Report on Arata's Paper and Lecture about his "Solid Fusion" Reactor

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LENR-CANR.org
July 11, 2008

Abstract

This paper describes the recent demonstration (May 2008) of anomalous heat and helium production, presented by Prof. Yoshiaki Arata, when two different materials are exposed to D_2 near room temperature.

Introduction

On May 22, 2008, in celebration of his 85th birthday, Yoshiaki Arata of Osaka National University gave a lecture and public demonstration of his latest cold fusion device, and he distributed a paper in Japanese, [1] a partial translation of the paper into English, [2] and a book describing it. [3] Documents in Japanese were translated by one of the authors (JR).

The method described by Prof. Arata consists of exposing unique powders made from a mixture of Pd and ZrO_2 or an alloy of Zr+Ni+Pd to pressurized D_2 gas at or near room temperature. Anomalous heat and helium are said to result. This method was described previously using finely powdered Pd metal and produced the same result. [4-16] The previous work was replicated at SRI [17]. The present work has not yet been replicated.

This work shows that two more materials, in addition to palladium-black, are able to generate anomalous energy and helium when they are exposed to D_2, but not to H_2. Like palladium-black, these materials react quickly with hydrogen isotopes and start producing anomalous power once the chemical reaction has reached completion. This happens more quickly than it did with Arata's previous design, the double-structured cathode, because the gas does not have to diffuse through the outer shell of the double-structured cathode.

Experimental Procedure

A schematic of the experimental device is shown in Fig. 1. From left to right, it consists of: a tank of high pressure, highly purified deuterium or hydrogen gas; a controller for the valves; vacuum pump; and the cell (reactor) that is a high vacuum stainless steel vessel with a sample of finely divided ZrO_2-Pd material at the bottom. Two thermocouples are used; T_{in} which measures the inside temperature at the location of the sample, and Ts, which measures the outside surface temperature of the cell under the insulation. Not shown is a QMS mass spectroscope, used to measure helium in the cell gas.

Photographs of the experiment (such as Fig. 2) and the video of the demonstration show that the cell is insulated. This is not shown in Fig. 1, and it is not mentioned in the paper. Consequently, we presume the photograph in Fig. 2 and the drawing in Fig. 1 describe the same apparatus.

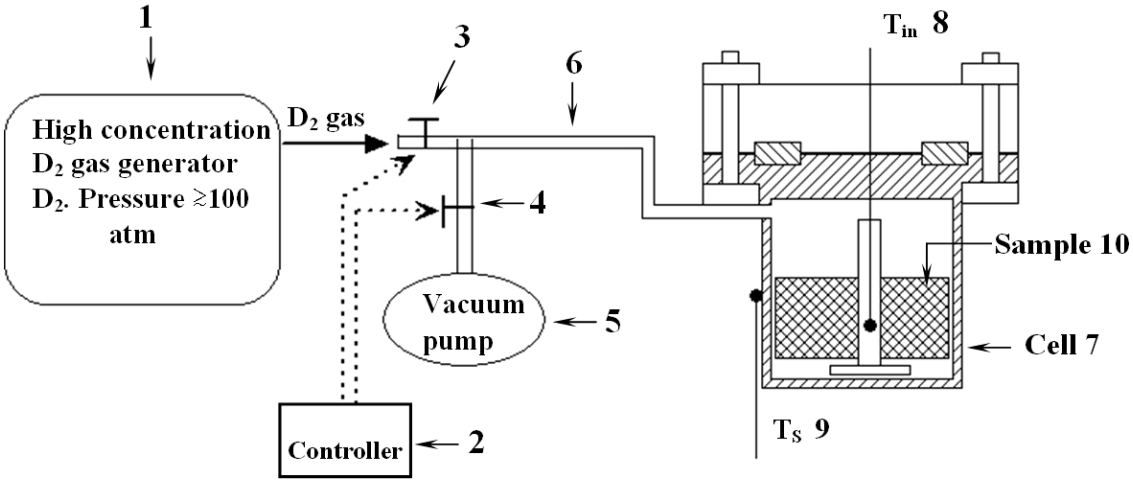

FIGURE 1. A simplified drawing of the apparatus: 1. High concentration gas generator; 2. Controller; 3, 4. Valves; 4. Vacuum pump; 6. Gas feedline; 7. Cell; 8. T_{in} (inside) thermocouple; 9. T_s (surface) thermocouple; 10. Sample. The cell is not drawn to scale. From Arata and Zhang, [2].

