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SOME PRACTICAL ASPECTS ON THE INFRA-RED THERMOGRAPHY OF BUILDINGS

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heater. With the heater off a range of 5 K brings in all five colours in the IR picture to show considerable temperature non-uniformity. With the heater operating and the range set to 500 (Figure 4a) the wall and the heater surround have a much more uniform colour, with only the glow bar and immediate surroundings taking different colours. Reducing the range to 200 (Figure 4b) identifies a warm patch on the floor.

To specify accurately the temperature range, the manufacturer's calibrations must be used at each temperature level. To set the temperature level a known reference temperature has to be included in the picture - Figure 5. An adjustable isotherm facility is useful in defining where the reference temperature is on the scale - Figure 6.

Images of temperatures cooler than the set scale appear conveniently as an extra colour, black. Temperatures warmer than set scales are not so conveniently defined, since they are all imaged in the warmest colour. This is illustrated in Figure 7 where the warmest parts of the human body surface (≃ 33°C) appear red around the isotherm, as does the glowing bar of the electric heater (≃ 750°C) with 10 K as the set scale.

For most of the views here the IR camera was fitted with a lens having a field of view of 40°. A conventional camera with its normal lens gives ordinary photographs with a very similar field of view as the IR camera when used alongside it and this is apparent in the figures. Narrower angle lenses are available for the IR camera, and when these are used a telephoto lens will be needed on an ordinary camera to obtain a similar field of view.

3. EXTERNAL VIEWS

A number of external views of buildings are shown in Figures 8 to 11, taken in visible light and IR radiation. The first (Figure 8) shows a pair of semi-detached houses heated inside to about 15 K above the outside temperature. The house in the left hand side of the picture is well insulated with double glazing and insulation thicknesses in the walls of 50-100 mm (U-value ≃ 0.5 W/m^2K). The house on the right hand is uninsulated having single glazing and solid external walls of 9 inch brick (U-value ≃ 2 W/m^2K). The IR picture has five colour bands each representing approximately 1 K at the levels 8 to 13°C.

The colours follow generally the expected pattern. Most of the external surface of the front wall of the insulated house is green, which is a colour cooler than the purple of the uninsulated house. The blue replacing the green in the left hand corner suggests a borderline temperature of 8/9°C, possibly caused by cold outside air circulating behind the cladding. In this house the lower sections of the windows have been insulated to a similar level to the rest of the front wall as shown by the colour. The colour green suggests surfaces 2 K warmer than outside, and purple 3 K warmer. Temperature differences calculated using the U-values are considerably less at 0.4 K and 1.6 K respectively.

The surfaces of most of the double glazed windows are purple and white compared with white and red for those windows which are single glazed. The exceptions are red strips at the tops of the two upstairs, openable, double glazed windows. An explanation is that warm air is leaking out from inside.

The gable wall is insulated, yet its colours of purple and white indicate temperatures higher than the purple alone of the solid brick wall of the uninsulated house, suggesting that the gable wall is not insulated. The explanation is the residual effect of the sun. The IR photograph was taken about four hours after sunset on a sunny November day. The ordinary photograph was taken mid-afternoon on that day and shows clearly the sun shining on the wall.

The roof shows uniformly blue and thus cold, and therefore appears to be uniformly well insulated. In fact the loft insulation was 300 mm thick in the insulated house compared with only 20 mm thick in the other. What is being registered by the IR camera is a reflection of the cold night-time sky and the radiation from the edges of the roof tiles which are exposed to the external air.

Another comparison of double and single glazing is shown in Figure 9. The outer surfaces of the double glazing are cooler than those of the single glazing with the house heated to a uniform temperature throughout. A similar picture would be obtained with single glazing throughout if the temperature downstairs was warmer than upstairs as suggested in the caption to the figure.

Room lighting through glass windows is registered as warm areas in the IR of Figure 10. Such imaging could be interpreted wrongly since double glazing could have the warmer appearance obtained with single glazing.

Figure 11 shows two variations on the IR picture in Figure 8. The walls and windows (Figure 11a) are in only two colours, white and red. Such a picture could be used to contrast 'insulated' and 'uninsulated' areas.

The lower picture was taken with the sun shining on the roofs of the two houses. Here they appear equally warm and therefore equally poorly insulated in contrast with Figure 8 where they both appeared equally cold and therefore well insulated.

