Anomalous heat production in hydrogen-loaded metals: Possible nuclear reactions occurring at normal temperature

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This paper reports results of anomalous heat generation in hydrogen-loaded metals at a temperature below 1300°C. The heat was produced in the fuel sample (mixture of nickel powder and $LiAlH_4$), which was added to a nickel cell, and then the cell was placed in a sealed stainless-steel chamber. Results of two runs are demonstrated. Excess heat lasted for seven days in the first run. The first run maximum excess heat power was greater than 450W and the excess heat energy was evaluated to be 78 MJ for the first 72 hours. In the second run, excess heat lasted for 120 minutes after external heating was turned off, and the maximum excess heat power was 450W. The self-sustaining effect can be observed clearly when power was off in the second run. The maximum heat energy from possible chemical reaction was estimated to be 26 kJ, a value much smaller than the excess heat energy. Therefore, excess heat could not originate from any chemical reactions and it might originate from a nuclear reactions.

Keywords: Excess heat, Ni-H heat generation, Low energy nuclear reaction.

1. Introduction

Over the past 20 years, much has been published about cold fusion, commonly known as Low-Energy Nuclear Reactions (LENR) [1-7]; however, due to poor experimental reproducibility, and the lack of an accepted theory to explain cold fusion, it is a controversial subject. In recent years Andrea Rossi (Rossi) announced that he invented a device, which contains nickel and other "catalysts" at 1400°C or lower may produce a lot of heat. This heat is claimed not to be generated by a chemical reaction, but may come from a nuclear reaction; however, the reaction mechanism is unclear. Each of the Rossi's heat generating devices, called the Rossi E-Cats, can produce heat of about 10 kW. Together, his 100 unit array constitutes a 1 MW reactor, assembled in the size of a export cargo container [8-9]. Compared to conventional nuclear reactors, the E-Cat does not produce harmful radiation, its fuel mainly nickel and hydrogen which are both plentiful on Earth, and available at low cost. However, Rossi has kept the E-Cat's core components confidential, such as the added catalyst, as well as not having provided a generally accepted theory of operation. This has held the scientific community skeptical of the E-Cat's authenticity. On the other hand, if Rossi's claims are true, the E-Cat technology and its scientific research are of great significance. Because of the possible significance, scientists in many countries have carried out related experiments.

Over the past two years Russian scholar Alexander Parkhomov (Pa Hamo Fu) performed experiments replicating Rossi's work. Parkhomov announced the details of the experiment; for example, he used a fuel that is a mixture of 1g of nickel powder and 0.1g of lithium aluminum hydride . The experiment produced abnormal heat [10-11]. Under the auspices of the Fund, China Institute of Atomic Energy has carried out research into exothermic reaction of nickel with hydrogen. In earlier experiments using a fuel comprised of nickel wire or nickel powder, also in a stainless steel container with hydrogen at a temperature of 1000°C abnormal heat inside the container was observed. This paper reports the results of two rounds of similar experiments performed in 2015. Both rounds used uniformly mixed nickel and lithium aluminum hydride as the fuel. The observed abnormal heat was much larger than past experiments. Earlier results have been published in <E-Cat World>, see:

http://www.e-catworld.com/2015/07/31/low-energy-nuclear-reaction-occurring-in-hydrogen-loaded-nickel-wire-songsheng-jiang

2. Experimental Device

The hydrogen-metal heat generator experimental setup is shown in Figure 1. The main component of the heat generator is the nickel powder fuel sample with lithium aluminum hydride, contained in a rectangular nickel box having dimensions of: length 160 mm, height 14 mm, and width 14 mm. The nickel box is placed in the center of a sealed cylindrical stainless steel container having an inside diameter of 30 mm, an outer diameter of 36 mm, and a length 280 mm. The stainless steel container is connected to a vacuum system and a hydrogen cylinder through a valve. This container placed in the tubular alumina ceramic heater comprised of resistance wire and a ceramic tube. The ceramic tube outer diameter is 70 mm, the inner diameter is 50 mm, and its length is 330 mm. The resistance wire used is a high temperature Fe-Cr-Al alloy wire [Kanthal-like] with a diameter of 0.5 mm and a length of 240 cm wound around the outer wall of the ceramic tube. The resistance wire heater has a resistance of about 25Ω. To prevent heat loss, the heater was surrounded with magnesium oxide (MgO). The magnesia (MgO) is mounted in a stainless steel cylinder, with the heater located on its central axis. The magnesia shield dimensions are: outer diameter 270 mm, length of 400 mm (Figure 1).

