CHAPTER 2

THE HOT-CAT "TYPE II DESIGN"

The picture here below, published in a skinny version in the patent application filed by *Industrial Heat* on April 26, 2014, shows a layered tubular **reactor device** (Fig. 4 in the cited document), also represented in cross-sectional view (Figg. 5 and 6). It is **the second of three** different **embodiments** described in such patent application, so hereinafter I'll indicate it as "*E-Cat HT – II*".

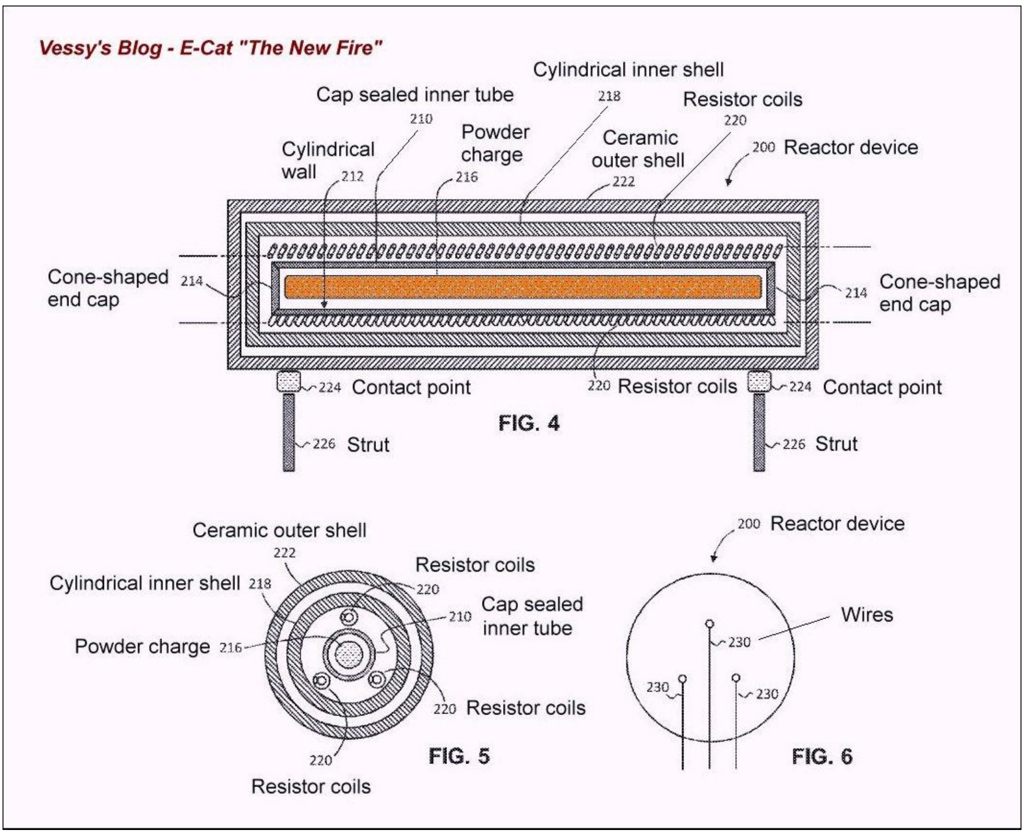

Fig. 2.1 - Diagram of a reactor device E-Cat HT "Type II design" (from IH's patent, slightly modified).

This reactor, with the powder charge widely and uniformly distributed along the central axis of the reactor, **was used in the second of the three tests**, or "experiments", described in the first *Third Party Report* (TPR-1). Such experiment consisted in a 96-hours run of the device **continuously powered** – i.e. never operating in self-sustained mode – and was performed, successfully, on December 13-17, 2012 in Ferrara, Italy.

Document	TPR-1	TPR-1	TPR-1	TPR-2
Test date	Novemb. 2012	Decemb. 2012	March 2013	March 2014
Location	Ferrara (IT)	Ferrara (IT)	Ferrara (IT)	Lugano (CH)
Reactor type	E-Cat HT - I	E-Cat HT - II	E-Cat HT - III	E-Cat HT - IV
Temperature	793 °C	436 °C	302 °C	1260-1400 °C
Fuel	Ni, H, ?	Ni, H, ?	Ni, H, ?	Ni, H, Li, ?
Duration	Failed	96 hours	116 hours	32 days
Self-Sustained	No	No	Yes	No
COP	not available	5.6 +/- 0.8	2.9 +/- 0.3	3.2-3.6

Tab. 2.1 - All the tests described in the Third Party Reports released from the scientists Levi et al.

According to the dispersive description given in the cited patent and widely integrating the information contained on this issue in TPR-1, the reactor device (200) used in this experiment was a layered cylindrical device having an **inner tube** (210). Such inner tube, made of AISI-310 steel, had a 3 mm thick cylindrical wall (212) with a 33 mm diameter.

Two cone-shaped **end caps** (214) made of **AISI-316** steel were hot-hammered into the longitudinal ends of the inner tube, sealing it hermetically. Cap adherence was obtained by exploiting the higher thermal **expansion coefficient** of AISI-316 steel with respect to AISI-310.

As such, the inner tube constitutes a **vessel sealed** against ingress or egress of matter, including gaseous hydrogen. This represents a distinction of this type of reactor over previous reaction vessels (normal E-Cat or, if you prefer, E-Cat LT, where LT stands for "Low temperature"), that were preloaded with **pressured gases** such as hydrogen (see the previous Patent Application *WO 2009125444*, international extension of an Italian patent filed in 2008).

Fig. 2.1 - The E-Cat HT "Type II design" before the Third Party test performed on December 13-17, 2012. You can see the black paint and the power cables to the three internal resistor coils.

The inner tube contained a powder **reaction charge** (216) uniformly distributed along the axis of the device, and consisting of a small amount of **hydrogen loaded nickel powder**. However the fuel was, more precisely, a mixture of nickel, hydrogen **and a catalyst** consisting, according to the TPR-1, of some "**additives**" pressurized with the hydrogen gas and not disclosed being an industrial trade secret.

A **silicon nitride** cylindrical **outer shell** (222), 33 cm in length and 10 cm in diameter, was coated with a special aeronautical-industry grade **black paint** (produced in the N-E of Italy), capable of withstanding temperatures up to 1200 degrees Celsius. A cylindrical inner shell (218), which was made of different ceramic material – **corundum** – was located within the outer shell.

The inner shell housed **three delta-connected** spiral-wire **resistor coils** (220), which were laid out horizontally, parallel to and equidistant from the center axis of the device. The three resistor coils essentially run the interior length of the device and were **independently** wired to a power supply by wires (230) that extended outward from the reactor device (see Fig. 6).

