"Excess heat" in a Gas-Loading D/Pd System with Pumping inside palladium Tube

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ABSTRACT

New equipment was set up to confirm the "excess heat" correlated with the deuterium flux permeating the thin wall of the palladium tubes. The experiment was designed to increase the excess heat and avoid any confusion caused by the reduction of the thermal conductivity of deuterium gas. This set of experiments has been consistent with the selective resonant tunneling theory.

1. Introduction

Gas-loading experiments at Tsinghua Univeristy have been conducted since 1989[1-4], because we believed that only the charged particles were the necessary products of any nuclear reaction. Hence, we did not try to replicate the prevailing electrolysis experiments, and did not attempt to detect neutrons. Instead we detected charged particles. In order to detect charged particles, we had to avoid using electrolyte which might stop the charged particles before they were detected. Hence the gas-loading system was used instead of electrolysis. However, high pressure and low temperature were applied at that time because we believed that the high loading ratio was the necessary condition, and that high pressure and low temperature was favorable to an exothermic loading process. In 1993, a description of the "heat after death" phenomenon was published and it encouraged our gas-loading approach[5]. Moreover, Flanagen and Oates' gas-loading paper[6] showed that gas-loading at low pressure and high temperature would have better reproducibility. In 1995 a gas-loading system at low pressure and high temperature was set up at Tsinghua University[7], which led to the discovery of the "pumping effect." "Pumping effect" means that when we start to pump out the deuterium:

(1) The temperature of a deuterium-loaded long, thin palladium wire increased.

(2) The electrical resistance of the palladium also increased.[8]

This was unexpected, because we thought that de-gassing was an endothermic process, and the resistance of palladium wire was supposed to decrease with de-gassing when the loading ratio was less than 1 [9]. This pumping effect was robust and reproducible. In order to confirm the excess heat was released by the pumping effect, a precise calorimeter was applied to measure this excess heat. This calorimeter was based on the

Seebeck effect, and was independent of the temperature distribution along the palladium surface. The precise calorimeter confirmed not only the excess heat, but also revealed the correlation between deuterium flux and the excess heat[10]. Moreover, the excess heat appeared while the D/Pd system was cooling down as theory predicted[11]; and the peak of the excess heat appeared in the temperature range of 140°C to 150°C. Therefore a self-sutaining excess heat system was proposed[12]. When this pumping effect was repeated in different laboratories in different countries[13,14], a question about the thermal conductivity was raised in two studies. This paper presents the preliminary results from a technique intended to eleminate the effect of thermal conductivity from the pumping inside the palladium tube.

2. Apparatus

Based on our previous experiments [10], we designed the apparatus as an enlarged gas-loading D/Pd system. With our previous C-80D calorimeter, we recorded 2 mW excess heat in a palladium tube of 2.6 cm length. In this new apparatus, 5 palladium tubes were used with length of 20 cm each in order to enhance the effect of excess heat. These palladium tubes were blocked at one end, and were connected to a manifold for pumping or feeding the gas (see Figure 1). 5 Pt-100 thermistors (#1 to #5) were attached on the palladium tube to record the temperature distribution along the palladium tube. This bunch of palladium tubes were sealed in a stainless steel vessel. The electrical heater winding on the surface of the stainless steel vessel can heat the palladium tubes to about 200°C. 5 Pt-thermistors (#6 to #10) were attached to the surface of the stainless steel vessel to record its temperature distribution also. An AC power supply with precise heating power was applied on this electrical heater. Two pressure gauges were used to record the pressure inside the palladium tube and pressure outside the palladium tube. Because of the limit in range, the pressure gauge read 13 kPa when the pressure inside the palladium tube was higher than 1 atmosphere, and another pressure gauge read 300 Pa when the pressure outside the palladium tube was higher than 300 Pa. However, they showed the time correctly when we started pumping inside or outside the palladium tubes. The whole stainless steel vessel and heater were enclosed by thermal insulation to reduce heating power.

3. Experimental Results

The experiments were conducted to confirm the pumping effect, i.e. excess heat correlated with the deuterium flux. We knew that the pumping would reduce the thermal conductivity of the D_2 gas; however, we might control the effect of the thermal conductivity of the D_2 gas, and show clearly the excess heat correlated with the deuterium flux permeating the thin wall of the palladium tubes.

