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Excess Heat Production During Diffusion Of Deuterium Through Palladium Tubes

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ABSTRACT

Following the work by several researchers we have undertaken experiments with deuterium gas flowing through the walls of a palladium tube. Tubes were heated at various temperatures and either filled with palladium powder or palladium compounds or empty. Our mass flow calorimeter enables us to accurately measure excess heat production. We usually used palladium tubes 10 cm long, 2 mm outer diameter with 200 µm thick walls, and closed at one end. Deuterium gas is introduced in the tube at various pressures, and temperatures and diffuses out through the walls of the tube. Thermal energy is determined by measuring inlet and outlet temperatures of cooling water and its mass flow. The energy yield of this calorimeter is 95-98% depending on input power. Our best result so far is an excess heat of 3 W with an input power of 47 W using an oxidized palladium tube filled with palladium powder. In addition to these results we describe an experiment where temperature oscillations have been measured, indicating the importance of temperature in excess heat production.

1. Introduction

Arata and Zhang (1) used a DS-cathode (that is, a “double-structured” cathode; i.e. a hollow palladium cathode filled with palladium nano powder). They show large excess heat production when using heavy water and no excess heat with ordinary water. They also measured production of helium-4 during these runs (2). Recently the same authors have developed an alternative technique to obtain similar results applying high pressure deuterium gas on the outside of a palladium tube filled with palladium nano powder.

Li et al. (3) have also observed excess heat when deuterium gas flows through a palladium foil. In 1989, Fralick et al. (4) reported a similar experiment. They loaded a hydrogen gas purifier with deuterium, and then pumped it out. They observed a temperature rise with deuterium versus no temperature change with hydrogen. However the experiments performed by Arata (2), Li (3) and Fralick (4) are based on temperature measurements, and do not provide accurate calorimetric data.

In a previous paper (5) we described in detail our experiments with deuterium diffusion through the walls of palladium tubes. This paper gives additional results, especially temperature oscillations that indicate the role of temperature on excess heat.

2. Experimental setup

The calorimeter used in this work is described in Fig. 1. In future experiments we have improved the design in order to avoid heat transfer by conduction and convection between the palladium tube and the walls of the calorimeter (5). The vacuum chamber is a stainless steel cylinder 7 cm in diameter and 50 cm long. It is surrounded by a second stainless steel envelope where 30°C de-ionized water circulates at a constant flow rate of 180 ml/min. Inlet and outlet water temperatures are measured with two calibrated thermistors. A palladium tube closed at one end usually 10 cm long and 2 mm in outer diameter is welded on a 6 mm diameter stainless steel rod which is attached to a 6 mm diameter stainless steel tube with a Swagelok® fitting (Fig. 2). A thermocouple is inserted inside the stainless steel rod up to the center of the palladium tube. In the case of powder filling, the thermocouple is at the edge of the tube. Due to heat losses by conduction (through metal parts) and non-uniform heating, the temperature of the palladium tube is not uniform along the tube.

The palladium tube is heated by radiation with a Thermocoax® direct-current resistor wrapped around it. Four stainless steel concentric reflectors are positioned around the resistor in order to minimize heat losses by radiation. Input heat applied to the resistor is dissipated mainly by radiation and is collected by the water cooled envelope. However part of the heat is lost by conduction through the 6 mm stainless steel tube attached to the palladium tube and also through the metal flange which holds the electric feedthroughs and the various pumping tubes.

