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

Balancing Ventilation Systems Using Thermography

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BALANCING VENTILATION SYSTEMS USING THERMOGRAPHY

SYNOPSIS

It has been shown that thermal imaging can give an indication of air flow rates through small cracks (1). Using a finite difference analysis package it is possible to determine the surface temperature of an air transfer grille when subjected to air flow rates at higher temperatures than the grille surface.

This paper will address this technique by presenting the results of the finite difference analysis package for a specific grille. It will then present the results of a series of experiments to calibrate a range of air transfer grilles using thermal imaging, and finally will demonstrate how the technique can be applied to checking the air flow rates in a ventilation system.

LIST OF SYMBOLS

α	=	$1/(1+ h * L/K)$
A	=	$h * T_{air}$
f	=	convergence coefficient (0.5)
h	=	surface heat transfer coefficient
	=	$(0.664 * Re^{0.5} * Pr^{0.33}) * K/L$
		(W/m^2 deg C)
L	=	Element Thickness (m)
K	=	Thermal Conductivity of grille blades
		(W/m deg C)
Re	=	Reynolds Number
Pr	=	Prandtl Number
D	=	Length of grille blade (m)
v	=	Viscosity of Air (m^2/s)
$t_{2(1)}$	=	temperature of node 2 at time step 1.

1. FINITE DIFFERENCE ANALYSIS OF AIR TRANSFER GRILLE

Fundamental heat transfer theory for heat flow over flat plates in turbulent flow conditions were used to establish the surface temperature of the fins of a grille. Figure 1 shows the way in which the grille element was broken down for the finite difference analysis and the equations for the surface node and internal node are:

$$t_{1(1)} = \alpha(t_{2(1)} + A) \qquad ...(1)$$

$$t_{2(1)} = f * t_{1(0)} + t_{2(0)} * (1-2^{a})+f * t_{3(0)} \qquad ...(2)$$

The Reynolds Number is a function of the air velocity:

$$Re = (vel_{air} * D)* 10^5/v \qquad ...(3)$$

It can therefore be seen that the surface temperature is a function of the velocity of the air passing over it and therefore it should be possible to determine the velocity from a knowledge of the surface temperature history.

The above equations formed the basis of a finite difference programme which was written specifically to look at the surface temperature variations for different air flow rates.

Figure 2 shows the results of the analysis for a range of air flow rates which indicate that there is a significant difference in the surface temperature for different air flow rates.

2. INITIAL MEASUREMENTS USING REMOTE TEMPERATURE SENSING

Using a hand held Infra-Red thermometer with a print out facility, a domestic air grille's surface temperature was measured over a period of time when the heating system was switched on. The resulting plot (Figure 3) shows that the predicted air flow rate for this grille was approximately 2.5 m/s. Flow rates measured prior to and after the tests were in the region of 2.3 to 2.5 m/s which indicate that the IR technique may be able to predict air flow rates over grilles.

3. CALIBRATION OF AIR TRANSFER GRILLES

In order to establish if the technique described above was able to be applied to a ventilation system it was necessary to carry out a series of tests on a variety of air transfer grilles. A simple ventilation system incorporating air heater, dampers and variable pitch axial fans was constructed. A range of different grilles was made available by a large UK manufacturer and these were tested for a range of supply air temperatures and flow rates.

3.1 Surface Temperature: Variable Heat Input Rates

The first series of tests carried out were to establish if the variation in the surface temperature of a specific grille was a function of the air velocity and the heat input to the system.

Figure 4 shows the results of this series of tests and it is quite clear that as the heat input to the system was increased the surface temperature also increased. The air velocity also had an effect on the final conditions.

3.2 Surface Temperature: Different Grilles

The next series of tests were designed to establish if there were significent differences between the various grilles. Figure 5 shows the results of this series of tests and it is clear that each grille has it's own characteristic. However the differences are small and there could easily be an overlap in practice. At higher volume flow rates the differences disappear and all the grilles appear the same.

