Experimental Studies of Nickel-Hydrogen Reaction with Abnormally High Heat

Alexander G. Parkhomov

R & D Laboratory КИТ

English translation by Bob Higgins

First experiments with nickel saturated with hydrogen

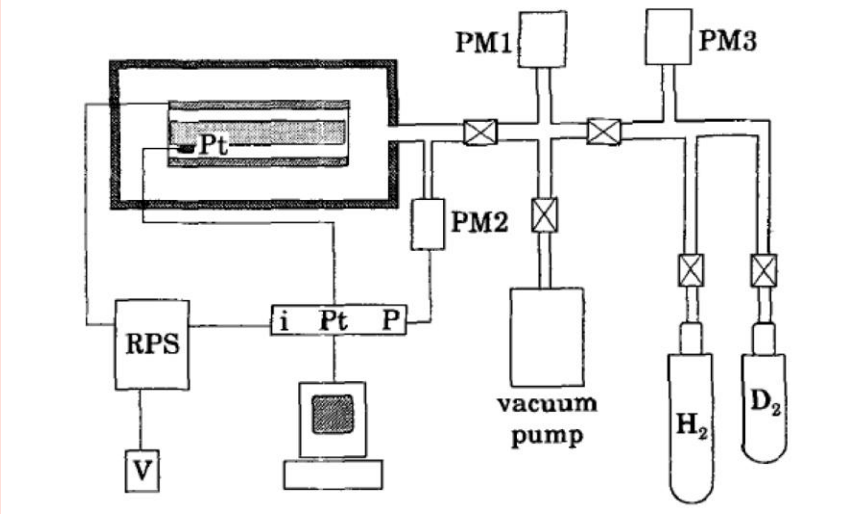
Since 1992, at the Physics Department of the University of Siena (Italy), a group of researchers led by Francesco Piantelli conducted experiments in which anomalous heat generation was observed when hydrogen interacted with nickel. The results of these studies were published in the prestigious scientific journal, "Nuovo Cimento"

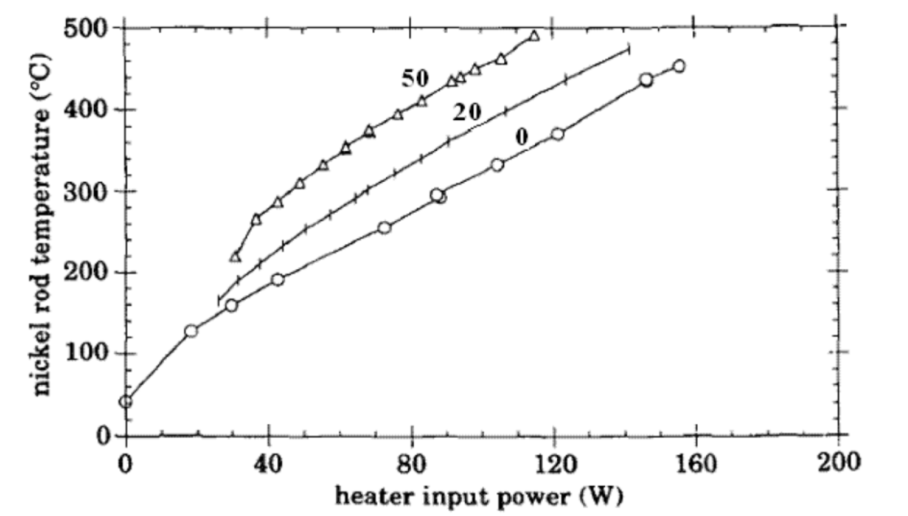
- **Focardi S., Habel R. and Piantelli F.** - *Anomalous Heat Production in Ni-H Systems,* Nuovo Cimento, 1994, **vol.** 107 A, N.1, p. 163 - 167

- **Focardi S., Gabbani V., Piantelli F.** , et al. - *Large excess heat production in Ni-H systems*, Nuovo Cimento, **1998,** vol. 111 A, N. 11, p. 1233 - 1242

- **Battaglia A., Daddi L., Focardi S.** , et al. - *Neutron emission in Ni-H systems*, Nuovo Cimento, 1999, **vol.** 112 A, N.9, 921-931.

Experiments by Italian Physicists





System schematic for nickel-hydrogen saturation and thermal studies.

Performed cyclic pumping and filling the chamber with hydrogen (natural mixture of protium and deuterium) to a pressure of about 0.55 bar at a temperature of 440°C. In one pumping cycle , the temperature suddenly rose from 440 to 480°C at a constant power of electrical heating.

This represented an addition to the electric heating of about 20 watts. After several additional cycles, excess heat reached 50 watts.

Plot of nickel rod temperature versus heater input power showing different values of anomalous heat energy

At the same temperature, a nickel rod saturated with hydrogen achieved a thermal power output approximately two times greater than a nickel rod without hydrogen.

The system was operated for 24 days continuously at an average excess thermal power of 44 watts. In total, for this time, the system generated about 90 MJ of thermal energy in excess of electrical input.

An improved system produced 68 watts of excess power and worked for 278 days, producing approximately 900 MJ of excess heat. Another experiment produced 18 watts of excess heat and worked 319 days, producing approximately 600 MJ of excess heat. This heat is equivalent to that generated by combustion of more than 10 kg of oil.

Note that the mass of the hydrogen absorbed which partly reacted with the nickel was less than 100 mg.

After the operation of one of the reactors , the nickel surface of the sample was subjected to scanning electron microscope analysis. Chromium and manganese were found on the nickel surface, but were not present in the reactor materials.

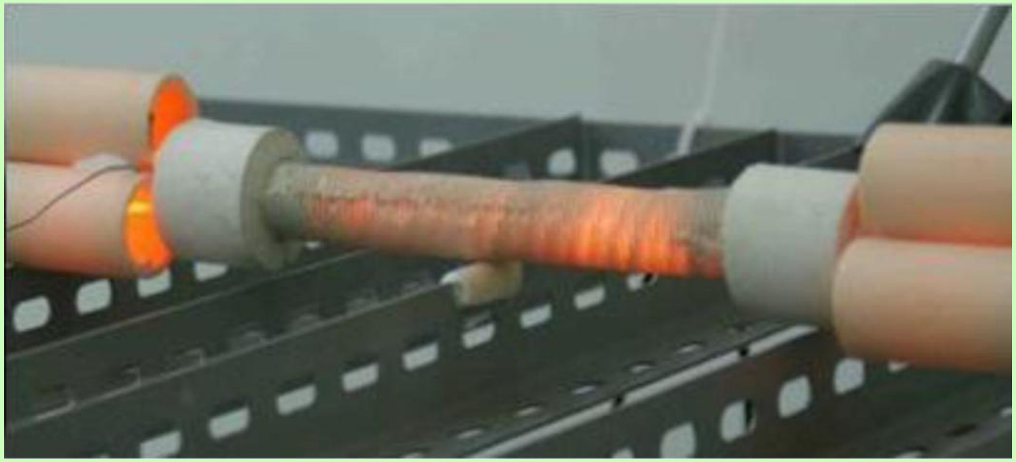
Thermo-Generators of Andrea Rossi

Andrea Rossi and Sergio Focardi near one of his early experiment installations [E-Cat]

Nickel-hydrogen heat generator with heat capacity of 10 kW [concept, hypothetical]

Heat generating system with thermal capacity of 470 kW

Rossi's "Lugano" reactor



This reactor was reported to have an excess heat to electrical consumption ratio of 3.2 [COP] at 1250°C and 3.6 at a temperature of 1400°C.

The spent fuel was measured to have significantly increased the relative content of ^{6}Li and reduced content of ^{7}Li. The content of all isotopes of nickel were substantially reduced except ^{62}Ni. The ^{62}Ni isotopic content increased from 3.6% to 99%.

No significant radiation (gamma, neutron) was detected above background levels.

The device, weighing 450 grams, and containing 1 gram of fuel, was operated continuously for a month. According to experts, 5800 MJ or 1.6 MWh of excess thermal energy was produced. To create an equivalent heat energy, you would need to burn more than 100 kg of oil.

On the basis of the experts' report of testing Rossi's high-temperature heat generator in Lugano, it was surmised that the reactor was simply a ceramic tube, sealed with temperature-resistant cement; inside of which was placed nickel powder and lithium aluminum hydride. To initiate the process producing excess heat, the tube must be heated to a temperature of 1200-1400°C.

On the basis of this assumption, many reactor devices have been evaluated in Russia and abroad.

What happens inside Rossi's reactor?

$$2\,Li[AlH_4] \xrightarrow{125\text{ - }180\ ^{0}C} 2\,LiH + 2\,Al + 3\,H_2$$

$$2\,LiH \xrightarrow{>850^{0}C} 2\,Li + H_2$$

First, upon heating, the lithium aluminum hydride decomposes.

1 g of lithium aluminum hydride can release 0.105 g of hydrogen, which is 1.17 liter (at standard temperature and pressure)

The gaseous hydrogen released reduces the surface of the nickel from oxide. Thereafter, hydrogen begins to dissolve into the nickel.

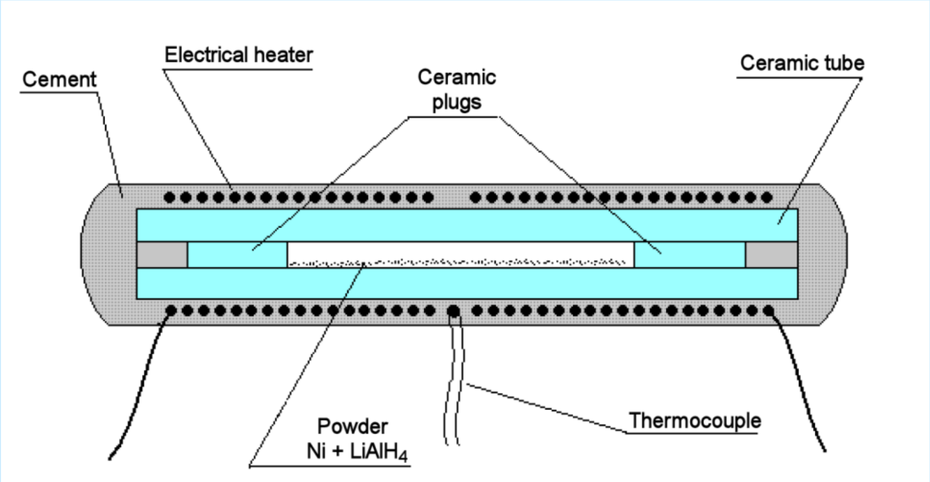
At temperatures typical of Rossi's Lugano reactor during operation (1200 - 1400°C), a hydrogen-rich nickel alloy with lithium and aluminum is formed in hydrogen, lithium vapor, and liquid aluminum.