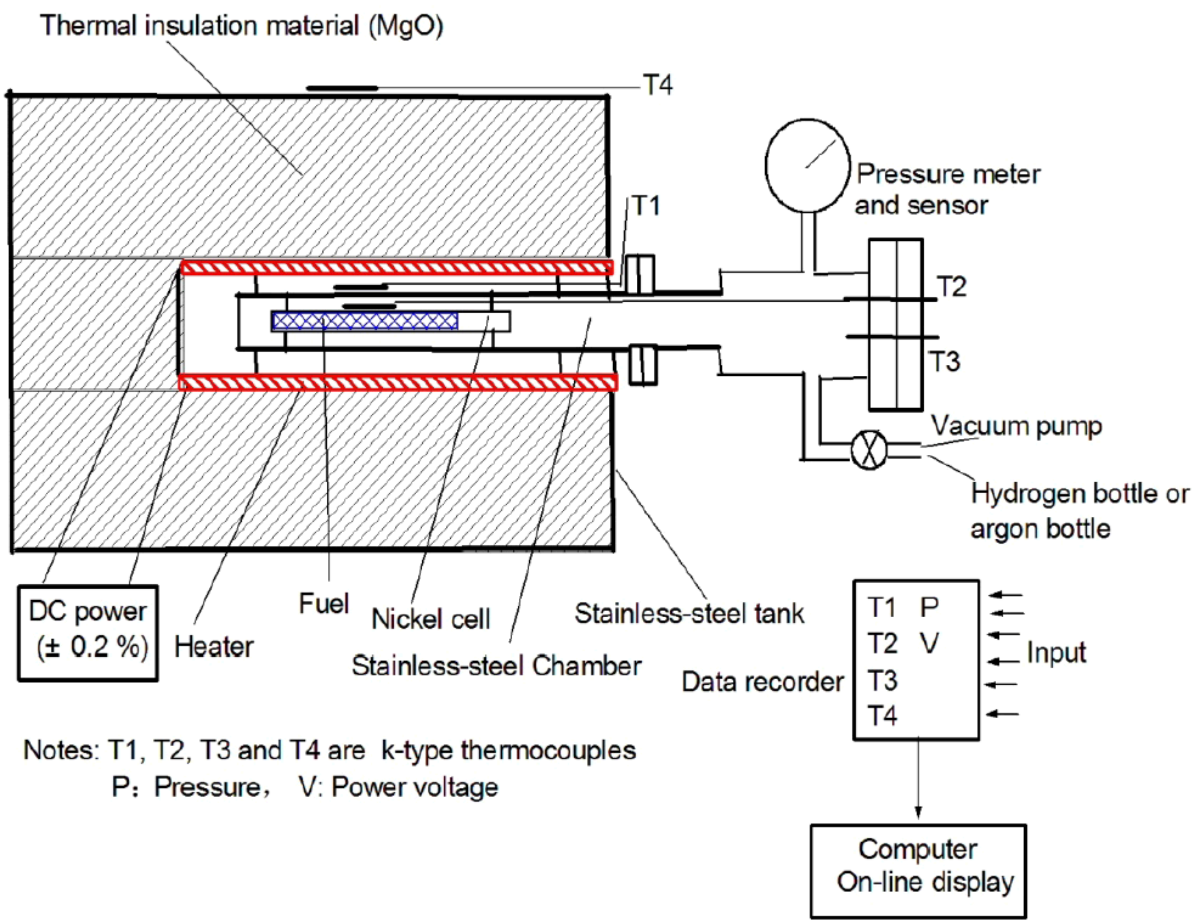

Fig. 1: Schematic diagram of the experimental setup. The fuel was nickel powder + $LiAlH_4$. Thermocouple T3 was not installed.

The stainless steel wall of the container (T1), the outer wall of the sample cell (T2), and the outer wall of the shield (T4) were monitored with K-type thermocouples (see Fig. 1). Temperature measurement, the internal hydrogen pressure within the stainless steel vessel, and the DC power supply voltage were recorded and were also displayed in real-time on the computer. Under normal circumstances, the measured temperatures of thermocouples T1, T2, and T4; and the heater power are interrelated. Temperature T1 is initially higher than temperature T2 because T1 is physically closer to the heater than T2. If the nickel sample cartridge began to generate heat, the heat will increase T2, and the T2-T1 temperature difference will be reduced. Often, during heat generation, the T2 temperature may exceed T1. Heat generation is seen as increasing T2-T1 temperature difference for different fuel compositions.

