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Research Article

Research into Heat Generators Similar to High-temperature Rossi Reactor

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Abstract

Devices similar to a high-temperature Rossi reactor were made. Excess heat at the temperature of about 1100°C and higher was demonstrated. No nuclear radiation above the background level was observed during the excess heat production.

Keywords: Element composition, High temperature, Hydrogen, Isotope composition, Nickel powder, Nuclear radiation, Power consumption, Power production, Reactor

1. Introduction

According to a report by experts observing a test of the high-temperature Rossi reactor in Lugano [1], we assume that reactor itself is just a ceramic tube sealed using a heat-resisting cement, also containing nickel powder with lithium aluminum hydride addition. To initiate the process, it is necessary to heat the tube from 1200 to 1400°C. Based on this assumption, we made two versions of a device which is similar to the high-temperature Rossi reactor. In the devices of the first type [2], the amount of heat produced was measured using the mass of the evaporated water. In devices of the second type [3], the amount of heat produced was measured by comparing the power consumed by the reactor with fuel and without fuel.

2. Design of First Type Device

Alumina ceramic tubes 120 mm length with outer diameter 10 mm and inner diameter 5 mm were used (Fig. 1). Nichrome wire as electrical heater was wound around the tube. One gram of Ni powder with 0.1 g $Li[AlH_4]$ are placed inside the tube. A thermocouple was placed in contact with the outer surface of the tube. The ends of the tube were sealed with the heat-resistant cement. The entire reactor surface is coated with the same cement.

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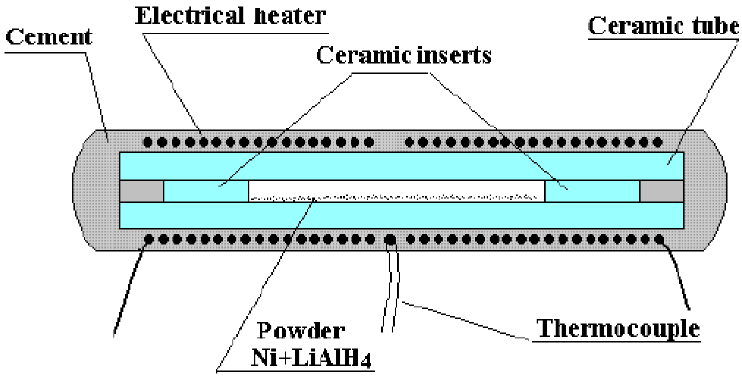

Figure 1. Schematic of the first type device.

3. Heat Output Measurements

The measurement method used during the Rossi's reactor test is very complicated. In our experiment, we used a method based on the amount of water boiled during the operation. This method was verified repeatedly during various experiments, including experiments with plasma electrolysis.

The reactor is placed in a closed metal vessel (Fig. 2), which is submerged in water. Some amount of water is steamed away when the reactor is in operation. Measuring the amount of water evaporated and using the heat of vaporization (2260 kJ/kg), we calculated the heat produced. We can also calculate the heat loss through the thermal isolation taking into account of the cooling rate after the reactor is switched off.

The reactor was placed either in the air on the alumina supports or immersed into alumina powder and put it into a metal box. The latter method requires 2–3 times less power to heat up the reactor to a given temperature, but in this mode, reactor operation is less stable.

4. Equipment for Heater Power and Diagnostics

The equipment used to measure and control power consumption and temperature measurements is shown in Fig. 3. We used a transformer with switching coils. The coils are switched manually and automatically by the regulator which is controlled by the thermocouple signal. When the temperature rises above a threshold, the regulator switches to the lower voltage. When temperature goes below another threshold, the voltage is increased. This allows long-duration operation at a preset temperature, which makes reactor's operation more stable. To measure the power consumption, we use a voltmeter and an ammeter, and a wattmeter that allows data recording to a computer.