4. INTERNAL VIEWS

Infra-red thermography can be used internally possibly with greater precision than externally but perhaps less dramatically. Figure 12 shows an ordinary and IR photograph of an external wall of a room with a door into an external porch. This wall has been subjected to numerous heat flow measurements, although the ordinary picture shows no temperature irregularities. The IR picture however shows significant variations of 3 K with four colours (blue, green, purple and white) represented, each colour band representing about 1 K. This picture had to be made from four separate photographs because the room was too shallow for the lens angle to cover the whole wall in one exposure. Lines showing the joins can be seen. Care was taken to keep the temperature level constant and to take the photographs in quick succession so that for all of them the same colour represented the same temperature.

Generally, the wall temperature increases with height through about 2 K (green to purple to white). A representative position (X) is marked in the purple where heat flow through the wall was measured[2]. Apparent cold spots are shown blue, around the door due to air infiltration, and in the lower right hand corner (at Y). It is important to measure heat flows at cold spots such as Y because they may not be places where local heat flows are high, but where cold outside air is infiltrating, which would reduce local outward heat flow. Cold spots D arise from the plaster dabs fixing the dry-lining to the wall.

To compute accurate U-values from the IR picture would need accurate values of local air and radiant temperatures 100-200 mm from the wall. These temperatures would have to be measured in different positions vertically, because it is almost certain that at least the air temperature would have a similar vertical gradient to the wall temperature. Then taking a heat transfer coefficient for the inner surface (8 W/m^2K) from the CIBS Guide[3] heat flow can be calculated. The U-value would then be derived by dividing this heat flow by the inside to outside temperature difference. This IR method for assessing heat flow has not been used, instead the heat flow has been measured directly. This is easier than measuring local temperatures, especially when the IR camera is in use at the same time.

5. CONCLUDING REMARKS

IR thermography of buildings can be very useful qualitatively even though the pictures obtained are open to easy misinterpretation. Considerable extra instrumentation has been found necessary to obtain experimental U-values, and the IR work has contributed only in identifying the positions for measuring heat flows. The problem of using IR to obtain U-values is in measuring the small differences between surface and room or outside temperatures, coupled with the complexities of combined convective and radiative heat transfer at the surfaces.

6. REFERENCES

1) Paljak J. & Petterson B. "Thermography of buildings" Svensk Byggtjänst, Stockholm, 1972

2) Siviour J. B. "Experimental thermal calibration of houses" Conference on Comparative Experimentation of Low Energy Houses, Liege, Belgium, 6-8 May 1981

3) CIBS Guide A3 Chartered Institute of Building Services, 1970

7. ACKNOWLEDGEMENTS

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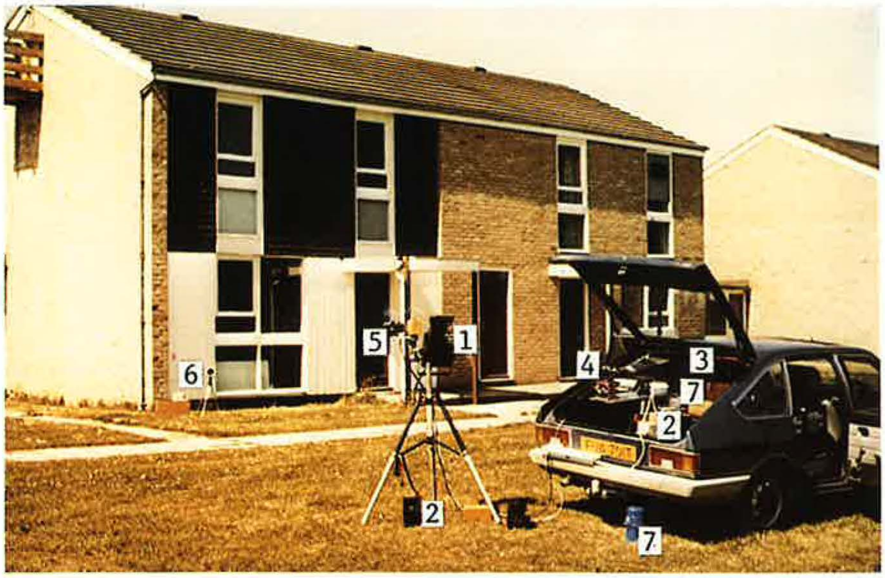

