# Summary of research results of experiments on anomalous heat generation in nickel-hydrogen systems

Songsheng Jiang, China Institute of Atomic Energy
E-mail: jiang@ihep.ac.cn

**Abstract**

This paper summarizes some of successful experiments by which excess heats were produced in nickel-hydrogen systems. The experiments were carried out at different laboratories by using different experimental devices and techniques in Italy, USA, Russian and China. In the most of the experiments the fuel was mixture of nickel powder and lithium aluminum hydride. Hydrogen is formed after decomposition of lithium aluminum hydride. The COP factors (ratio of sum of excess heat and input power to input power) are 1.2-2.7 normally, however，COP factors were estimated to be about 3.2-3.6 in the E-Cat test in 2014. The temperature in the reactors was about 1100-1400 $^{0}$C.

## Ⅰ. Introduction

In 1989, Fleishmann, Pons and Hawkins claimed that anomalous production of heat obtained in palladium cathodes with saturated deuterium during an electrochemical experiment at room temperature [1]. The anomalous heat is produced by D-D nuclear fusion, commonly known as "cold fusion".

In 1994, Focardi, Gabbani and Piantelli reported on the existence of an anomalous heat production observed in hydrogen-loaded nickel rods [2]. The phenomenon occurs when a cell containing a nickel rod is maintained at temperatures above a critical value and is filled with gaseous $H_2$ at subatmospheric pressures. A constant input power was used to raise and keep the cell temperature constant at its working value (corresponding to about 700 $^{0}$C for the Ni rod). It was possible to induce an increase of the sample temperature from its working value to about 820 $^{0}$C. The anomalous heat was 50 W.

In 2011, Rossi claimed that he invented a device, in which the fuel is hydrogen-loaded nickel and catalyst, and it can produce large amounts of heat at high temperature above 1000 $^{0}$C. Each heat generator, or E-Cat (named by Rossi), can produce heat power of about 10 kW. About 100 heat generators have been assembled as a 1 MW reactor [3]. The heat is not produced from chemical reaction, but from nuclear reaction. Compared with conventional nuclear reactors, E-Cat may have no harmful nuclear radiation, and the fuel mainly is nickel. Nickel is rich in the Earth and is cheap too. Two E-cat devices tests also reported in 2013 and 2014 [4, 5]. Parkhomov imitated Rossi experiment, and excess heat was obtained. The fuel used in the test was the mixture of nickel powder and $LiAlH_4$ [6]. Also Songsheng Jiang reported his research team works on anomalous heat production in hydrogen-loaded nickel systems [7, 8]. Research works on anomalous heat production in hydrogen-loaded nickel systems were also reported in other laboratories [9, 10, 11].

## Ⅱ. Description of the Ni-H experiment devices and techniques

## 1. Rossi E-Cat HT

The E-Cat HT was a product manufactured by Leonardo Corporation (Fig. 1). As in the original E-Cat, the reactor fuel is a mixture of nickel, hydrogen, and a catalyst which is kept as an industrial trade secret. The heat production set off after reaching appropriate temperature. Once operating temperature for heat production in the reactor was reached, it was possible to control the reaction by regulating the electric heater power.

The operation of the E-Cat HT carried out in two runs [4]. The first test experiment, lasting 96 hours, from Dec. 13 to Dec. 17, 2012, while the second experiment, lasting for 116 hours from March 18 to March 23, 2013. The two test measurements were conducted with the same methodology on two different devices: a first prototype, termed E-Cat HT, and a second one, resulting from technological improvements on the first, termed E-Cat HT2 (Fig. 2). Both have indicated heat production from an unknown reaction. In the March test, about 62 kWh of excess heat were produced, with a consumption of about 33 kWh, In the December test, about 160 kWh of excess heat were produced, with a consumption of 35 kWh. The excess heat in both devices was several orders of magnitude higher than the chemical sources.

**Fig. 1.** E-Cat HT on support frame. The power cables to the internal resistor coils are visible, as well as the IR camera in the lower part of the photograph.

**Fig. 2.** The E-Cat HT2 used for the March test. The device appears as a steel cylinder, 9 cm in diameter, and 33 cm in length, with a steel circular flange at one end 20 cm in diameter and 1 cm thick.

## 2. Rossi E-Cat 2014

The reactor, named E-Cat, is charged with a small amount of hydrogen-loaded nickel powder plus some additives, mainly lithium. The reactor was primarily initiated by heat from resistor coils around the reactor tube. Measurements of the radiated power from the reactor were performed with high-resolution thermal imaging cameras. The measurements of electrical power input were performed with a large bandwidth three-phase power analyzer. Data were collected during 32 days of running in March 2014 [5].

The reactor investigated on this occasion is outwardly quite different from the ones used in the tests held in the past years. Its external appearance is that of an alumina cylinder, 2 cm in diameter and 20 cm in length, ending on both sides with two cylindrical alumina blocks (4 cm in diameter, 4 cm in length), non-detachable from the body of the reactor, which henceforth will be referred to as "caps". An image of the reactor is given in Fig. 3. Whereas the surface of the caps is smooth, the outer surface of the body of the E-Cat is molded in triangular ridges, 2.3 mm high and 3.2 mm wide at the base, covering the entire surface and designed to improve convective thermal exchange (cylinder diameter is calculated from the bases of the ridges). In this way, the current model of E-Cat is capable of attaining higher temperatures than the earlier models, avoiding internal melting, a previously fairly frequent occurrence.

The reactor operating point was set to about 1260 ºC in the first half of the run, and at about 1400 °C in the second half. The measured energy balance between input and output heat yielded a COP factor of about 3.2 and 3.6 for the 1260 ºC and 1400 ºC runs, respectively. The total excess heat power obtained during the 32 days run was about 1.5 MWh.

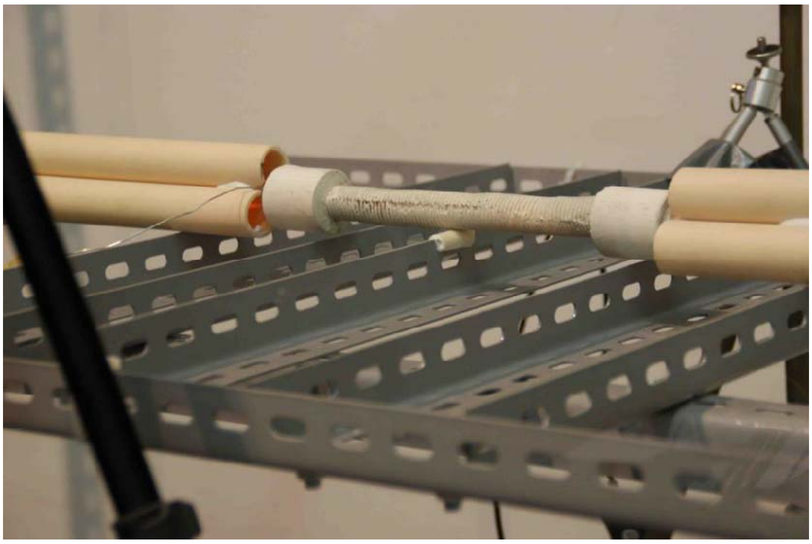

**Figure 3**. The E-Cat is installed on its metal frame. On the left, the cable connecting to the K-type thermocouple may be seen. The strut under the center of the reactor has been covered with alumina cement, which provides thermal insulation of the reactor from the strut.

