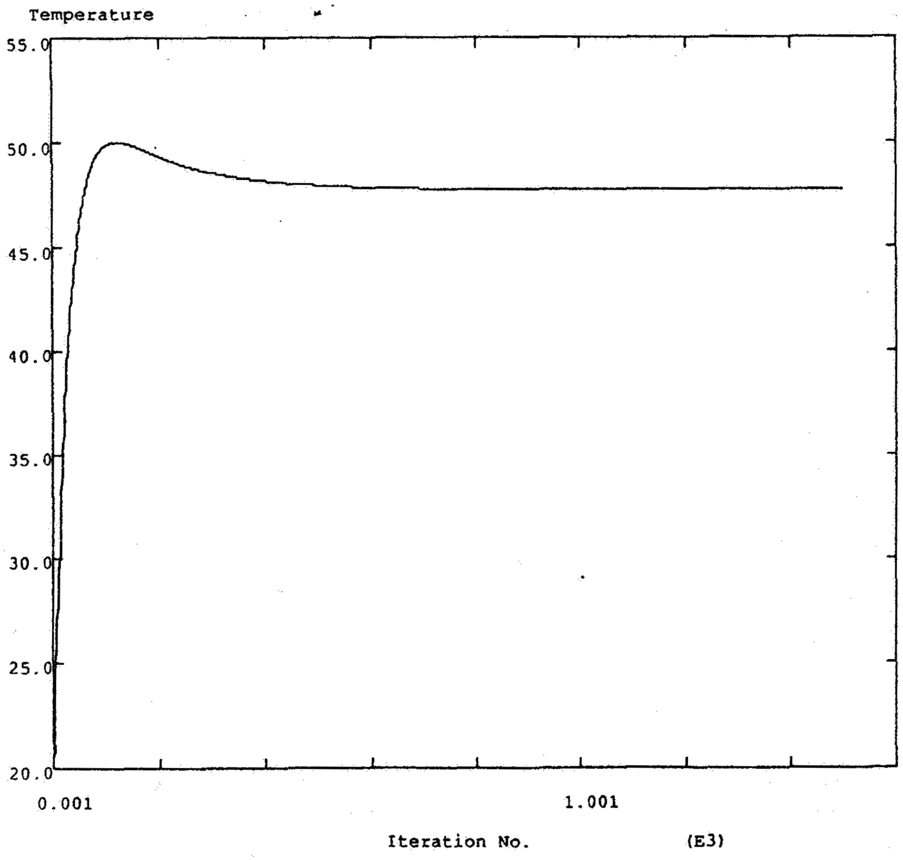

Figure 3: Flovent output showing the temperature profile of a point in the middle of the top crack plotted against time for the boxes heated by a unit heater.

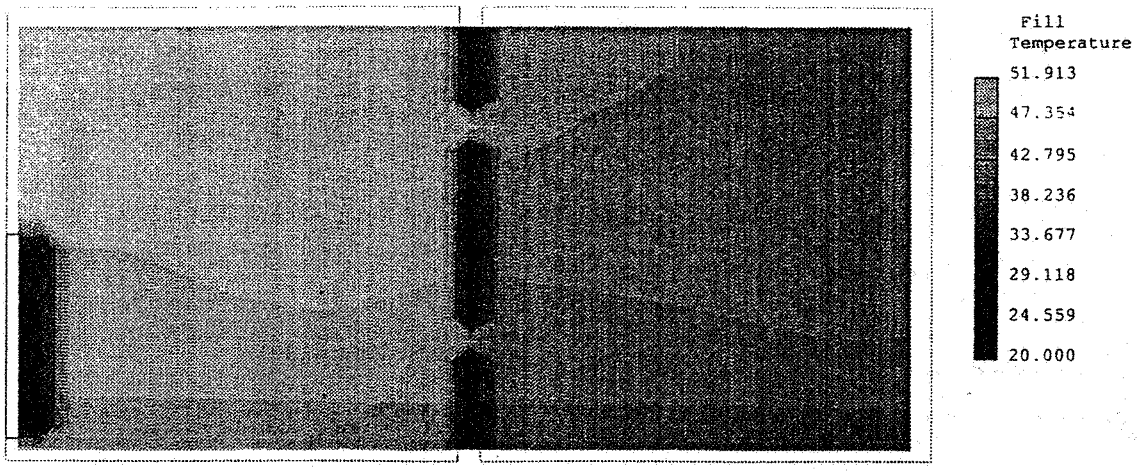

Figure 4: Flovent output showing the temperature contours for the boxes heated by a unit heater. The lighter areas correspond to hotter regions. The key is shown in °C.

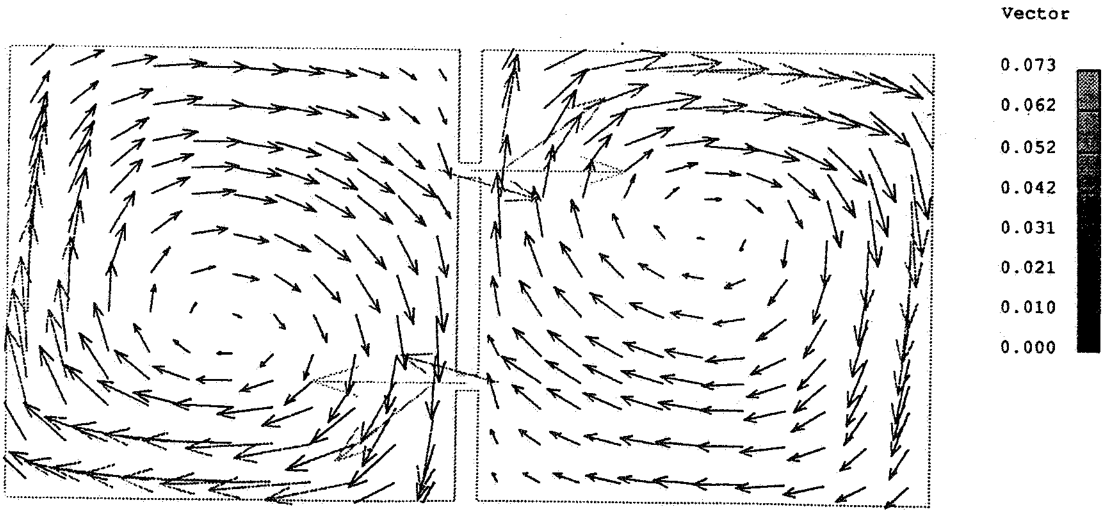

Figure 5: Flovent output showing airflow velocity vectors for the boxes set at a constant temperature.