To monitor the radiation level, we used a Geiger counter, a dosimeter DK-02 and neutron-activation technique with indium. Counter SI-8B has a thin mica input window that allows it to detect not only beta and gamma radiation, but also alpha particles and soft X-rays. The dosimeter DK-02 is a capacitor-based ionization chamber with measurement range 200 mR (beta and gamma rays). Indium plates, placed in the calorimeter water, are used to monitor neutrons. To measure indium activity, we used two Geiger counters. Impulses from the counters are recorded by the computer. The large surface of the indium plate (18 cm^2) allows the detection of slow neutrons that have a flux density more than 0.2 neutron/cm^2 s. In addition, the computer recorded impulses from the counter mounted on the reactor's top and impulses from the wattmeter. Another computer running PCLAB-2000 was coupled with a data logger. It displayed

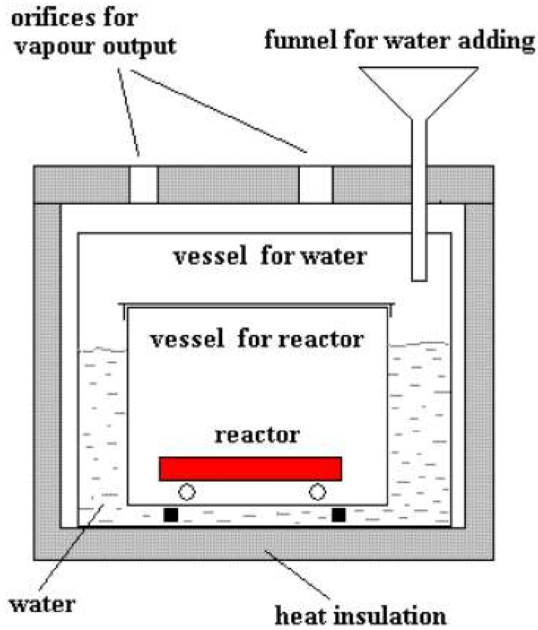

Figure 2. Schematic of the calorimeter with vaporized water.

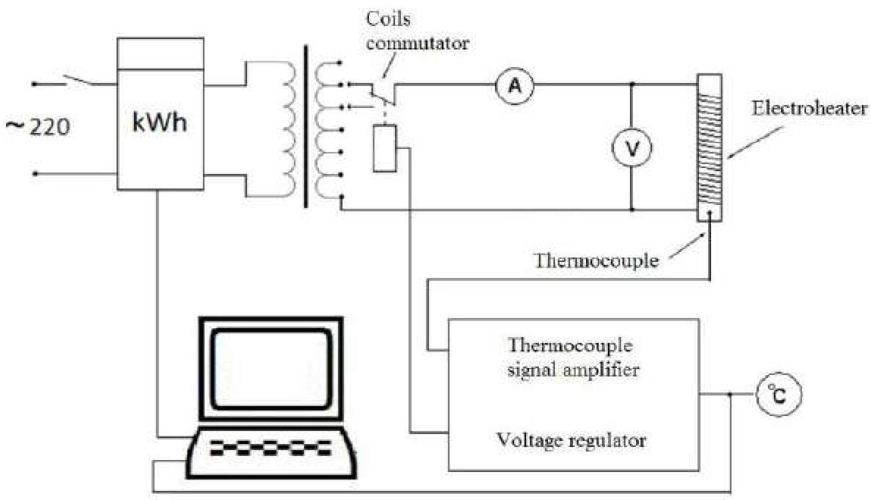

Figure 3. Schematic of power supplies and the resistance heater power regulation.

Figure 4. First type of reactor during operation.

and recorded the reactor temperature, and the signal from the DK-02 counter.

5. Temperature Changes during the Heating

To operate the device with heat production exceeding the input electric power, the following conditions must be met: Li[AlH_4] decomposition to hydrogen release, clarification of nickel granules surface, absorption of the emitted hydrogen by nickel, and finally the device must be operated at a high temperature. The production of energy is a result of processes in the fuel mix. It is important to note that the speed of heating has to be low in order that the emitted hydrogen can be absorbed by nickel to avoid an excessive increase of hydrogen pressure.

As an example, we show diagrams of the temperatures rising for experiment 20-12-2014. We slowly increased the power of the heater from 25 up to 500 W (Fig. 5). The temperature of 1000°C was reached after 5 h of heating. In the same diagram, we also show the count rate of the Geiger-counter SI-8B. As one can see during the entire heating process, the radiation level was similar to the background. The DK-02 dosimeter did not show the dose above the accuracy limit (5 mR) during the experiment. No noticeable activation of indium was detected.