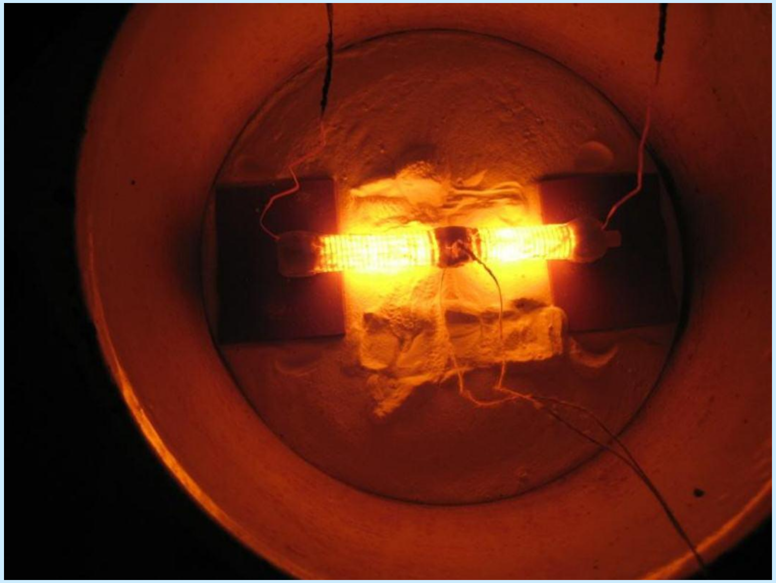
Challenges in creating a high-temperature reactor

- **Finding structural materials that can withstand the aggressive environment at high temperature and high pressure**
- **Sealing at high pressure and high temperature**
- **Creating electrical heaters that can continuously operate at high temperatures**
- **Finding ways to reliably measure heat**
- **Developing methods for power control of the reactor**
- **Running long experiments due to the slowness of treating the Ni powder and saturating with hydrogen**

The AP1 reactor design

reported at a seminar in РУДН on December 25, 2014





Reactor during operation

The reactors were made from Al_2O_3 ceramic tubes.

A heater coil was wound on the outside of the tube.

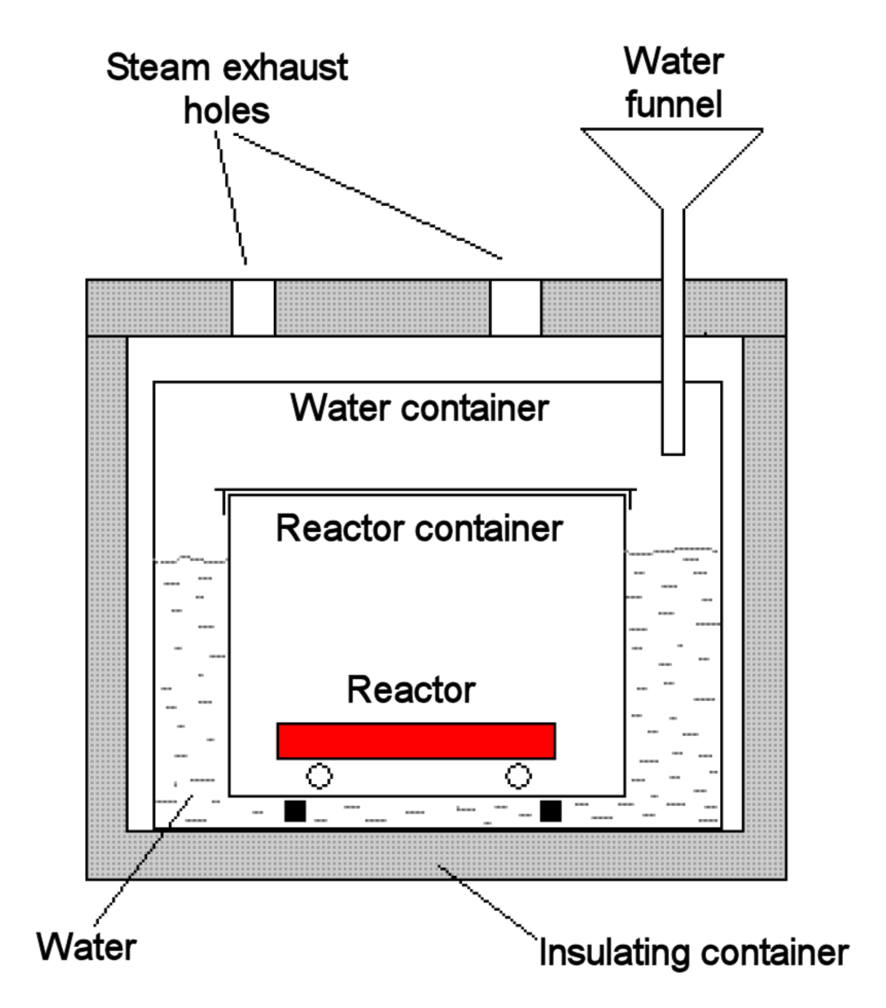
Inside the tube a fuel comprised of 1 g of Ni powder + 10% Li $[AlH_4]$.

A thermocouple was cemented in place in contact with the outer surface of the tube.

The open ends of the tubes were sealed with heat-resistant cement.

Similarly, the entire surface of the reactor tube assembly was covered with cement.

Measurement of emitted heat



The reactor is inside a closed metal vessel [Reactor container].

This vessel is immersed in water [Water container].

Due to heating from the reactor, a portion of the water converts to steam and exits to atmosphere [via the Steam exhaust holes].

By measuring the water lost to steam, and by calculation using the known heat of vaporization (2260 kJ / kg), it is easy to calculate the heat generated by the reactor.

A correction was made for the loss of heat through the insulation which was determined by the cooling rate after the reactor was shutdown.

Reactor with Fuel

Date	Temp °C	Duration Min	Input Watts	Output Watts	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

Electric Heating Without Fuel

Date	Temp °C	Duration Min	Input Watts	Output Watts	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

In this experiment, the reactor heat was determined using a method based on the amount of water boiled to steam.

These tables show the results obtained in the experiments.

In addition to the experiments with fueled reactors loaded with a mixture of Ni + Li[AlH_4], control experiments were conducted using reactors without fuel.

In cases of control experiment reactors, as well as reactors with fuel at a temperature below 1000°C, the ratio of the released thermal energy to electrical power input [COP] was measured to be close to 1.0

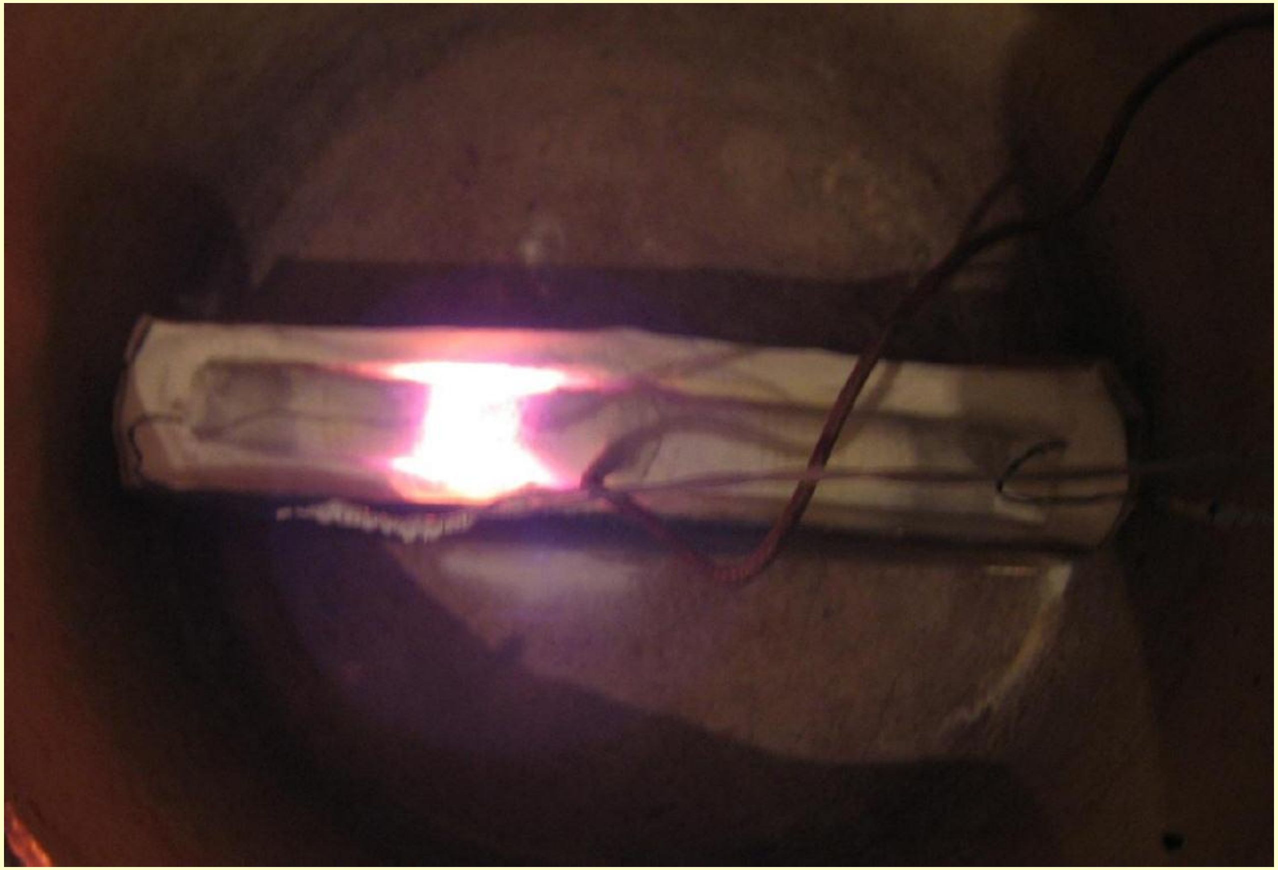
Significant excess thermal energy was only observed in the reactors having fuel and operating at temperatures of 1100°C and above.

Conclusions from a series of experiments in December 2014 - January 2015

Experiments run using models of Rossi's high temperature reactor, loaded with a fuel mixture of lithium aluminum hydride and nickel, have shown that at temperatures of 1100°C or higher, these devices actually produce more energy than is consumed.

The level of ionizing radiation measured during operation of the reactor did not significantly exceed background rates. Measured neutron flux density was not greater than 0.2 neutrons / cm2 .