In order to establish if measuring the surface temperature of a grille could give an indication of the flow rate, if was suggested that the variation in the grille surface temperature with time could be treated as a first order equation.
In practice this did not prove to be the case and a simple steady state surface temperature was found to be a better means of determining the flow rate.

The temperatures used in this analysis were the difference between the surface air temperature and the room temperature. This gave an indication of the performance of the grille.

4. APPLICATION IN A VENTILATION SYSTEM

The next stage in the experimental work was to establish if a ventilation system could be balanced using the IR System and the results of the calibrated grilles.

4.1 Balancing the Ventilation System

The tests carried out on the simple test rig proved inconclusive. Although it appeared to work when one heater setting was involved as soon as the heat input was varied the results could not be relied upon.

4.2 Checking on Balancing

A second set of tests were carried out to see if the IR System could be used to check if the system had gone out of balance. This was done by first setting up the system using conventional balancing techniques.

IR measurements were used to confirm the temperature/ time history of the index grille.

The system was then deliberately put out of balance by altering one of the dampers. The IR tests were then applied again and the results plotted in Figure 6.

It can be seen from this figure that there is a difference to be found from the results before and after the damper was changed. This appears optimistic.

5. CONCLUSIONS

The initial suggestion that remote temperature measurement techniques could be used to balance a ventilation system from a knowledge of the temperature/time history of a grille did not seem to work.

The tests carried out have indicated that the temperature/time history of a ventilation grille may be used to establish if the ventilation system has gone out of balance. However further work is necessary to quantify and prove these initial results.

6. REFERENCES

(1) SERC Grant. An Investigation of the potential use of thermography for building air leakage. GR/G51718, Start October 1991.

7. ACKNOWLEDGEMENT

The author would like to thank Gilberts (Blackpool) Ltd. for supplying the grilles which enabled this work to be carried out. Also to Mr R Burani and Mr J Rochford for their help in carrying out the tests.