Figure 6 shows the temperature changes with heating powers 300, 400, and 500 W. One can notice that with constant heating power the temperature gradually increases, especially in the last interval. It should be pointed out that excess heat occurs in addition to the electrical heating. At the end of the interval, at the maximum temperature, some temperature oscillations occurred. This interval ended when the electrical heater burned out, terminating the electrical heating. After that, the temperature became constant at 1200°C for 8 min, and afterwards begins to decrease. It should be noted that the reactor at this time was producing heat at kilowatt levels without electrical heating.

Thus, from the heating diagram itself we can see that reactor is capable of generating large amounts of heat in addition to the electrical heating.

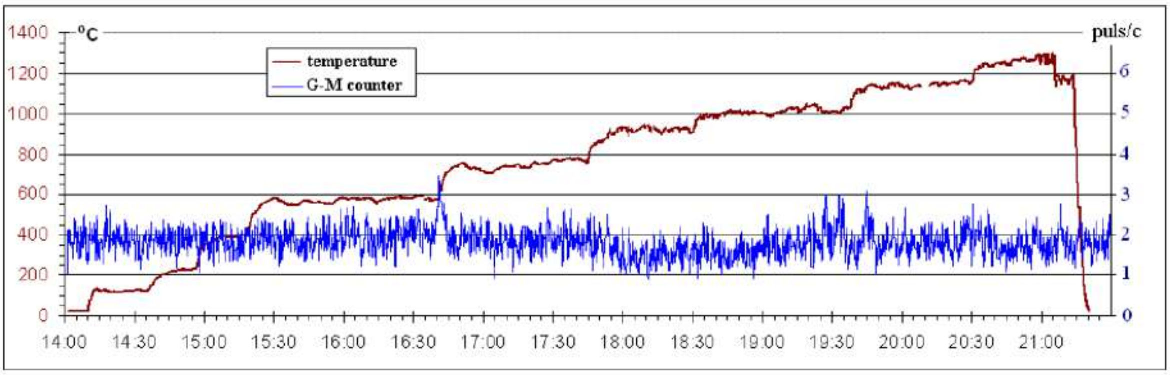

Figure 5. Dynamics of temperature and data from the Geiger counter during the experiment on 20-12-2014.

6. Produced Heat and COP Calculation

In Table 1 calculations are made for three reactor's operation modes: with temperature about 1000°C, about 1150°C, and 1200–1300°C. With temperatures 1150°C and 1200–1300°C the heat produced is meaningful exceeds the consumed energy. While operating in these modes, for about 90 min, about 3 MJ or 0.83 kWh was produced. The energy would be produced by burning about 70 g of gasoline.

Table 2 shows results obtained in all the experiments from December 2014 to January 2015. Besides the experiments with reactors loaded with Ni + Li[AlH_4] mixture, we also did experiments with a mock-up reactor without fuel. In cases with the mock-up reactor, the ratio of produced to consumed energy was close to 1, as it was in the experiments with fuel but with temperature below 1000°C. Significant excess heat was observed only when the reactor is loaded with the Ni + Li[AlH_4] fuel and held at a temperature about 1100°C or higher.

7. The Problem of Uncontrolled Local Overheating

The maximum duration reached with this type reactor operating in excess heat mode was 1.5 h. The causes of such short operating time are the failures due to local overheating. A view of the reactor during this kind of overheating

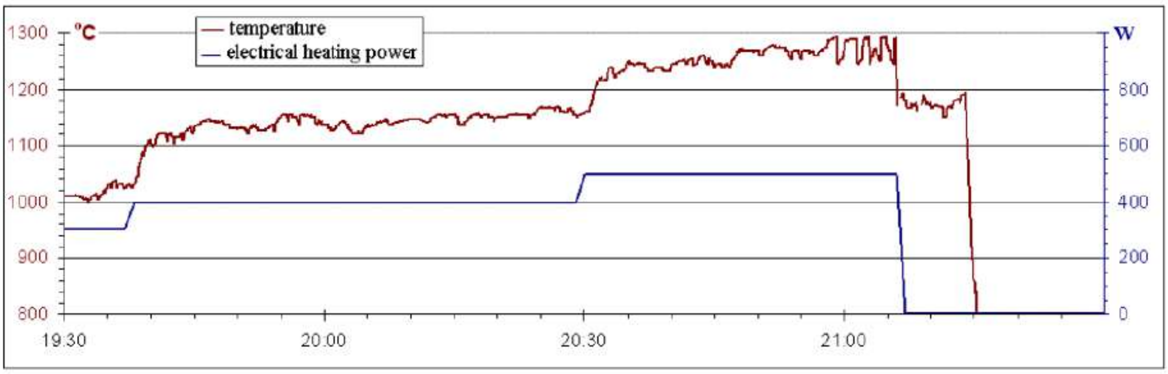

Figure 6. Dynamics of temperature and the power of electrical heating at high temperature for the experiment on 20-12-2014.