FIGURE 1 ON SITE WITH THE IR CAMERA AND ASSOCIATED EQUIPMENT

(1) Infra-red camera* and tripod

(2) Battery or mains electric supply

(3) Colour monitor

(4) Camera for colour picture in IR radiation

(5) Camera for picture in visible radiation

(6) Black body reference temperature

(7) Liquid nitrogen flask and box

*Aga 750

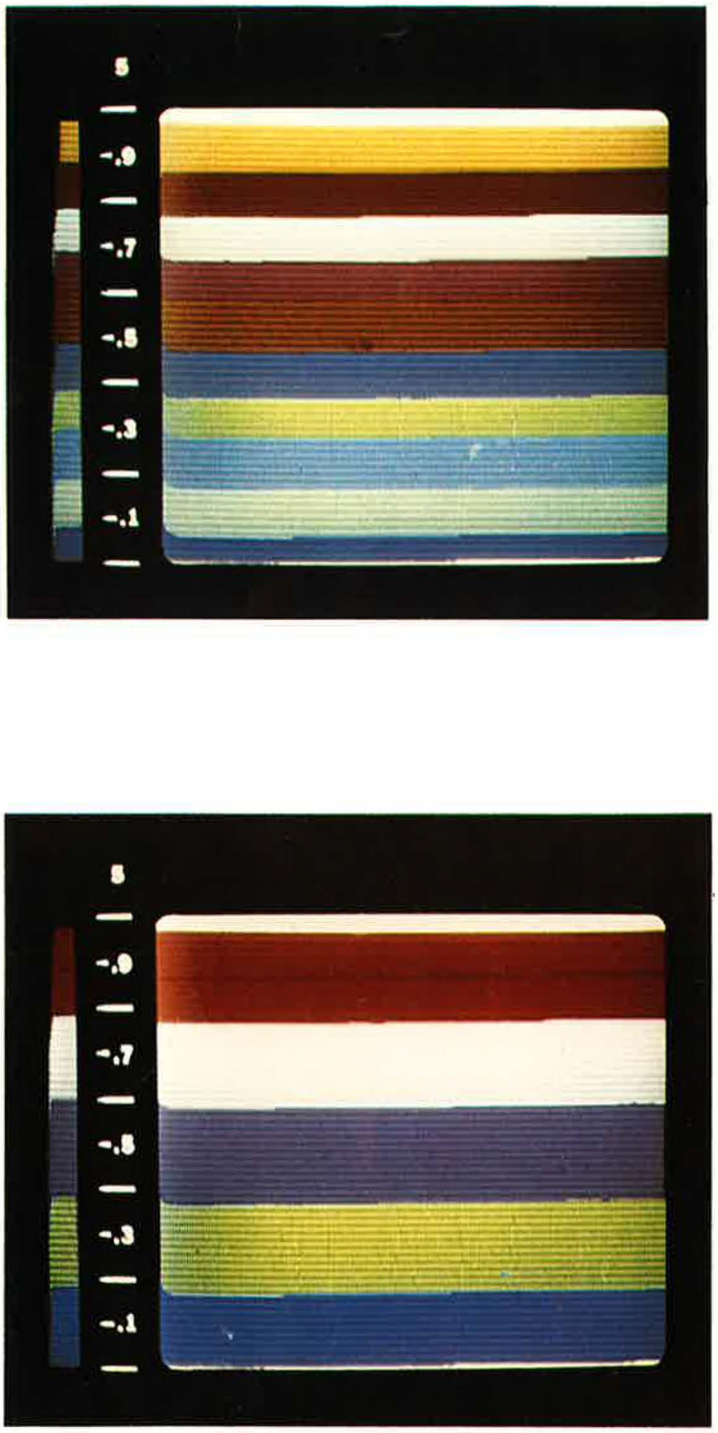

FIGURE 2 COLOURS ON THE INFRA-RED COLOUR MONITOR. THE FULL (10 BAND) COLOUR RANGE IS SHOWN ABOVE, AND BELOW THE 5 BAND SET WHICH IS ADEQUATE AND EASIER TO USE IN THERMOGRAPHY OF BUILDINGS. BLACK AUTOMATICALLY APPEARS REPRESENTING SURFACES COOLER THAN THE RANGE COVERED BY THE COLOURS