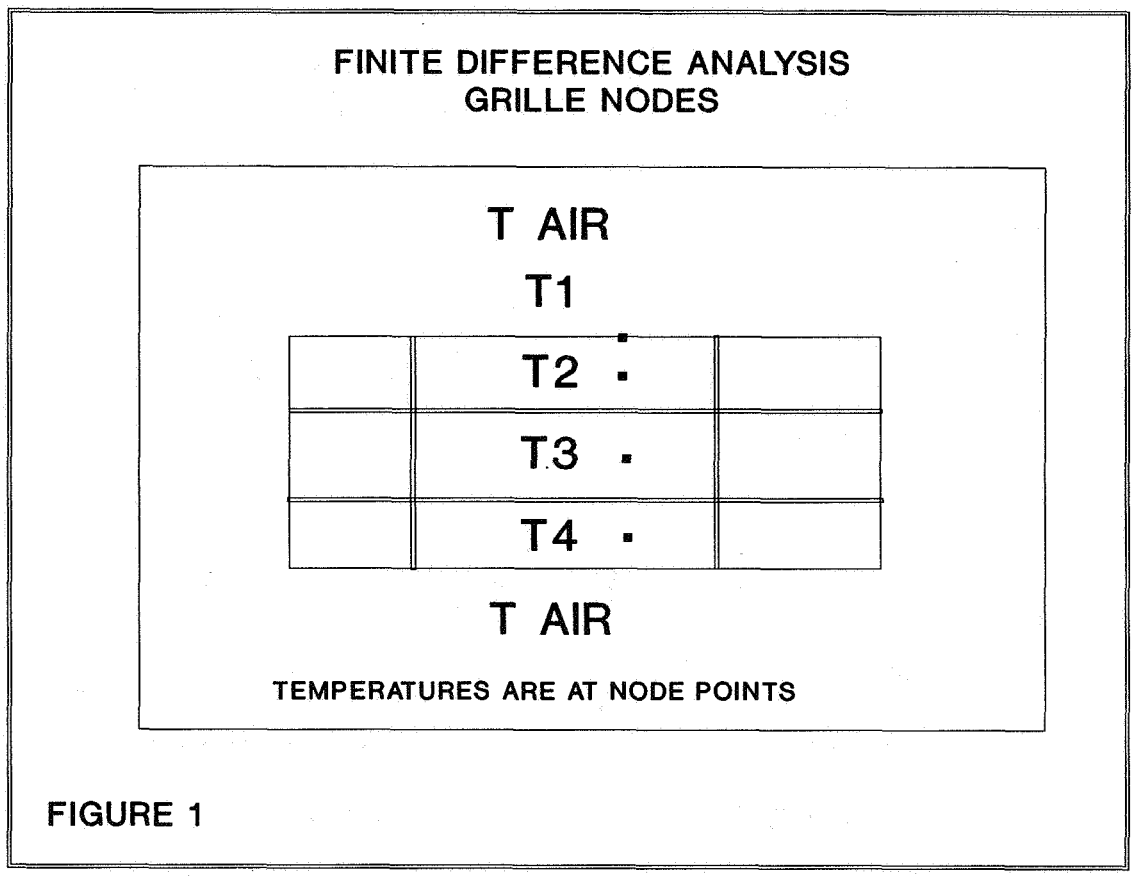

FIGURE 1

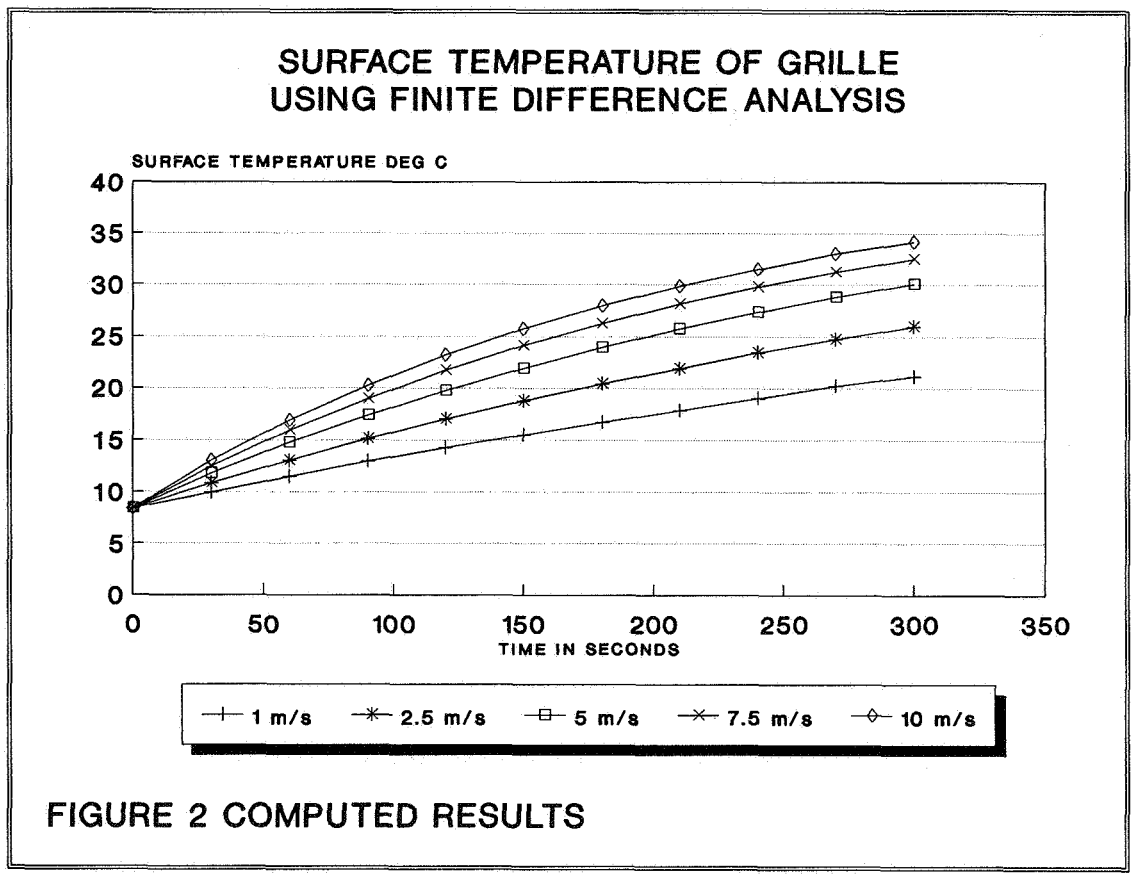

FIGURE 2 COMPUTED RESULTS