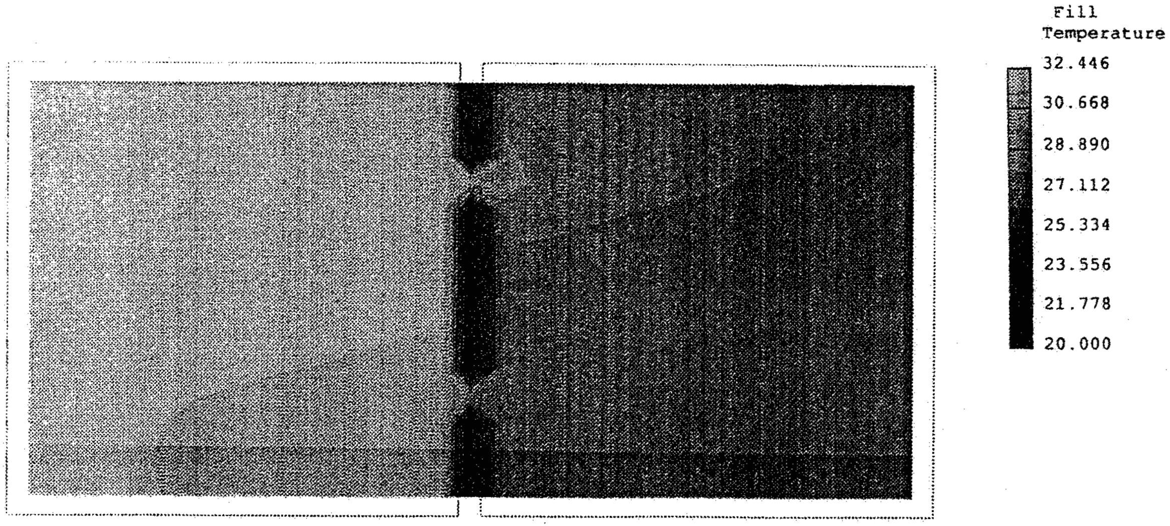

Figure 6: Flovent output showing the temperature contours for the boxes set at a constant temperature. The lighter areas correspond to hotter regions.The key is shown in °C.

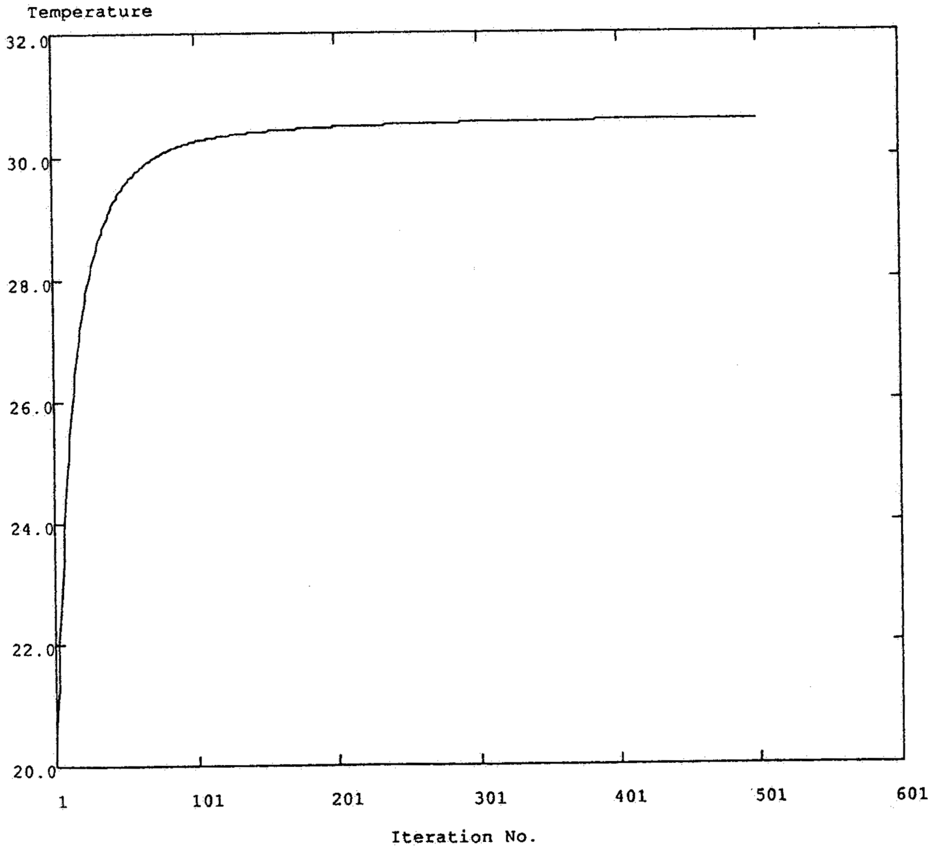

Figure 7: Flovent output showing the temperature profile of a point in the middle of the top crack plotted against time for the boxes set at a constant temperature.