The resistor coils within the reactor were fed by a **Triac power regulator** device (302, see Fig. 7) which interrupted each phase periodically, in order to modulate the power input with a controlled waveform, which is an industrial trade **secret waveform**. This procedure, needed to **properly activate** the powder reaction charge, had no bearing on the power consumption of the device, which remained constant throughout the experiment.

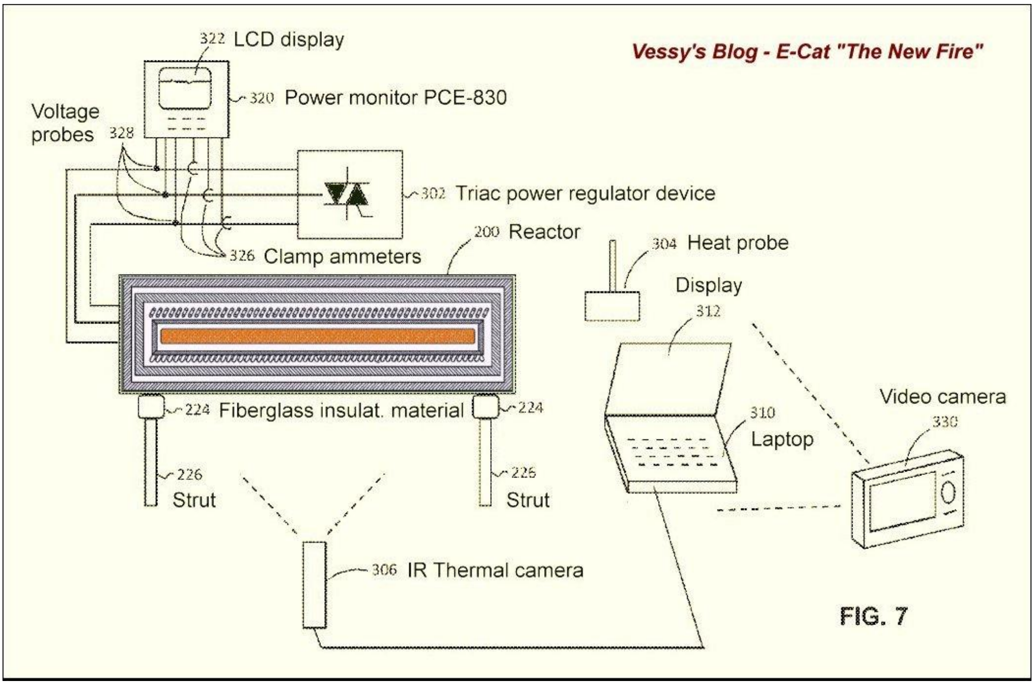

Fig. 3.1 - The experimental setup of the second test on a Hot-Cat reactor described in this article.

Due to the failure in the first test performed in November 2012, when the primer resistor coils were run at about 1 kW, in this second experiment the continuous **power input** to the reactor was limited to a much lower value, **360 W**, so the E-Cat HT's hourly power consumption was 360 W. The E-Cat HT's power production was **almost constant**, with an average of 1609 W (Fig. 8).

A wide band-pass **power quality monitor** (320) – a *PCE-830 Power and Harmonics Analyzer* produced by PCE Instruments – measuring the electrical quantities on each of the three phases was used to record the power absorbed by the resistor coils. It was connected directly to the reactor device resistor coil power cables by three **clamp ammeters** (326) and three **probes** (328), respectively for current and voltage measurements.

Finally, an **IR thermography camera** (306), model *Optris PI Thermal Imager*, was used to acquire a thermal image on a display (312) and to measure the surface temperature of the reactor device with a **2% precision** of measured value, in order to make an **infrared thermographic calorimetry**. The thermal camera was positioned about 70 cm below the reactor device in order not to damage the camera itself from the heat transferred by rising convective air currents.

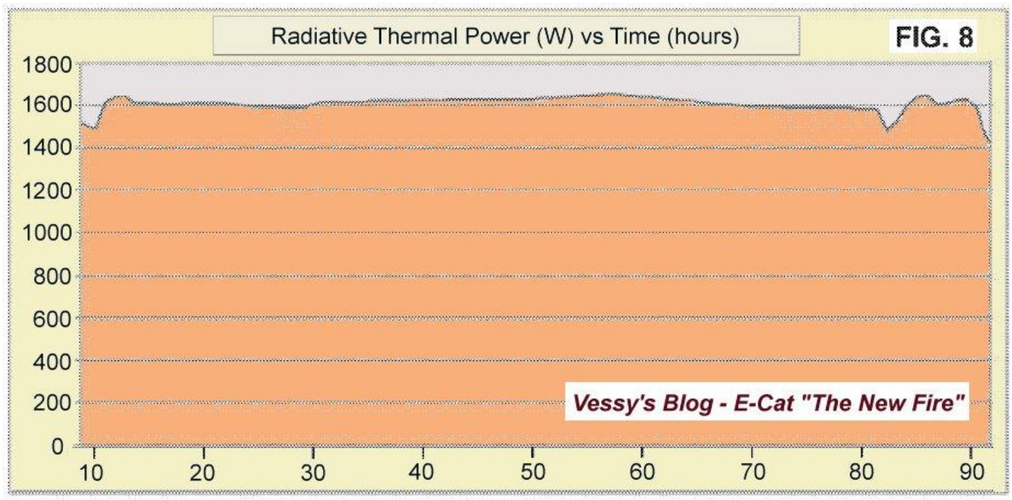

Fig. 4.1 - The almost constant radiative thermal power of the tested reactor, useful for estimating COP.

The **Coefficient of Performance** (COP) of the reactor device was obtained as the ratio between the total energy emitted by the device (radiated power + the power dispersed by convection) and the energy consumed by its three resistor coils. The resulting COP, with **many conservative assumptions**, was **5.6 +/- 0.8** (would be 4.5 taking into account only the radiative energy).

CHAPTER 3

THE HOT-CAT "TYPE III DESIGN"

The picture here below, published in a skinny version in the patent application filed by *Industrial Heat* on April 26, 2014, shows a layered tubular **reactor device** (Fig. 11 in the cited document), also represented in cross-sectional view (Fig. 12). It is **the third of three** different **embodiments** described in such patent application, so hereinafter I'll indicate it as "*E-Cat HT – III*".