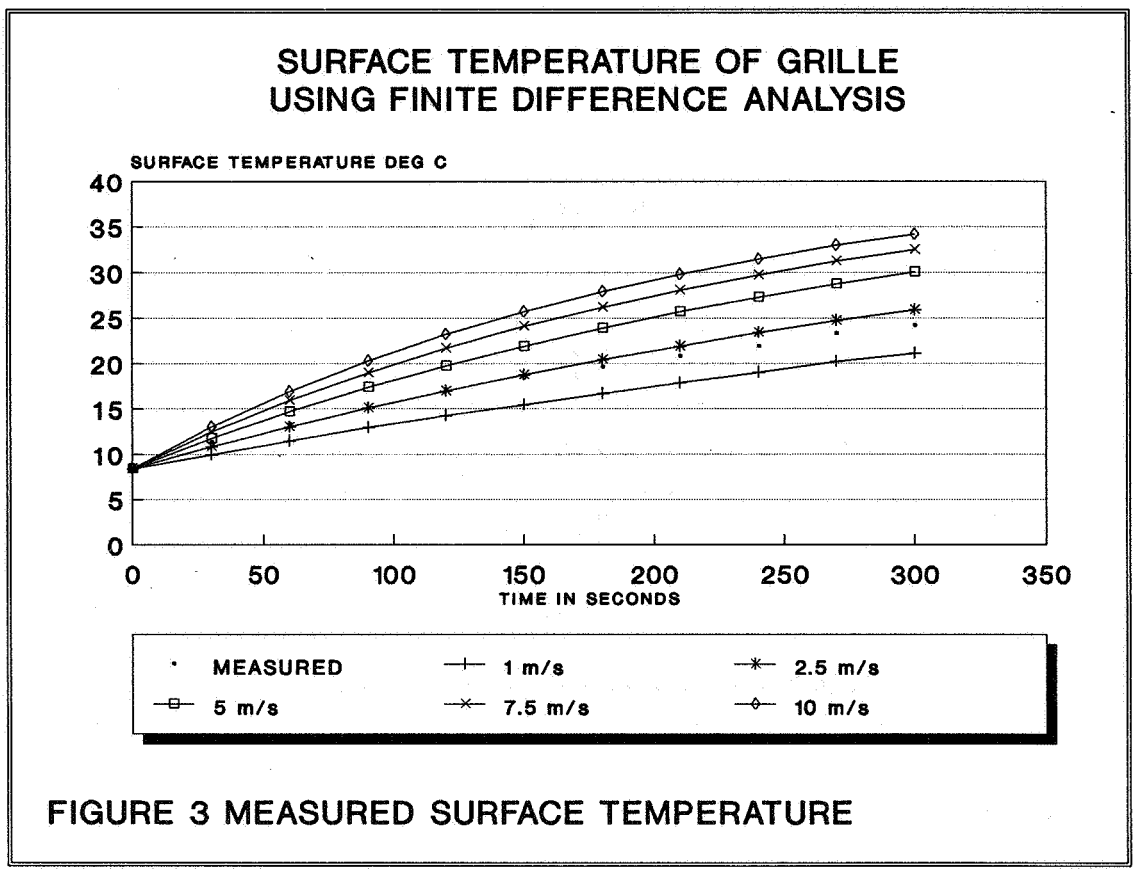

FIGURE 3 MEASURED SURFACE TEMPERATURE

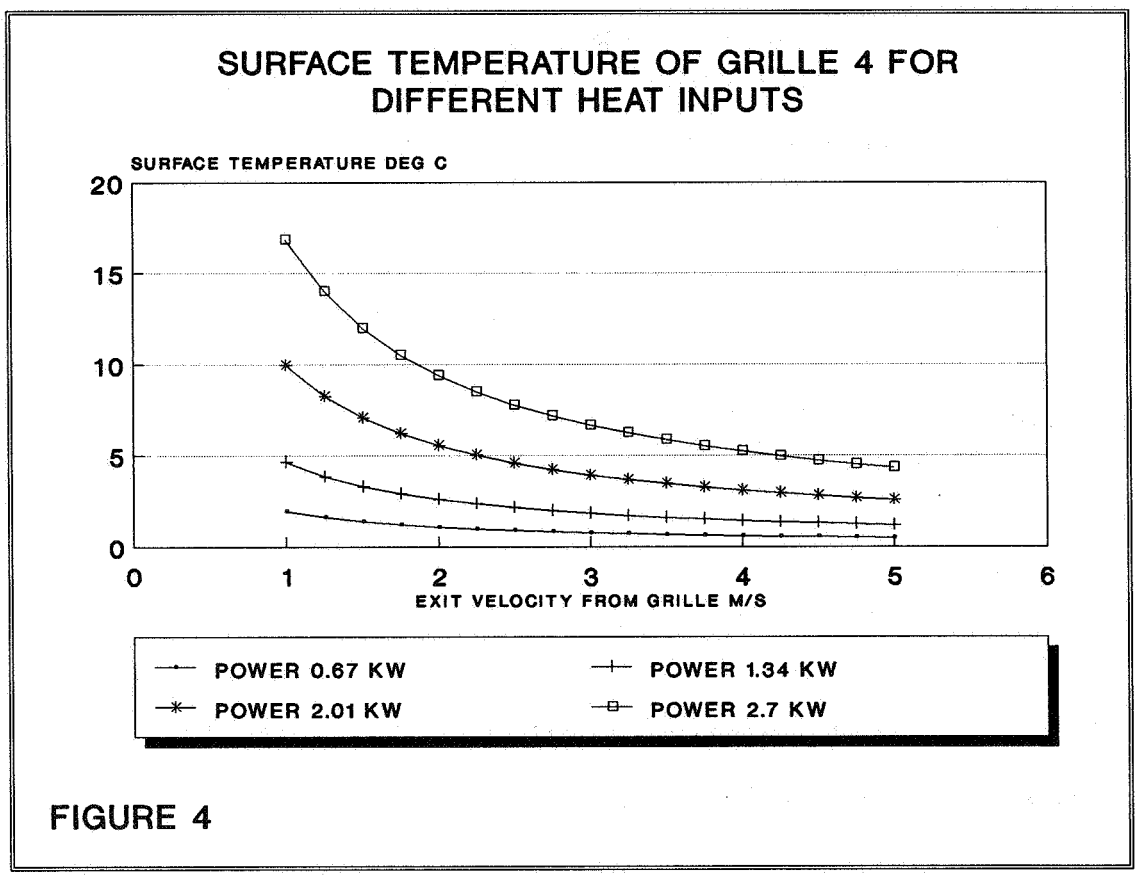

FIGURE 4