## 3. AP1 reactor

AP1 reactor - the first device like high Rossi-temperature heat source, reported by Parkhomov, which excess heat was achieved in December 2014 [6]， and the reactor was manufactured with a tube of alumina ceramics having 120 mm long, outer diameter of 10 mm and an inner diameter of

5 mm. Heater was wound on the tube, 1 g of Ni powder and 10% lithium aluminum hydride was inside the tubes. The thermocouple was contacted on the outer surface of the tubes. The ends of the tubes are sealed with heat-resistant cement. Similarly, the entire surface of reactor was covered with cement (Fig. 4).

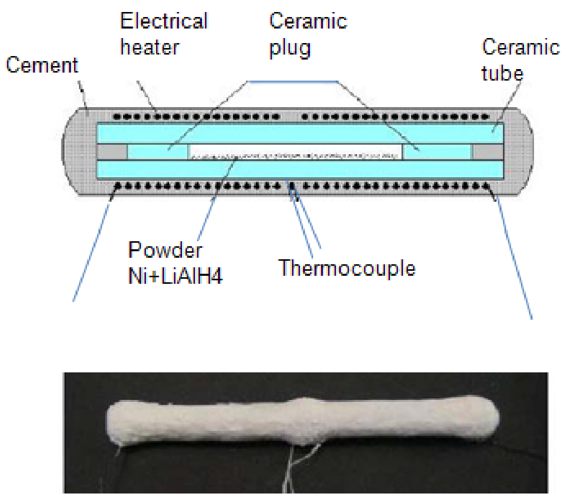


**Figure 4.** The AP1 reactor

The released heat was measured with technique based on the amount of water boiled out. This vessel was immersed in water. The amount of heat liberated was determined by the weight of water that was added to remain its constant level, and the known value of the heat of vaporization (2260kJ / kg). Correction for heat loss through heat insulation was calculated from the rate of cooling after reactor shutdown.

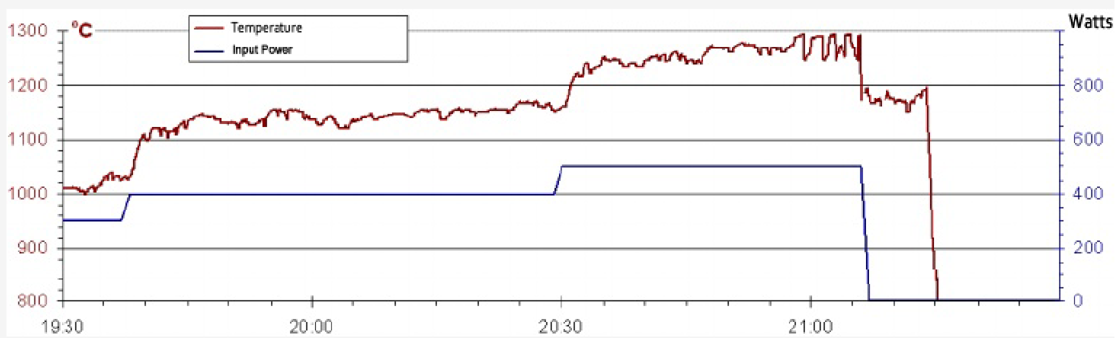


**Figure 5**. The reactor temperature versus input power. This ends with termination of the heater input due to overheating (burn-out) of the heater winding. After this, during 8 minutes, the temperature was maintained at nearly 1200 $^0$C, and only after this period starts to decrease sharply. This shows that the reactor is producing heat during this time at the kilowatt level without any electric heater input..

In addition to the experiments with reactors loaded a mixture of Ni + $LiAlH_4$, the control experiments was carried out without fuel in reactor The reactor with fuel at a temperature below 1000 $^0$C, the ratio of the released heat energy absorbed by water to electricity energy (COP) was close to 1. A significant excess of the released thermal energy of the absorbed power (up to 2.7

times) was observed only in the reactors with the fuel at temperatures above about 1100◦C (Fig. 5). During these times (90 minutes) energy was produced in excess of electricity consumed by about 3 MJ, or 0.83 kWh.

## 4. Project of Glowstick

The MFMP (Martin Fleischmann Memorial Project) reactor, named Glowstick, developed by Alan Goldwater was set up [9]. The reactor consists of a ceramic tube, around which two identical, series connected electric heaters are placed. One heater coil heats the fuel mixture (Ni 300mg + $LiAlH_4$30 mg) and one heats the control portion of the tube containing a similar mass of inert $Al_2O_3$powder (Fig. 6). In the presence of excessive heat generation temperature of the reactor with fuel should be higher than temperature without fuel. The experiment results show in Fig. 7.

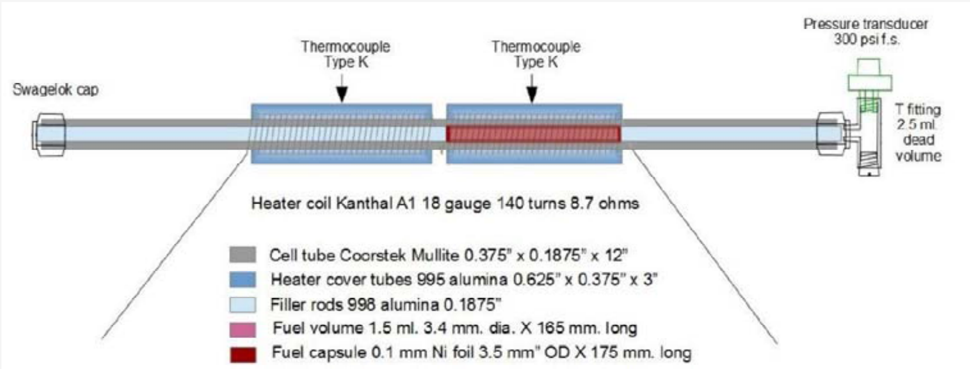


**Figure 6.** MFMP Glowstick reactor

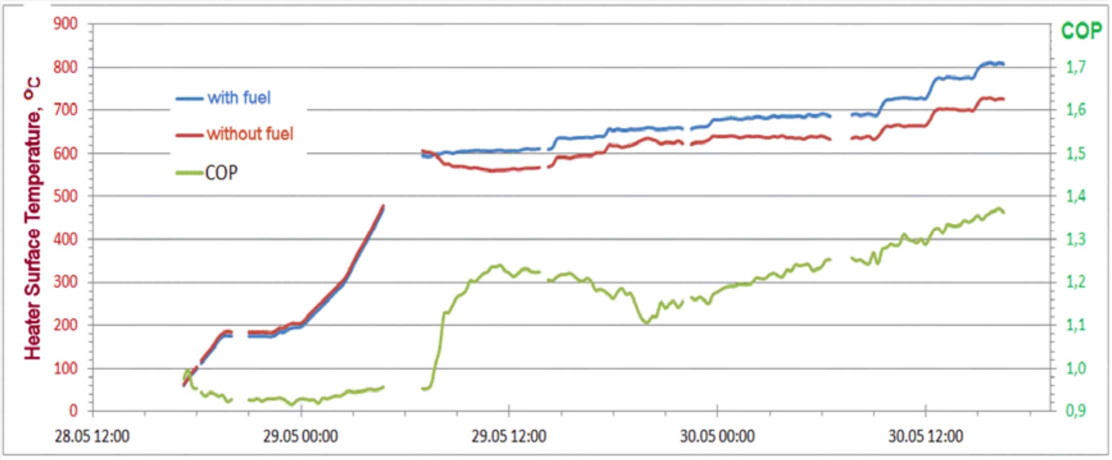


**Figure7.** A chart of control and fueled reactor temperatures during the experiment of 28 - 30 May 2015. The temperature at the reactor surface is greater than 600 $^0$C (about 1000 $^0$C inside the core of the reactor) slowing that the temperature of the fueled reactor is much higher than that of the control reactor.

In this mode, the reactor worked for about 30 hours at an average excess power of 160 watts, having 4.8 kWh (17 MJ) of excess energy.