The problem of uncontrolled hot spots

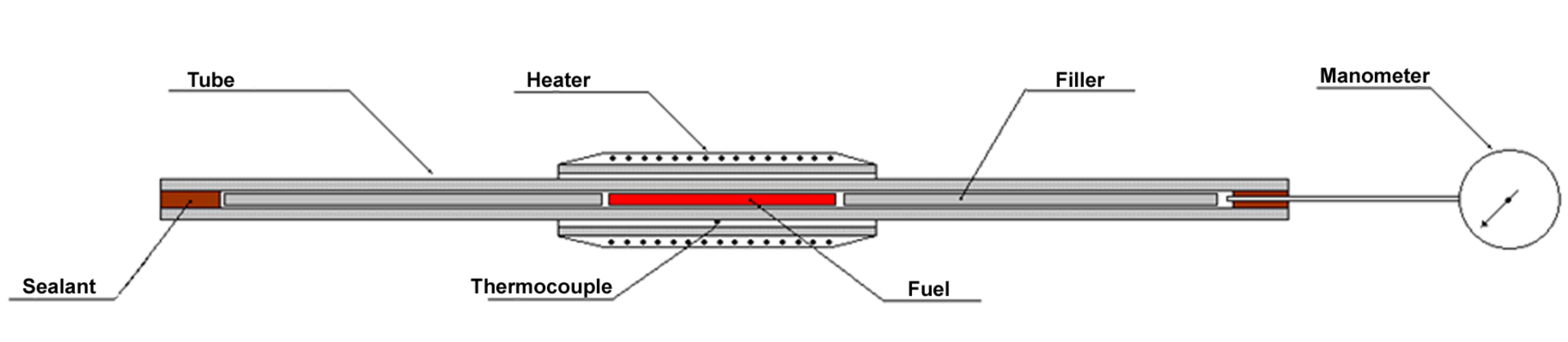


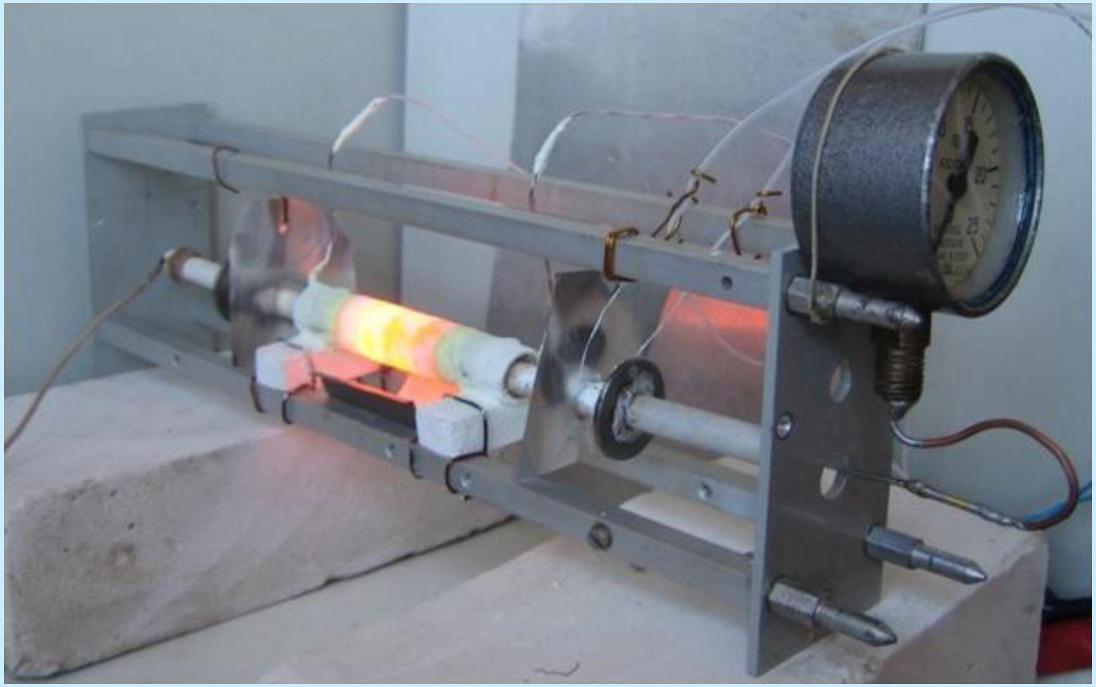
Local overheating that resulted in destruction of a reactor.

The main problem: short lifetime operation of the reactors, connected to the destruction caused by local overheating.

Reactor design AP2

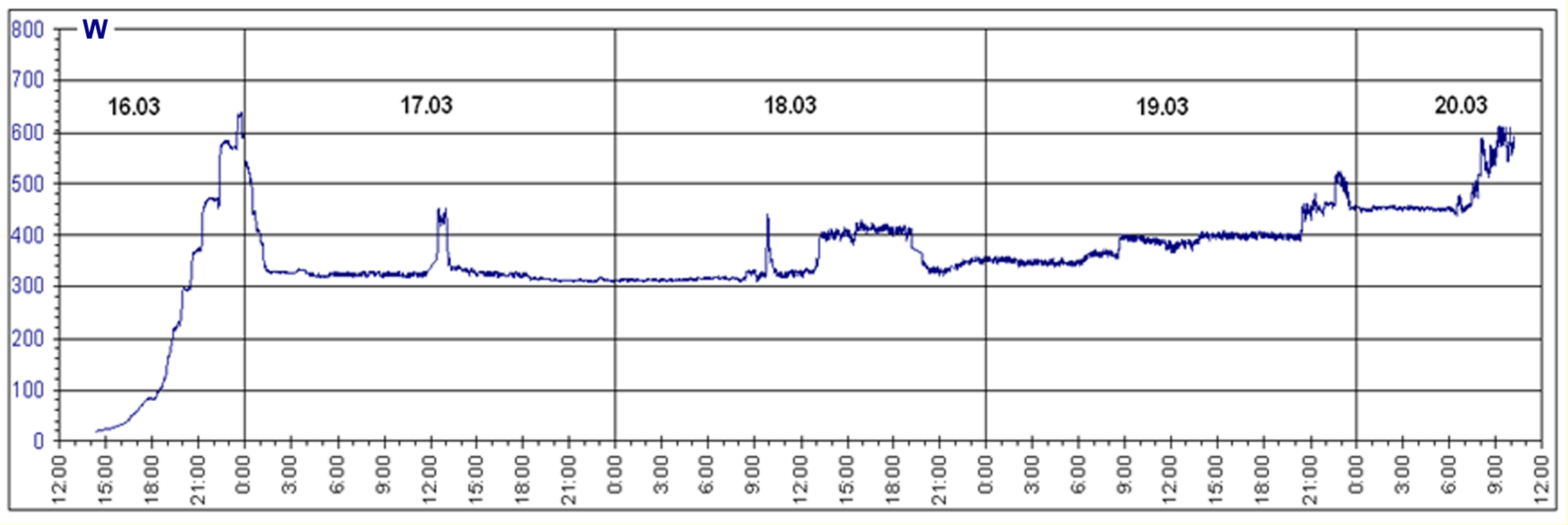
which was reported March 26, 2015 at a seminar in РУДН





The fuel mixture used (640 mg Ni + 60 mg $LiAlH_4$) was placed in a container made of thin stainless steel inside the alumina tube.

The power of the electric heater for 4 days



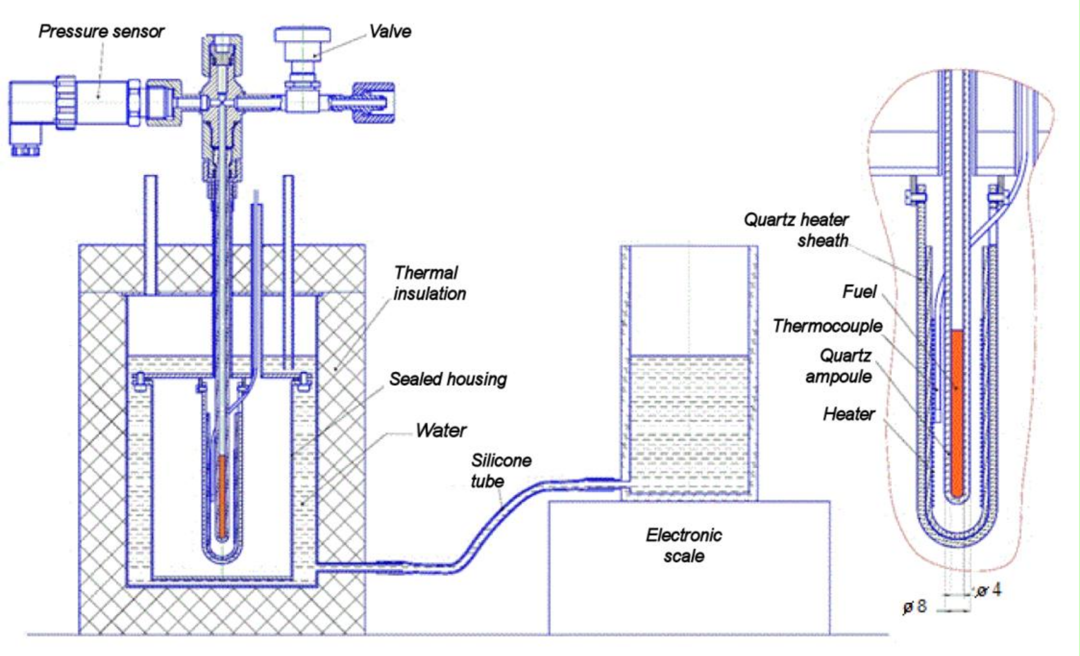
A temperature of 1200°C was achieved in 12 hours on the surface of the reactor tube as a result of the gradual increase of the electric heater power to 630 watts. Thereafter, for about 1 hour, the temperature of 1200°C was maintained with a reduced power of 330 watts.

For almost three days the surface of the reactor tube was maintained at temperature of 1200°C with an electric heater input in the range of 300 - 400 watts. Shortly before the heater burned out, power began to grow and at the time of burnout had reached 600 watts.

Heat output exceeded electric heater power input by a factor of 2.4 [COP]. Total output heat in excess of electrical heater consumption was more than 40 kWh or 150 MJ.

The Experiments of Eugene Buriak

VNIIEF in Sarov, April-May 2015



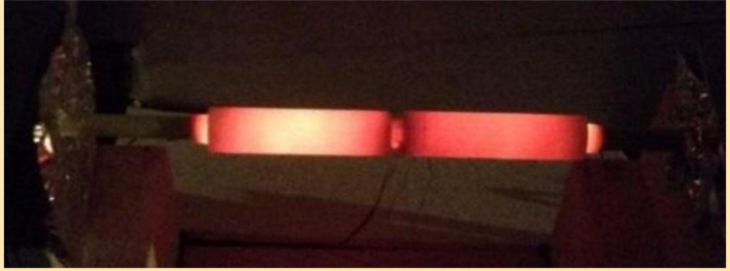
Fuel (500mg Ni + 50mg $LiAlH_4$) is located in a stainless steel container placed in a quartz ampoule.

A nichrome heater was powered with pulses of 0.76 ms, the fundamental period of the regulated pulse frequency.

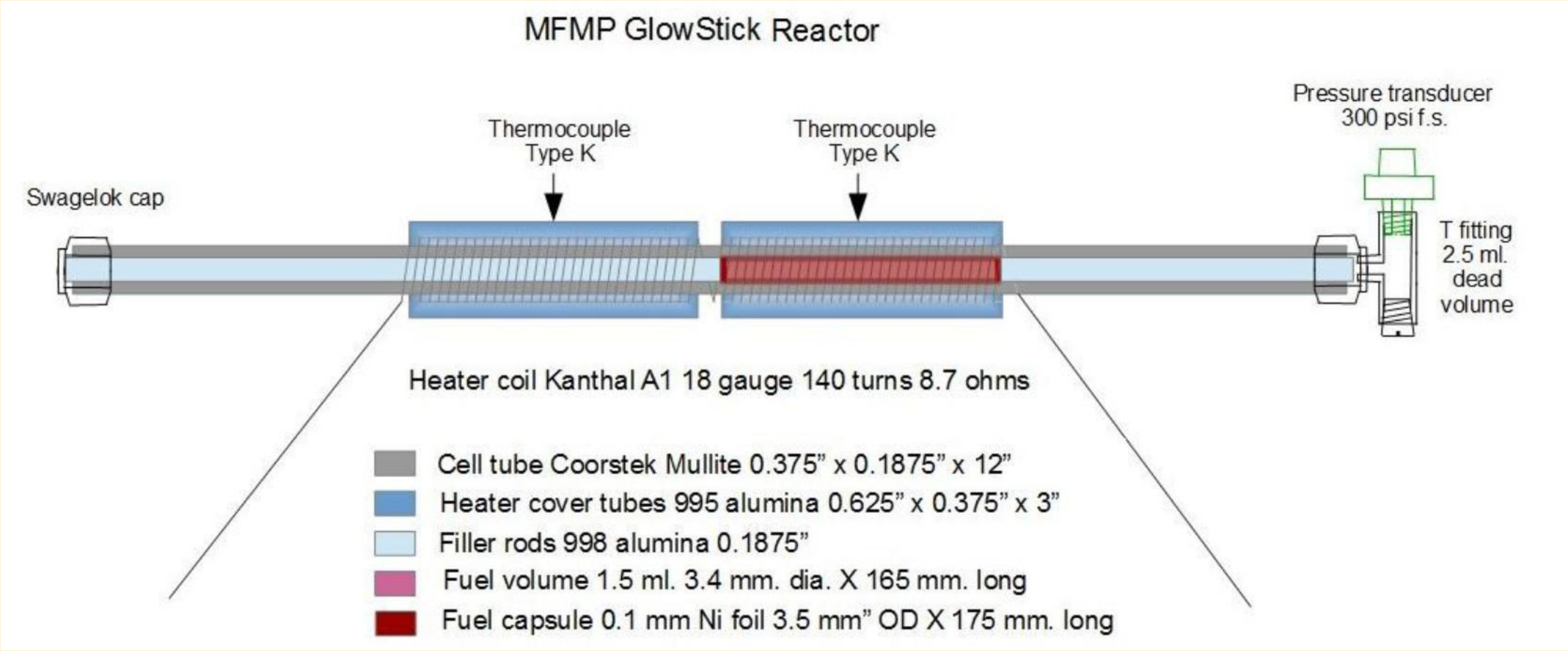
The reactor was heated at a rate of 0.02°C/s until the temperature came to 1000 or 1200 °C. Then, for an additional hour the temperature was kept stable.