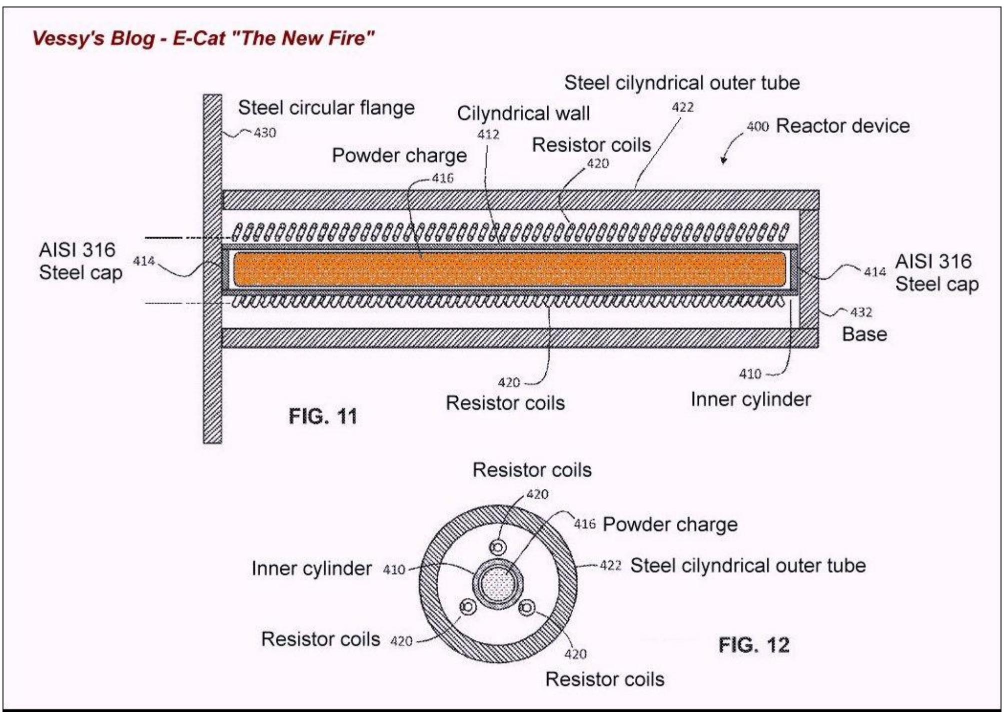

Fig. 3.1 - Diagram of a reactor device E-Cat HT "Type III design" (from IH's patent, slightly modified).

This reactor, with the powder charge widely and uniformly distributed along the central axis of the reactor, **was used in the third of the three tests**, or "experiments", described in the first *Third Party Report* (TPR-1).

Such experiment consisted in a 116-hours run **in self-sustained mode** of the device and was performed, successfully, on March 18-23, 2013 in Ferrara, Italy.

Document	TPR-1	TPR-1	TPR-1	TPR-2
Test date	Novemb. 2012	Decemb. 2012	March 2013	March 2014
Location	Ferrara (IT)	Ferrara (IT)	Ferrara (IT)	Lugano (CH)
Reactor type	E-Cat HT - I	E-Cat HT - II	E-Cat HT - III	E-Cat HT - IV
Temperature	793 °C	436 °C	302 °C	1260-1400 °C
Fuel	Ni, H, ?	Ni, H, ?	Ni, H, ?	Ni, H, Li, ?
Duration	Failed	96 hours	116 hours	32 days
Self-Sustained	No	No	Yes	No
COP	not available	5.6 +/- 0.8	2.9 +/- 0.3	3.2-3.6

Tab. 3.1 - All the tests described in the Third Party Reports released from the scientists Levi et al.

According to the dispersive description given in the cited patent and widely integrating the information contained on this issue in TPR-1, **the reactor device** used in this experiment **differed** from the so-called "Hot-Cat" reactors characterized by the earlier described Type I design and Type II design both **in structure and control systems**.

Externally, the reactor device (400) had a **steel cylindrical outer tube** (422) which was 9 centimeters in diameter and 33 centimeters in length, with at one hand a **steel circular flange** (430) 20 cm in diameter and 1 cm thick. An important purpose of such flange was to allow the reactor device to be supported while inserted in one of various **heat exchangers**.

The outer surface of the outer tube and one side of the flange were coated with **black paint**, different from that used for the second experiment. The black paint used was *Macota* enamel paint (produced by Macota srl, Italy), capable of withstanding temperatures **up to 800 degree** Celsius. The **distribution of the temperatures** along the device is not uniform, and the higher temperatures are reached in the central part of the cylindrical body.

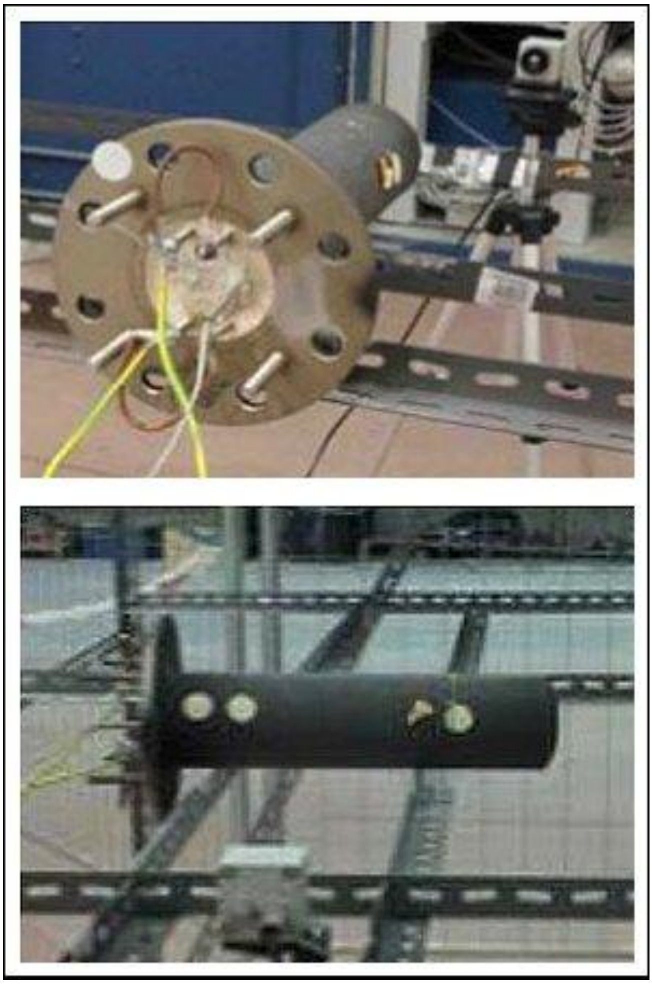

Fig. 3.2 - The E-Cat HT "Type III design" before the Third Party test performed on March 18-23, 2013. Electrical power is fed through the two yellow wires, the third connection is a PT-100 sensor.