## 5. The reactor AP2

The reactor worked on 16-20 and 21-22 March, 2015 [11]. A tube reactor had an inner diameter of 5 mm and an outer diameter 10 mm, and length of 29 cm, and only the central part (7 cm) was heated. Heater made of alloy H23YU5T (Cr-Al alloy). The ends of the tube were sealed with epoxy resin. Fuel mixture (640 mg N +60 mg $LiAlH_4$) was in a container made of thin stainless steel. To expel excess air from the reactor a tube was inserted into ceramic inserts. Manometer measurement limit is 25 bar and was connected to the reactor through a thin stainless steel tube (Fig. 8).

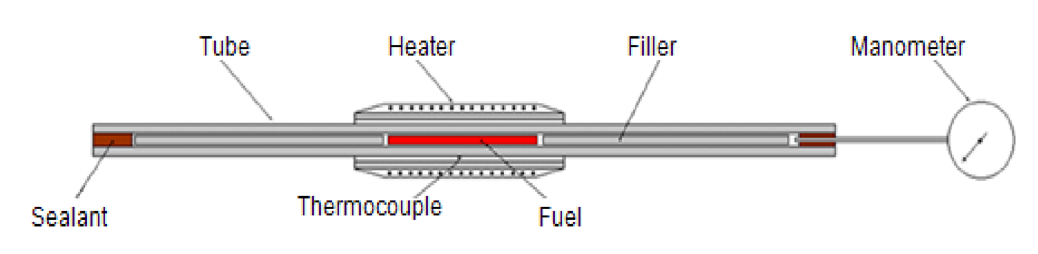


**Figure 8.** The construction of reactor AP2

An electric heater was connected to the power through a thyristor regulator. To measure consumption of electricity, electronic meters were used, which allows the computer to record information on the consumption of electricity. For reactor temperature control the chromel-alumel thermocouple was used, which was placed on the surface of the reactor tube in the middle of the heating zone. The signal from the thermocouples was used to adjust supplied to the electric power in such a way as to maintain the desired temperature. Fig. 9 shows reactor AP2 during test.

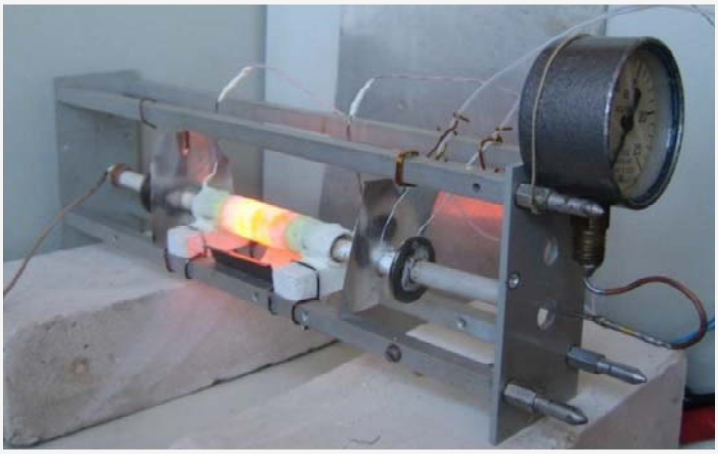

**Figure 9.** Reactor AP2 during testing.

The temperature of surface of the reactor tube was reached 1200 $^0$C for 12 hours in a gradual increasing the electric heater power up to 630 watts. Thereafter, it takes to maintaining the temperature for about 1 hour and then power is dropped up to 330 watts at 1200 ◦C. For almost 3 days the temperature on the surface of the reactor tube was 1200◦C, the power of electric heater was in the range of 300 - 400 Watts. On average, the Joule heat exceed the power consumed by the electric heater was 2.4 times. Reactor operation interrupted due to heater burnout.

The pressure inside the tube at about 180$^0$C rapidly increased to 5 bar. On further heating, pressure is gradually decreased to less than atmospheric pressure at a temperature greater than 900 $^0$C (Fig. 10).

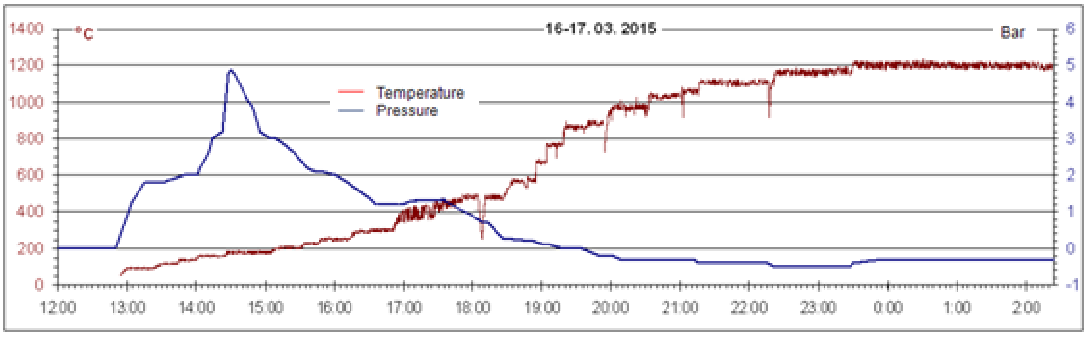


**Figure10.** The pressure during heating process

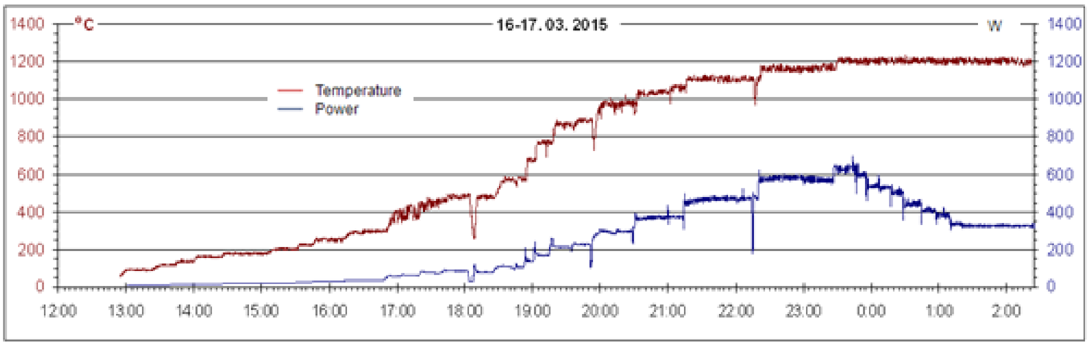


**Figure 11.** Relation of reactor temperature and input power during testing.

. When working with a second heater and temperature was maintained 1200◦C. The electric heating power varied from 500 to 700 watts. Heat capacity was exceeded consumption electric heater of 1.3-1.7 times (Fig.11). The produced excess heat exceeds electricity more than 40 kWh or 150 MJ in 4 days of operation of the reactor.

## 6 Experiment at China Institute of Atomic Energy (CIAE)

The experiment was carried out on May 2015 by Ni-H research team at CIAE, reported by Songsheng Jiang [7]. The fuel sample was uniformly mixed 20g of nickel powder and 2g of lithium aluminum hydride contained in a rectangular nickel box having dimensions of: length 160 mm, height 14 mm, and width 14 mm (Fig. 12).


**Figure 12.** The outline of fuel box

The nickel box was placed in the center of a sealed cylindrical stainless steel chamber having an inside diameter of 30 mm, an outer diameter of 36 mm, and a length 280 mm (Fig. 13). The stainless steel chamber was connected to a vacuum system or a hydrogen bottle through a valve. The stainless steel chamber was placed in a tubular alumina ceramic heater comprised of resistance wire and a ceramic tube.