Determination of released heat was carried out by measuring the mass of water lost as steam.

At a temperature of 1000°C the excess heat was 42 W (COP = 1.21), and at 1200°C, the excess heat was 83 W (COP = 1.25).

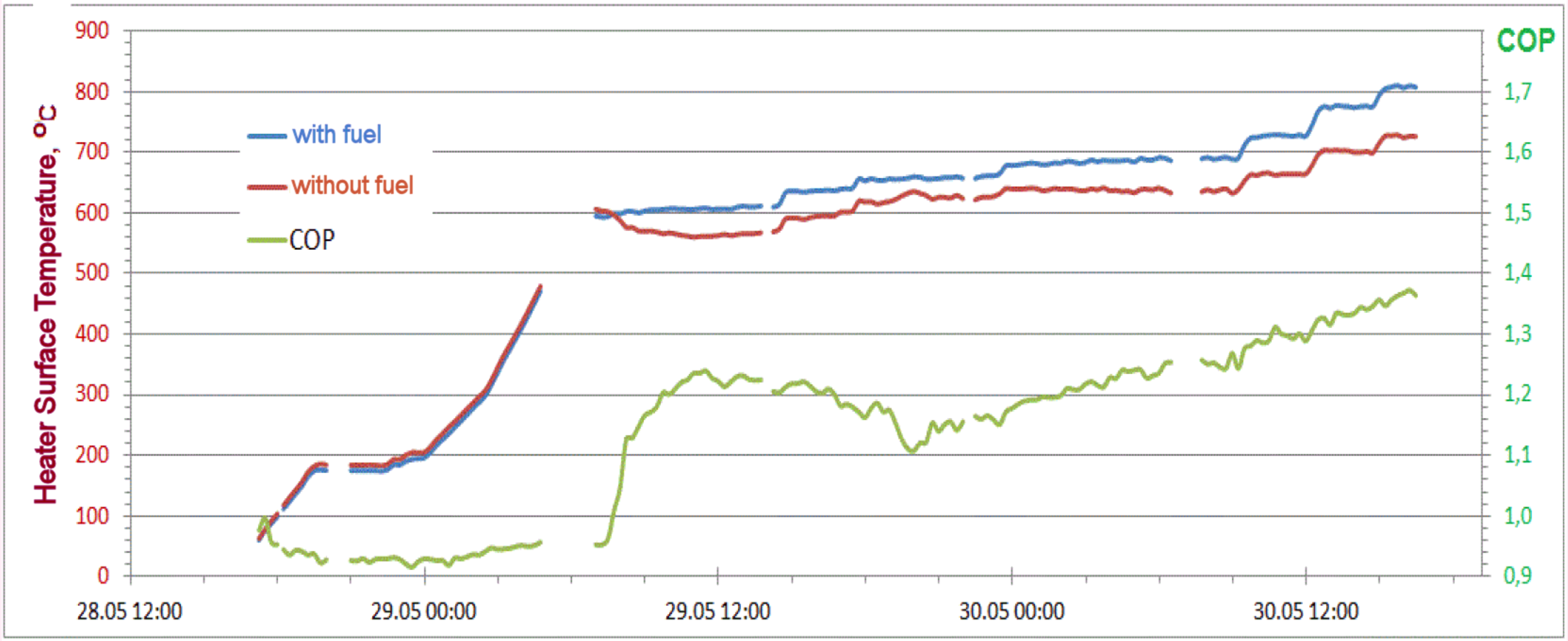


Project GlowStick
Alan Goldwater



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. In the presence of excess heat the temperature of the fueled reactor will be higher than that of the inert control reactor.

GlowStick 3



Above is a chart of control and fueled reactor temperatures during the experiment of 28-30 May 2015. The temperature at the heater surface is greater than 600°C (about 1000°C inside the core of the reactor) showing 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 heat of 160 W – developing 4.8 kWh (17 MJ) of excess energy

Songsheng Jiang

Ni-H Research Group

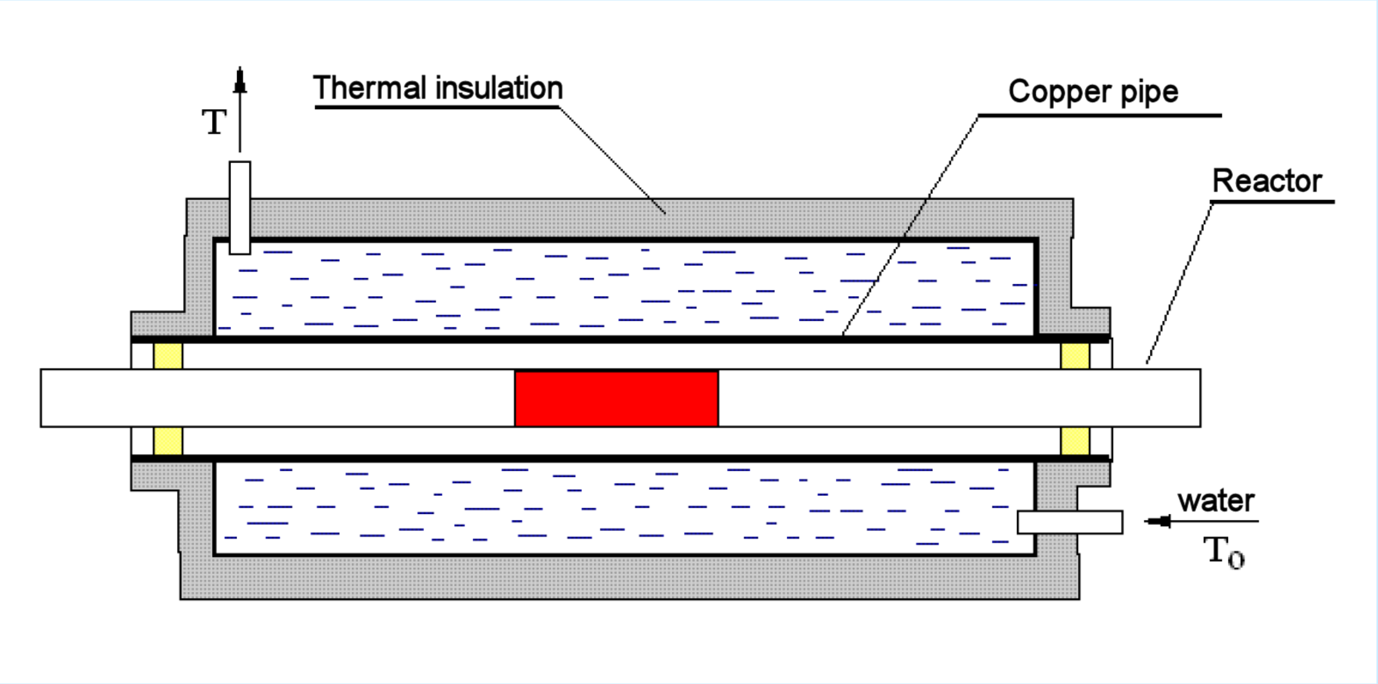
China Institute of Atomic Energy, Beijing, China, 4-8 May 2015

Fuel (Ni + 10% $LiAlH_4$) 20 g of the nickel is placed in a stainless steel reactor vessel. The heater is surrounded by insulation, and powered by a stabilized DC source.

With gradual heating to decompose the $LiAlH_4$, the pressure increased to 4 bar. During the next 18 hours of heating, the pressure dropped further to 0.9 bar.

When the temperature inside the reactor core reached 950°C, the temperature quickly rose to such an extent that the center thermocouple failed. The temperature on the surface of the stainless steel reactor vessel exceeded 1370°C, and became much higher than the temperature nearer the electric heater. That indicates a heat source within the reactor cell having a magnitude of not less than 600 watts. Excess heat was maintained for about 6 hours.