As in the previous reactors Type I and II, a **powder charge** (416) was contained within a smaller AISI 310 steel cylindrical inner tube (410). Such inner tube had a **cylindrical wall** (412) that was 3 cm in diameter and 33 cm in length. The inner tube was housed within the outer tube together with the **resistor coils** (420), and closed at longitudinal ends by two AISI 316 steel caps (414).

Electrical power was fed through the flange to power the resistor coils. The third connection was a **PT100 sensor** (418), used to give a **feed-back temperature signal** to the control box in order to regulate the

ON/OFF cycle followed in this third experiment. The PT100 sensors are platinum resistance **thermometers** commonly used in industry.

The power supply used in this experiment was not a three-phase supply, but **single-phase supply**: that is, the Triac power supply used in the second experiment was replaced by a **controller circuit** having a three-phase power input and single-phase output, within a housing whose contents were not available for inspection, inasmuch as they are part of the **industrial trade secret**.

A significant difference between this Type III reactor device and the earlier described Type II reactor device lies in the **control system**, which now allows the reactor to work in **Self-Sustaining Mode** (SSM). That is, the reactor device can remain operative and active, while powered off, for **much longer periods** of time with respect to those during which power is switched on.

During this third experiment, after an **initial phase** lasting about two hours in which power fed to the resistor coils was gradually increased up to operating conditions, an ON/OFF phase was finally reached. In such ON/OFF phase, power to the resistor coils was **automatically regulated** by the temperature feedback signal from the PT100 sensor (see the resulting behavior here below).

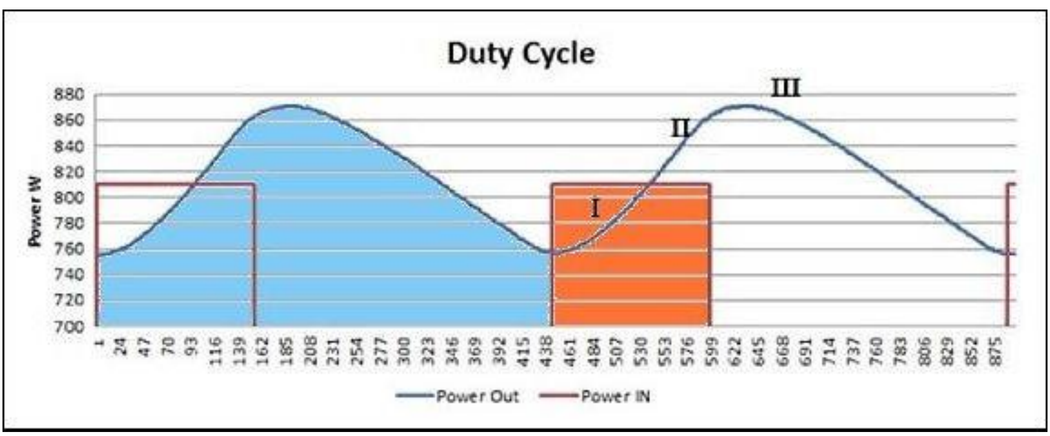

Fig. 3.3 - The first two periods of the ON/OFF cycle of the E-Cat reactor described in this article. It corresponds to Fig. 15 in the patent application and to Plot 8 in the TPR-1.

Upon initiation of the test, the **initial power input**, i.e. the instantaneous power absorbed, was about 120 W, gradually stepping up during the following two hours, until a value suitable for triggering the self-sustaining mode was reached. From then onwards, and for the following 114 hours of the tests, power input was no longer manually adjusted, and the **ON/OFF cycles** of the resistor coils followed one another at almost **constant time intervals**.

In the ON/OFF phase, the resistor coils were powered up and down by the controller circuit (402, see Fig. 13 of the patent) at observed regular intervals of about **2 minutes for the ON** state (equal to the 35% of the time, during which the instantaneous power absorbed was in the range of 910-930 W) and **4 minutes for the OFF** state (equal to the remaining 65% of the time, during which the temperature of the device continued to rise for a limited amount of time).

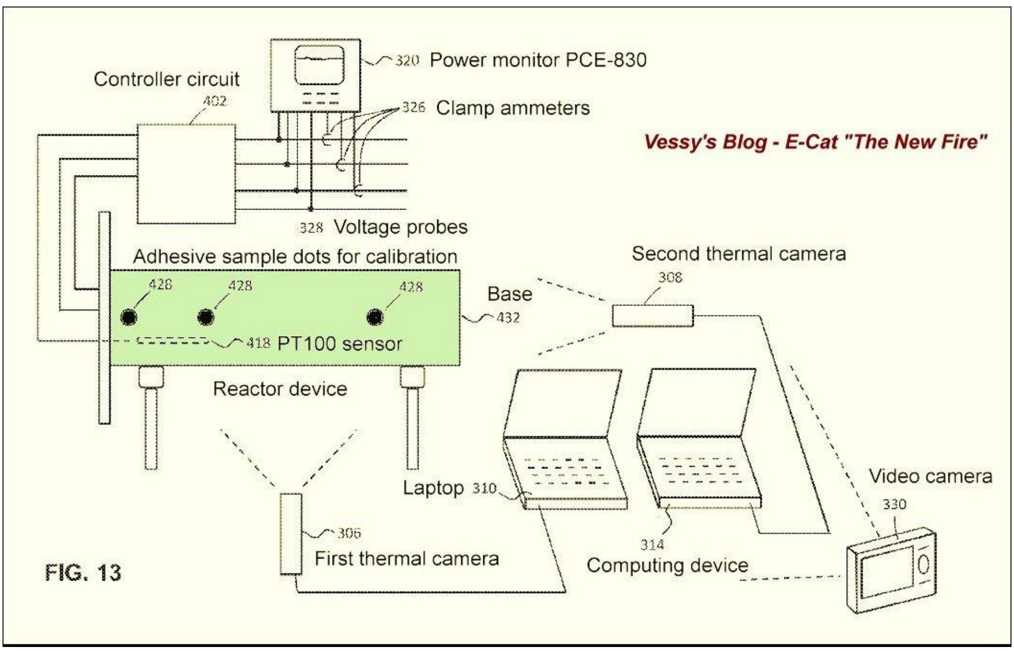

Fig. 3.4 - The experimental setup of the third test on a Hot-Cat reactor described in this article. You can use this image provided that you leave its attribution and a proper link.