**Figure 13.** The body of reactor chamber

The tubular alumina ceramic heater had outer diameter of 70 mm, inner diameter of 50 mm, and length of 330 mm. The resistance wire used was a high temperature Kanthal-like alloy wire with diameter of 0.5 mm and length of 240 cm. The wire was wound on the outer wall of the ceramic tube. The wire resistance of the heater was about 25Ω. A stabilized DC power (0.2%) was used for heater. To prevent heat loss, the heater was surrounded with magnesia (MgO) as heat insulation. The magnesia was mounted in a stainless steel cylindrical container having outer diameter of 270 mm and length of 400 mm. The experiment set-up is given in Fig. 14.

The temperatures of the outer wall of the stainless steel reactor chamber, the outer wall of the fuel box and out wall of insulation tank were measured with sheathed K-type thermocouples，T1, T2 and T3, respectively.

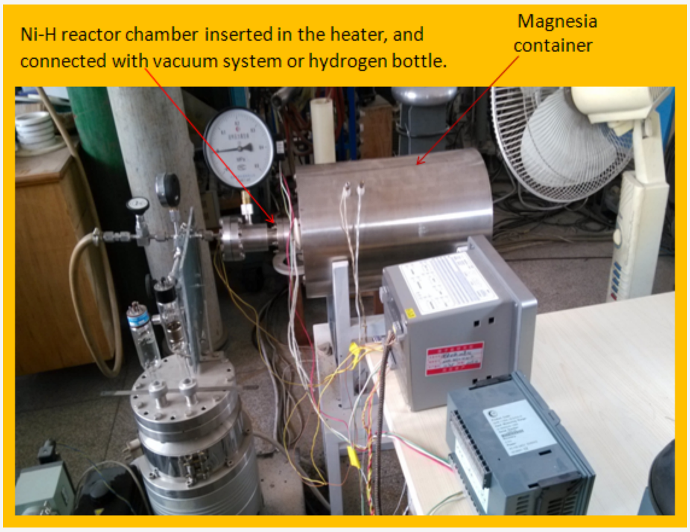


**Figure 14.** The **e**xperiment set up at CIAE, 2015.

The chamber was evacuated at beginning of the experiment, followed by gradual heating was on. As a result, $LiAlH_4$ decomposition at temperature 150-300◦C pressure has increased to 4 bar. After 18 hours the pressure was below atmospheric.

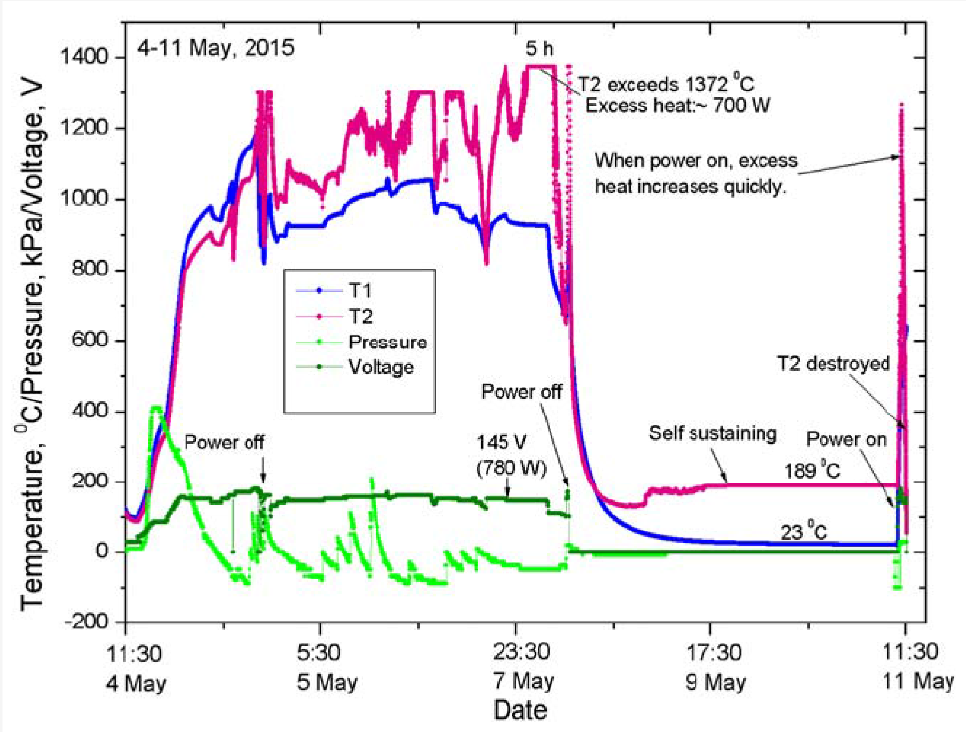


**Figure 15.** Variations of T1, T2 temperature, power voltage and pressure in reactor chamber versus time on 4 -11 May, 2015.

As can be seen in Figure 14, at the start, T1 is closer to the heater temperature; and T2 is lower than temperature T1. However, when fuel sample began to produce energy, the temperature T2 was rapid rise, from 1100°C rises to 1300°C (the data logger reached its temperature limit). It can be also seen that when external power was decreased to T1 temperature at 850 $^{0}$C, T2 temperature dropped down to a temperature lower than T1, the anomalous heat ceased. Then, the power was increased to T1 temperature at 950 $^{0}$C, the T2 temperature rose again, and exceeded T1. Anomalous heat was re-produced and can be lasted for a long time (Fig. 15).

According to the specification for the K-type thermocouple, its temperature range is -200°C to 1350°C. To protect the thermocouples, with 1100°C being the maximum for long-term operation, and 1300°C may only kept for a short time as shown in Fig. 14. After continuous operation for four days, the electric power was turned off in the weekend (May 8 afternoon - May 10 Morning).

In the subsequent two days of cooling, when T1 temperature had dropped to room temperature (23°C), temperature T2 remained at about 189 °C (Fig. 15) by self- sustaining 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, when electric power turned on, 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 (Fig. 15). Unfortunately, in the process of rapid heating, thermocouple T2 failed which forced termination of the experiment over 7 days.

In the experiment, the maximum excess heat power is found to be 450 W, and the average heat energy generated in the first four days was 100 MJ. The coefficient of performance (ratio of sum of input heat and excess heat to input heat)，COP，is 1.2-1.5. The possible energy generated by chemical reaction is calculated to be 26 kJ. The anomalous heat output from the experiment is large than that of chemical energy by greater than 3 orders of magnitude.

**7. Experiment with nickel wire at CIAE**

The experiment was also carried out by Ni-H research team at CIAE, and reported by Songsheng Jiang [8]. .In this experiment, the nickel wire was used as fuel material in the hydrogen – loaded chamber. The reactor chamber is same as used in the experiment described above. The nickel wire has a diameter of 0.5 mm, the purity was 9.999% and total weight was 16 g, which was wound on a stainless-steel tube with inner diameter of 10 mm, external diameter of 12 mm and length of 150 mm (Fig. 16). The wound nickel wire was placed in the center of the chamber. The chamber was connected to a vacuum system and a hydrogen bottle through a valve.

**Figure 16.** The nickel wire wound on the stainless-steel tube.

The temperature was measured by K-type thermocouples, thermocouple T1 is located on the outer surface of the reactor chamber, T2 is placed in contact with the surface of the nickel wire and T3 is inserted inside the stainless-steel tube.

A commercial 220 AC supply was used and the voltage was adjusted by an electric regulator. The upper limit of temperatures of T1, T2 and T3 was setting at 1000 $^0$C in this experiment, and the constant T1-temperature (1000 $^0$C) was controlled by an electric circuit to adjust the input power, if no generation of large excess heat in the chamber, variation of T1 temperature is within ±10 $^0$C.