Reactor device in a flow calorimeter



Measured heat power from water flow: $W = c\,(dm / dt)\,(T - T_o)\,(1 + \alpha)$

where: c = the specific heat of water

dm/dt = mass flow of water per second

α = correction for heat loss

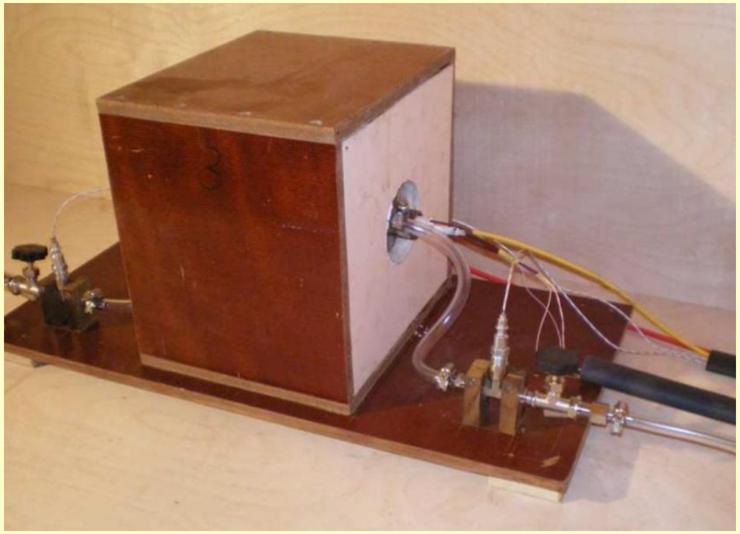
T_o = water inlet temperature

T = water outlet temperature

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

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

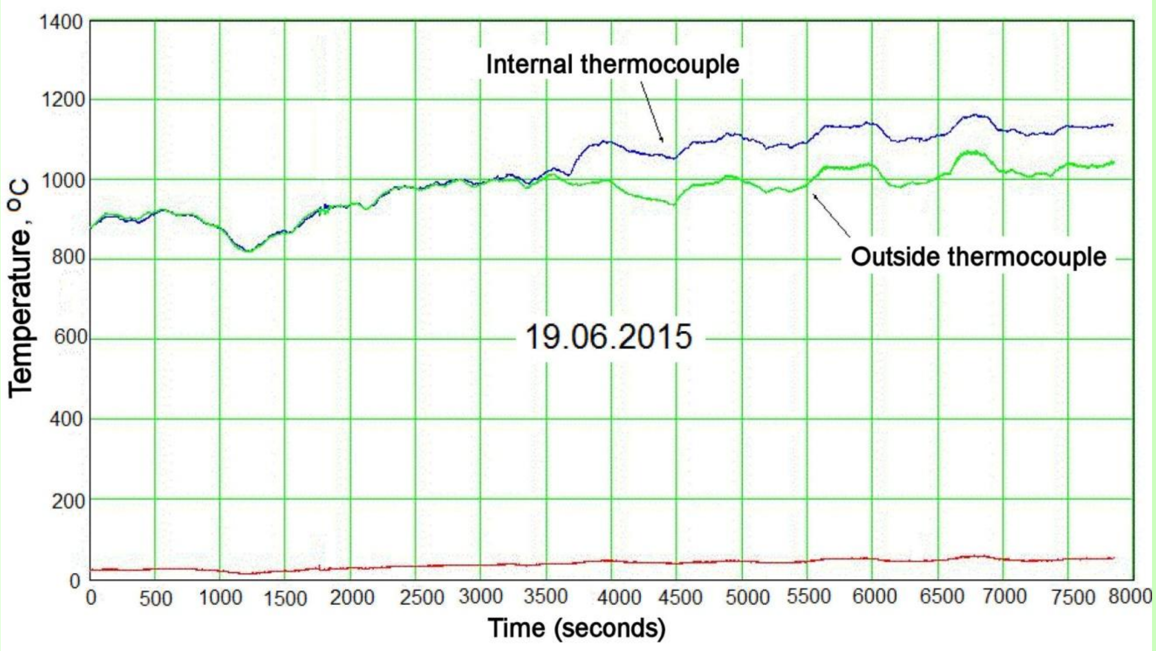
Electric heater (ceramic tube wound with Fe-Cr-Al heater wire)



Reactor in flow calorimeter within the outer insulating box.

Flow calorimeter cell without the outer thermal insulation

Experiments of Yu. Malahova, Nguyen Quoc Chi, I. Stepanova



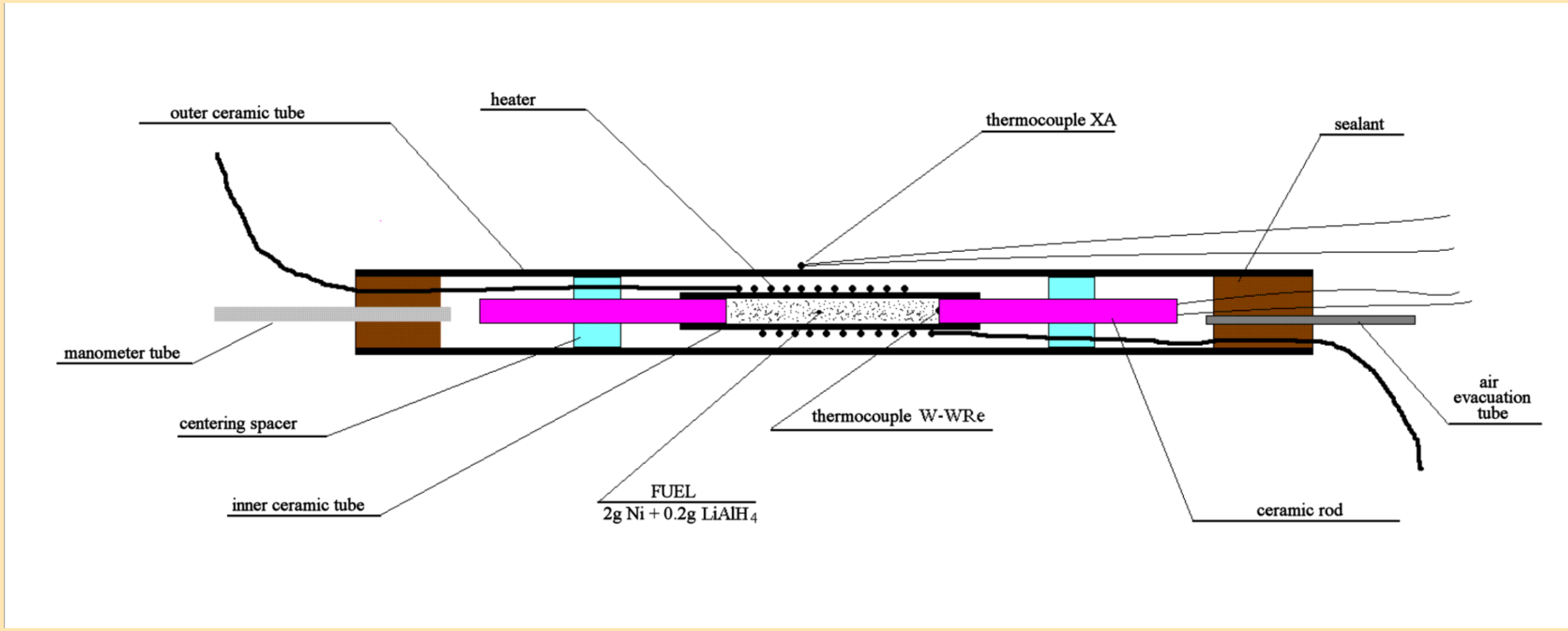
The temperature inside and outside the reactor tube.

After three attempts to launch that each ended with the rapid destruction of the cell due to uncontrolled overheating, one managed to achieve stable operation with the release of excess energy. This surviving experiment lasted more than an hour at a temperature of about 1100°C .

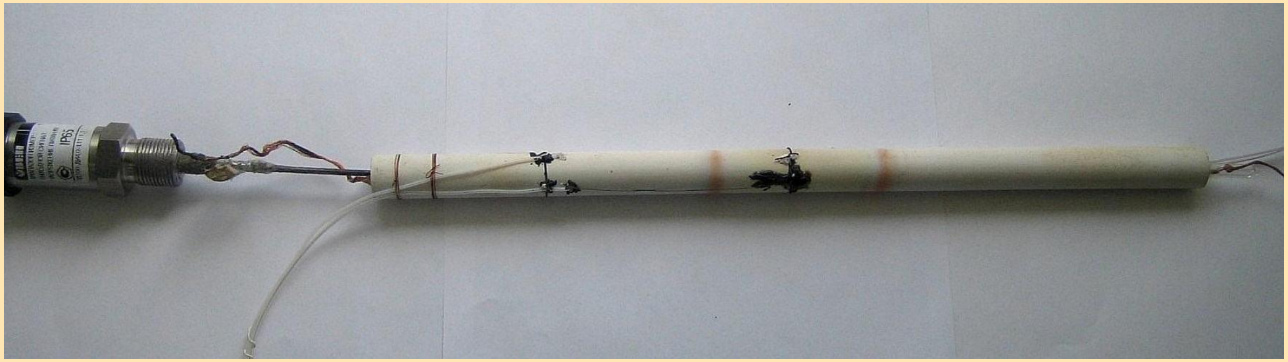
At temperatures below 1000°C the temperatures inside and outside the reactor were approximately the same. At higher temperatures, the temperature inside the reactor was larger than the outside, indicating the presence of heat originating within the reactor.

Calorimetry measured 2100 Watts of output heat while the electrical power input was only 850 W (COP = 2.5)