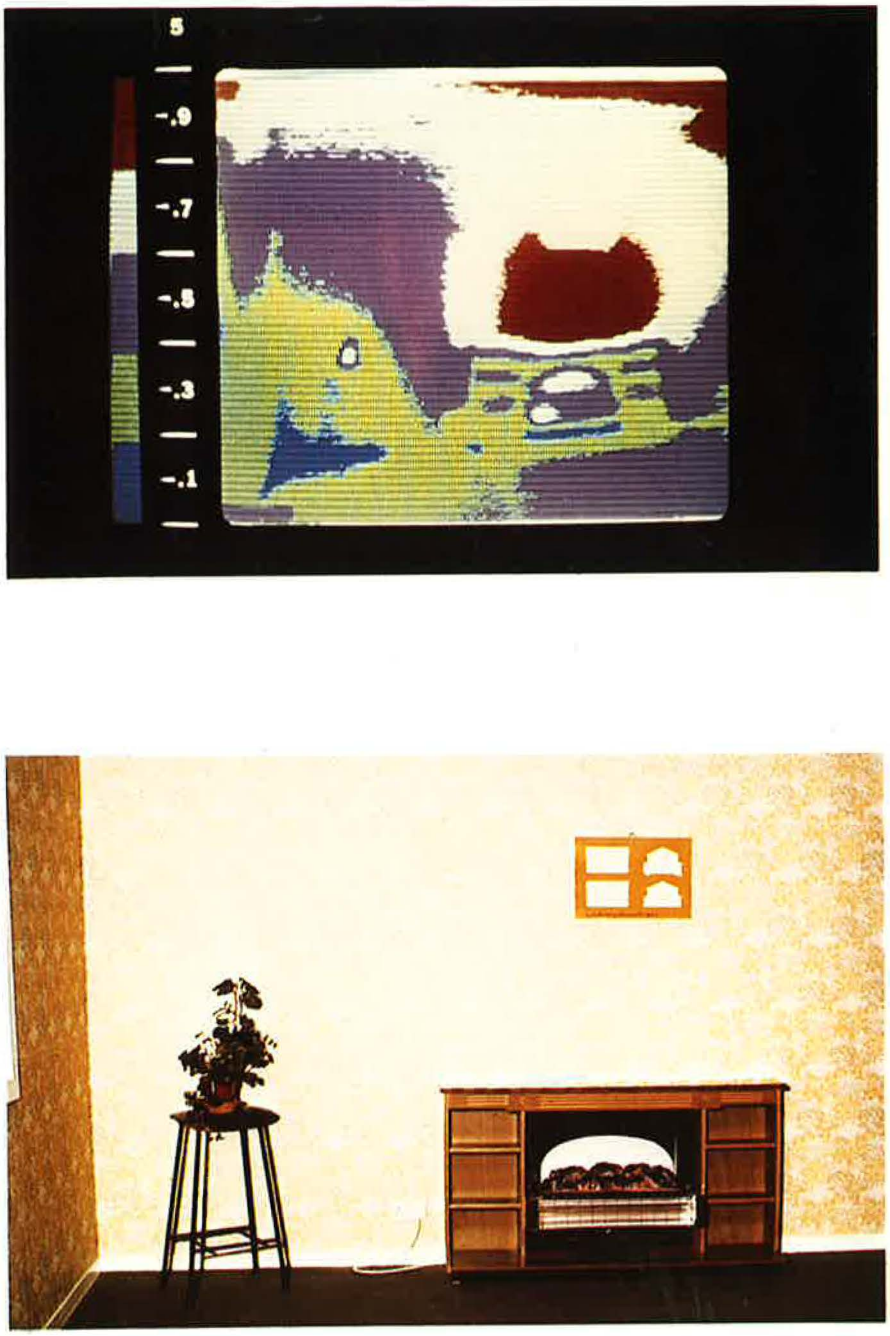

FIGURE 3 LIVING ROOM VIEW IN INFRA-RED AND VISIBLE RADIATION.
THE HEATER IS OFF AND ALL SURFACES LIE WITHIN THE 5 K RANGE, FROM THE COLD CORNER (BLUE) IN THE LOWER LEFT THROUGH GREEN, PURPLE, WHITE AND A RED PATCH ABOVE THE HEATER WHICH IS WARM BECAUSE OF THE LIGHTING ARRANGEMENT

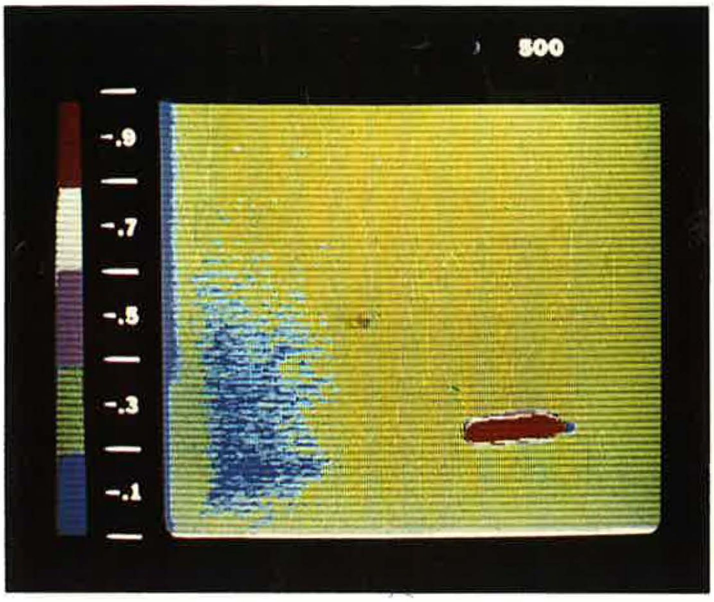

FIGURE 4 INFRA-RED VIEW OF THE ROOM - FIGURE 3 WITH THE HEATER OPERATING. ON THE TEMPERATURE RANGE OF 500 (TOP) ONLY THE GLOW BAR (RED) AND IMMEDIATE SURROUND SHOW COLOURS DIFFERENT FROM THE BACKGROUND. ON A RANGE OF 200 (BOTTOM) THE WARMER FLOOR IN FRONT OF THE HEATER NOW STANDS OUT FROM THE BACKGROUND AS WELL.