The nickel wire-wound stainless-steel tube was loaded in the reactor chamber on 27 May, 2014. The hydrogen pressure in the vessel was 1250 mbar at room temperature of 20 $^0$C, and 1650 mbar at T1 temperature of 600 $^0$C. For hydrogen loading into the nickel lattices, the chamber was heated to 400-600 $^0$C for about 7 days. The pressure in the vessel decreased to 1000 mbar at temperature of 600 $^0$C.

After the process of gradually heating, when a temperature reaching about 900◦C, there was a rapid rise in temperature, the three thermocouples showed a temperature above the limit value (1000◦C). The anomalous heating continued for about 80 minutes. After two hours, the temperature of nickel wires and inside the tube rose 3$^0$C for 3.5 hours. An estimate of the excess heat gives a value of 240 W (1500 kJ) in the first event, and 7 W (64 kJ) in the second event (Fig. 17). Control measurements without nickel wires found no abnormal heat generation.

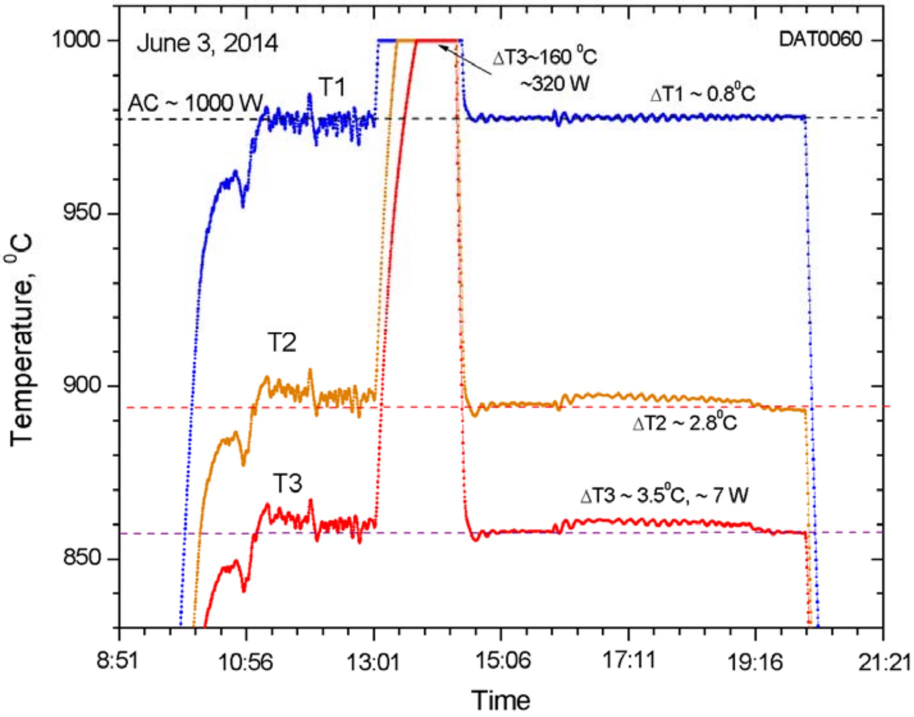


**Figure17.** The excess heat production in the hydrogen-loaded Ni wire system.

The expansion and loose of nickel wire is observed after experiment, that shows the temperature may reach to above 1000 $^{0}$C on the nickel wire, The appearance of nickel wire was examined by scanning electron microscopy. The micro "hot spots" was found after experiment (Fig. 18).

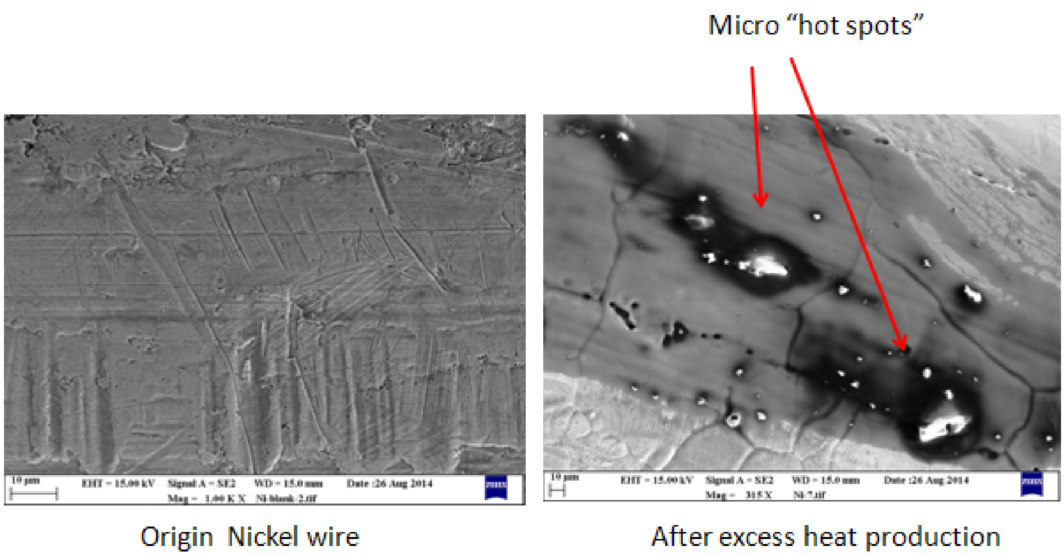


**Figure 18**. The variation of the surface structure of nickel wire was found using scanning electron microscopy after experiment.

## 8. Experiments of I. Stepanova (Moscow State University) Yu.Malahova and Nguyen Quoc Chi (MEI)

The main part of the reactor was a ceramic tube with 160 mm in length, the internal diameter of 4 mm, external - 6 mm. The inner volume was filled with fuel (a mixture of nickel powder weighing 0.9 g and 0.1 g lithium aluminum hydride [11]. One end of tube was hermetically sealed with heat-resistant cement, and a chromel-alumel thermocouple was installed at the other end (Fig.19). A second thermocouple was located on the central part of the outer surface of the heat cells. This tube was placed inside the heater - ceramic tube, on the outer surface of which was wound fehralevy wire coated with heat-resistant cement (Fig. 20). To determine the released heat flow calorimeter was used. For stabilization of the water flow rate, a damping tank was applied. Measurement of flow rate and the water temperature at the inlet and outlet of the calorimeter allowed to determine the power heat in the reactor.

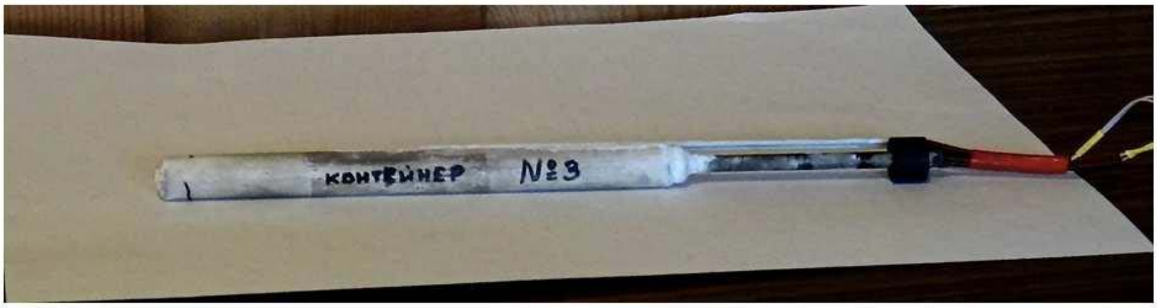


**Figure 19.** Ceramic tube with fuel and thermocouples sealed with temperature-resistant cement.

**Figure 20.** The heater with the thermal cell installed inside

After four start-up attempts, due to uncontrolled overheating, the cell was completely destroyed in June 19, 2015. During stable operation (9 hours) excess energy was released. At a temperature below 1000 $^{0}$C the temperature inside and outside the reactor were about the same. At higher temperature, the inside temperature became larger than the outside, indicating the presence of additional heat (Fig. 21).