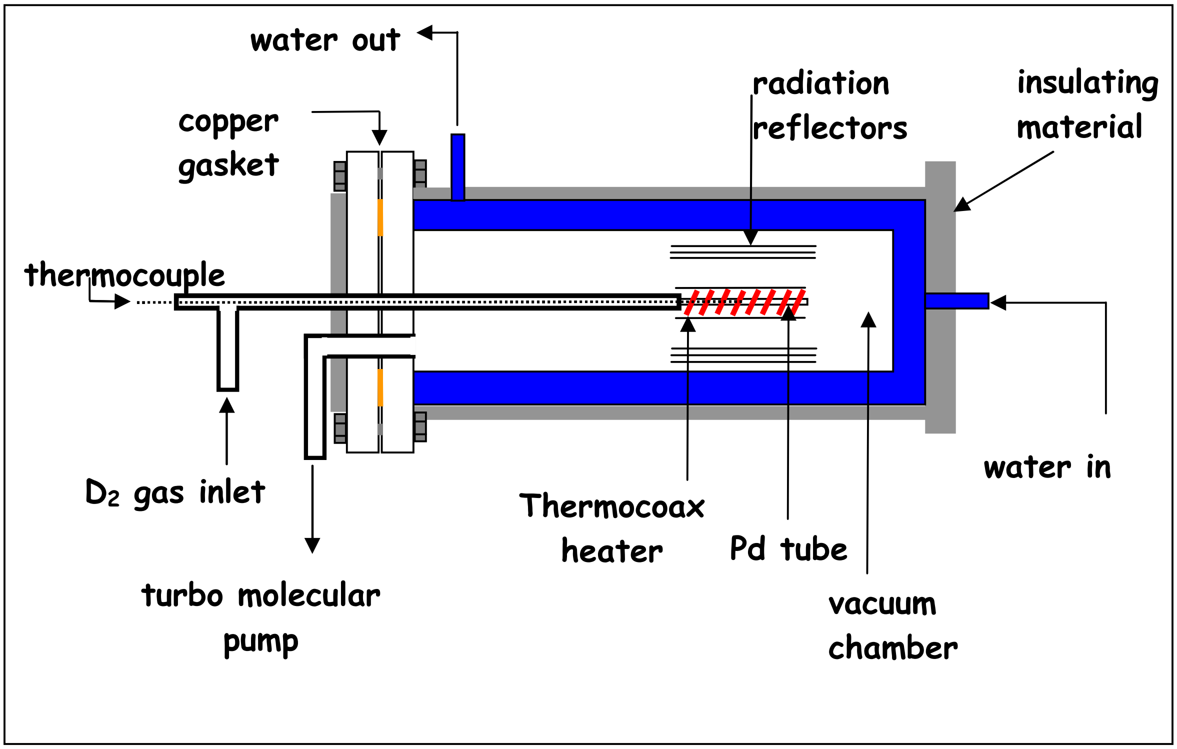

Figure 1. Design of the mass flow calorimeter.

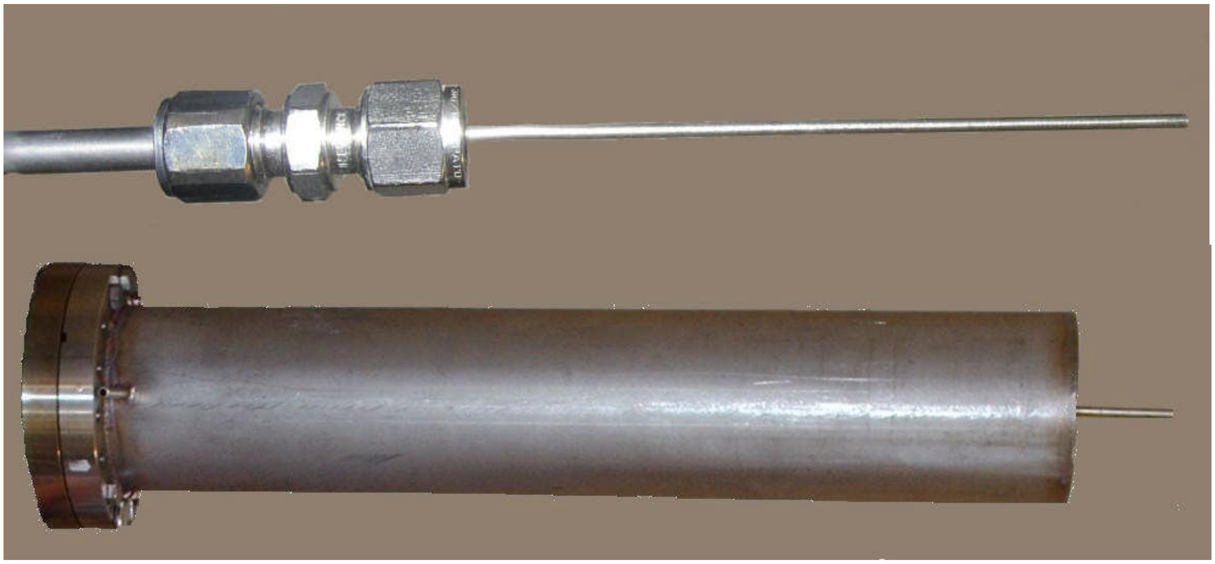

Figure 2. Top: photograph of the palladium tube. Bottom: photograph of the vacuum chamber.