Figure 2 shows the results of one of our experiments. The air was pumped out first from the stainless steel vessel and from the palladium tubes. Then, D_2 gas was fed into the stainless steel vessel and the palladium tubes. The pressure inside the palladium tubes was about 80 kPa. The pressure outside the palladium tubes was higher than 300 Pa; hence, it was beyond the range of that gauge. When we started electrical heating power, the pressure inside the palladium tubes increased with the temperature and was quickly out of the range of the gauge (130 kPa) also. The heating power was kept at about 80 W. After 6 hours the temperatures of the system reached a steady state (138°C to 178°C for #1 to #5). Near 28000 seconds, we started pumping inside the palladium tubes. The pressure inside the palladium tubes dropped quickly down, and a pressure gradient across the thin wall of the palladium tubes was established. A deuterium flux permeating the thin wall of hot palladium tubes was generated by this gradient, and this deuterium flux was correlated with a temperature rising in all 5 thermistors on the palladium tube. The maximum temperature rise was about 6°C. This experiment has been repeated three times, and the excess heat correlated with deuterium flux was confirmed again in this scaled-up system.

4. Discussion

There are some frequently asked questions related to the thermal conductivity of the deuterium gas:

(1) Some might wonder if the thermal conductivity of the deuterium gas was reduced by the pumping. If so, the palladium tubes were better insulated from the environment such that the temperature of the palladium tubes increased with the same heating power. However, if we look at the path of heat transfer (Fig. 3), we will understand this is not the case. Figure 3 shows the location of these thermistors and their temperatures before or after pumping. It is evident that the palladium tubes were enclosed by a hot deuterium gas and the radiation from the stainless steel vessel. The only path to transfer heat from the palladium tubes to the environment was the thermal conduction of the palladium tubes and the metal leads connected on the thermistors. In comparison with the conductivity of these metal parts, the thermal conduction of the deuterium gas inside the palladium tubes was negligible. Hence, when we started the pumping, the heat transfer from the palladium tubes to the environment did not change substantially. Indeed the heat transfer from the stainless steel wall to the palladium tubes might be reduced by pumping, because the thermal conduction of deuterium gas outside the palladium tubes was comparable with the net thermal radiation from the stainless steel wall to the tubes. Consequently, we were supposed to observe a temperature decrease when the pumping was started. In reality we observed the temperature rising instead of decreasing. The temperature rise of the

palladium tubes was good evidence of a heat source in the palladium tube.

(2) To support this argument, we might look at the temperature of the stainless steel vessel (thermistors #6 to #10). If heat transfer from the stainless steel wall to the palladium tubes reduced by pumping, then, the temperature of the stainless steel vessel should increase when the pumping was started. This is true (Fig. 2, second row).

(3) According to the thermal kinetics of molecules, the thermal conductivity of the gas does not change until the mean free path of the molecules is comparable with the scale of the temperature gradient. In the present case, the distance between the stainless steel wall and the palladium tubes is about 1.5 cm; hence, the thermal conductivity of the deuterium gas does not change until its pressure drops down to less than 10^2 Pa. The third row in Fig. 2 (right ordinate, dotted line) shows that the pressure outside the palladium tubes dropped down only to about 150 Pa after pumping; hence, we do not expect a big change in thermal conductivity of deuterium gas. The temperature rise of thermistors #1 to #10 is mainly due to the excess heat from the palladium tubes which was related to the deuterium flux.