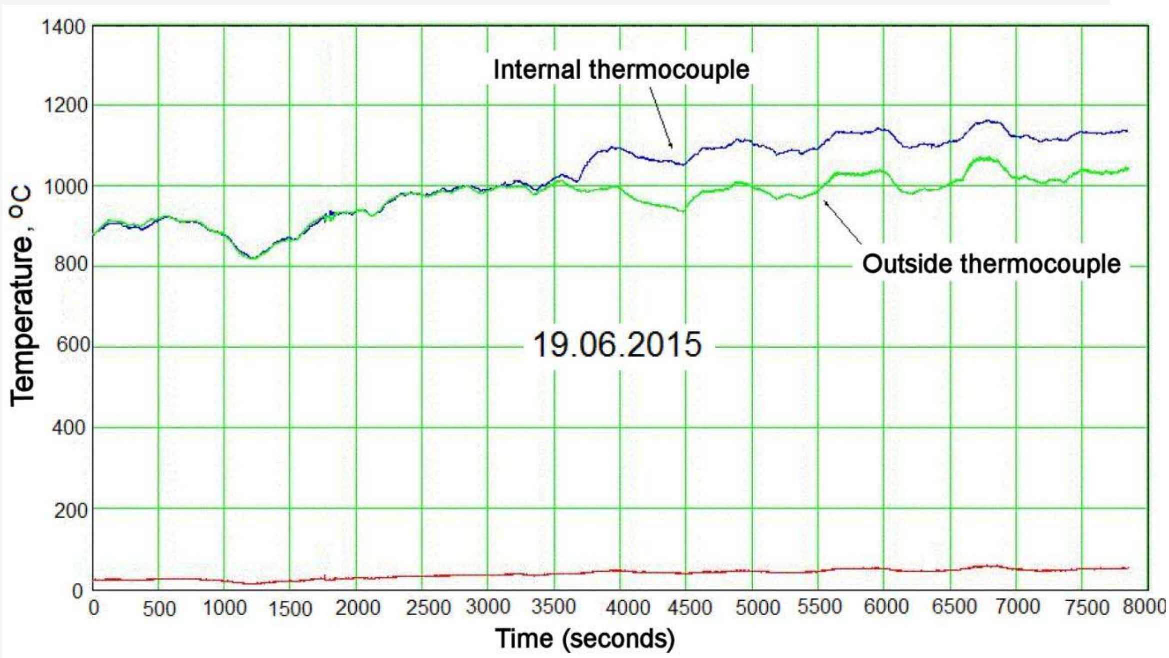


**Figure 21.** The temperature inside and outside the reactor tube.

Working with the excess heat lasted for more than an hour at a temperature of about 1100◦C. Calorimetry showed that the heat power was 2100 W , when the electrical power input was about 850 W (COP = 2,5).

**9. Reactor Plotoк-6, reactor C1 and reactor BB3**

The reactor Plotok-6, reactor C1 and reactor BB3 were tested at KIT Lab, reported by Parkhomov [12, 13].

(1) reactor Plotok-6

The reactor design is described in Fig. 22. The fuel (1.8 g nickel powder and 0.2 g lithium aluminum hydride) was contained in a ceramic tube, which had length of 80 mm, outer diameter of 7.7 mm and inner diameter of 5 mm [12]**.** The appearance of the reactor Plotok-6 before installation in the colorimeter is shown in Fig. 23. Reactor was installed in flow calorimeter (Fig. 24).

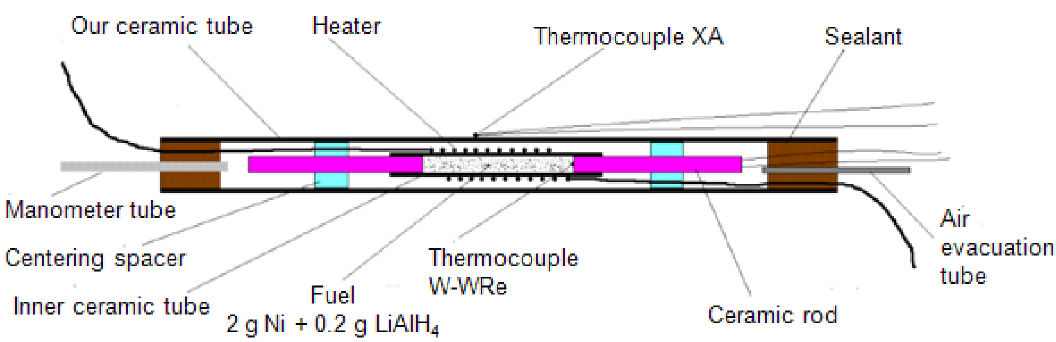


**Figure 22.** Reactor design.

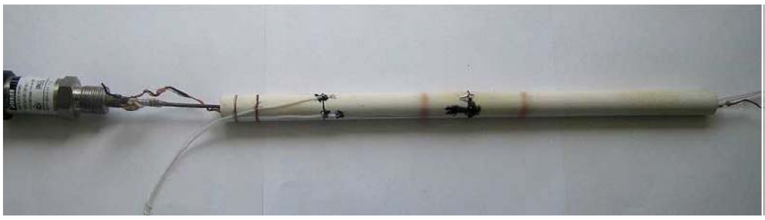

**Figure 23.** The appearance of the reactor Plotok-6 before installation in the colorimeter.

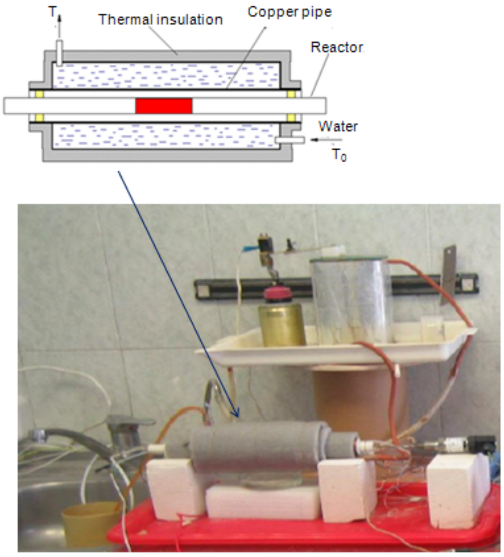


**Figure 24.** Experiment set-up of reactor Plotok-6.

At preparation process, reactor heated up to 120 $^0$C, a vacuum pump was evaluated the residual gases in the reactor. Then the reactor chamber was disconnected the vacuum pump, and reactor was heated to 180-200 $^0$C. Lithium aluminum hydride was decomposed to release hydrogen at this temperature. The pressure in the reactor chamber reached 4.25 bar. Afterwards, the temperature was increased up to 400 $^0$C, and lasted for 20 hours. At this time, the pressure dropped to 4 bar. By opening the valve located on the tube, the pressure was reduced to 0.4 bar (Fig. 25). Then gradual increasing temperature up to 1100 $^0$C, the pressure slightly increased. However, a further increase of temperature, the pressure began to drop and on the 14 days from the beginning of the experiment it became below atmospheric pressure (0 bar).