3. Calibration

Input power is measured accurately since the heater is driven by a DC power supply. Output power is measured via the temperature difference given by two thermistors, one at the inlet, and the other one at the outlet. Temperature is measured with precision of +/- 0.01 K. The mass flow rate of the de-ionized cooling water is measured with accuracy better than 1%. As mentioned above, most heat is recovered by the flowing water, and therefore taken into account in determining the output power. However some heat is lost through the large flange of the vacuum chamber which is not cooled by the flowing water. In order to have an accurate value of the losses, we performed a blank run without the palladium tube. We replaced it with an open stainless steel tube. Our calibration shows that a correction of 2 to 5% of the input power must be added to the output power to take into account the heat loss. This value varies with input power: the larger the input power the less correction is needed percentage wise.

However, to avoid having to perform this correction, it is even better to compare the output power with deuterium to the one with the tube under vacuum. No correction is therefore needed; we simply compare the two situations.

4. Experimental results

4.1 Excess heat

Most experiments we have performed so far have been described previously (5). Figure 3 shows excess heat of 1.8 W without any correction, and probably 3 W when corrected for heat loss. The palladium tube was oxidized in air at 500°C for two hours and filled with palladium powder from Goodfellow (80–180 nm). The deuterium pressure was 9 atmospheres; and the temperature measured at the base of the tube was 85°C. More details about this work are described in Ref. 5.

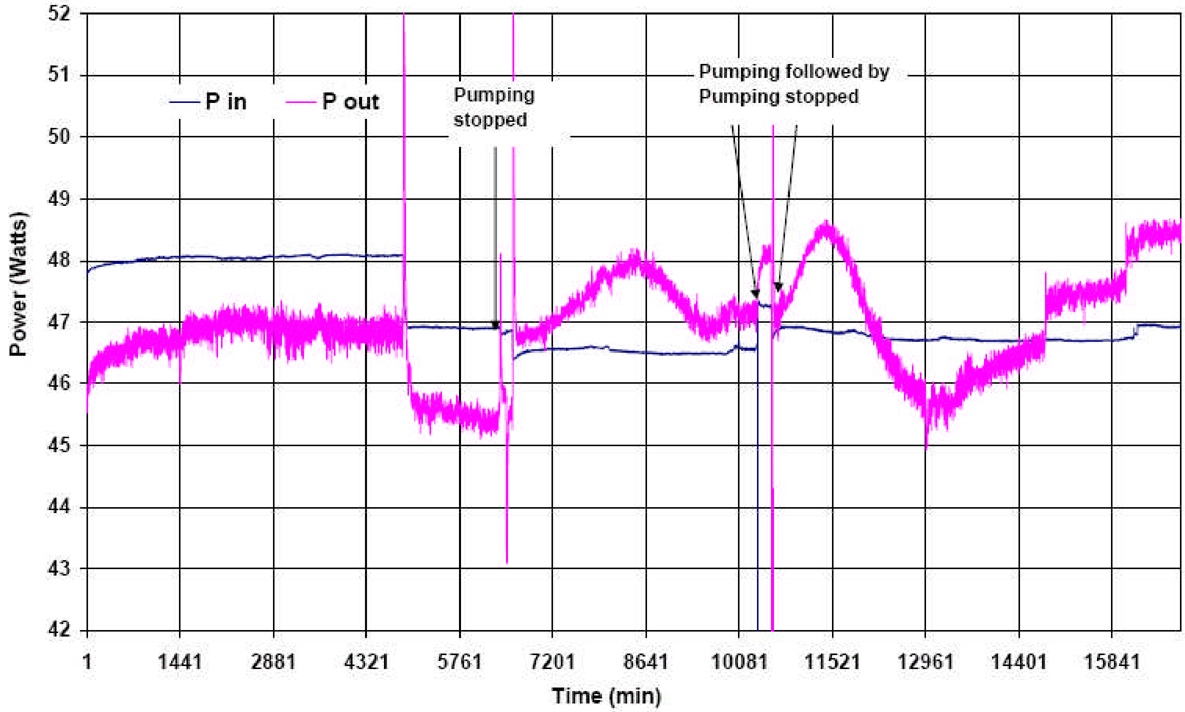

Figure 3. Input and output power during the final phase of the experiment, showing an uncorrected excess heat of 1.7 W.