Table 1. COP calculation for the experiment on 20-12-2014.

Average temperature (°C)	970	1150	1290
Duration of regime (min)	38	50	40
Electrical input power (W)	300	394	498
Electrical input energy (kJ)	684	1182	1195
Mass of evaporated water (kg)	0.2	0.8	1.2
Energy to heat water to boiling (kJ)	63	251	377
Energy spent on evaporation (kJ)	452	1808	2712
Heat leakage through insulation (W)	70	70	70
Heat leakage through insulation (kJ)	159	210	180
Total emitted heat energy (kJ)	674	2269	3269
Ratio of the emitted heat energy to input energy	0.99	1.92	2.74

Table 2. COP in experiments in December 2014 and January 2015 (Reactor loaded with fuel).

Date	Temp. °C	Duration min	Cons. W	Prod. W	COP
20-12-2014	970	38	301	297	0.99
20-12-2014	1150	50	395	758	1.92
20-12-2014	1290	40	499	1365	2.74
04-01-2015	940	131	304	305	1.00
04-01-2015	1020	75	377	407	1.08
10-01-2015	1080	73	161	284	1.77
18-01-2015	800	90	308	293	0.95
18.01.2015	1080	38	78	135	1.73

Table 3. COP in experiments in December 2014 and January 2015 (Reactor loaded without fuel).

Date	Temp. (°C)	Duration (min)	Concentration (W)	Production (W)	COP
02-01-2015	210	56	211	227	1.07
02-01-2015	470	88	433	414	0.95
02-01-2015	1050	16	928	1035	1.12
21-01-2015	1000	69	297	296	1.00
21-01-2015	1080	43	306	297	0.97
28-01-2015	900	65	95.5	105	1.08
28-01-2015	1100	66	116	116	1.00
28-01-2015	1200	50	151	147	0.97

is shown in Fig. 7. The level the temperature reached was enough to melt the alumina (melting point 2040°C) (see Fig. 8).

8. Type-2 Reactor Works for Long Duration

The experiments with the above-described devices showed that the mixture of Ni + Li[AlH_4] heated in a hermetically closed ceramic tube at temperatures higher than 1100°C produce significantly more heat than the input energy. However, the operating time of these reactors before they fail is too short to produce measurable isotopic or atomic changes, and thus to short to show that the release of the excess heat is caused by cold nuclear transmutations.

To achieve longer continuous work durations, we had to make many changes to the design of the reactor. First of all, we had to abandon calorimetry based on the measurement of the quantity of evaporated water, because it is difficult

Figure 7. The local overheating that leads to reactor's failure.

to add make-up water all day long.

9. Construction of Type-2 Reactor

The reactor tube is designed for long duration operation is 29 cm long. Only its central part is heated. Due to the low thermal conductivity of the ceramic, the ends of the tube are not very warm (at 1200°C in the center, the ends are not

Figure 8. Fragment of the reactor destroyed due to local overheating.

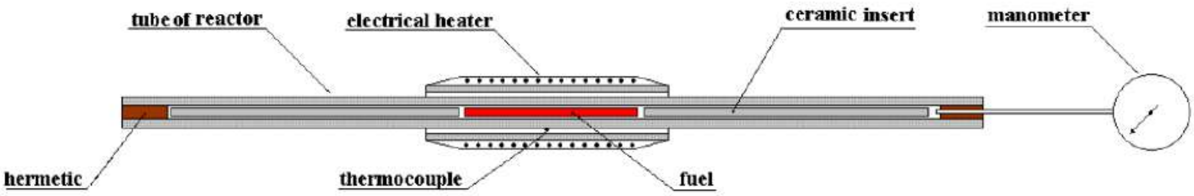

Figure 9. Construction of the reactor for long duration work.

warmer that 50°C); this allows the use of epoxy hermetic sealant to close the tube (Fig. 9).