A wide band-pass PCE-830 **power monitor** (320), in addition to providing voltage and current values for each phase, allows one to check both the **waveform** and its **spectral composition in harmonics** of the fundamental frequency (50 Hz). Voltage waveforms were confirmed as sinusoidal and symmetrical, and there were **no levels of DC** voltage. The instrument's stated measurement error is 2% within the 20th harmonics, and 5% from 21th to 50th.

As far as measurements of current are concerned, it was ascertained – by the third party team performing the test – that **no current** was present in the third phase and that, for the two other phases, the waveform harmonics spectrum, which appeared to be the one **normally associated with a Triac** regulator, was contained within the interval **measurable** by the instrument.

The **Coefficient of Performance** (COP) of the reactor in this third test was **2.9 +/- 0.3**. The reasons for the appreciable differences between the COP's values obtained in the 2nd and 3rd experiment (COP 5.6 and average temperature of 438 °C vs. COP 2.9 and average temperature of 302 °C) could depend on the **different quantities of powder** used and/or simply on the tendency of the COP, noticed even in the first experiment, to **increase with temperature**.

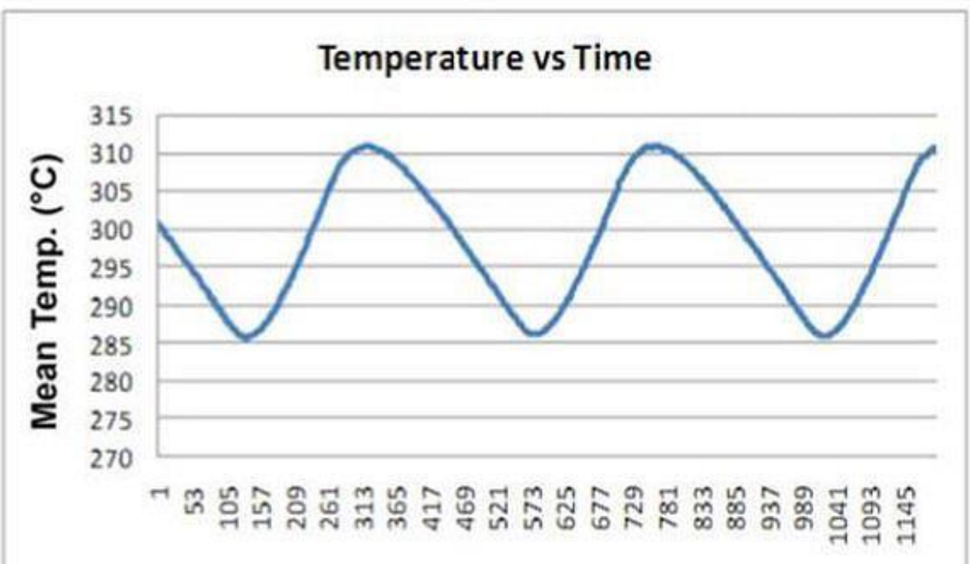

Fig. 3.5 - The average surface temperature of the E-Cat reactor in the test described in this article. It corresponds to Fig. 14 in the patent application and to Plot 3 in TPR-1.

This third test also included a **calibration** of the experimental setup **without the active charge** present in the E-Cat HT. In this case, no extra heat was generated beyond the expected heat from the electric input. The electrical power to this "unloaded" device was applied **continuously** as opposed to ON/OFF cycling, and stepped up gradually until a value of 910-920 W, including the power consumption of the **control box** (that was approximately 110-120 W).

Upon completion of this third test, the reactor device was opened, and **its parts weighed**. Before removal of the powder charges, the innermost cylinder sealed by caps was weighed (1537.6 g). Lastly, the inner powders were extracted and the cylinder was weighed once again (1522.9 g). The weight that may be assigned to the **powder charges** is therefore on the order of **0.3 grams**.

CHAPTER 4

THE HOT-CAT "TYPE IV DESIGN"

The image here below, a composition of two photos published in the 2nd Third Party Report (TPR-2) released on October 8, 2014, shows a "dog bone"-like **reactor device** used in a test performed in Barbengo (Lugano), in a laboratory placed at disposal by Officine Ghidoni SA. It is **the fourth of four** different known **embodiments** of a high-temperature E-Cat, or Hot-Cat, so hereinafter I'll indicate it as "*E-Cat HT – IV*".

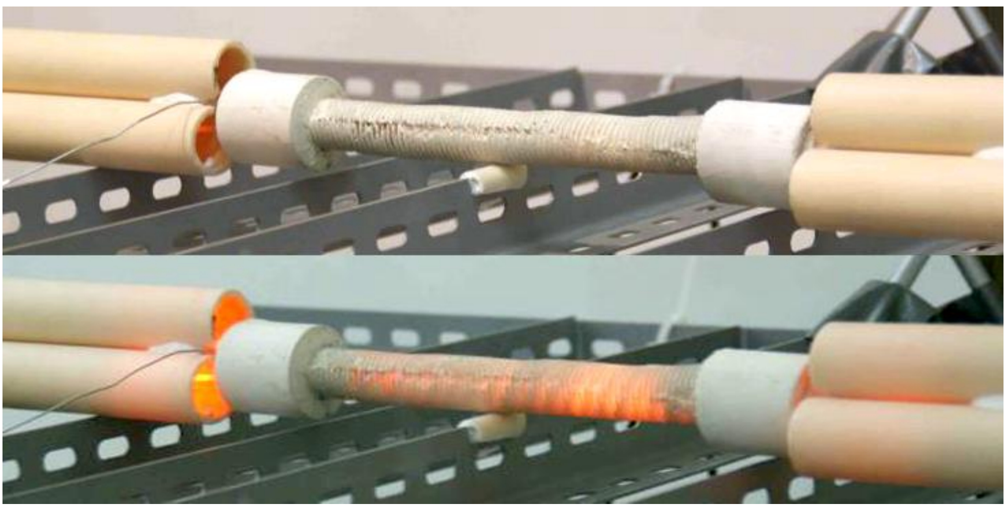

Fig. 4.1 - The "Type IV design" reactor, before the electrical ignition and during the test.

Data were collected during 32 days of running, from February 26 to March 29, 2014, a **much longer period** compared to the previous three tests described in the 1st Third Party Report (TPR-1), that I've illustrated in detail in previous chapters. The E-Cat reactor was tested by the **same collaboration** of scientists performing the tests described in TPR-1, in both the case with the financial support of Elforsk AB, Sweden.