DIFFERENCES IN SURFACE TEMPERATURES OF FOUR GRILLE TYPES FOR VARIOUS AIR FLOWS

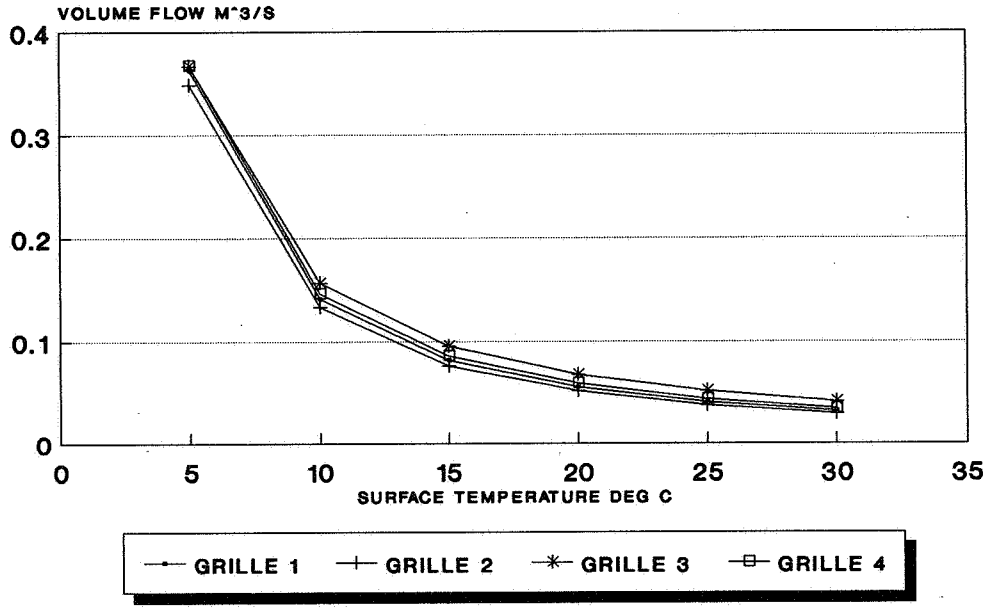