The heater made from Kanthal A1 that works up to 1400°C. The fuel mixture (640 mg Ni + 60 mg $LiAlH_4$) is in a container of thin stainless steel. To displace the air from the tube, we used ceramic inserts. A manometer with a limit of measurement of 25 bar is connected to the reactor with a thin tube of stainless steel.

10. Equipment for Heater Power Supply, Measurement of the Consumed Energy and Control of Temperature

The electric heater is connected to the power supply through a thyristor regulator. An AC ammeter and a voltmeter are used to monitor and control the power consumption. Because the thyristor regulator distorts the sinusoidal form of current, such devices do not give correct measurements. To get correct measurement of the consumed electric power, the electronic watt-meter is used. This displays not only the amount of consumed electric power but it also sends consumption data to the computer.

To control of reactor temperature, a K-type thermocouple is used. The hot junction is placed on the surface of the reactor tube in the middle of the heating zone. The thermocouple data is displayed on a hand-held meter and also sent to the computer. The signal from the thermocouple is also used to thermostatically regulate the electric heater power so that a fixed temperature is maintained.

The computer used to record the temperature had to be switched-off periodically to recharge the battery. At this time, temperature control was maintained with the hand-held meter, and the temperature continued to be printed on paper. Figure 10 shows Type-2 reactor during testing.

11. Change of Temperature and Pressure during Reactor Operation

Figure 11 shows how temperature changed during heating, and it shows the power needed to reach the set temperature. The temperature of 1200°C at the surface of the reactor tube was reached after 12 h of stepwise increases of temperature, at heater power of 630 W. After 1 hour the power needed to maintain the temperature of 1200°C decreased to 330 W.

In Fig. 12, the change of pressure in the reactor chamber in the course of heating compared to the change in temperature is shown. The increase of pressure starts around 100°C. Maximum pressure of app. 5 bar was attained at 180°C. After this pressure starts to fall and at 900°C was lower than atmospheric pressure. The greatest decrease (–0.5 bar) was attained at 1150°C, then the pressure starts to increase slowly to atmospheric pressure.

In Fig. 13, the power of the electric heater for 4 days until burn-out of the heater wire as a result of its gradual oxidation is shown.

For almost 3 days the power necessary to maintain the temperature of the reactor tube at 1200°C was in the range of 300–400 W (Fig. 13). Before the power supply burned out, the power started to increase and at the time it burned out, power was 600 W. The burning out was caused by gradual oxidation of the resistor.

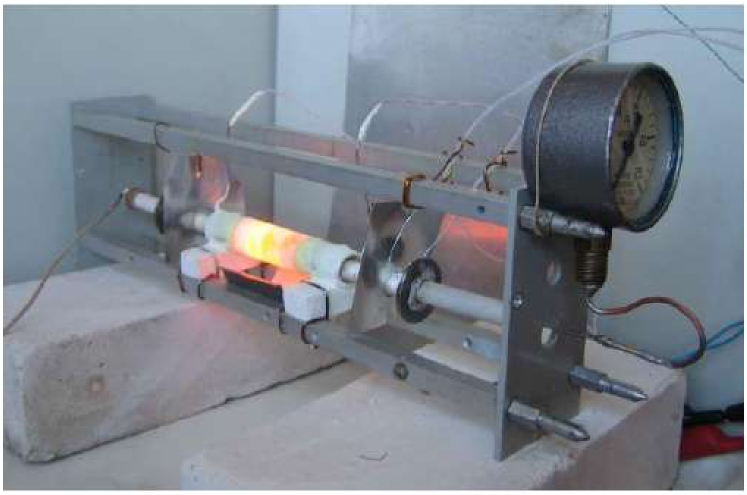

Figure 10. Type-2 reactor during testing.

12. Operation of the Reactor with the New Heater

One day after the heater burned out, the reactor was switched on repeatedly with the same reactor tube, but with a new heater. Figure 14 shows the power consumed by the reactor after replacement of the heater. Unlike the first heating, here after achievement of temperature 1200°C essential decrease in power consumption did not occur. The power which is required for maintenance of temperature 1200°C was in the range 600–700 W, i.e. was approximately the size it was at the time of burn-out of the first heater. Only at the end of repeated turning on the reactor power consumption decreased a little.