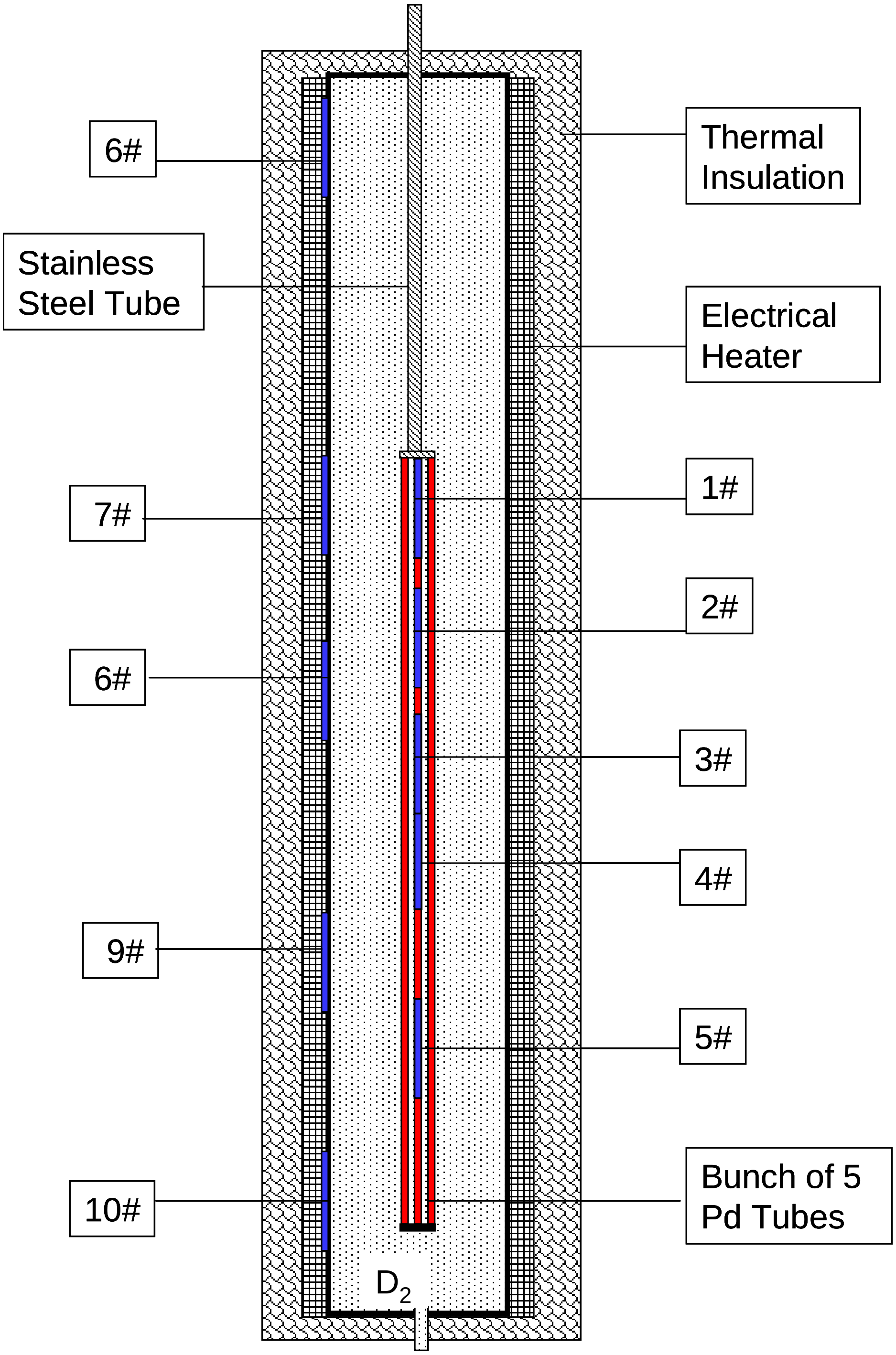

Figure 1. Schematic of the improved D/Pd system

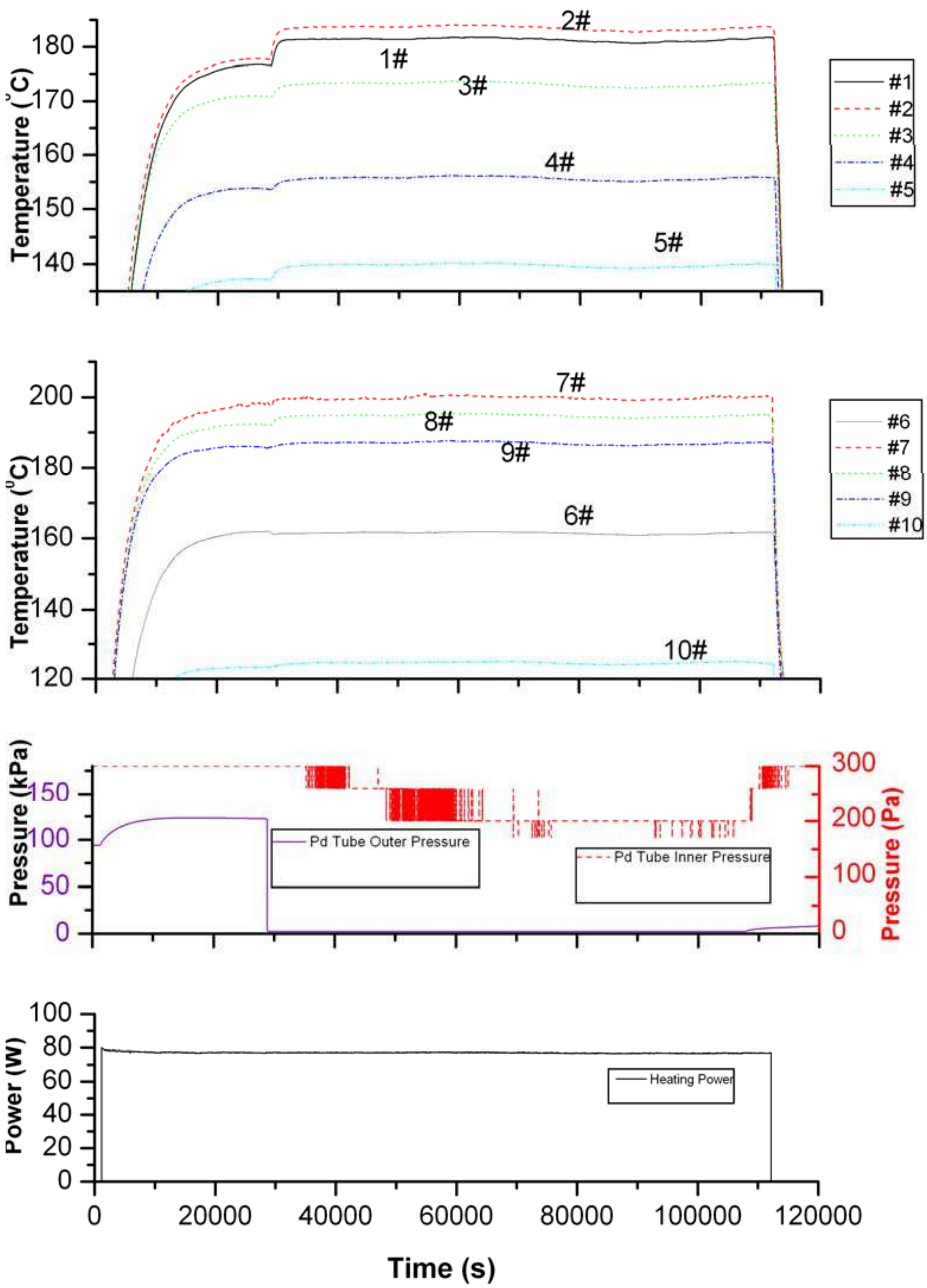

Figure 2. Pumping inside the palladium tubes. Row 1: Temperature of palladium Tubes; Row 2: Temperature of stainless steel vessel; Row 3: Pressure inside the palladium tubes (left) and outside the palladium tubes (right); Row 4: Electrical heating power.