Document	TPR-1	TPR-1	TPR-1	TPR-2
Test date	Novemb. 2012	Decemb. 2012	March 2013	March 2014
Location	Ferrara (IT)	Ferrara (IT)	Ferrara (IT)	Lugano (CH)
Reactor type	E-Cat HT - I	E-Cat HT - II	E-Cat HT - III	E-Cat HT - IV
Temperature	793 °C	436 °C	302 °C	1260-1400 °C
Fuel	Ni, H, ?	Ni, H, ?	Ni, H, ?	Ni, H, Li, ?
Duration	Failed	96 hours	116 hours	32 days
Self-Sustained	No	No	Yes	No
COP	not available	5.6 +/- 0.8	2.9 +/- 0.3	3.2-3.6

Tab. 4.1 - All the tests described in the Third Party Reports released from the scientists Levi et al.

A longer test was also motivated to investigate the **long-term stability** of the E-Cat operation, as well as running it at two different operational settings for comparison. The reactor operating point, indeed, was set at about **1260 °C** (corresponding to a measured electric power input of about 810 W) in the **first half of the run** (10 days), and at about **1400 °C** (corresponding to slightly above 900 W) in the second half (22 days).

It was chosen **not to induce** a self-sustained mode, i.e. the ON/OFF power input mode used in the third TPR-1 test. However, subsequent calculation by the authors of TPR-2 proved that increasing the input by roughly **100 watts** (from about 800 W to 900 W) had caused **an increase** of about **700 watts** in power emitted. The picture 4.2 shows the E-Cat net power production trend throughout the test.

The present E-Cat reactor is an improved version running **at much higher temperatures** then the earlier versions used in TPR-1's experiments, but avoiding at the same time **internal melting** – a previously fairly frequent occurrence – because in the course of the year following the previous tests the IP of E-Cat technology was transferred to **Industrial Heat**, USA, where the reactor was replicated and improved.

Thus, the reactor used in 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 centimeters in diameter and 20 centimeters in length, ending on both sides with two cylindrical alumina blocks (4 cm in diameter, 4 cm in length), not detachable from the body of the reactor, which henceforth will be referred to as "**caps**".

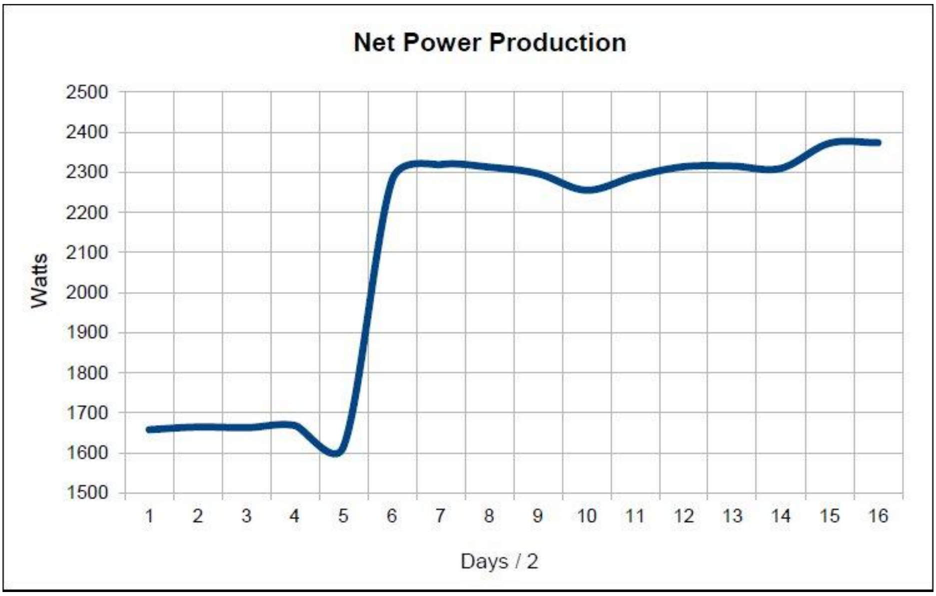

Fig. 4.2 - The E-Cat net power production trend throughout the test, given by the difference between the total watts produced by the reactor and the watts consumed by it. It shows how much emitted power is exclusively due to the E-Cat's internal reaction.

It is interesting to notice that, upon completion of the test, the authors of TPR-2 took a **sample of the material** constituting the reactor. Subsequently, Prof. Ennio Bonetti (who teaches Physics of Matter at the University of Bologna) subjected it to X-Ray spectroscopy. The results confirmed that it was indeed alumina, with a purity of at least 99%.

Whereas the surface of the caps is smooth, the outer surface of the body of the E-Cat is molded in **triangular ridges**, each 2.3 mm high and 3.2 mm wide at the base, covering the entire surface and designed to **improve the dissipation** surface for natural convective thermal exchange (cylinder diameter is calculated from the bases of the ridges).

The power supply cables run through the two caps. According to TPR-2, "three braided high-temperature grade **Inconel cables** exit from each of the two caps: these are the resistors wound in parallel non-overlapping coils inside the reactor". Moreover: "the reaction is primarily initiated by heat from resistor coils around the reactor tube". I've cited exactly the words used in the report because they are very important.

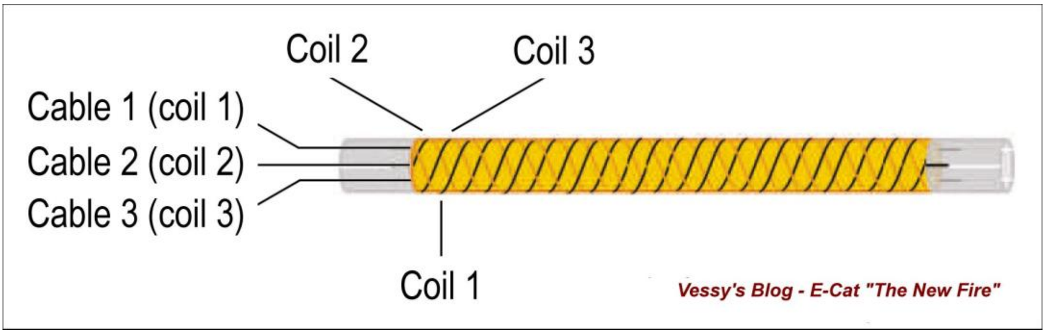

Fig. 4.3 - The three parallel non-overlapping resistor coils inside a "dog-bone"-like reactor.

As pointed out by the authors of the report, it is well known that some Inconel cables have a crystalline structure that **is modified** by temperature, and are capable of withstanding high currents only if they are operated **at the appropriate temperature**. If these conditions are not met, microscopic melt spots are liable to occur in the cables.

This generated some perplexity in the readers of the report. In response to questions about this issue, Andrea Rossi, some days after the release of TPR-2, admitted on his JoNP: "The coils of the reactor are made with a **proprietary alloy**, and the Inconel is only a **doped component** of it". It also said, in an open letter to Stephan Pomp, that "the resistances do not have a linear response to the temperature in the coil of the E-Cat".