Approximately a day after repeated turning on of the reactor it was switched off by gradual reduction of heater power.

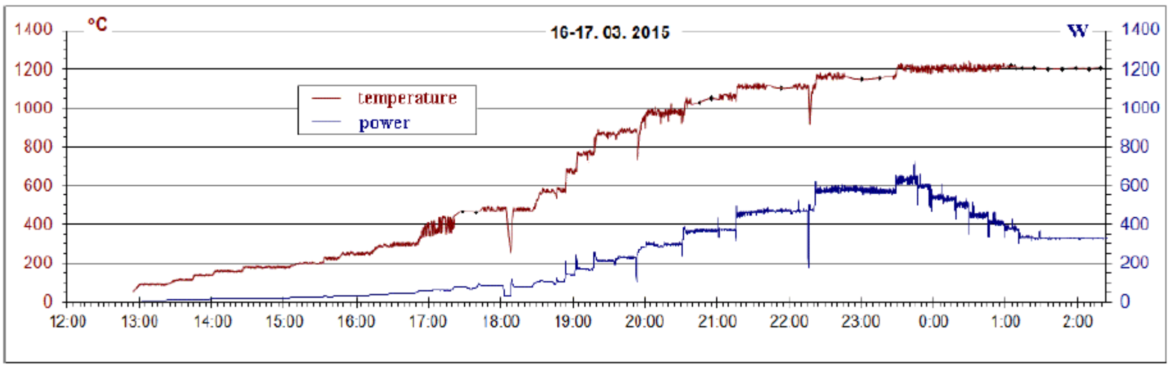

Figure 11. Heating of reactor to working temperature. Moscow time is shown on the horizontal scale.

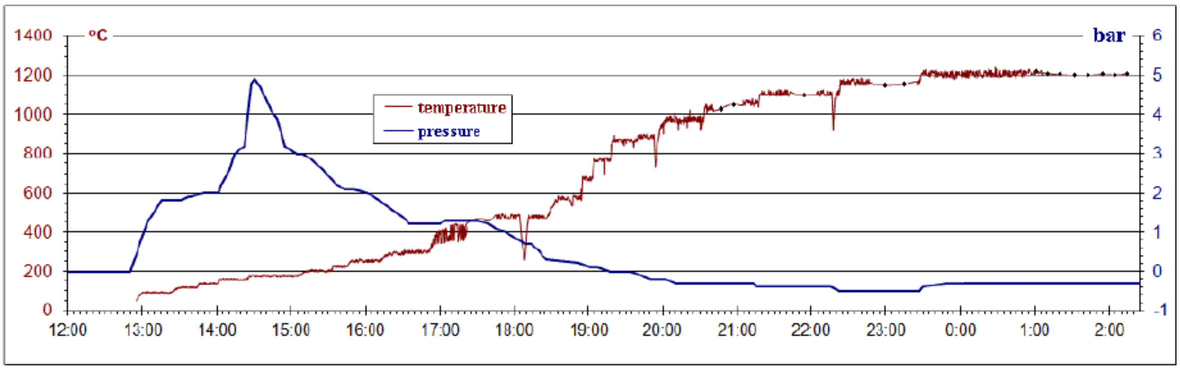

Figure 12. Heating of reactor to working temperature. Change of pressure during the course of heating.

13. Detection of Radiation

For radiation level detection, the same instruments were used as in the type-1 experiments: and SI-8B Geiger counter and the DK-02 dosimeter. For neutron measuring a neutron-activation technique with indium was employed. Measurements showed that the level of nuclear radiation in reactor operating time does not significantly exceed background.

14. Ratio of produced heat and the consumed electric power (COP)

As in the described experiment direct measurement of amount of the heat cannot be done, and reliable measurement of it is quite a complex challenge. This problem can be solved by comparing parameters of the reactor containing the fuel mix and the reactor without the fuel mix.

Figure 15 shows the power necessary to achieve the set reactor temperature without fuel and with fuel. It can be seen that at temperatures above 700°C the reactor with fuel consumes less electric power than the same reactor without fuel. This indicates the existence of a heat source besides the electrical heater.