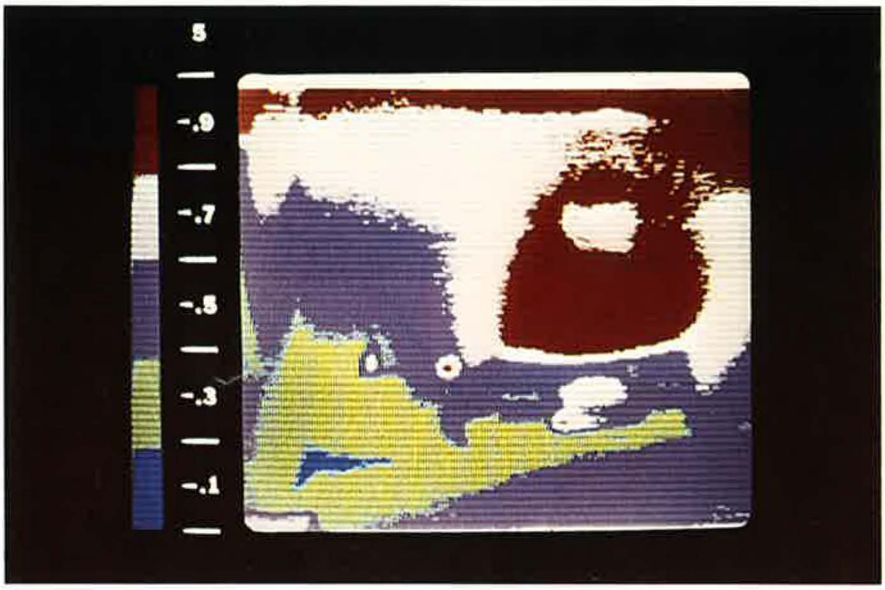

FIGURE 5 USE OF A REFERENCE TEMPERATURE TO DEFINE THE TEMPERATURE LEVEL. THIS IS A REPEAT OF FIGURE 3 BUT INCLUDING A KNOWN REFERENCE TEMPERATURE. IT IS JUST IN THE RED COLOUR BAND SO THAT ITS TEMPERATURE IS AT THE WHITE/RED CHANGEOVER.

FIGURE 6 USE OF THE ADJUSTABLE ISOTHERM LINE TO HELP IDENTIFY THE REFERENCE TEMPERATURE POSITION ON THE COLOUR BANDS. THIS IS A REPEAT OF FIGURE 5. THE ISOTHERM FRINGES THE RED AREA IN THE PICTURE, AND ITS POSITION IS IDENTIFIED IN THE COLOUR BAND SCALE ON THE LEFT BY THE LINE NEAR THE TOP OF THE WHITE.