A so-called "K-type" **thermocouple probe**, inserted into one of the caps, allows the control system to manage power supply to the resistors by measuring the **internal temperature** of the reactor. The thermocouple probe cable is inserted in an alumina cement cylinder, which acts as a **bushing** and perfectly fits the hole, about 4 mm in diameter.

The hole for the thermocouple probe is **also the only access point** for the fuel charge. When charging the reactor, the bushing is pulled out, and the charge is inserted. After the thermocouple probe has been lodged back in place, the bushing is sealed and secured with a mixture of

water and alumina powder cement. To extract the charge, pliers are used to open the seal.

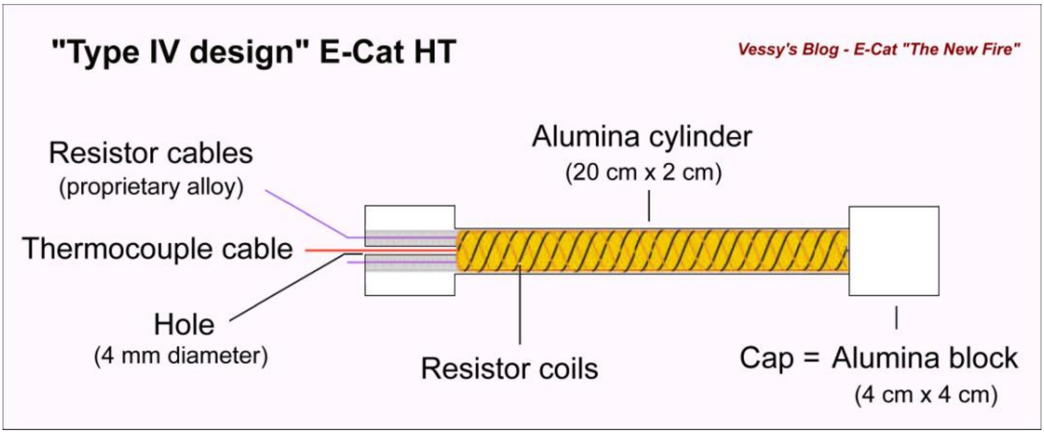

Fig. 4.4 - Diagram, that I've derived from the above description, of a reactor device E-Cat HT "Type IV design".

The resistors and the copper cables of the three-phase power supply are connected, outside the caps, in the classic "**delta configuration**", illustrated later. For 50 cm from the reactor, the power cables are contained in hollow alumina rods (three per side), 3 cm in diameter. The purpose of the rods is to **insulate thermally and electrically** the supply cables and protect the connections that run through them.

Both the reactor and the rods lie on a **metal frame**, the points of contact with the frame being thermally insulated with alumina cement. The whole frame lies on an insulating rubber mat on the floor. We found that the ridges made thermal contact with any thermocouple probe placed on the outer surface of the reactor **extremely critical**, making any direct temperature measurement with the required precision impossible.

The reactor is charged with a small amount of hydrogen-loaded nickel powder plus some **additives**, **mainly Lithium** (the others are a secret). The powder charge had been weighed before insertion in the reactor, resulting in about 1 g. Samples of both **fuel and ash** powders were taken and properly analyzed. In addition, the resistor coils are fed with some **specific electromagnetic pulses**, also covered by industrial trade secret.

The E-Cat's control apparatus consists of a three-phase **Triac power regulator**, driven by a programmable microcontroller; its maximum nominal power consumption is 360 W. The regulator is driven by a **potentiometer** used to set the "operating point" (i.e. the current through the resistor coils, normally 40-50 Amps), and by the **temperature read** by the reactor's thermocouple.

The input power was carefully monitored with appropriate instruments: two **PCE-830** for electric power measurements, and **three digital multimeters** to verify that no DC components were present in the power supply. The output power was determined by measuring, with two high-resolution **thermal imaging cameras** *Optris PI 160 Thermal Imagers*, the emitted radiation as well as calculating the heat dissipation from convection.

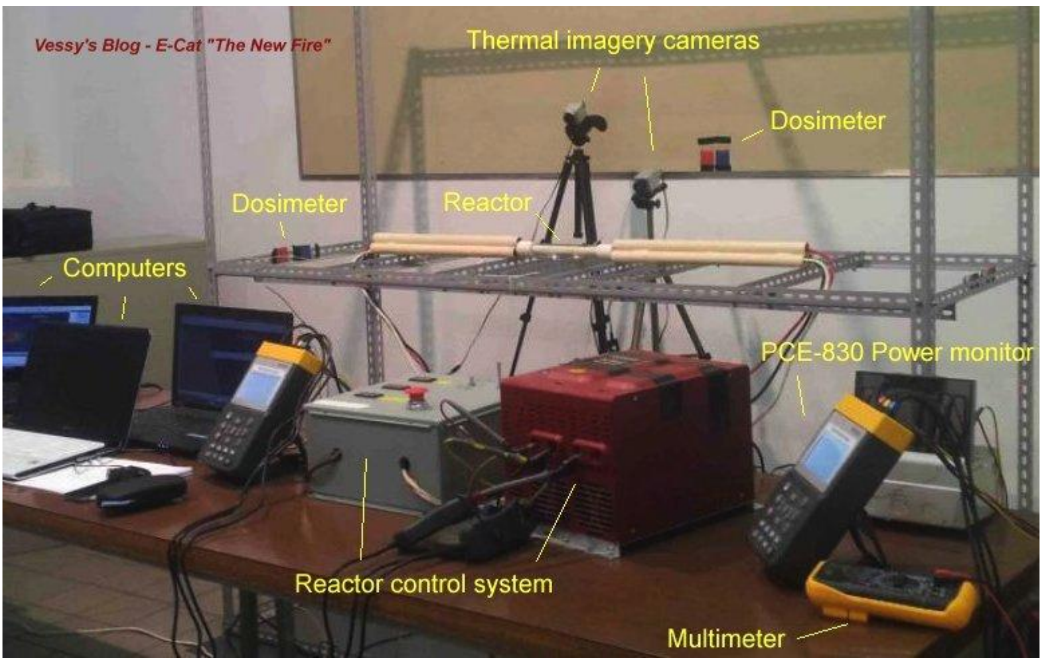

Fig. 4.5 - Photo of the experimental setup used for the measurements (text added).

All the instruments used during the test are **property of the authors** of TPR-2, and were calibrated by their respective manufacturers, but a further check was made to ensure that were not yielding anomalous readings. Throughout the test, all the above instruments were connected to the **same computer**, wherein all the acquired data were saved. For both the PCEs and the IR cameras, **data acquisition frequency** was set at 0.5 Hz.

