Radiant heaters

Introduction

The comparison of the rates of heating of a black body versus a silvered body can be done with proprietary apparatus, either the Low Voltage Radiant Heater made by Philip Harris (B6H25547, £41. Figure 1), or the Radiant Heat Source by Nicholl Education, which operates at mains voltage and is well insulated. Both heaters get red hot and are suitably guarded against accidental contact. They are both the right products for this experiment and can be recommended.

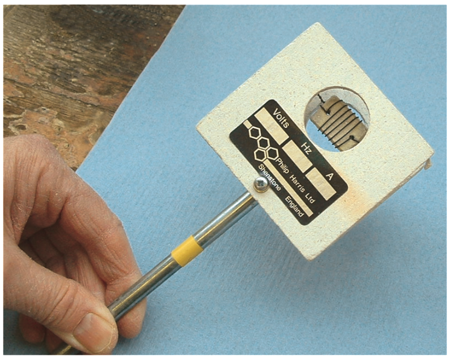

Figure 1 - Harris Radiant Heat Source

But why not get pupils making their own heating elements? That would be more fun, and more instructive. If provided with the apparatus, all that the pupils have to do is watch the temperature creep up. How boring! But if they have learnt how a heater is made, and had the satisfaction of making one, getting it to work and testing it out, then the consequent experiment becomes much more pleasing.

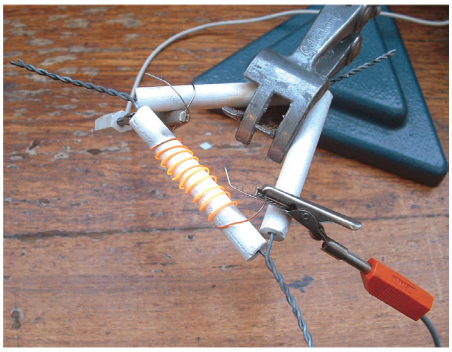

Figure 2 - Nichrome wire winding on pipeclay triangle.

A heater element can be made by wrapping about 25-30 cm of 24 SWG nichrome wire around one rod of a pipeclay triangle. The turns should be tight and neat, but not touching, nor overlapping. There should be about 6 cm extra nichrome wire at both ends of the heating coil to secure by a single turn around an adjacent pipeclay rod (Figure 2) for better mechanical holding. The overall length of nichrome wire needed is about 40 cm, but perhaps no more than 30 cm conducts the current. Contact with flexible copper leads can be made with croc clips. The power supply is 12 V ac, delivering about 7-8 A. The nominal radiant power is 100 W.

The pipeclay orientation can be horizontal (Fig. 2) or vertical (Fig. 3). The latter orientation would let two calorimeters to be irradiated simultaneously.

Figure 3 - DIY Radiant Heat Source mounted vertically between black and silver cans

Experimental notes

Two separate vessels can be heated simultaneously for comparison. Suitable ones are thin-walled aluminium cans with recessed bases. One ready-made set are the Radiation Cans, TD-8570A, from PASCO (Fig. 2) (the set of three are coated black, silver and white, the white is not shown). These have a capacity of 320 ml. Other suitable vessels are 100 ml, used, drinks' cans, such as ones that had held Schweppes' tonic water, painting one matt black and covering the other with aluminium foil.

The setup is shown in Fig. 3. The heating element must be off until the vessels are in place. Each is filled with water, which should be a few degrees cooler than room temperature, the weights being evened by weighing. The uniform separation of 10 mm was achieved by using a 4 mm plug as a spacer (the width of the plastic holder is 10 mm). The element is switched on for a period of 5 minutes with a 100 ml vessel, or 10 minutes for one with a larger capacity. The risk of harm from accidentally touching the hot element is quite low because, with the cans in place, they act as guards. The experiment is reasonably safe.

Results with both sets of cans (Table 1) show the effectiveness of the method.

The method can be criticized in that the silvered flask reflects much of the radiation that is incident on it towards the black flask. On the other hand the black flask emits more black-body radiation than the silvered one and some of its flux will be absorbed by the silvered flask. Therefore the experimental conditions aren't ideal. Heating the cans one by one, while overcoming these errors, introduces another, the continual fluctuation of mains voltage. Because power varies as voltage squared, the radiant output should not be presumed to be constant and can vary by quite a lot. Simultaneous heating overcomes this problem. Another problem is that the water in the canisters cannot be agitated to mix the contents during the heating process for fear of displacing the cans. Therefore the telling temperature is the final one, after the heater has been switched off and the can picked up and shaken.

While the main place for this heat experiment is in Second Year Science, it could also form the subject for an Advanced Higher Physics Investigation. Consider the facts. (The following data is from the black PASCO can and not with the results in Table 1.) By Euclidean geometry, about 15% of the radiant emissions from the heating element falls on the can's surface. In one run with a single, black can, the electrical energy supplied in 10 minutes was 56.0 kJ ± 0.3 kJ. Therefore the energy radiated towards the can was 8.4 ± 0.9 kJ. From the temperature rise, the energy taken in was 8.2 ± 0.7 kJ. The values agree. Virtually all of the radiated energy was absorbed. This was a quick look at the energy changes. There would seem to be scope for much more research for anyone so-minded.

Risk assessment - Because of the risk of fire and burns, the heater must be held in a clamp stand before being energised. This should be set up over a heat-resisting mat, away from the edge of the workbench. There would seem to be no simple way of shielding the element from accidental contact, particularly so when it is being tested during the construction stage. Pupils therefore must be warned not to touch the element, and of the risk of fire. They must be supervised throughout the practical. During the experimental phase, canisters of water on either side act as barriers against accidental contact (Fig. 3).

	100 ml drinks' cans	PASCO Radiation Cans
Capacity (ml)	100 (nominal)	320
Mass of water (g)	160	320
Period heater was on (s)	300	600
Temperature rise (°C)		
Silvered can	0	4
Blackened can	5.5	8

Table 1 - Temperature rises of water in irradiated cans, both cans, black and silvered, irradiated simultaneously.