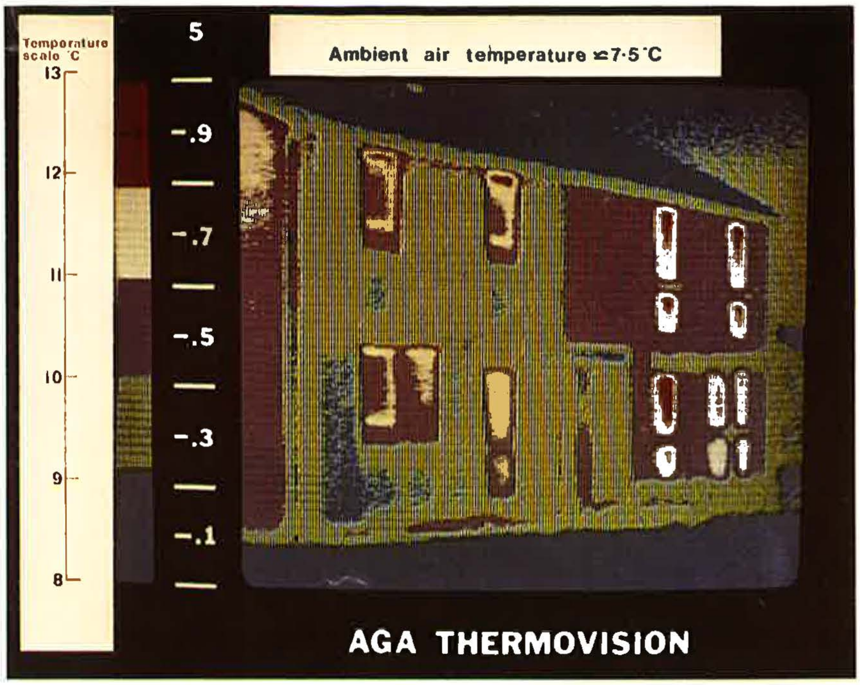

FIGURE 8 VIEW OF TWO HEATED HOUSES IN INFRA-RED AND VISIBLE RADIATION. THE ONE ON THE LEFT IS WELL INSULATED (DOUBLE GLAZED AND WALL $U \simeq 0.5\ W/m^2K$) AND THE ONE ON THE RIGHT POORLY INSULATED (SINGLE GLAZED AND WALL $U \simeq 2.0\ W/m^2K$). THE INFRA-RED PICTURE WAS TAKEN 4 HOURS AFTER SUNSET, BUT THE RESIDUAL EFFECT ON THE GABLE WALL OF THE INCIDENT RADIATION IS SHOWN BY THE PURPLE AND WHITE COLOURS. OTHER POINTS DISCUSSED IN THE TEXT ARE THE RED STRIPS AT THE TOP OF THE WINDOWS AND THE UNIFORMLY BLUE ROOF.

