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SHORTER COMMUNICATIONS

THE USE OF EVACUATED THERMAL INSULATION AS A MEANS OF THERMAL EMISSION CONTROL

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INTRODUCTION

THE CONDUCTION of heat through high temperature thermal insulation materials (up to 800°C) is mainly by gaseous conduction through the air within the insulation. This means that the effectiveness of the insulation can be increased by evacuating, and can be varied by varying the degree of evacuation. The extent of this variation has been evaluated by Dickson [1], and is sufficient even at a relatively crude vacuum of 1 mm Hg to be of interest in applications where a variable conductance is useful, for example in thermal storage heaters.

The effectiveness of this heat transfer control technique has been determined in realistic test rigs as part of a larger programme investigating its application to storage heaters, completed recently at the Electricity Council Research Centre. The results obtained from these test rigs are reported in this paper.

EXPERIMENTAL RIGS

Two insulation materials were tested, and two different designs of test rig were used, one of the insulations being tested in both rigs. The first test rig, shown schematically in Fig. 1, used a double-skinned five-sided box, formed from stainless steel, containing the insulation. This box was placed over an electrically heated thermal storage core formed from 200 kg of sintered iron oxide bricks. The box was in turn surrounded by an outer casing, to improve appearance and to reduce surface temperatures. The insulation used was based on an opacified microporous silica aerogel, enclosed in pillows of glass fibre.

The second test rig was in the form of a sealable heavy steel box, with removable lid, as shown in Fig. 2, which contained 137 kg of core material together with the insulation. This rig was tested with the silica aerogel insulation, and then with an aluminosilicate fibre blanket. In every case, the thickness of the thermal insulation was 12 mm.

The insulations used had comparable fractional changes of thermal conductivity with pressure, but over different pressure levels. Table 1 gives conductivity values, showing that the silica aerogel has constant conductivity below 10 mm Hg, whereas aluminosilicate fibre continues changing even below 1 mm Hg.

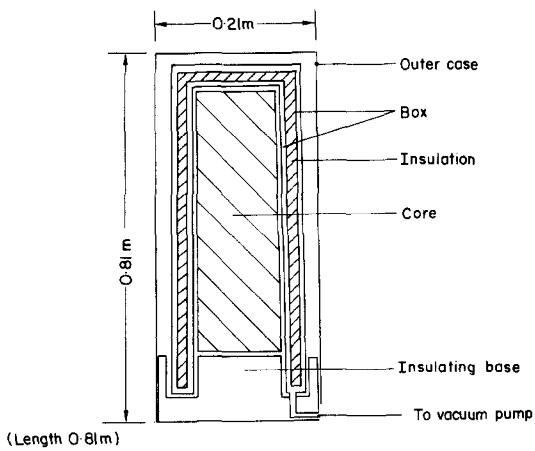

FIG. 1. Construction of first rig.

Table 1. *Thermal conductivity values* (W/m°C)

Material	Pressure (mm Hg) 0·1	1·0	10	100	760
Opacified silica aerogel (Hot face 675°C)	0·013	0·013	0·013	0·016	0·028
Aluminosilicate fibre blanket (Hot face 550°C)	<0·020	0·027	0·052	0·067	0·073

The rigs were calibrated by attaching a number of thermocouples to their outer surfaces, operating the heating elements at reduced voltages until steady conditions were obtained, and thus obtaining the relation between mean outer surface temperature and power. The test area was protected from draughts, and a correction was applied for changes in ambient temperature.

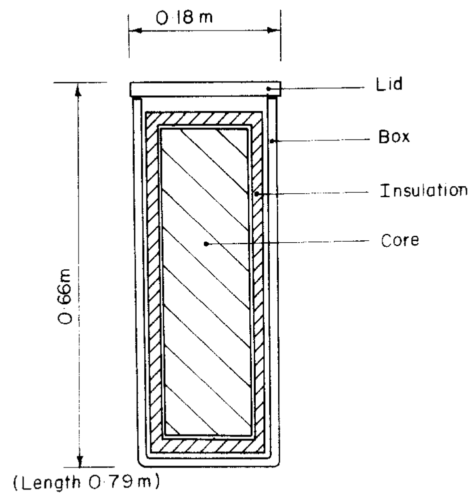

FIG. 2. Construction of second rig.

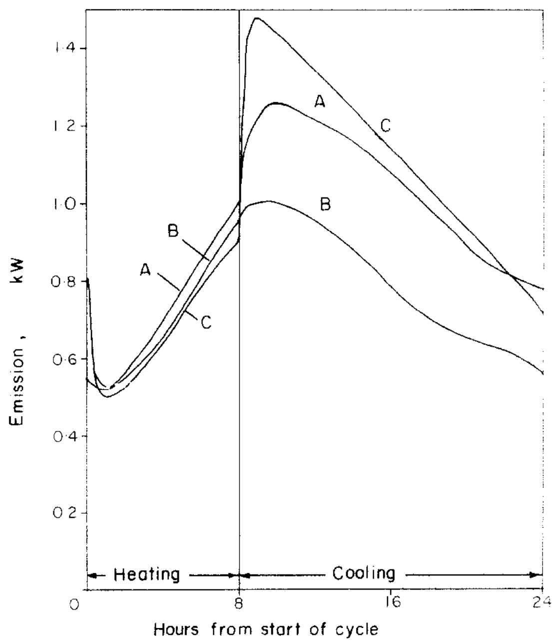

FIG. 3. Emission from first rig, using silica aerogel based insulation.
A—Pressure rise 0–550 mm Hg during cooling period.
B—Pressure held below 1 mm Hg.
C—Pressure atmospheric during cooling.