4.2 Temperature oscillations

In a previous work, we measured the temperature of the palladium tube, while lowering the input power. We observed an anomalous effect of temperature oscillations with a magnitude of 9°C, as shown in Fig. 4. These oscillations do not seem to exist at all temperatures. This is an indication of a role of temperature in the reaction. Unfortunately when these temperature anomalies were recorded, the excess heat could not be measured due to a problem with the water mass flow which was unstable.

Later experiments were performed with palladium powder inside the tube, so that the temperature measured corresponded to the temperature at the Swagelok fitting, and therefore small variations in temperature of the tube were damped by the heat capacity of the stainless steel. So that these temperature oscillations have not been observed again.

Figure 5 shows Scanning Electron Microscopy images of the surface of the tube after the experiment showing the formation of melted area and volcano type.

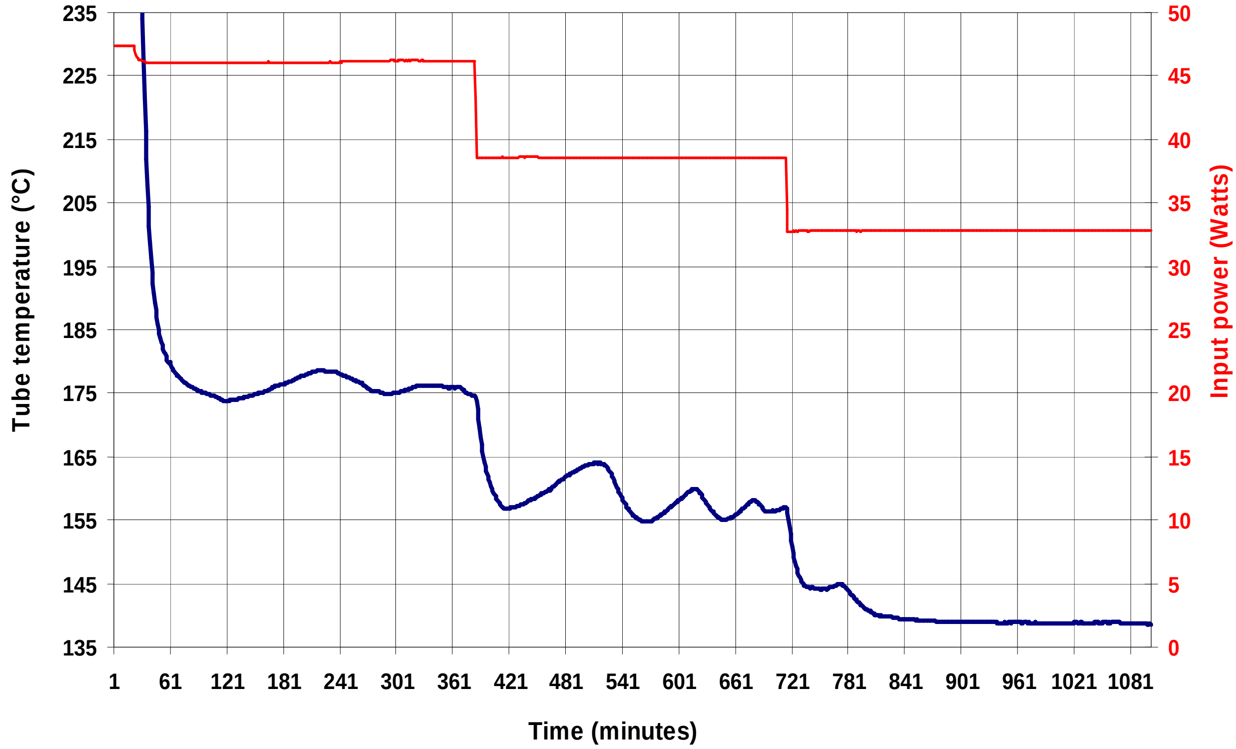

Figure 4. Temperature oscillations of the palladium tube as the input power is decreased by steps.