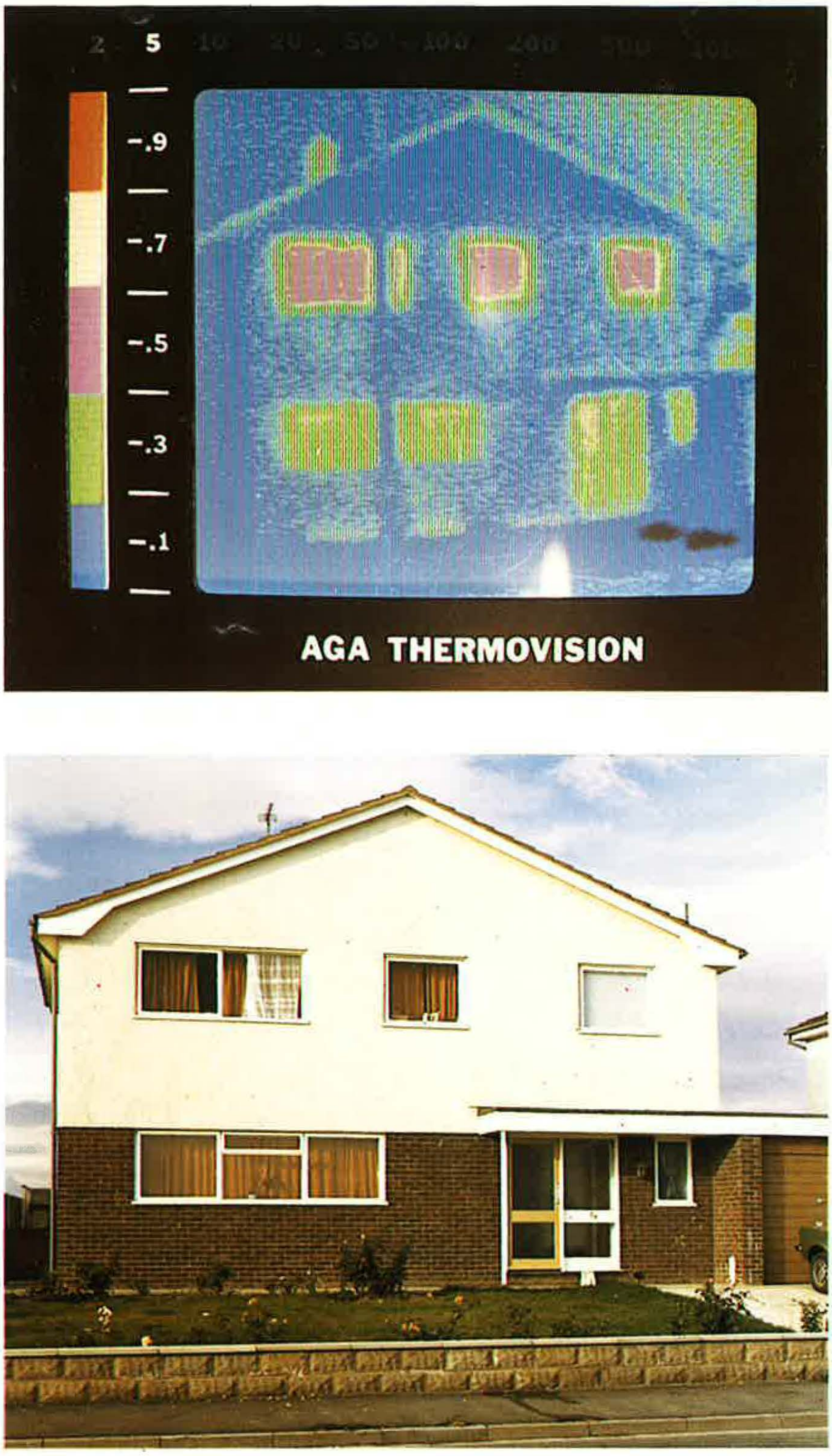

FIGURE 9 SINGLE GLAZING (UPSTAIRS) AND DOUBLE GLAZING (DOWNSTAIRS) SHOWN BY THE COOLER OUTSIDE SURFACES OF THE DOUBLE GLAZING WITH UNIFORM TEMPERATURES INSIDE. A SIMILAR IR PICTURE WOULD BE OBTAINED FOR ALL SINGLE GLAZING IF THE DOWNSTAIRS ROOMS HAD A TEMPERATURE ELEVATION ABOVE THE OUTSIDE OF ABOUT TWICE THAT OF THE UPSTAIRS ROOMS, FOR EXAMPLE, 10°C OUTSIDE, 20°C DOWNSTAIRS AND 15°C UPSTAIRS.