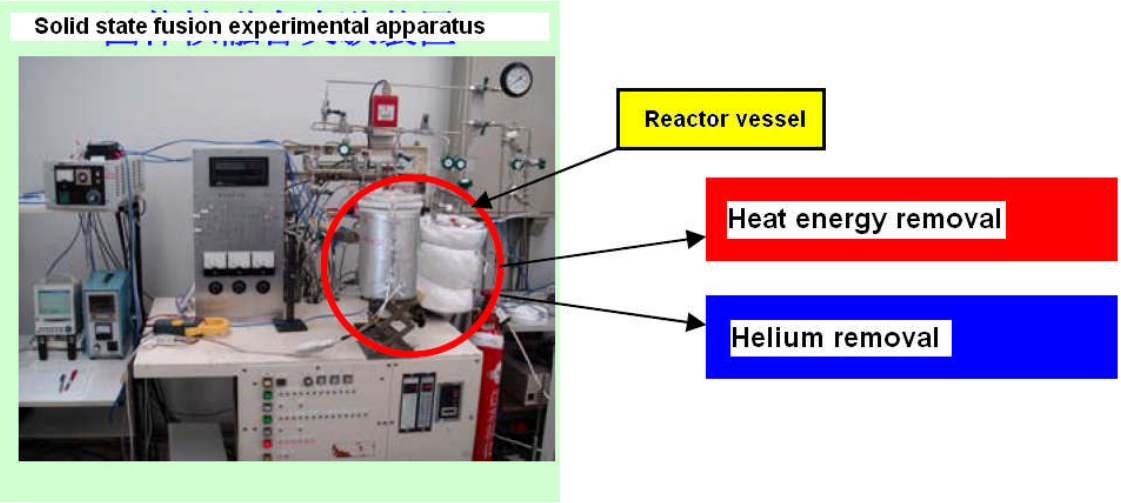

FIGURE 2. Photo of experimental device, from announcement for the May 22, 2008 lecture distributed by A. Kobyashi.

Two kinds of samples were used: a mixture of ZrO_2+Pd, or an alloy composed of Zr+Ni+Pd, both in powdered form. Preparation of the ZrO_2+Pd material is described by Yamaura et al. [18]. The powder was heated under vacuum in the cell before D_2 gas was added in order to remove impurities. The D_2 gas was prepurified before entering the cell by diffusion through palladium. According to Arata, this step is important to remove helium. However, the purity was not stated.

Tests using D_2 and H_2

Sequential exposure to D_2 and H_2 were used to show anomalous behavior when D_2 was used.

Figure 3 shows the behavior when a 7 g sample of ZrO_2-Pd was exposed to hydrogen. The sample was initially heated under vacuum and allowed to cool to 24°C, as noted by the dashed line. At an arbitrary time starting at 50 min on the graph, H_2 was slowly allowed to enter the cell. This gas reacted with the Pd in the sample, causing the temperature of the sample to increase, as shown by the green line. At the same time, the temperature located at the outside surface of the container increased. This reaction also fixed the pressure in the cell at a small value that is too small to be seen on the graph. After about 20 min, the sample had completely reacted with the H_2, thereby allowing the pressure to rise and the temperature to decrease as heat production stopped. After about 100 min, the sample and wall temperatures were identical, as expected. The temperature of the apparatus slowly approached the initial temperature, which is occasionally noted as room temperature. This study provides an example of how the system is expected to behave when no anomalous energy is produced.