When the fuel sample generates heat, it is indicated by increase of temperature T2; the fuel generated power is calculated with an experimentally evaluated conversion factor, called the temperature-power conversion factor. The relationship between temperature changes at T2 and the power supply changes are obtained at equilibrium. A temperature - power conversion factor of 1.5 ± 0.5 W/°C was experimentally derived. Since the external heater produces a different temperature at T2 for a given input power as compared to heating from within the nickel fuel sample box, the power value calculated by the method above has large systematic errors. A more reliable temperature-power conversion factor will be evaluated in further research.

3. Experimental results

Two experiments are described here which clearly showed abnormal heat generation. The first round experiment showing abnormal heat was conducted over May 4-11, 2015. In this experiment the fuel sample is uniformly mixed 10g of nickel powder and 1g of lithium aluminum hydride. The stainless steel container became filled with hydrogen as the lithium aluminum hydride decomposed. The chemical reaction process is as follows [12]:

$3\ LiAlH_4 \rightarrow Li_3AlH_6 + 2\ Al + 3\ H_2$ (125-180°C) (1)

2 Li3AlH6 → 6 LiH + 2 Al + 3 H2 (> 400°C) (2)

$2\ LiH + 2\ Al \rightarrow 2\ LiAl + H_2$ (500°C) (3)

$2LiH \rightarrow 2Li + H_2$ (> 800°C) (4)

In the beginning of the experiment, at 100°C, the stainless steel vessel was evacuated to remove residual gas chamber, especially oxygen, for more than 20 hours. The degree of vacuum reached 10^{-4} mbar. Then, the stainless steel chamber was filled with hydrogen at1bar, and was maintained for 10 hours at 100°C. Slowly, as the temperature was increased above 100°C, the lithium aluminum hydride began to decompose. Fig. 2 shows the temperature, pressure and power supply voltage versus time. As can be seen in Figure 2, when the temperature was raised, the pressure within the vessel gradually increased. When heated to about 220°C, the pressure rose to 400 kPa. Above this temperature the pressure starts to gradually decrease. Pressure drop indicated that the fuel metal, such as nickel, etc. absorbed the hydrogen released in decomposition via the chemical reaction (1). The hydrogen-absorbing metal lattice takes in a hydrogen atom into the metal lattice, at 450°C. Temperature and pressure changes at disturbances, and other external factors cause metal-hydrogen nuclear interactions, such as hydrogen forming a highly excited Rydberg atom(s). The outer electrons provide a shield to overcome the Coulomb barrier and enable the metal-hydrogen nuclear reactions.