Prototype reactor for use in calorimeter at КИТ lab

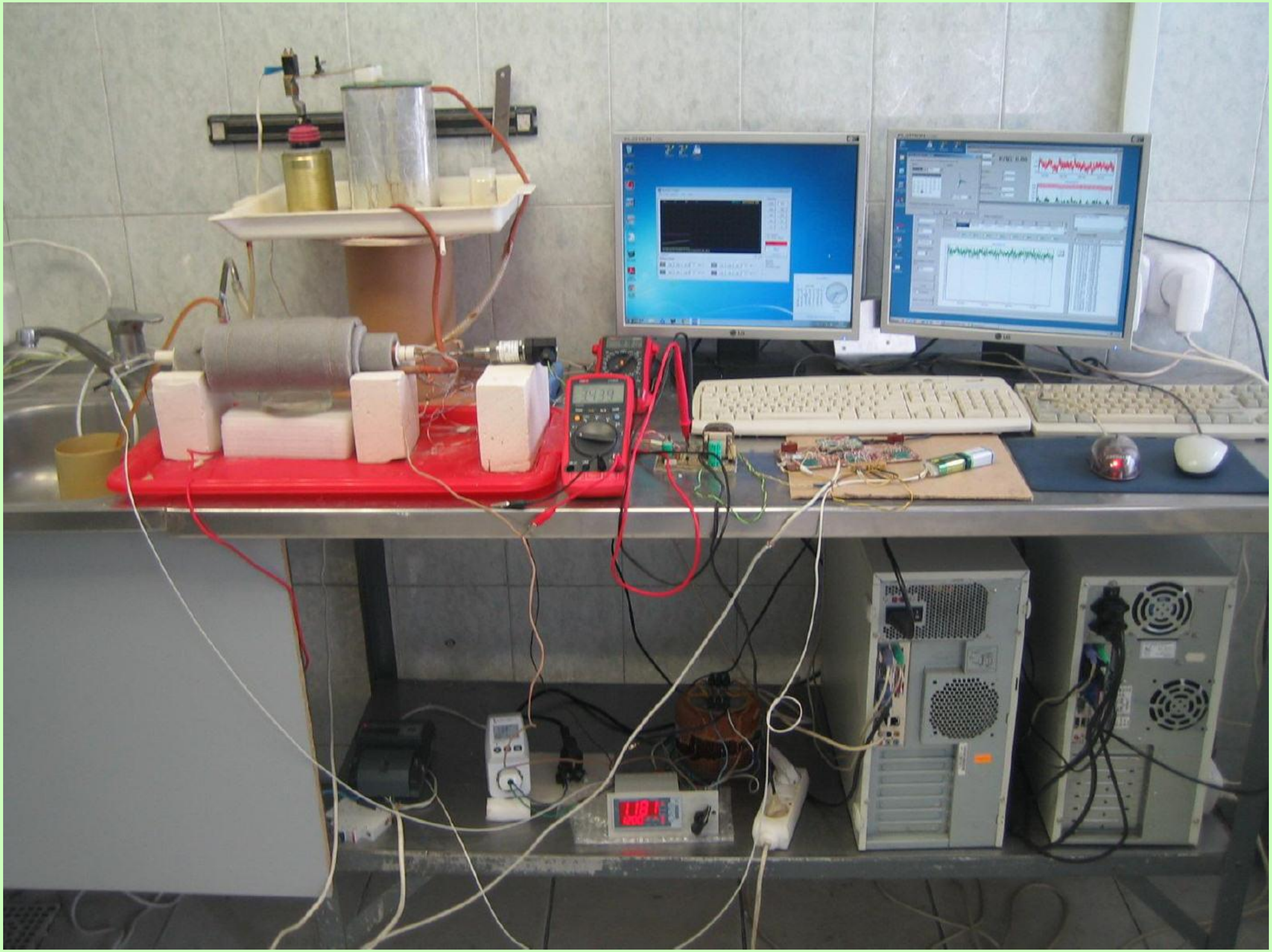


Reactor design for use in the flow calorimeter that was tested

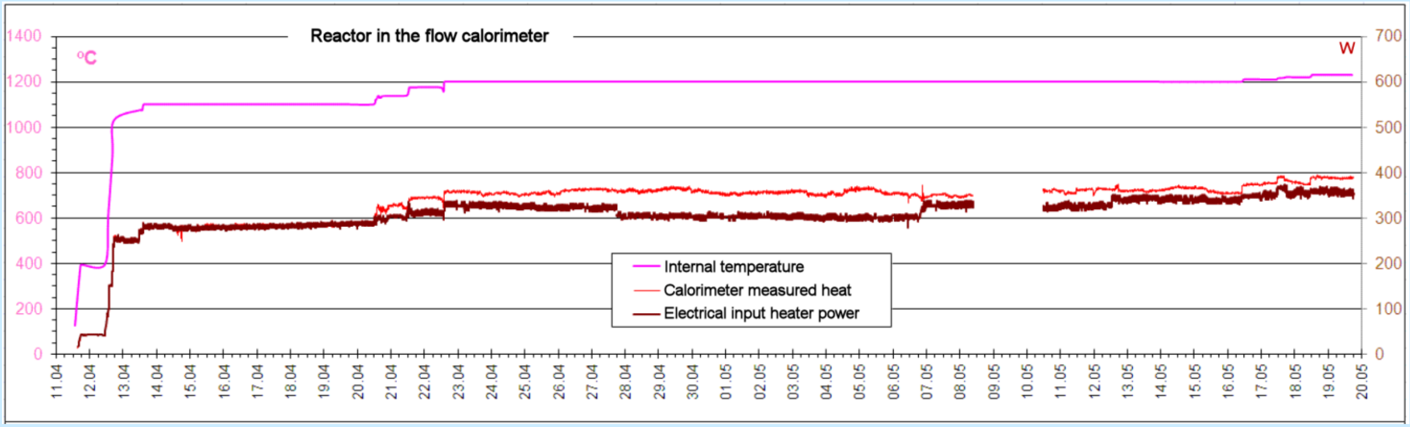


Reactor appearance before installation in the calorimeter

Prototype КИТ lab flow calorimeter



Reactor «Проток – 6»



Changes in temperature, power consumption, and heat generation during power operation of the reactor

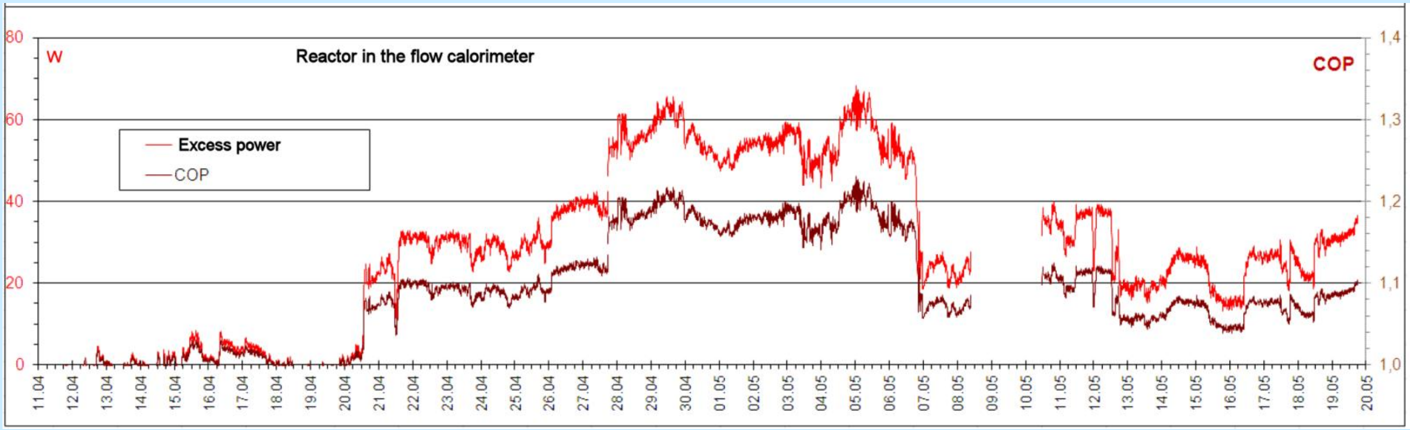


Chart of the excess power and COP (ratio of calorimeter measured heat output to electric heater input power)

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 is much higher than the electric heater input power. The excess heat output of 30-60 watts lasted 29 days.

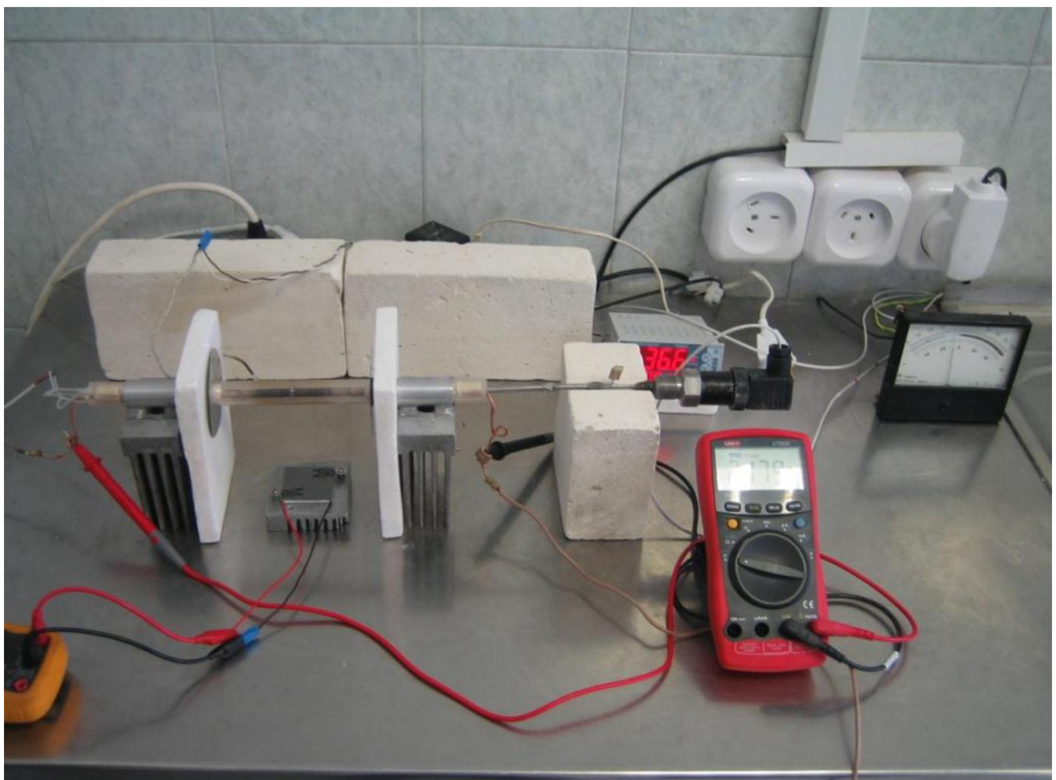
The reactor produced approximately 100 MJ (28 kilowatt-hour) of thermal energy above the consumed electrical energy.

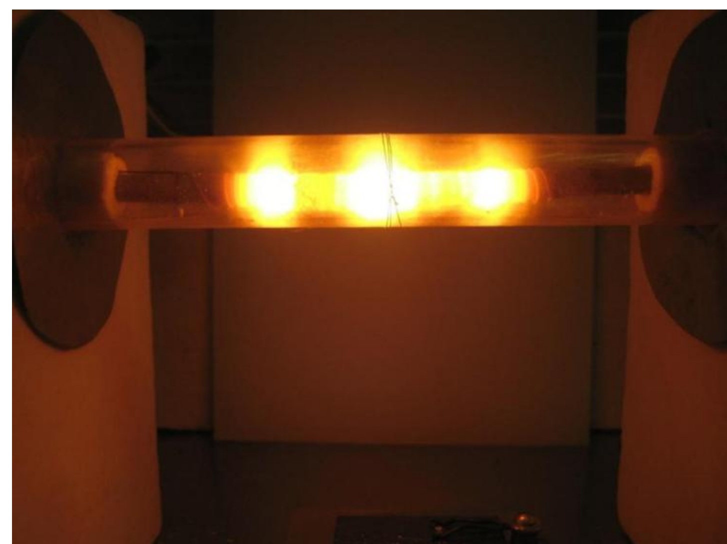
Reactor C1

Reactor C1 used a transparent sapphire tube to demonstrate the ability to use nickel-hydrogen systems as a light sources.

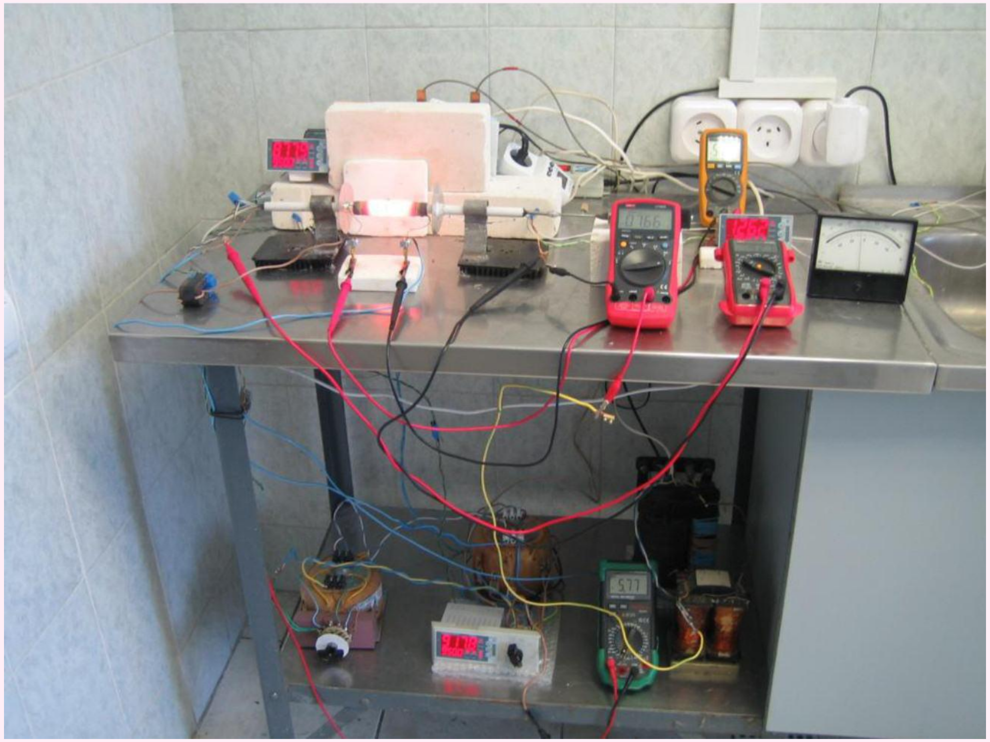
The reactor worked for 10 hours with an excess heat of up to 350 watts.