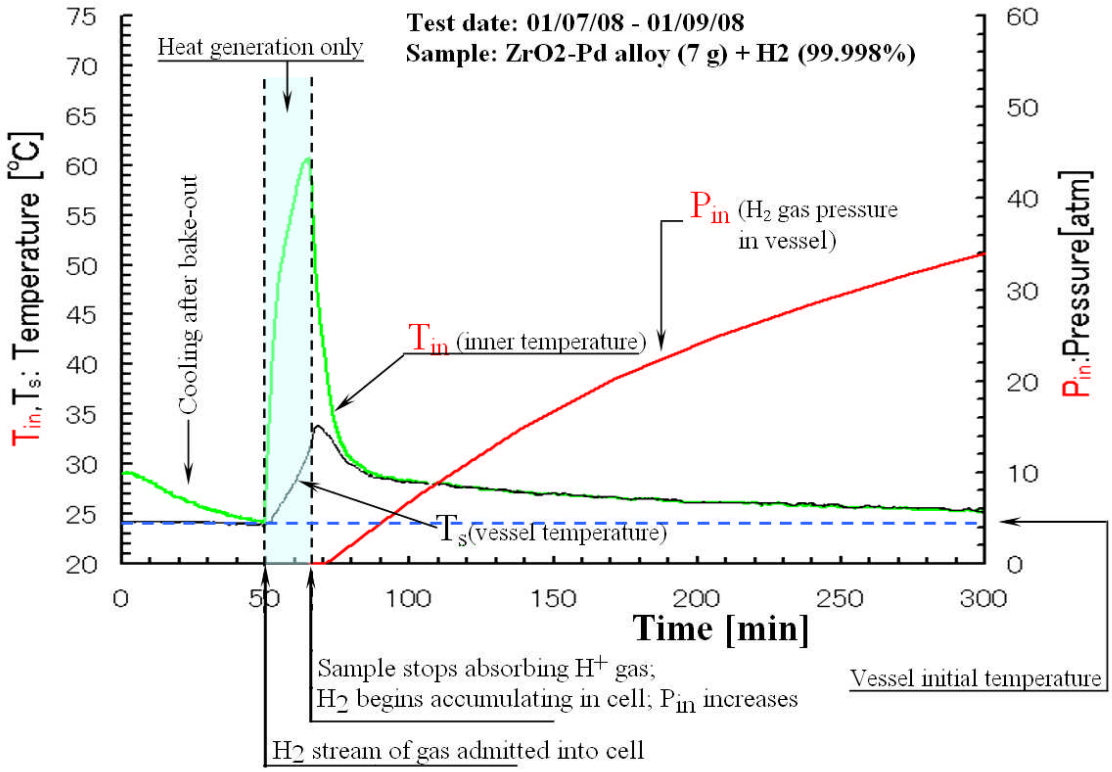

FIGURE 3. Example of behavior produced by exposing ZrO_2-Pd to hydrogen. From Arata and Zhang, [2], with figure labels edited by J. Rothwell

A study using D_2 gas is shown in Fig. 4. As was seen when H_2 was used, the temperature started to increased when D_2 was added to the cell at 50 min. The chemical reaction lasted for about 20 min, similar to the behavior when H_2 was used, but the maximum temperature was greater. This greater temperature is unexpected because formation of beta-PdD (ΔH=-15.7 kJ/mole $PdD_{0.7}$) is less energetic than the formation of beta-PdH (ΔH=-18.4 kJ/mole $PdH_{0.7}$) [19]. This behavior shows that heat loss from this sample was not identical to that when H_2 was used. Nevertheless, the temperatures of the sample and wall decreased as occurred during the H_2 study, but unlike the H_2 study, the two temperatures never became identical. In addition, the temperature of the apparatus did not drop to the initial temperature as was observed when H_2 was

used. In other words, extra energy was apparently being generated within the sample that lasted for at least 3000 min, as will be described below. Arata designates the time chemical energy is being produced as the "Jet-Fusion" phase and the time during which nuclear energy is produced as the "Skirt-Fusion" phase. He states that the chemical energy amounted to 4 kJ and the nuclear energy reached 200 kJ. However, based on the known enthalpy of formation of beta-$PdD_{0.7}$ from the Pd in the Pd+ZrO_2 mixture, the total energy is expected to be near 0.4 kJ. This discrepancy combined with the primitive nature of the calorimetry makes the claimed amount of nuclear heat highly unlikely. Insufficient information is provided to make a more accurate determination possible. Efforts to obtain additional information from Prof. Arata about the method of calibration have remained unsuccessful (July 2008).