About 1100 W of power is needed to maintain a temperature of 1200°C without fuel. In the presence of fuel (at the first switching) in the beginning 650 W is needed to maintain this temperature, and an hour after reaching it, only 300–330 W were required. Based on these data, it is possible to make an assessment of the COP. It is necessary to

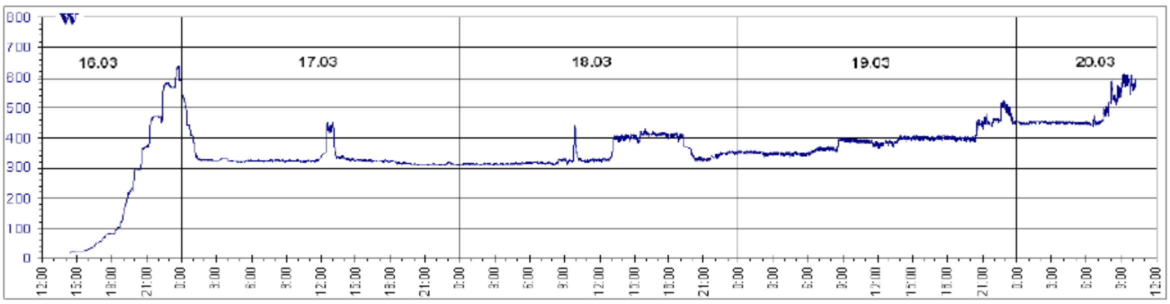

Figure 13. The power of heating during almost 4 days until the heater burned out. After reaching a temperature of 1200°C at 23:30 16-03-2015 this temperature was supported until 10:50 20-03-2015 by automatic adjustment of heater power.

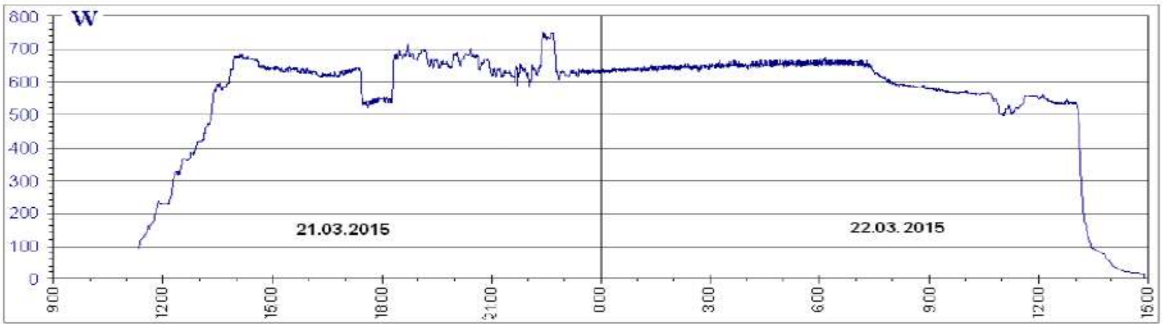

Figure 14. The power consumed by the reactor during repeated switching with the new heater. After reaching the temperature of 1200°C at 13:50 21-03-2015 this temperature was supported until 13:00 22-03-2015 by automatic adjustment of power of the heater.

consider the difference between processes in the reactor without fuel and with fuel when there is an additional thermal emission.

The intensity of heat exchange (produced power) depends on the temperature at the border of the environment, i.e. the external temperature of the heater. In the absence of an internal source of heat, the temperature outside and inside cannot strongly differ. In the presence of an additional thermal emission in the center of the reactor there is a thermal flux from inside to outside, which causes a temperature gradient. Therefore, the temperature measured by the thermocouple on the reactor tube surface (inside the heater tube) is higher than heater outer surface temperature (Fig. 16).

Measurements by the additional thermocouple show that with fuel at a temperature 1200°C on the reactor's inner tube heater outer surface temperature (at the first switching) was near 1070°C. As the produced power is defined by external temperature, the reactor overall makes a lot of heat, about 800 W, which is how much input was required