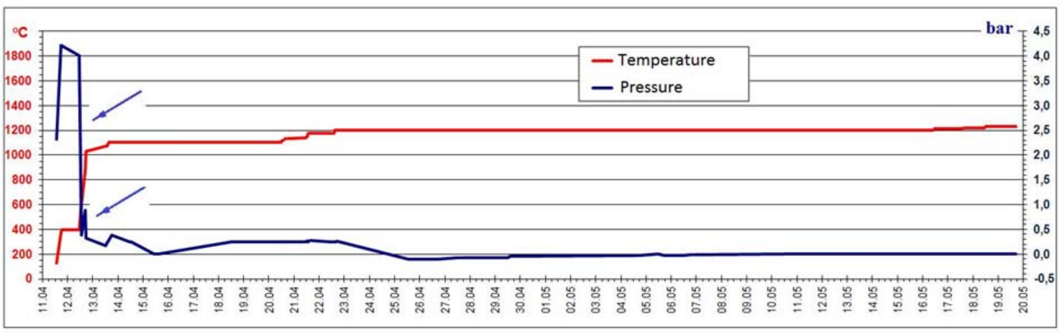


**Figure 25.** Chart of pressure and temperature [14].

At temperatures up to 1100°C the heat measured by the calorimeter was almost equal to the power delivered to the electric heater. After the temperature reached 1150°C, heat measured by the calorimeter was large than the electric heater input power. The excess heat output of 30-60 watts lasted 29 days (Fig. 26). The reactor produced approximately 100 MJ (28 kilowatt-hour) of thermal energy above the consumed electrical energy. The COP (ratio of calorimeter measured heat output to electric heater input power) varied from 1 to 1.2 (Fig. 27). The reactor destroyed after 38 days operation.

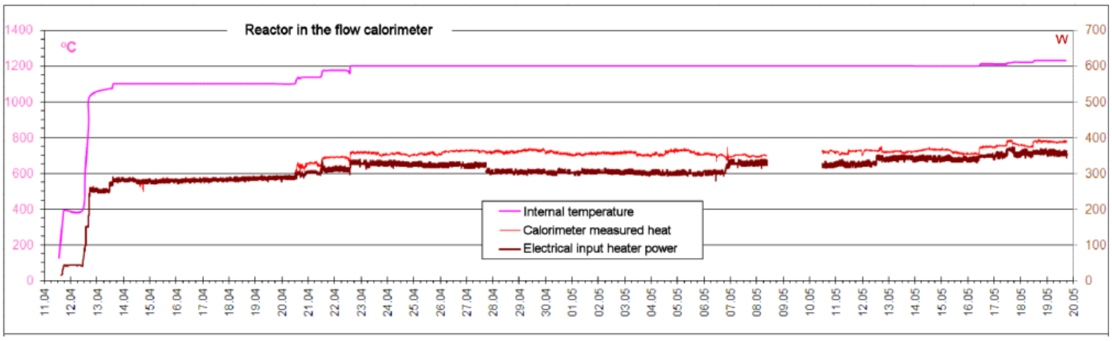


**Figure 26.** Variations of temperature, power consumption and heat output in reactor testing.

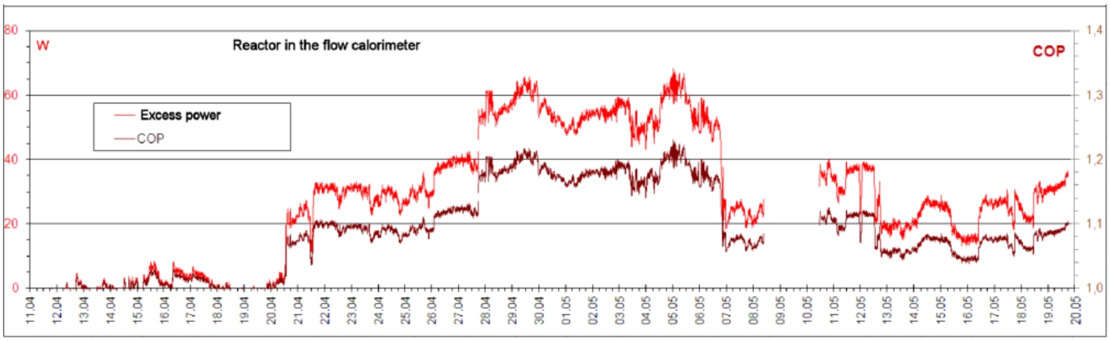


**Figure 27.** Plot of the excess power and COP.

(2) Reactor C1

Reactor C1 used a transparent sapphire tube to demonstrate the ability to use nickel-hydrogen systems as a light source [13]. Fig. 28 shows the reactor C1 before installation in the colorimeter. The reactor worked for 10 hours with an excess heat of up to 350 watts. Output heat exceeded the electrical power consumed. COP was 1.6 -2.4 (Fig. 29).

**Figure 28.** The appearance of the reactor C1 before installation in the colorimeter.

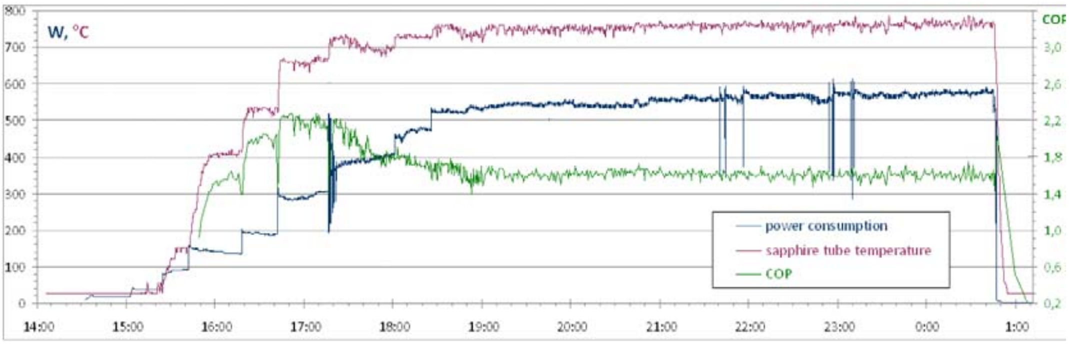


**Figure 29.** Plot of sapphire tube temperature, electric power and COP [15].

(3) Reactor BB3

Reactor BB3 spent 40 days in production of excess heat, exceeding the electrical consumption by 1.6 times (COP) [13]. Excess heat of up to 300 watts was produced. The total excess heat produced was 640 MJ (180 kWh). Fig. 30 shows reactor BB3 under testing.

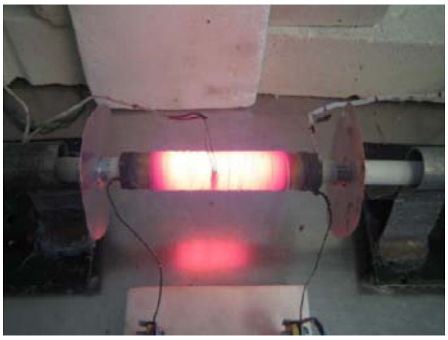

**Figure 30.** Reactor BB3 under testing.

## 10. Reactor-51 experiment by Zhang Hang

Zhang Hang, a Chinese cold fusion researcher, works in his own laboratory. Reactor-51 experiment was carried out on March 1017 [16]. The fuel (2 g raney nickel + 0.2 g $LiAlH_4$) was loaded in the of nickel tube with an inner diameter of 4 mm, outer diameter of 6 mm and length of 210 mm. The nickel tube was inserted in a corundum vessel having inner diameter of 8 mm and length of 500 mm. The vessel was placed in the silicon carbide heating tube (Fig. 31) and connected to vacuum pump and pressure sensor (Fig. 32).

**Figure 31.** The assembly of the corundum vessel and silicon carbide heater.

For thermal insulation the heater is installed in a big ceramic tube with alumina fibers packing outside. The alumina fibers are packed with a stainless steel sheet (Fig. 32).