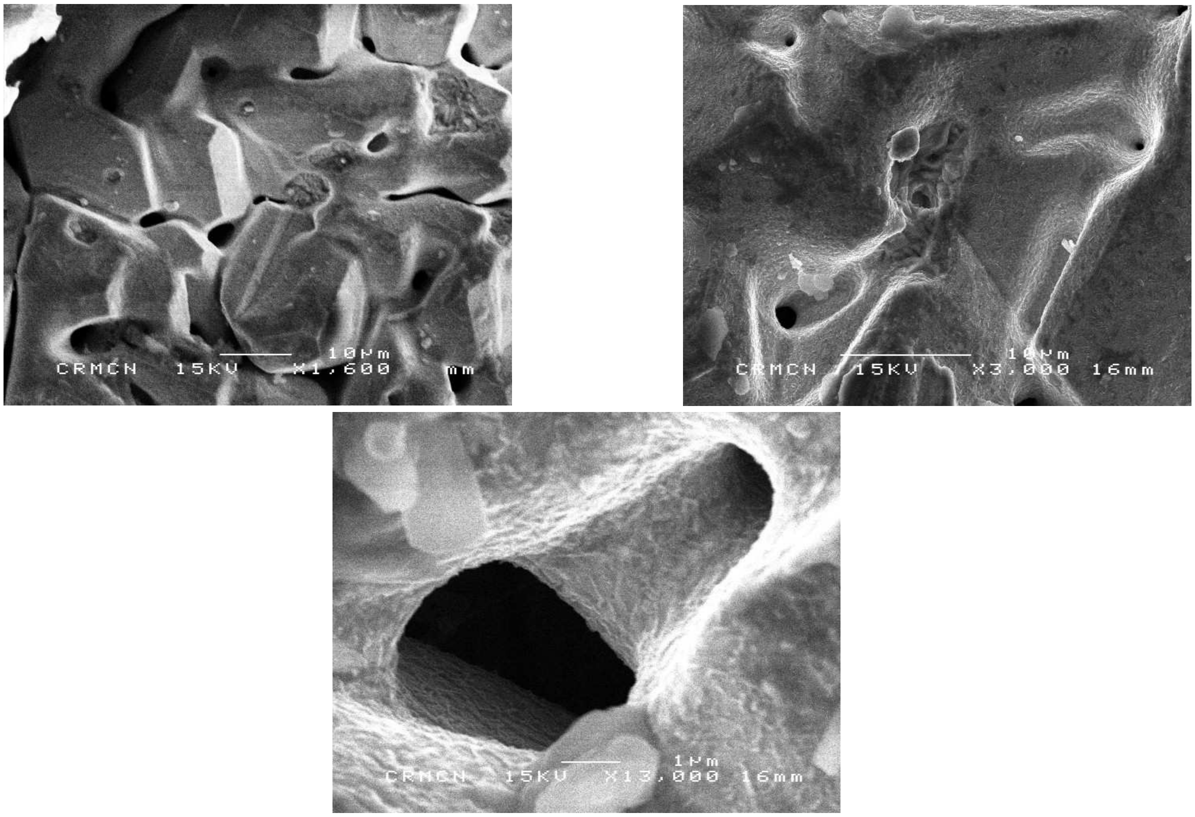

Figure 5. SEM images of the palladium surface.

5. Conclusion

We have shown that anomalous heat effects are produced when deuterium gas under a pressure of 9 atmospheres flows through the walls of a palladium tube. We have measured excess heat up to 3 W when the tube is oxidized in air at 500°C and filled with palladium micro powder. Also we have shown temperature oscillation anomalies when the power input is reduced. These oscillations have an amplitude up to 9°C, and need a theoretical explanation that might be helpful in understanding the actual mechanism of the Fleischmann-Pons effect.

Acknowledgments

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