Test cycles started with an 8 h heating period, during which the core was heated to approximately 700°C, this temperature being controlled from thermocouples in the core. There was then a 16 h cooling period, during which the air pressure in the insulation was either held below 1 mm Hg or else allowed to rise in a controlled manner. The rates of rise were selected on the basis of the known properties of the insulation, to give a cooling curve with a characteristic appropriate to a domestic space heating appliance. Evacuation was by means of a single stage rotary pump, and pressure rise was controlled by a precision needle leak valve.

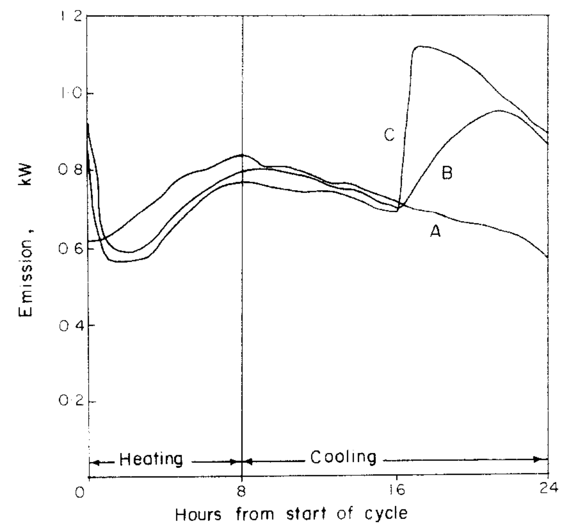

FIG. 4. Emission from second rig, using silica aerogel based insulation.
A—Pressure held below 1 mm Hg.
B—Pressure rise 75 mm Hg/h over last 8 h.
C—Pressure atmospheric over last 8 h.

RESULTS

The results for the first rig are seen in Fig. 3. Curve B represents the lowest possible cooling rate, Curve C the highest, and Curve A gives the most level rate of cooling for a linear pressure rise.

Figure 4 shows comparable results with the second rig, scaled by a factor of 200/137 to compensate for the reduced core size. Curve A represents the lowest possible cooling rate, and is notably flatter than the corresponding result (curve B) with the first rig. This demonstrates the effect of

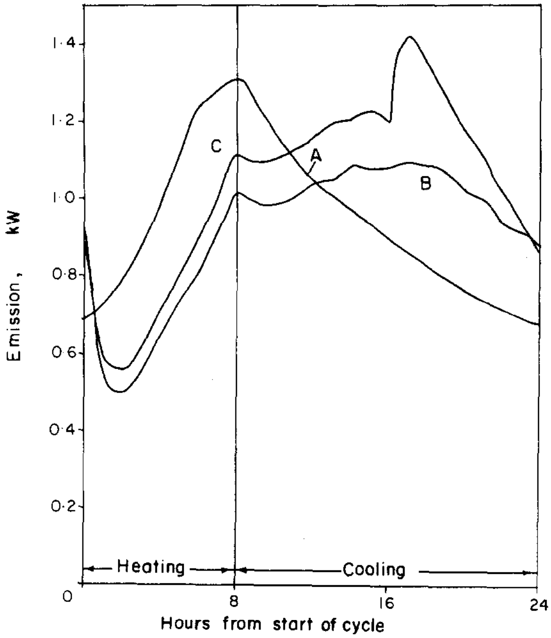

FIG. 5. Emission from second rig, using aluminosilicate fibre insulation.
A—Pressure held below 1 mm Hg.
B—Pressure below 1 mm Hg during heating, rising to 2 mm Hg at 13 h, and to 7 mm Hg at 24 h.
C—Pressure rise to 3 mm Hg from 8 to 16 h, atmospheric over last 8 h.

metallic bridging in the first rig, around the bottom of the insulation. Curve C demonstrates the maximum rate of rise of emission half way through the cooling period. In a thermal storage space heater, heated off-peak from 2300 h to 0700 h, this last curve would give a peak emission at 2000–2100 h, an ideal situation.

Figure 5 shows the results from the second rig with aluminosilicate fibre insulation, again scaled by 200/137. Curve A is the natural cooling curve, fully evacuated. B represents an approximately level cooling curve, and C rises to a peak after 8–9 h, dropping rapidly thereafter. Although the control is worse with this insulation, the total emission over the test cycle is greater, due to the greater conductivity of the material.

CONCLUSIONS

Conductance variation by evacuation of high temperature thermal insulation is technically feasible, and can give very attractive cooling characteristics. The results reported here represent good potential performance curves for storage radiators. Engineering and commercial problems need to be resolved before new domestic heating appliances can be expected to incorporate this technique, but more sophisticated applications appear to be promising, particularly in the field of industrial electroheat.

REFERENCE

1. D. J. DICKSON, Evacuated load bearing insulation up to 800°C, ASTM Conference on Thermal Insulation Systems, Philadelphia (16–17 April 1973).