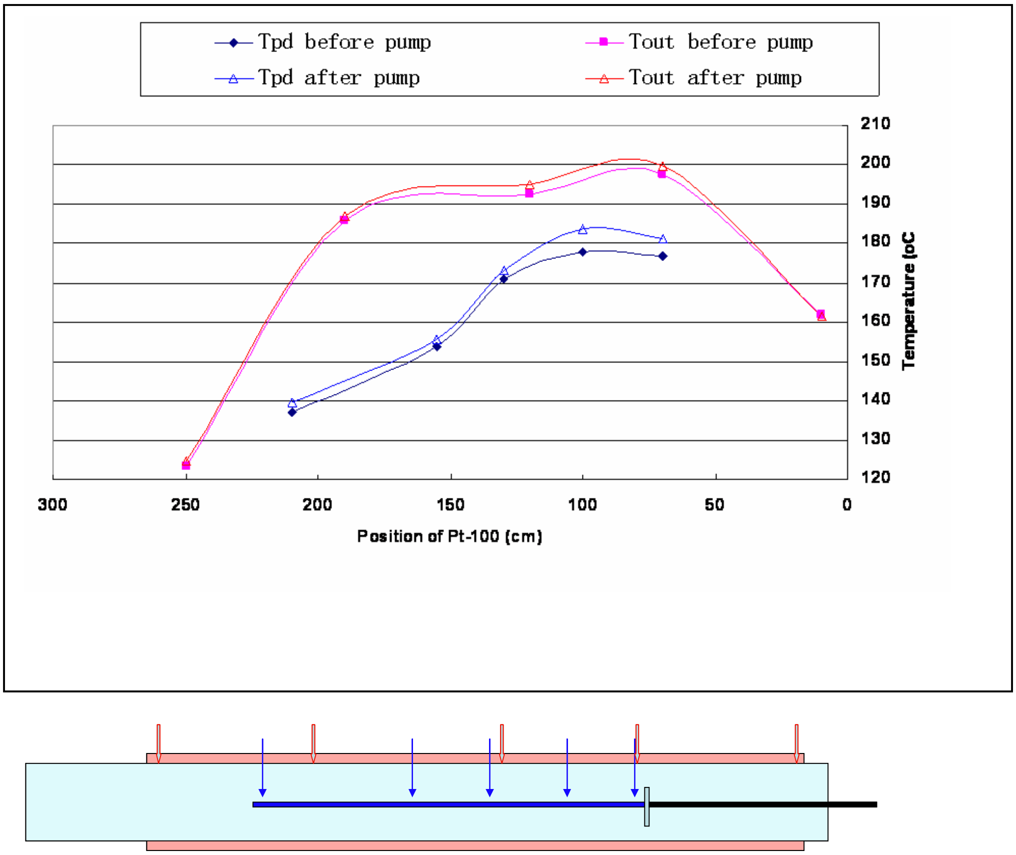

Figure 3. The locations of 5 thermistors on the palladium tube (#1-#5 arrows with single line) and 5 thermistors on the surface of stainless steel chamber (#6-#10 arrows with double line).

How much was the excess power during pumping inside the palladium tube? We are able to make a semi-quantitative estimate. The excess power should be of the same order of magnitude as that of other channels of heat transfer; otherwise the pumping should not cause any detectable change in temperature. In the previous section we discussed mainly the thermal conductivity between the stainless steel chamber and the palladium tubes. There are, of course, other heat loss paths including thermal radiation, thermal convection of deuterium gas, conduction of the palladium tube, conduction of the deuterium gas inside the palladium tube, and conduction of metal leads which connected the Pt-100 thermometers to the interface between vacuum and atmosphere. Estimates showed that the major channel for heat transfer was the 10 copper leads (this was several watts). The second largest heat transfer channel was the thermal radiation between the stainless steel chamber and the palladium tube (also several watts). The heat transfer through the palladium tube was ~100 mW, because its thickness was only 30 μm. The heat transfer through the deuterium gas inside the palladium tube is of the same order of magnitude. Consequently the excess power should be on the order of 100 mW. This is reasonable. When we used a precision calorimeter (C-80D) the excess power correlated with deuterium flux was 2 mW with a palladium tube 26 mm long (ϕ 4 mm × 100 μm)[10]. In the present experiment, we have 5 palladium tubes. Each tube is 20 cm long (ϕ 3 mm × 30 μm). Hence, the scaling up by a factor of 50 is reasonable. A calibration heater will soon be installed in the palladium tube to confirm this estimate.

The selective resonant tunneling theory predicts that a deuterium flux is necessary to keep a steady state of resonant tunneling in order to generate detectable excess heat[16]. This set of experiments has been consistent with the selective resonant tunneling theory.

Acknowledgements

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