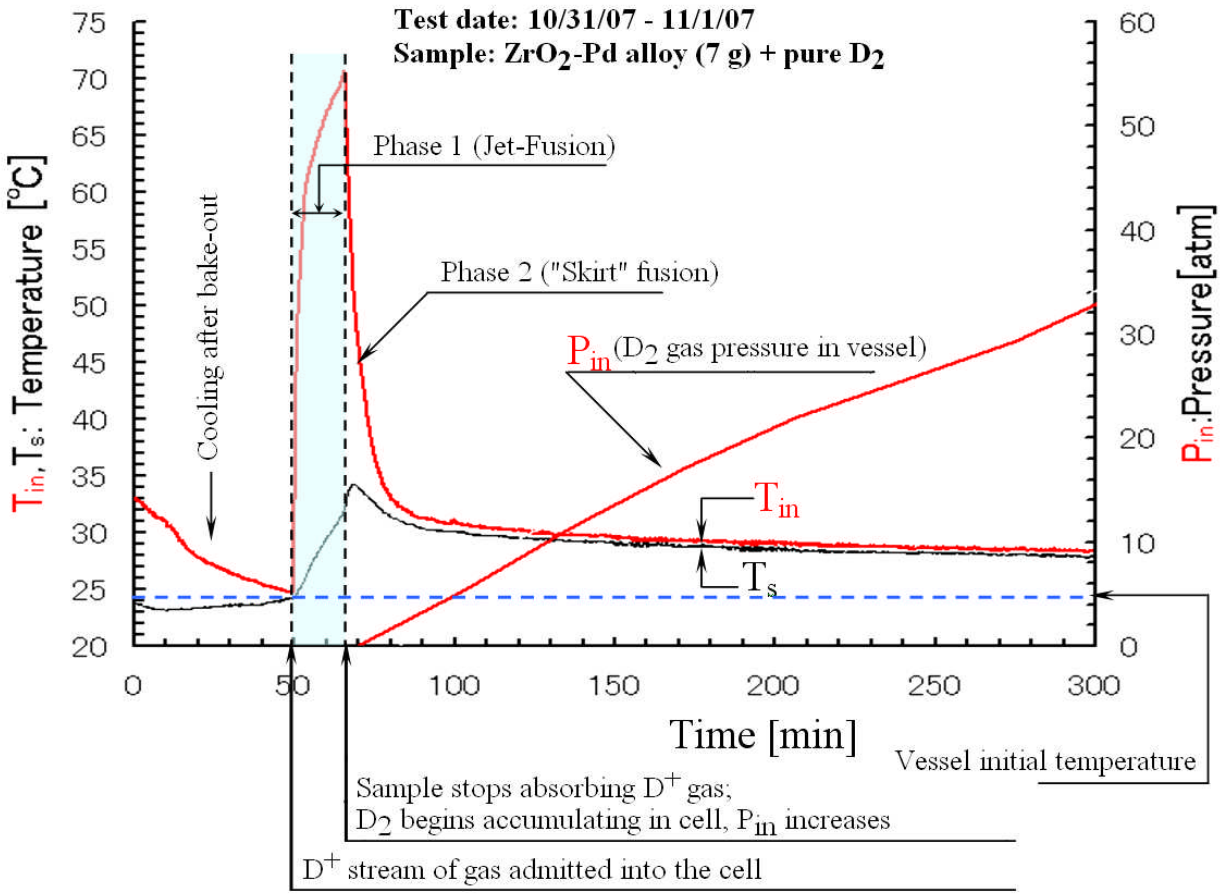

FIGURE 4. Example of behavior when ZrO_2+Pd is exposed to D_2. From Arata and Zhang [2], with figure labels edited by J. Rothwell

In addition to the ZrO_2+Pd sample, 18.4 g of a Pd+Zr+Ni alloy was also subjected to the same treatment in D_2. The behavior is shown in Fig. 5. In this case, the chemical reaction lasted for a longer time and produced a smaller temperature increase. This behavior indicates a much slower reaction rate compared to ZrO_2+Pd. During this longer time, the wall temperature increased and neatly equaled the sample temperature when the sample stopped reacting with the gas. After this source of chemical heat stopped, the sample and cell cooled, but a small temperature difference remained between the two temperatures, similar to the behavior of ZrO_2-Pd.

This persistent temperature difference between the sample, the cell wall, and the reference temperature can be seen clearly in Fig. 6. The amount of anomalous power being produced is apparently greater for the ZrO_2-Pd compared to the Zr+Pd+Ni sample.