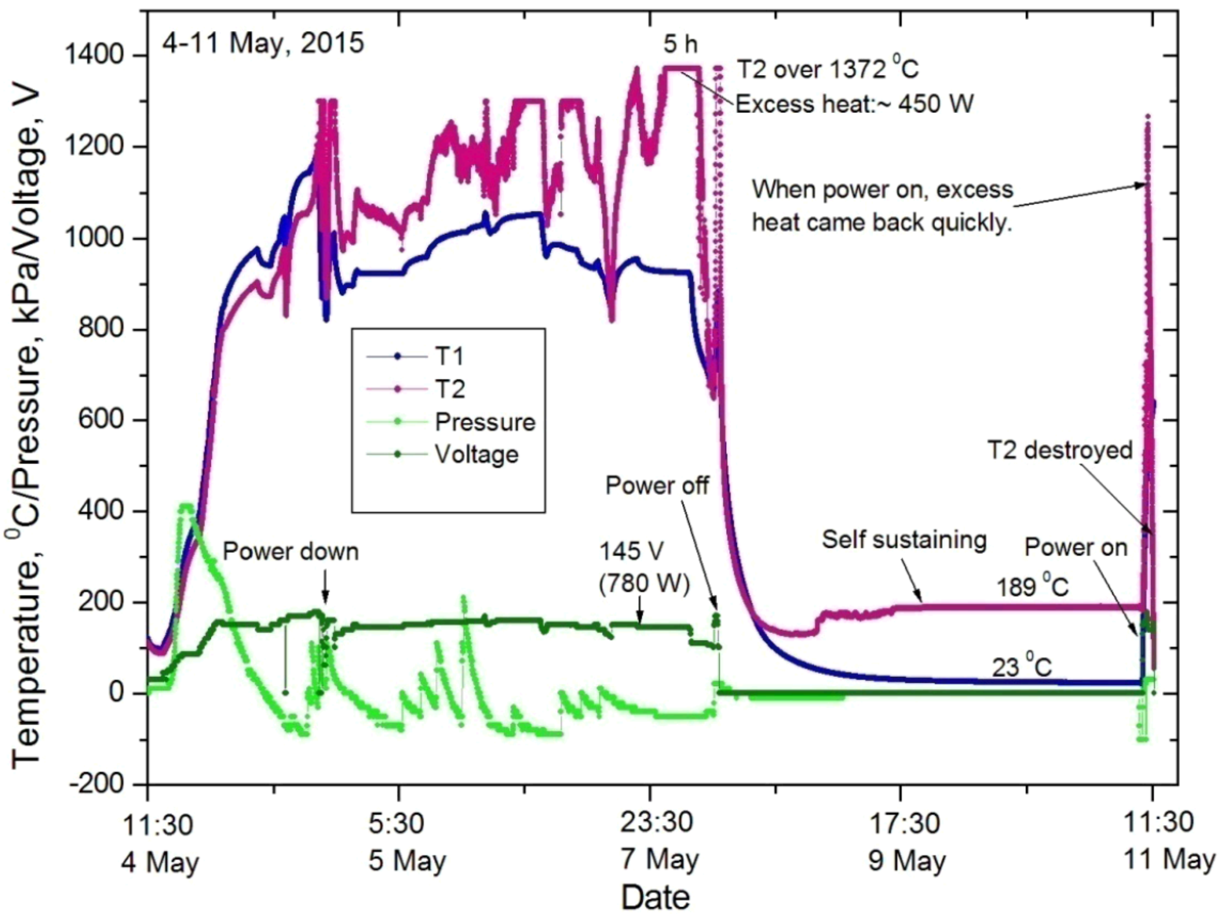

Fig. 2. Variations of T1, T2, power, voltage, and pressure in the chamber versus time in the first run. Excess heat onset at T2 temperature of 1050°C, and then T2 temperature increased rapidly to above 1300°C and exceeded T1 temperature more than 300°C. Excess heat lasted seven days before T2 was destroyed.

As can be seen in Figure 2, at the start, T1 is closer to the heater temperature; and is lower than temperature T1. However, when the nickel box fuel sample began to produce energy, the temperature T2 there was rapid rise in temperature T2, from 1100°C rises to 1300°C (the data logger reached its temperature limit). According to the specification for the K-type thermocouple, its temperature range is -200°C to 1350°C, with 1100°C being the maximum for long-term operation, and 1300°C may only used for a short time. To protect the thermocouples, 1300°C is maintained for only about 10 minutes, after which, the heating power is turned off. After the power shutdown, temperature T1 rapid declines, but temperature T2 remained at 1300°C for 20 minutes and then began to decline. This indicates that the thermal energy generated in the fuel sample does not require external heating for self-sustaining heat output for some time. When the T2 temperature dropped to 1000°C, the heating power supply was increased to 900 W, and temperature T2 rose above T1 again. To protect the thermocouple T2 for longer operation, most of the time T2 was kept lower than 1200°C. After continuous operation for four days, in the afternoon of May 8, the heating power supply was disconnected. In the subsequent two days of cooling, when the temperature had dropped to room temperature (23°C) for T1, temperature T2 remained at 189°C by self-heating from the fuel.

How could T1 and T2 temperatures differ by so much? This is because thermocouple T1 is in the atmosphere, and is easily equilibrated to room temperature. T2 is located in a sealed stainless steel vessel, and the gas inside the vessel is at a very low pressure, near vacuum, having better insulating properties like a thermos.

On the morning of May 11, the heater was re-activated to raise the temperature again to stimulate abnormal heat. The initial applied heating power was set to 800 W, and temperature T2 rose rapidly to 1250°C and temperature T1 only reached 537°C. Unfortunately, in the process of rapid heating, thermocouple T2 failed which forced termination of the experiment. The first round of experiments was carried out over 7 days.

The second round of experiments

The second round of experiments began again on November 4, 2015. The sample was uniformly mixed preparation of 10 g of nickel powder and 2 g of lithium aluminum hydride. The Ni and $LiAlH_4$ ingredients were from the same package as the first round of experiments. So, six months had passed since the original packages had been opened from their vacuum-seal. As a result, the nickel powder surface may have been oxidized in the moist air, which may hinders hydrogen and nickel chemical behavior in the experiment.