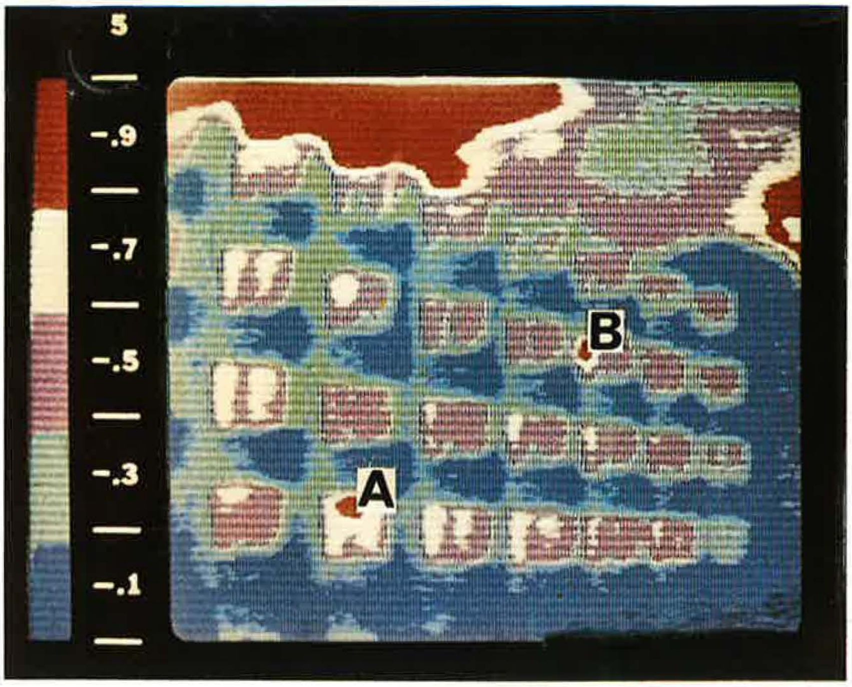

FIGURE 10 HOT SPOTS A AND B IN THE INFRA-RED PICTURE ARE CAUSED BY ELECTRIC LIGHTS THROUGH THE GLASS

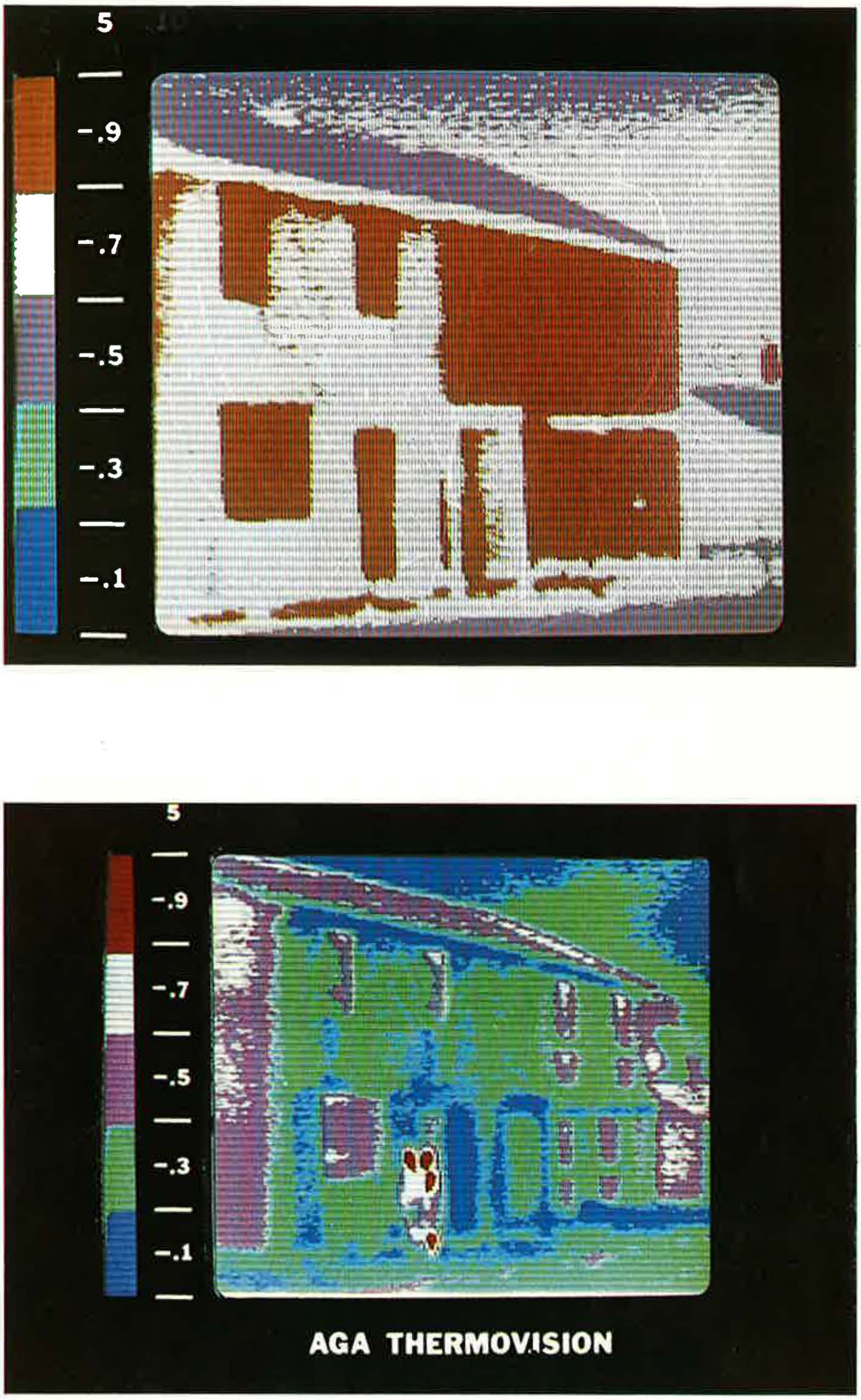

FIGURE 11 SHOWN HERE ARE TWO VARIATIONS OF IR PICTURE IN FIGURE 8. THE TOP PICTURE HAS THE SAME 5 K TEMPERATURE RANGE BUT AT A DIFFERENT LEVEL. THE WALLS AND WINDOWS ARE EITHER WHITE OR RED, AND COULD BE USED TO SHOW 'INSULATED' VERSUS 'UNINSULATED' AREAS.

THE LOWER PICTURE WAS TAKEN DURING THE DAY WHEN THE SUN WAS SHINING ON THE ROOF. IT THEN HAD A RELATIVELY WARM COLOUR (PURPLE) WRONGLY SUGGESTING LITTLE LOFT INSULATION IN BOTH HOUSES, WHEREAS IN FACT THE LEFT HAND HOUSE HAD INSULATION 300 mm THICK AND THE RIGHT HAND HOUSE 20 mm. PEOPLE ARE STANDING IN FRONT OF THE HOUSES.

FIGURE 12 PHOTOGRAPHS IN INFRA-RED AND VISIBLE RADIATION OF THE INSIDE SURFACE OF AN EXTERNAL INSULATED WALL ($U \simeq 0.6\ W/m^2K$). EACH COLOUR BAND REPRESENTS 1 K DIFFERENCE. POSITIONS ARE SHOWN FOR MEASURING REPRESENTATIVE (X) AND LOCAL (Y) HEAT FLOWS USING THE EQUIPMENT SHOWN IN THE ORDINARY PICTURE. BLACK APPEARS AT THE BOTTOM OF THE DOOR IN THE IR PICTURE SHOWING A TEMPERATURE COOLER THAN THE SET SCALE.