FIGURE 5

BALANCING VENTILATION SYSTEMS USING REMOTE TEMPERATURE SENSING

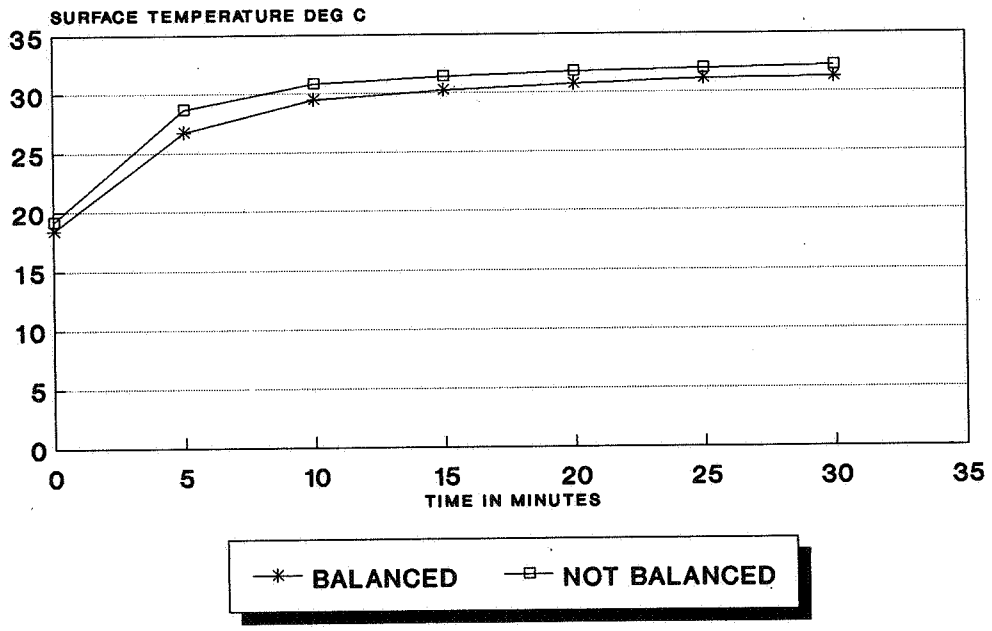

FIGURE 6