The second round of experiments was conducted in the period of October 26-30. After heating the fuel container to above 200°C the pressure remained at 400 kPa, while the pressure had decreased significantly in the first round of experiments near 200°C (see Fig. 2). This may indicate that in the second round experiment, the hydrogen decomposed from the lithium aluminum hydride was not being taken into the nickel powder. In four consecutive days of measurement, there was no abnormal heat generation.

Later, to further the nickel powder and hydrogen effect, the container was connected to a hydrogen cylinder to maintain an H_2 pressure of 100-500 kPa, with a T2 temperature 20-1100°C. Three days later, the second round of experiments began, and abnormal heat appeared in the experiment (Fig. 3). When temperature T1 reached 1250°C, T2 suddenly increased from 1150°C to beyond 1300°C. The power was turned off to protect thermocouple T2. Even though the heating power was disconnected, and T1 temperature decreased rapidly after the power is turned off, T2 temperature remained in the 1100-1300°C temperature range due to self-sustaining heating effect of the fuel sample. After 120 minutes, thermocouple T2 was broken and the experiment was over.

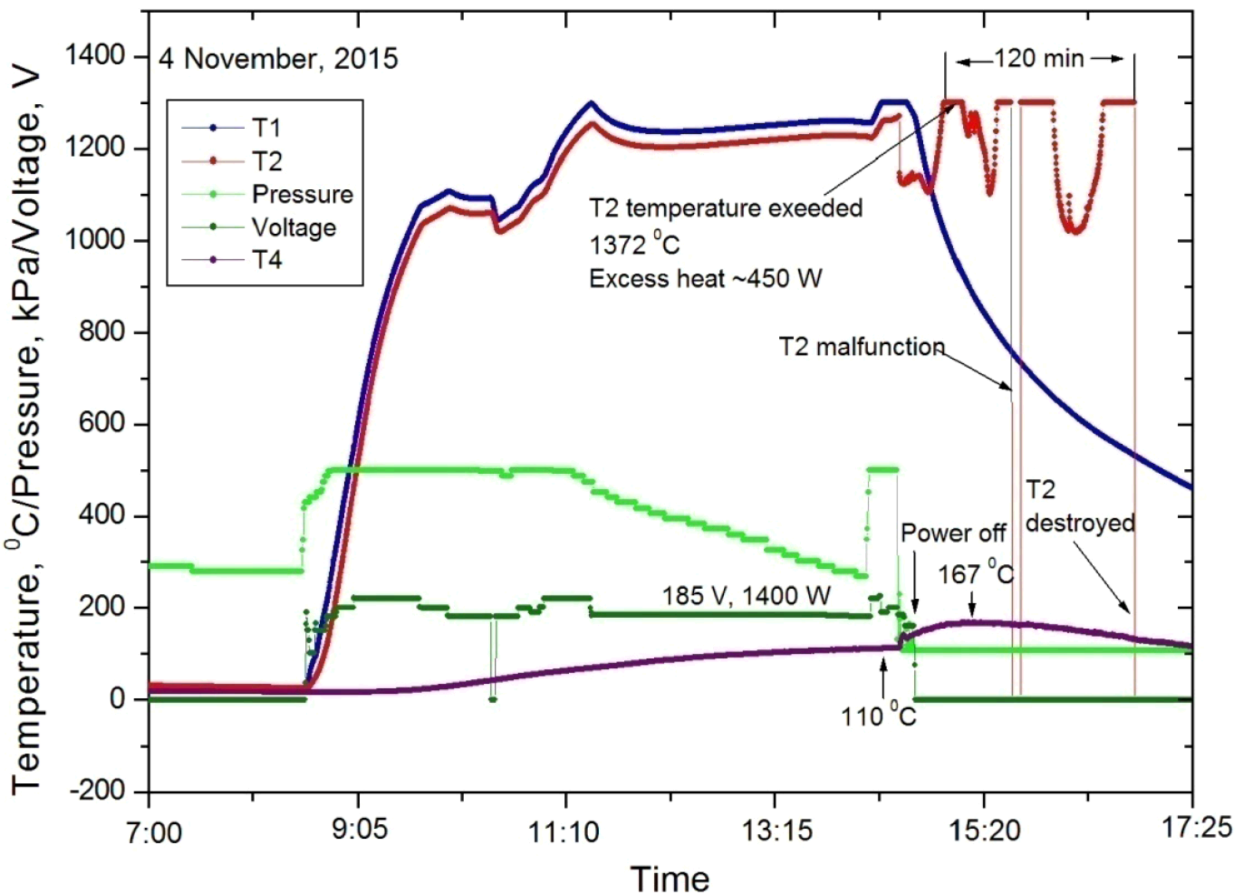

Fig. 3. Variations of T1, T2, T4 temperature, power, voltage, and pressure in the chamber versus time in second run. Due to self-sustaining heat production, T2 was kept above 1300°C for more than 120 minutes after power off, although T1 temperature dropped down quickly. When excess heat was produced, T4 temperature increased from 110°C to 167°C, although power was off.