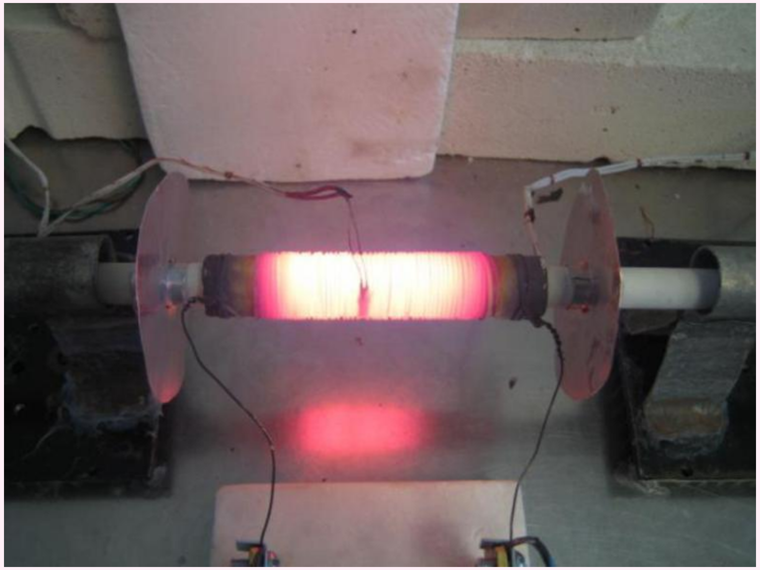
Output heat exceeded the electrical power consumed within the range of 1.6 - 2.4 [COP].





Reactor BB3





Reactor BB3 spent 40 days in production of excess heat, exceeding the electrical consumption by 1.6 times. [COP]

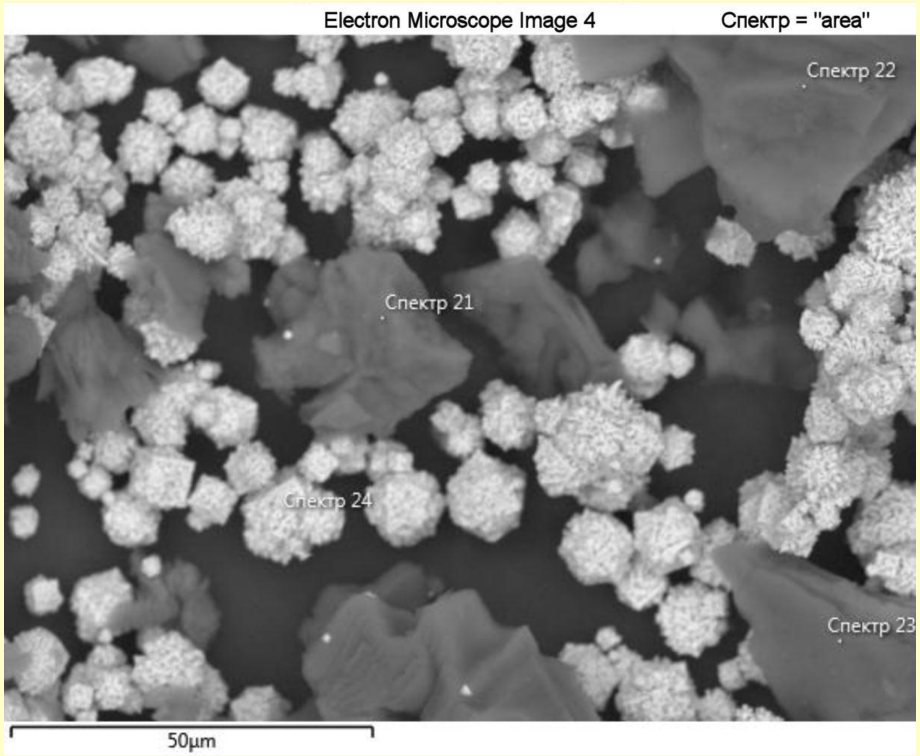
Excess heat of up to 300 watts was produced. The total excess energy produced was 640 MJ (180 kWh) as excess heat.

In the analysis of spent fuel, a significant change in the isotopic composition of lithium and nickel was measured.

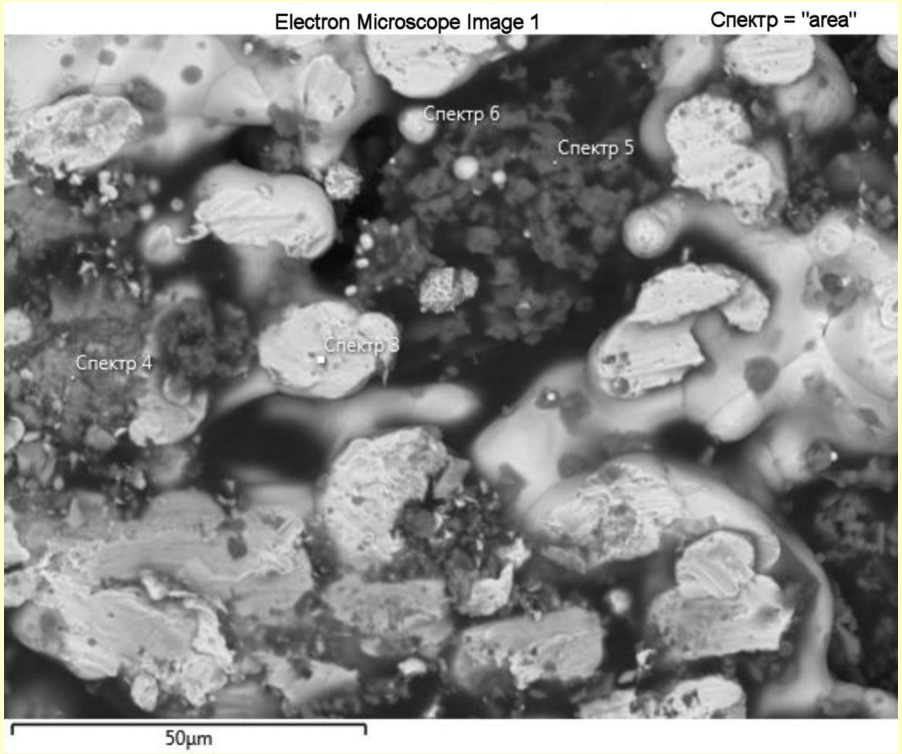
Scanning electron microscopy of the fuel (reactor AP2)

Studies conducted at ИОФ РАН.

Similar results were obtained in VNIIEF (d. Sarov)

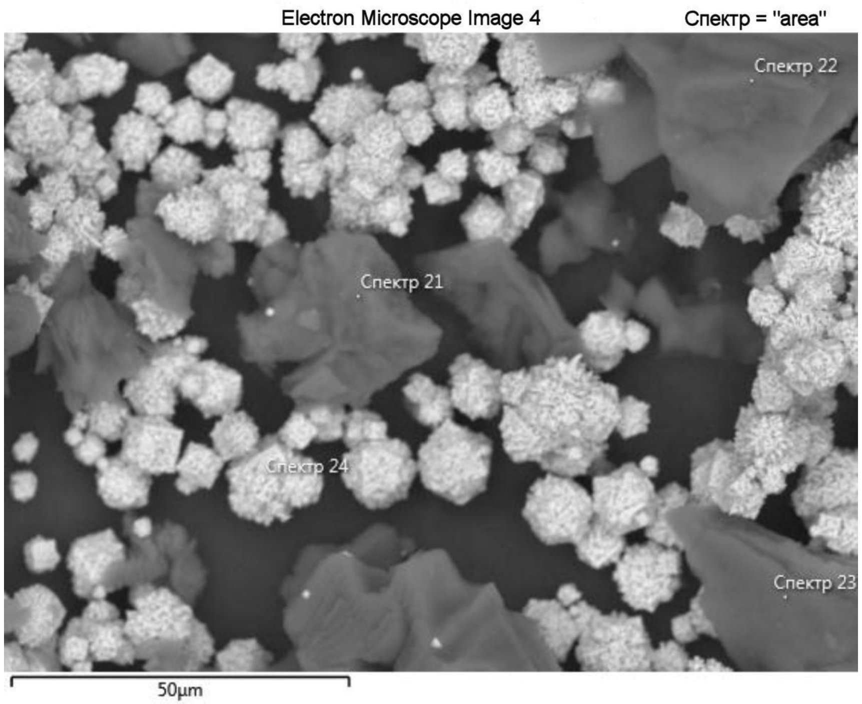


Fuel before heating in the reactor

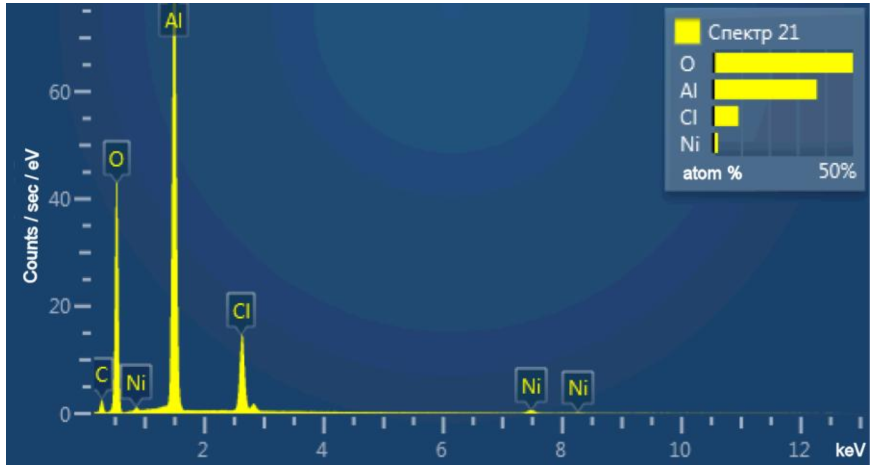


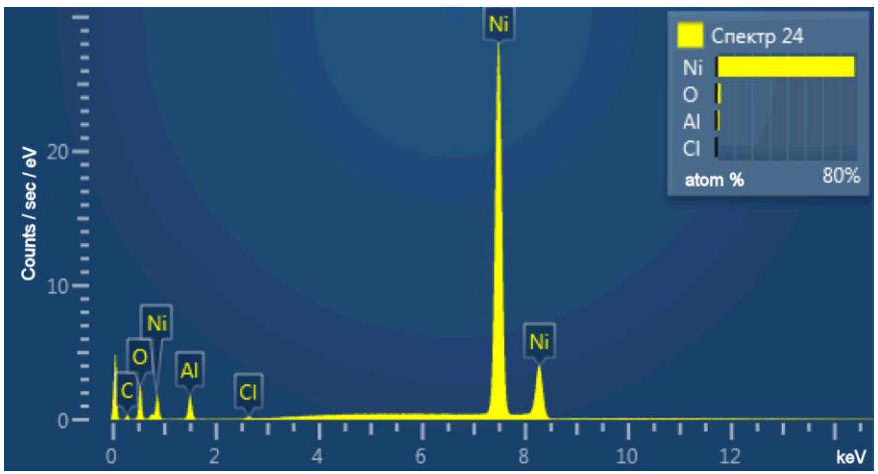
Fuel after heating in the reactor [ash]

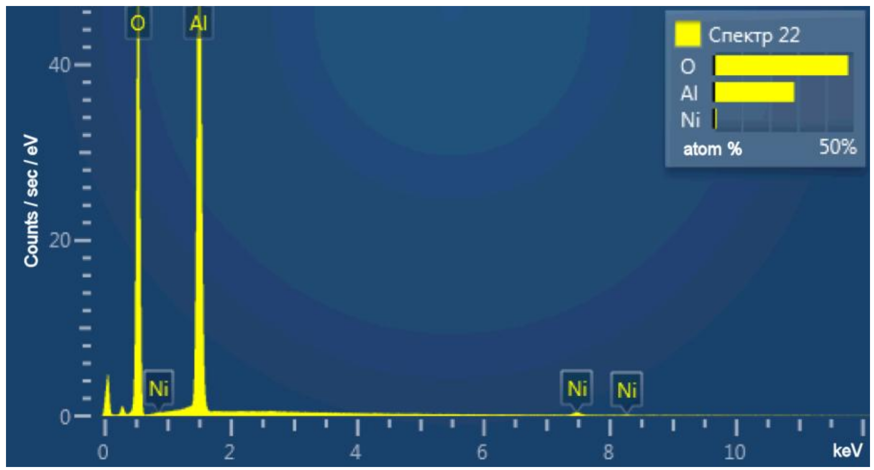
Electron microscope elemental composition analysis (*ИОФ РАН*)