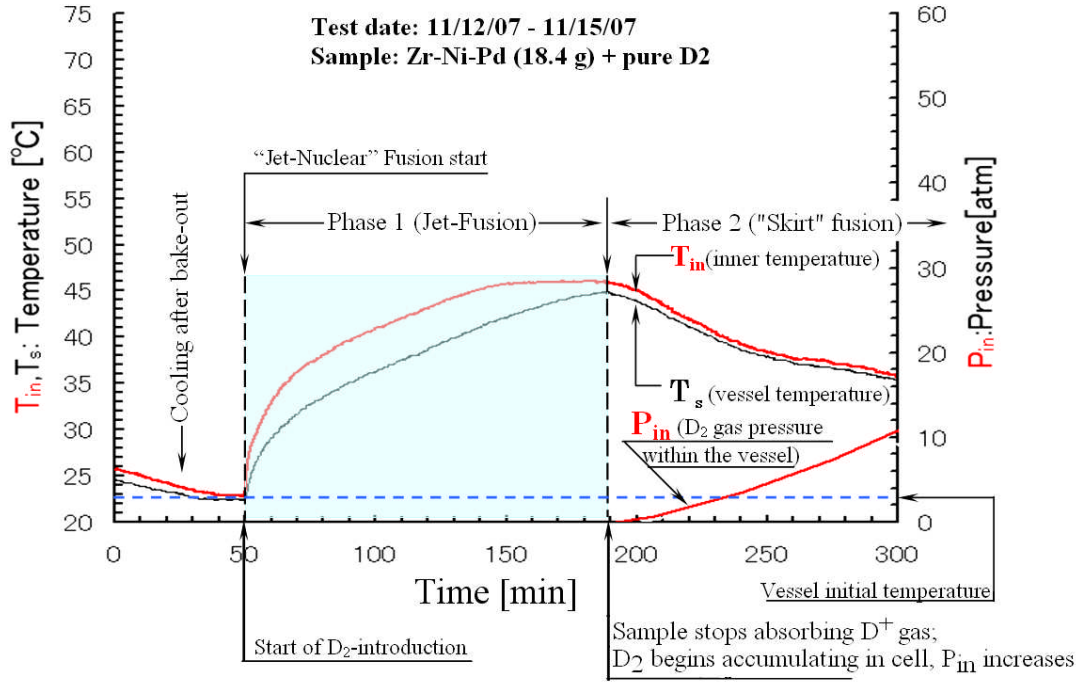

FIGURE 5. Behavior of a Zr+Pd+Ni sample exposed to D_2. From Arata and Zhang [2], with figure labels edited by J. Rothwell

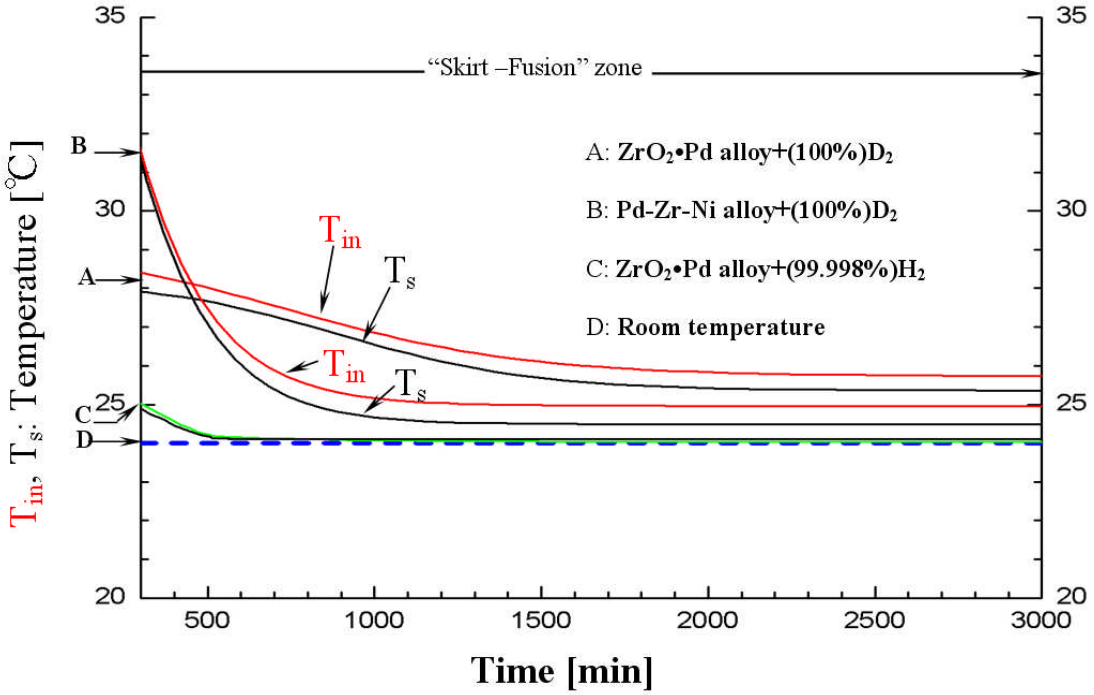

FIGURE 6. Behavior of the temperatures over a long time duration. From Arata and Zhang [2]

A blank run with no sample and deuterium gas is shown in Fig. 7. As expected, no heat was produced and the pressure increased immediately when gas was allowed to enter the cell.