In this second round experiment, thermocouple T2 was soon damaged due to abnormal heat after just a short duration. However, the self-sustaining heating effect in this experiment is very obvious. Another observation is this second round experiment is the temperature change of the outer wall of the heater shield (T4) after the power had been turned off. After the power source had been turned off, the outer wall temperature does not decrease, but increased from 110°C to 167°C (see Fig. 3), suggesting that during this experiment there was another heat source in the vessel.

During the first round of experiments the experimental device was placed in the vicinity of a Ge (Li) detector to observe nuclear radiation in the environment. No detectable Γ- ray radiation was found to exceed background levels.

A major problem in the two rounds of experiments was complete failure of the T2 thermocouple – it burned up and stopped reporting temperature. Was the thermocouple bad? How can the performance of this thermocouple be explained?

The K- type thermocouple specification shows that its temperature measurement range is -200°C to 1350°C, can work long hours in 0-1100°C, and can be used at 1300°C for a short time. In these experiments the thermocouple was damaged after 7 days, while most of the time the temperature was greater than 1100°C. It is believed that damage to the thermocouple is mainly associated with its life, not the quality of the thermocouple itself. The data does not show T2 thermocouple irregularities before it failed. Experimental results suggest that after some thermocouples malfunction at high temperature; the reported thermocouple temperature reading is reduced.

Data from abroad, such as the American National Standards and Technology Information Institute suggests that K- type thermocouple temperature range is -270-1372°C, and even at a high temperature in a reducing atmosphere (hydrogen).

In a long run, this thermocouple degradation will make the K- type thermocouples give low temperature readings. This indicates that for the temperature rises and T2 indications are probably correct before the thermocouple has failed - the measured data is reliable.

In the first round, during the abnormal heat generation, the external power supply is constant, yet temperature T2 rose from 1100°C to about 1400°C - a temperature increase of up to 300°C. Using the experimentally determined temperature - power conversion factor of 1.5 W/°C, the abnormal heat power is found to be 450 W, and the total heat energy generated by the first 72 hours is 78 MJ. Maximum chemical energy for these experiments due to reaction of hydrogen and oxygen can produce these interactions [13]:

$$2\ H_2 + O_2 \rightarrow 2\ H_2O + 242.8\ \text{kJ} \bullet \text{mol}^{-1}$$

The main experimental hydrogen source is decomposition of 1g of $LiAlH_4$. The chemical reaction between hydrogen and oxygen would release an energy of 26 kJ – 3 orders of magnitude smaller than the experimental amount of the abnormal heat generation. Thus, the abnormal heat generation of not derived from a chemical reaction.

4. Conclusion

In this paper, the experimental apparatus and method for measuring the high temperature heat anomalies were described in detail. The results show: nickel powder and lithium aluminum hydride, when used as a fuel sample, and heated to a temperature of 1100°C – 1300°C, generate abnormal heat. In the first round experiment, a maximum power of 450 W of abnormal heat was generated over a period of 72 hours, generating 78MJ of heat energy. In the second round of experiments, when the external power was disconnected, T1 temperature decreased while the temperature at T2 remained in the range of 1100-1300°C for about 120 minutes, demonstrating tolerance of the fuel samples for self-sustaining heat generation of about 450 W. In the second round experiment, when the external power supply was disconnected, temperature T4 on the outer shell of the assembly abnormally rose from 110°C to 167°C. This result indicates that, in addition to the heater power, there is another inner heat source to promote the T4 temperature.

The possible energy generated by chemical reaction was calculated to be 26 kJ. The abnormal heat output from the experiments was higher than that of chemical energy by 3 orders of magnitude. Therefore, such a huge excess heat may be caused by low-energy nuclear reactions (LENR).

Theoretical research of low-energy nuclear reactions has made significant progress in recent years, and there are many proposed mechanisms [14-18]. However, there is no single accepted theory.

Our results clearly show thermal abnormalities in heating of metal containing hydrogen; capable of generating heat at constant temperature. This opens scientific research into a new and important source of energy.

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