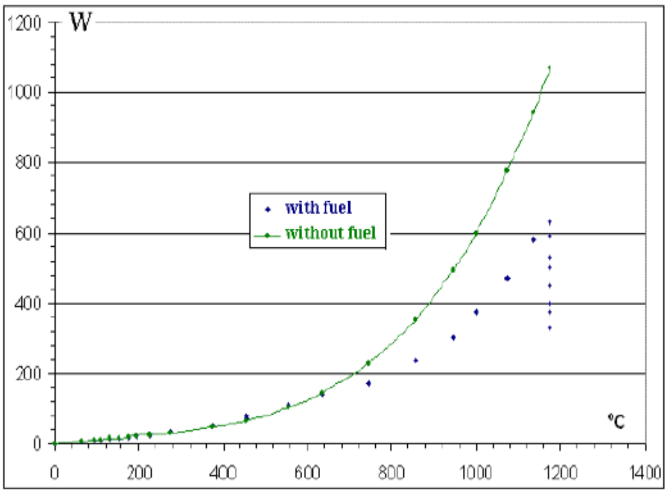

Figure 15. Power necessary for maintenance of the set temperature.

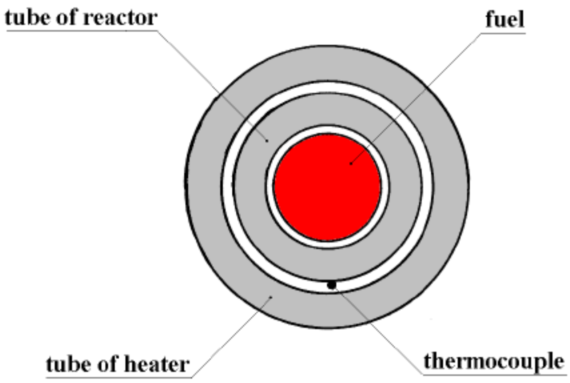

Figure 16. Cross section of the reactor central zone.

without fuel to maintain the temperature a 1070°C. Based on this, the COP is 800/330 = 2.4.

At repeated switching at a temperature 1200°C on a reactor tube surface, the heater surface temperature is 1130°C. The reactor makes apparent excess heat of about 950 W, which is how much input power was required without fuel to maintain the temperature 1130°C. Power consumption fluctuated from 550 to 700 W. Therefore, with repeated switching this COP is 1.3–1.7.

15. Research after the Test Run

After stopping and cooling the reactor, the tube of the reactor was opened, and the ceramic inserts and the container with fuel were removed from it. It was revealed that the container well remained though it and sites of ceramic inserts, close to it, became covered by a film of black color. The fuel extracted from the container represents caked substance of light gray color by the form very different from initial fuel mix (fine powder of black color). In optical microscope, it is visible that the used fuel has an appearance of baked small droplets of golden color with impurity of powder of gray color.

The images received on the electronic scanning microscope show that nickel in the initial fuel mix has an appearance of porous spherical clusters about 10 μm in size. Lithium aluminum hydride has an appearance of flakes with the size from 1 to 100 μm. In the fuel extracted from the reactor (after operation) we can identify two components: alloyed mass, consisting mainly of nickel, and flakes, consisting mainly of aluminum and oxygen.

16. Analysis of Compositions of the Initial and Used Fuel

Investigations of element and isotope composition of fuel mix are in progress. The analyses carried out so far did not reveal large changes in the isotopic composition of fuel. It is possible that it is connected with insufficient duration of this experiment. Lugano experiment which found strong isotope changes was 10 times longer at higher power.

Research *of element* structure on electronic microscope showed a very strong distinction for different places of test selection. Nevertheless, two fractions distinctly differ: in one aluminum and oxygen prevail, and in the other nickel prevails. The ratio of elements in fractions taken before and after operation of the reactor is approximately equal. After the reactor operates, in the fraction with nickel the contents of iron, chrome, silicon, sodium, potassium, titanium and some other elements considerably increased.

17. Conclusions

(1) Experiments with devices similar to the high-temperature Rossi heat generator loaded by mixture of Ni and $Li[AlH_4]$ demonstrated that these devices produce more energy than they consume at the temperature of about 1100°C and above.
(2) Type-2 apparatus worked continuously for more than 3 days, producing more than twice as much heat as the applied electrical energy. More than 40 kWh or 150 MJ were produced in excess of the electrical energy consumed. This is the amount of energy obtained by burning several liters of petroleum.
(3) The reactor chamber pressure during slow heating was relatively low.
(4) No ionizing radiation above the background level was observed while operating the reactor.
(5) Preliminary conclusions from the analysis of fuel element and isotope composition indicate a minor change in isotopic ratios and the emergence of new elements in the used fuel.

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