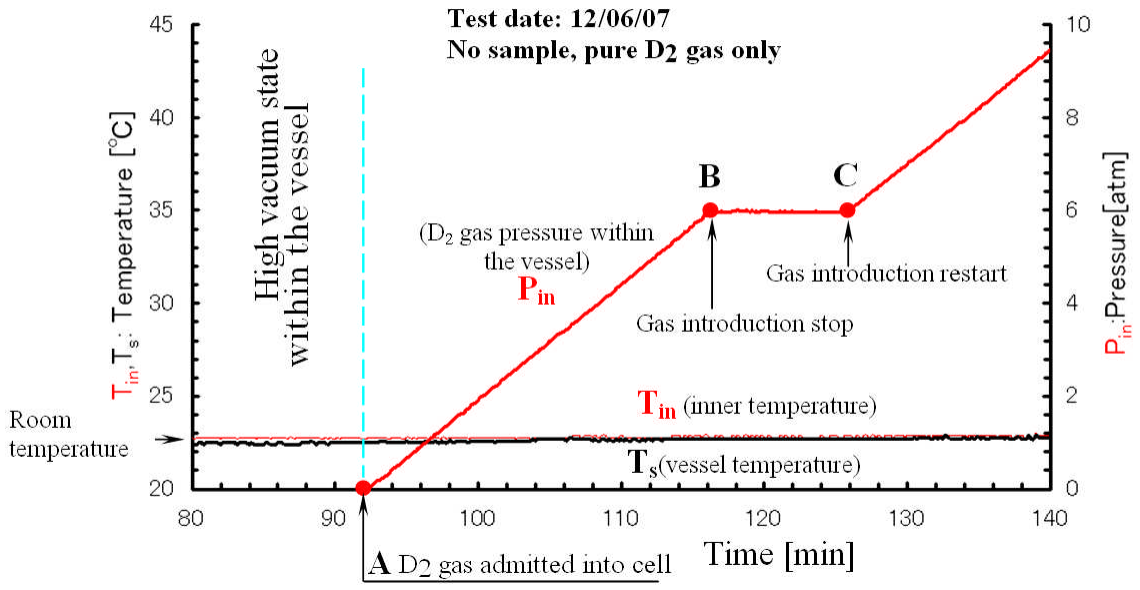

FIGURE 7. Blank run with D_2 gas only. No sample present.

Helium Production

Helium is claimed to be generated in the sample and gas. Unfortunately, this measurement is not described in either the English or Japanese versions of the paper. Based on a graph provided in the papers (Fig. 8), the data appear to be too rudimentary to support the any conclusion. The description notes only that most of the gas is trapped in the sample, and that high temperatures (more than "several hundred degrees") are needed to release it. The method used to achieve this release is not described. Arata believes that the helium in the gas comes from reactions occurring near the surface. He calculated the ratio of energy to helium and reported 24 MeV/atom of helium. The data on which this calculation is based is not provided and the method of energy measurement is too crude to allow such a value to be supported. At most, the data provided show only that some helium was in the gas and in the sample. Its source is unknown.