**Figure32.** Assembly of the reactor body, an infrared temperature sensor was used for measurement of temperature of reactor vessel, see left side.

A stabilized DC power was used. . A vacuum system was used to remove residual gases from the reactor vessel to $10^{-4}$ Pa initially before heating. The temperature of reactor vessel was measured using an infrared temperature sensor (Fig. 32), and temperature of outer wall of reactor body was measured using K-type thermocouple located inside the coved stainless steel sheet, the thermocouple cable can be seen in Fig. 31 on right side.

The control experiment was carried out with no fuel. The correlation of temperatures of reactor vessel and outer wall with input power was calibrated. If excess heat generate in the reactor vessel, the ratio of the temperature of vessel or outer wall to input power is high.

The result shows that when temperature of reactor container is increased up to 1100 $^{0}$C, the excess heat is generated (Fig. 33). At about 1200 $^{0}$C, the temperature is 52 $^{0}$C greater than the control temperature (Fig. 34), and the difference of temperature of outer wall for experiment with fuel and no fuel is 8 $^{0}$C (Fig. 35).

The experiment lasted for 3 days at vessel temperature above 1100 $^{0}$C. Excess heat power is 35-78 W, COP is about 1.2.

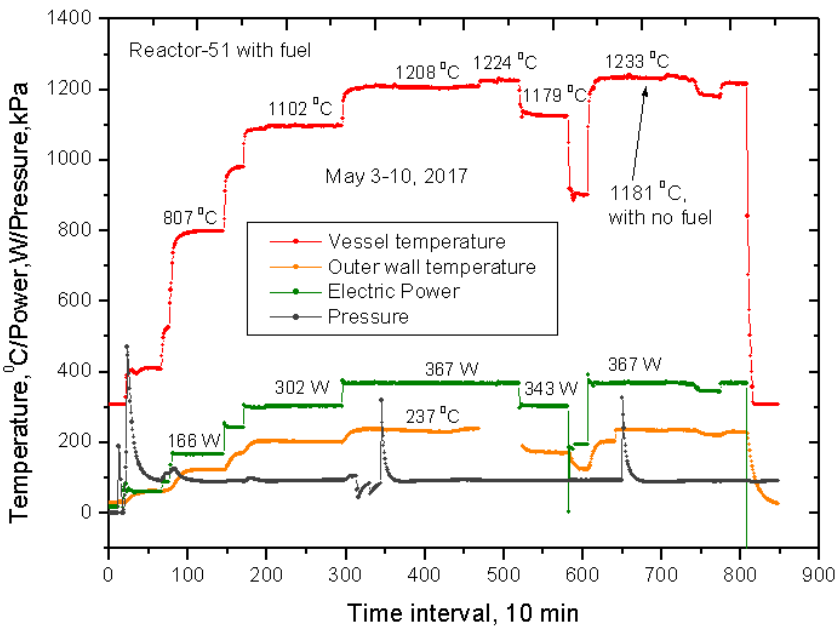


**Figure 33.** Recording data for experiment with fuel.

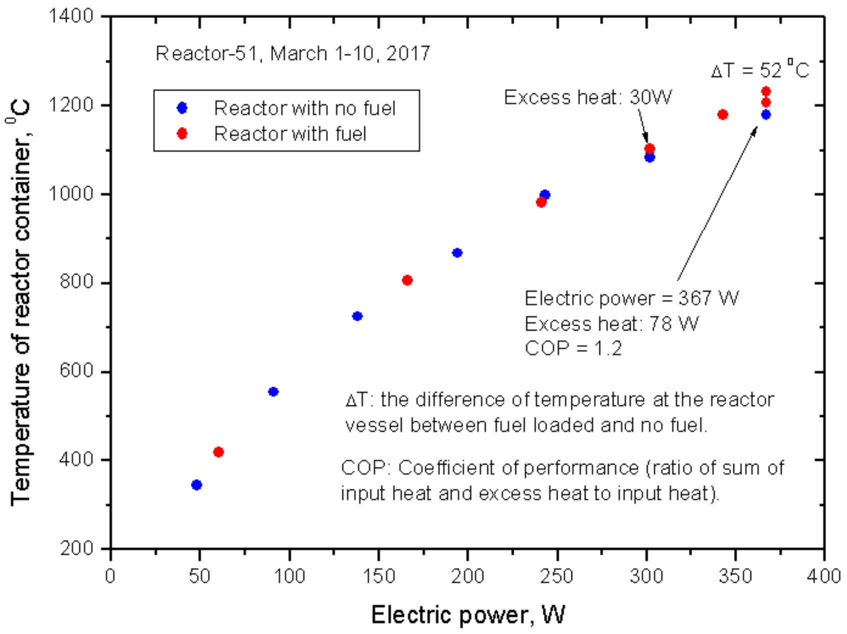


**Figure 34.** Temperatures of reactor vessel with fuel and no fuel against electric power.

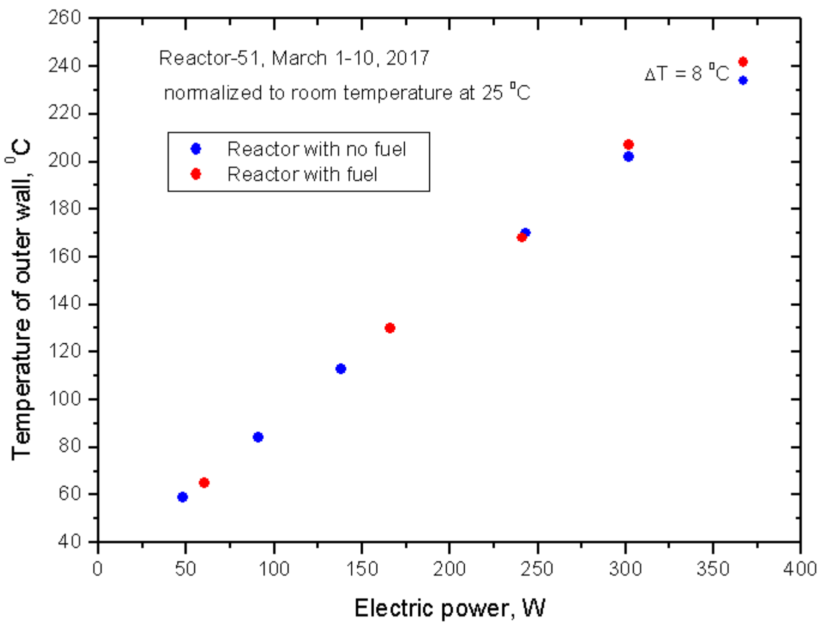


**Figure 35.** Temperatures of outer wall with fuel and no fuel against input electric power.

## Ⅲ. Conclusions

This paper summarizes anomalous heat generation in Ni-H systems of 12 experiments which were carried out in Italy, Russian, USA and China. The different experiment devices and techniques were used in each experiment.

In the most of the experiments the fuel mixture was used nickel powder and lithium aluminum hydride, hydrogen formed after decomposition, except for that gaseous hydrogen was used in nickel wire experiment in China. The fuel components are not quite clarified due to keeping secret in E-Cat test reports. The fuel components and properties may play a key role in excess heat generation.

In order to evaluate the heat, the method of comparison of temperature in reactors with and without fuel was used for the most of experiments, and special water-flow calorimeters were also, used in some experiments.

The excess heat normally appears at reactor temperature from 1100 to 1400 $^0$C, and COP factors were 1.2 to 2.7. Reproducibility of results cannot be controlled in the repeated experiments, frequently, repeated experiments failed. The methodology of anomalous heat production in Ni-H system still keeps a mystery.

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