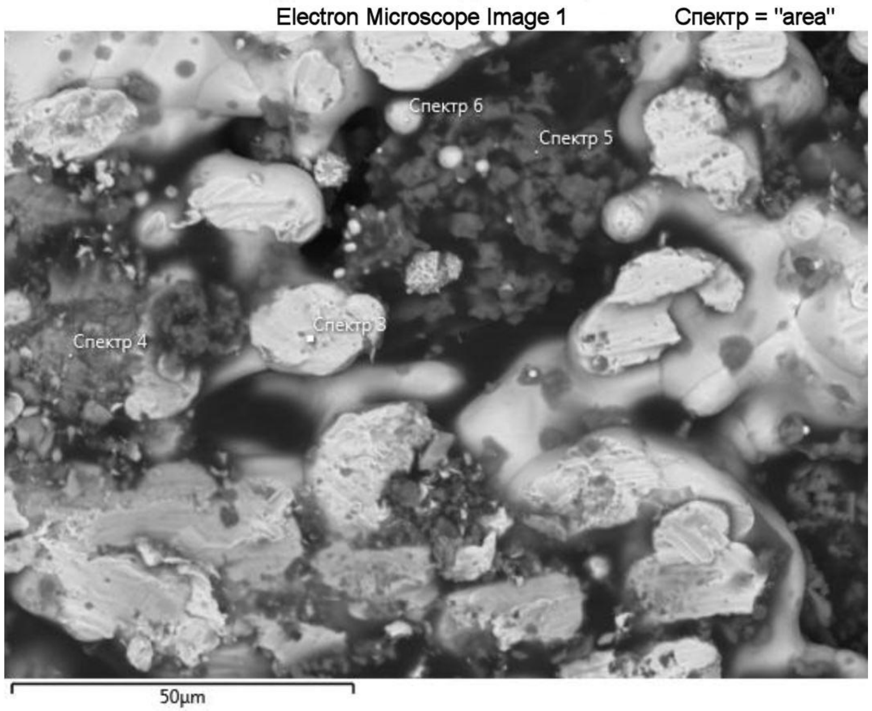
Fuel before heating in the AP2 reactor



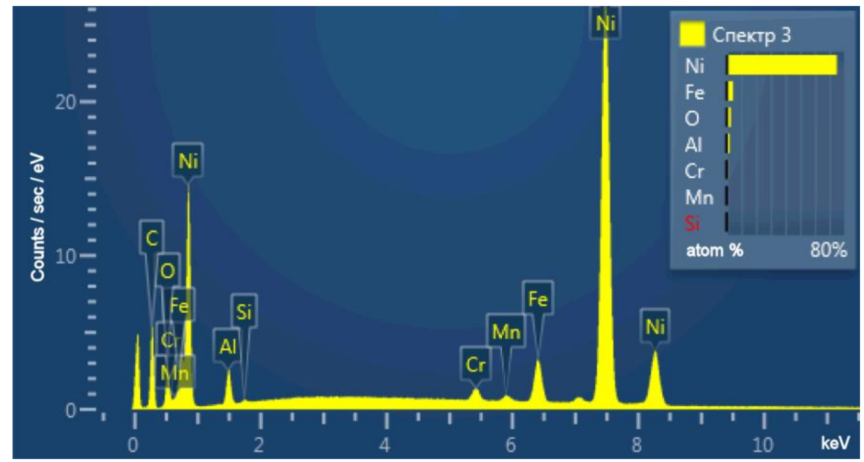


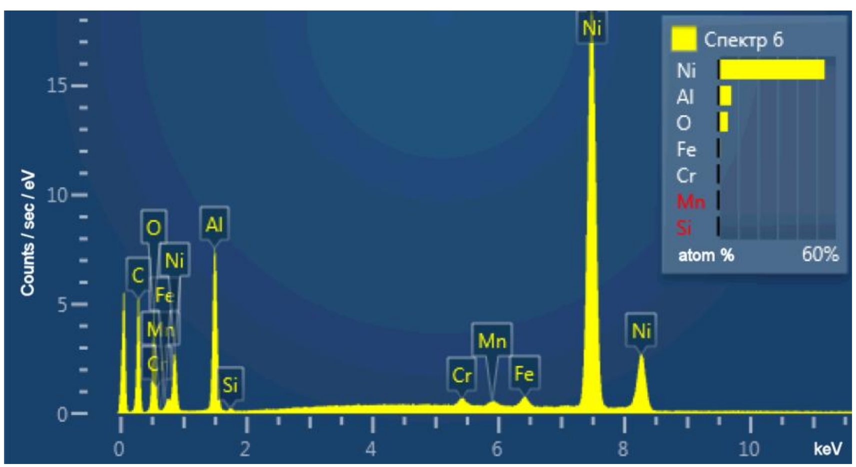


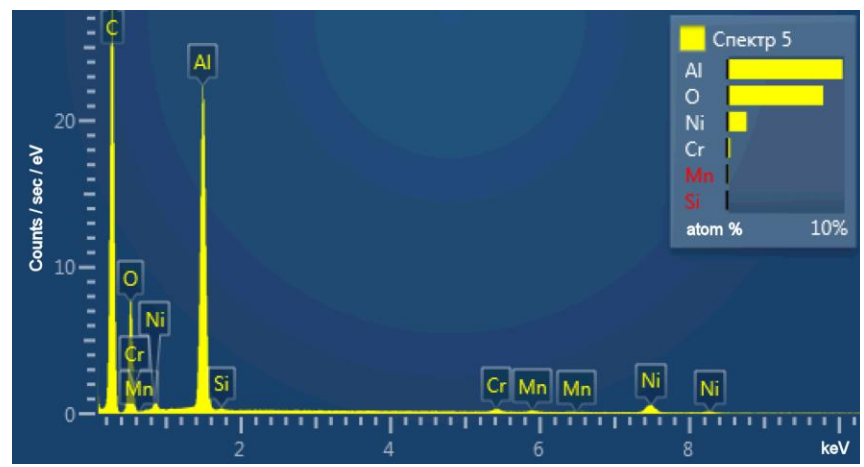
Electron microscope elemental composition analysis (*ИОФ РАН*)



Fuel after heating in and extraction from the AP2 reactor







Comparison of the isotopic composition of the source and the spent fuel Rossi's [Lugano] reactor (%), as well as the natural ratio of isotopes for these elements.

	Fuel (initial)		Ash (spent fuel)		Natural Abundance
	ToF-SIMS	ICP-MS	ToF-SIMS	ICP-MS	
^{6}Li	8,6	5,9	92,1	57,5	7,5
^{7}Li	91,4	94,1	7,9	42,5	92,5
^{58}Ni	67	65,9	0,8	0,3	68,1
^{60}Ni	26,3	27,6	0,5	0,3	26,2
^{61}Ni	1,9	1,3	0,0	0,0	1,8
^{62}Ni	3,9	4,2	98,7	99,3	3,6
^{64}Ni	1		0		0,9

Analysis of TOF- SIMS method is done at the University of Högskolan Dalarna (Sweden)

Analysis by ICP-MS is done at the University of Uppsala (Sweden)

1. **The ratios of lithium and nickel isotopes in the original fuel is virtually identical to natural.**
2. **The spent fuel has significantly increased content of ^{6}Li compared to ^{7}Li.**
3. **The spent fuel has greatly reduced content of nickel isotopes, except ^{62}Ni. The ^{62}Ni isotope content increased from 3.6% to 99%.**
4. **ToF-SIMS showed the presence of protium, but did not find evidence of deuterium.**

Isotopic analysis

Nuclides whose content in the spent fuel from baseline increased more than 5 times

A	Element(s)	Before	After	After/Before
11	B	3,1E-04	1,7E-03	5,7
54	Cr	8,3E-04	4,3E-03	5,2
56	Fe	9,7E-03	6,9E-02	7,1
57	Fe	2,2E-04	1,7E-03	7,6
71	Ga	6,5E-06	1,2E-04	19,0
90	Zr	2,8E-05	5,4E-04	19,3
91	Sr	4,9E-06	1,4E-04	27,7
92	Sr,Mo	1,1E-05	2,0E-04	17,3
94	Sr,Mo	6,5E-06	2,0E-04	31,1
96	Sr,Ru,Mo	1,6E-06	2,3E-05	13,8
105	Pd	1,6E-06	1,1E-05	6,9
108	Pd,Cd	1,6E-06	1,7E-05	10,4
115	In,Sn	1,1E-05	1,5E-04	13,3
123	Sb,Te	6,5E-06	6,8E-05	10,4
128	Te	1,6E-06	1,1E-05	6,9
140	Ce	6,5E-06	6,2E-05	9,5
209	Bi	2,0E-05	5,4E-04	27,4

Reactor «Проток – 6», working 29 days producing an excess energy of 100 MJ. The analysis is of the metal particles.

The analysis was performed at the Institute of Geochemistry and Analytical Chemistry VI. RAS Vernadsky (Geochemistry RAS) by ICP-MS

%	^{58}Ni	^{60}Ni	^{61}Ni	^{62}Ni	^{64}Ni
Before (Fuel)	65,67	27,69	1,29	4,27	1,08
After (Ash)	64,89	28,52	1,24	4,28	1,08
Natural concentration	67,85	26,22	1,19	3,66	1,08

The ratio of nickel isotopes before and after operation in the reactor

Change in the ratio of isotopes of nickel and lithium becomes noticeable with a large operating time of excess energy

Reactor AP2 produced 150 MJ of excess heat. Analysis by the ICP-MS method was made at Uppsala University (Sweden)

%	^{6}Li	^{7}Li		^{58}Ni	^{60}Ni	^{61}Ni	^{62}Ni	^{64}Ni
Before (Fuel)	7,4	92,6		68,1	26,2	1,14	3,63	0,93
After (Ash)	15,4	84,6		63,4	27,6	1,3	5,2	2,5
Natural	7,6	92,4		68,0	26,2	1,14	3,71	0,93

Reactor BB3 produced 640 MJ of excess heat. Analysis by the ICP-MS method was made in the NGO RAY (Podolsk)

%	^{6}Li	^{7}Li		^{58}Ni	^{60}Ni	^{61}Ni	^{62}Ni	^{64}Ni
Before (Fuel)	7,4	92,6		67,9	26,2	1,19	3,66	1,08
After (Ash)	18,1	81,9		20,9	67,5	3,1	7,9	0,5
Natural	7,6	92,4		68,0	26,2	1,14	3,71	0,93

Conclusions

- Numerous experiments carried out in different laboratories in many countries confirm excess heat in nickel-hydrogen thermal energy systems; exceeding heat possible from a chemical process by many times.

- Experiments with nickel-hydrogen systems that demonstrate long periods of excess heat are found to change the elemental and isotopic composition of the fuel. This suggests that high excess heat output from these systems involves transformations at the nuclear level.

- That such transformations occur at very low temperatures by nuclear standards, and lack prompt nuclear radiation and radioactivity, points to the need to look for unusual explanations for the observed effects.