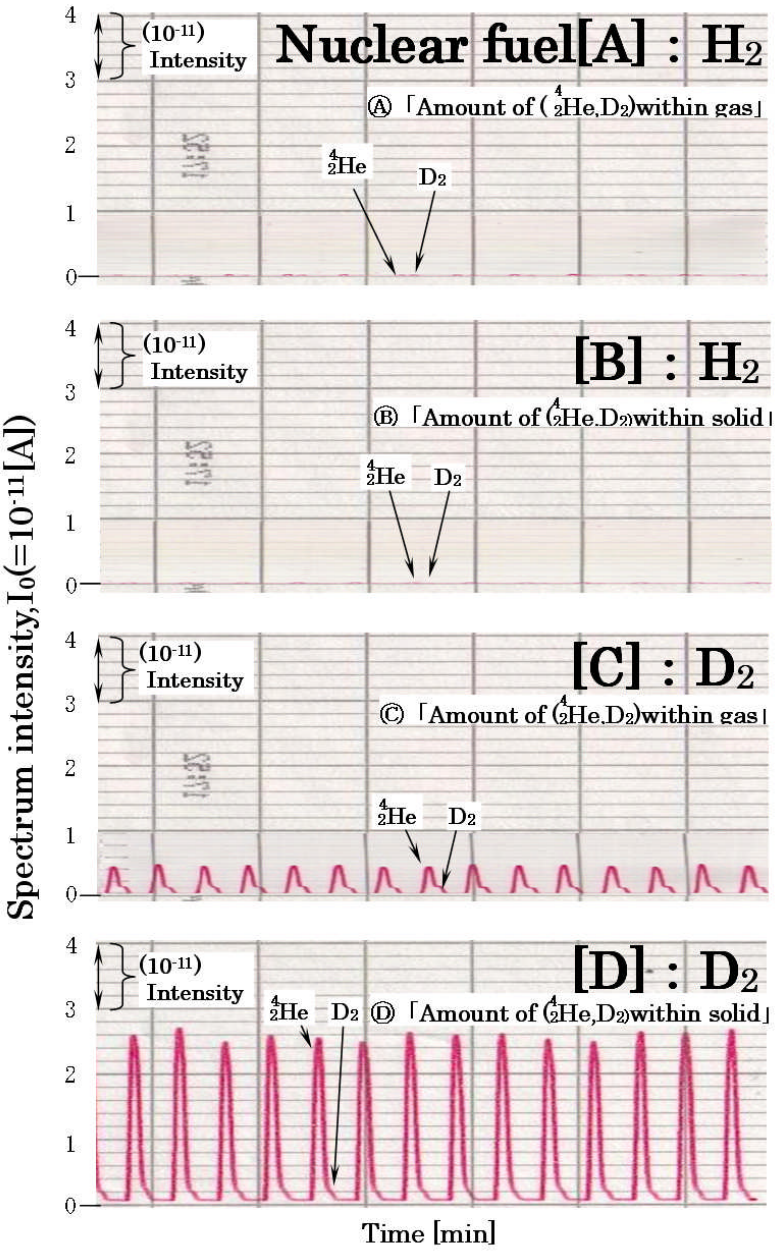

FIGURE 8. QMS mass spectroscope data for: A. test with H_2, helium-4 found in gas; B. test with H_2 helium-4 found in powder; C. test with D_2, helium-4 found in gas; D. test with D_2, helium-4 found in powder. From Arata and Zhang [2].

Discussion

Although the behavior of the temperature difference between the sample and the cell over an extended time indicates that extra power is being produced, insufficient information is given to determine the amount of this heating power. The absence of a described calibration greatly reduces the value of this work. In addition, the temporal shape of the curves indicate that conditions within the cell were not the same between the several studies. In order to accept the

conclusions made by Arata, we are required to accept the temperature measurements as being accurate and that the reference temperature remained constant. (The reference temperature is the "vessel initial temperature" in some graphs and "room temperature" in others.) Without a knowledge of the cell volume and the rate D_2 was added to the cell, the reaction rate between the sample and the gas cannot be calculated. This omission prevents the calculation of even an approximate heat production rate.

The claim for helium production rests on even shaker ground. Without a description of the method used for calibration and detection, quantitative values cannot be evaluated.

The claimed amount of generated nuclear energy does not appear to be correct based on the known chemical energy detected in the study. Clearly, many questions remain before this work can be fully understood. Because previous work using the same method, but using palladium black as the sample, gave well documented and replicated heat and helium, this work should be given the benefit of the doubt. Hopefully, more information will be provided by Prof. Arata and these claims will replicated soon.

Postscript, January 2010

In June 2009, Kitamura *et al.* published a replication of Arata's experiment with improved calorimetry and another type of ZrO_2-Pd material. [20] At ICCF15, Arata reported on an improved version of the experiment, with better calorimetry, different types of calorimeters, and a new cell design that allows the gas to reach the powder more readily. [21] Also at ICCF15, Kidwell *et al.* reported a replication with a high precision microcalorimeter. The experiment was repeated hundreds of times successfully. [22]

So, the basic claims of excess heat have been supported in several studies. The problems about calorimetry raised in this paper have largely been addressed. However, concerns about mass spectroscopy have not been addressed yet, so the source of the energy is still unclear.

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