The two PCEs are located **one upstream and one downstream** – as shown in the figure below – from the control instruments, the already mentioned Triac three-phase power regulator driven by a potentiometer and by the temperature read by the K-probe. Note that, in the picture, the three cables running from the control system to C are termed C1, whereas the six cables running from C to the reactor are termed C2.

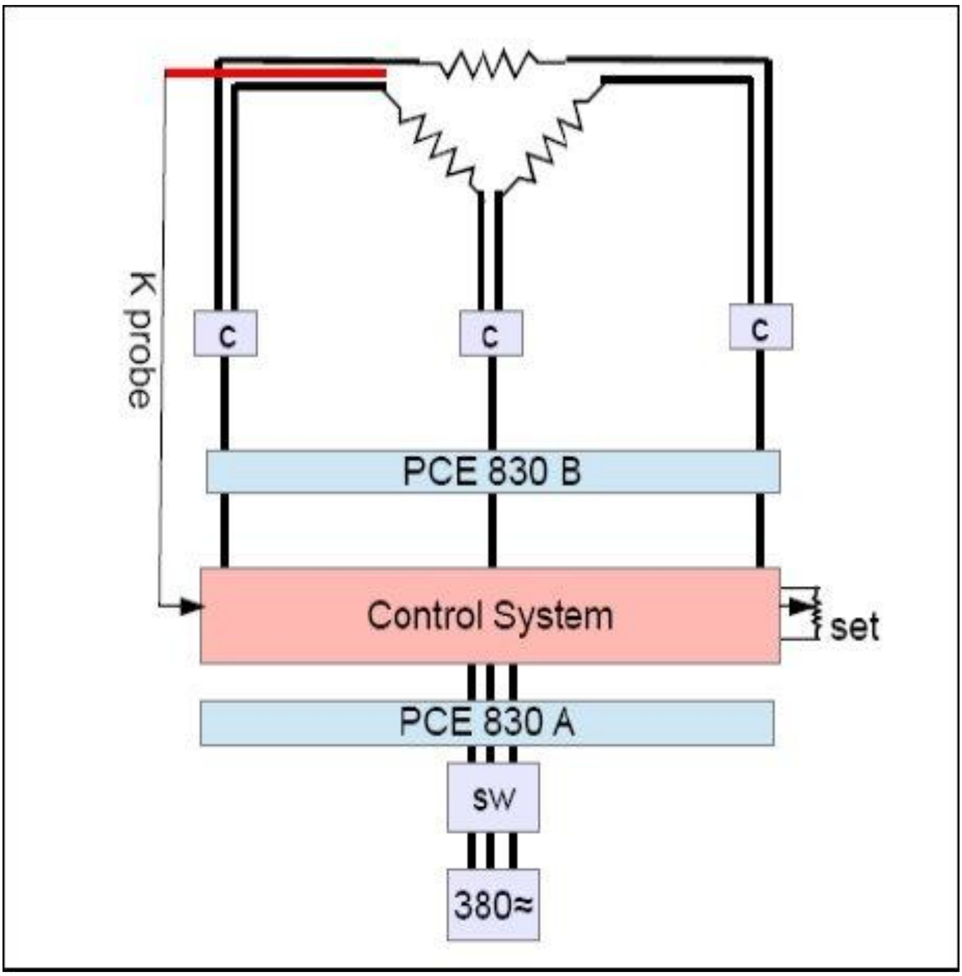

Fig. 4.6 - The wiring diagram of the test to a "Type IV design" Hot-Cat, as described in TPR-2. The resistors are connected in the so-called "delta configuration" (SW = Switch, C = Connection Box).

The **COP**, calculated as the ratio of the sum of the mean power emitted – by radiation and convection by both the E-Cat and the rods – to mean power consumption of the reactor (minus watts dissipated by the cables through Joule heating), resulted **3.1 +/- 8%**, corresponding to a net production of 1658 W in the first half of the run (10 days), and **3.6** in the second half (22 days).

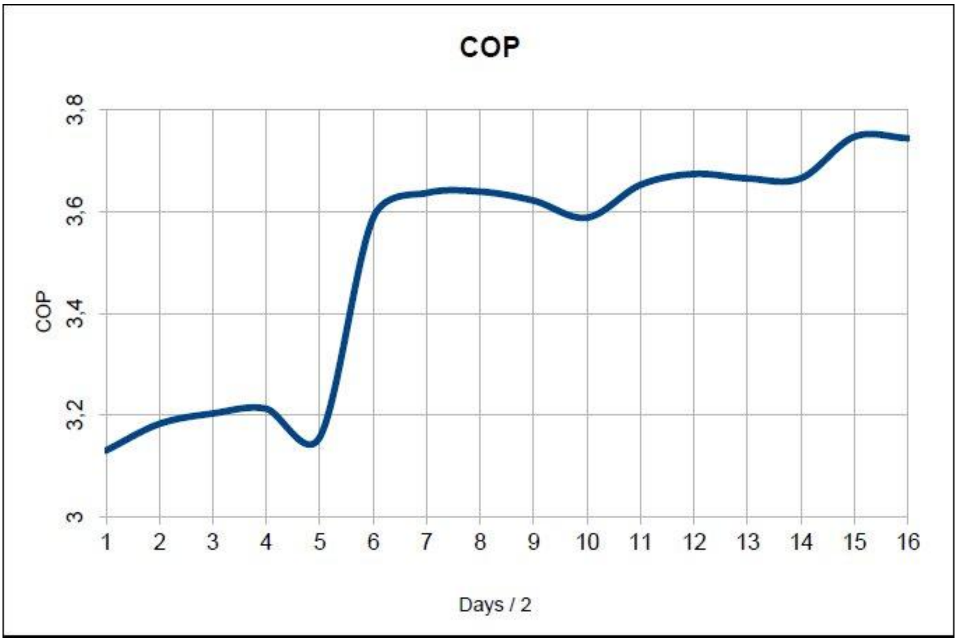

Fig. 4.7 - COP trend throughout the test. It gives an indication of the E-Cat's performance.

The **total net energy** obtained during the 32 days run was about **1,6 MWh**. This amount of energy is far more that can be obtained from any known chemical sources in the small reactor volume. Indeed, the authors of TPR-2 estimated – in a very conservative way – the **power density** and the **energy density** associated to the E-Cat's fuel, which resulted, respectively, **$2.1 \cdot 10^6$ W/kg** and **$1.6 \cdot 10^9$ Wh/kg**.

CHAPTER 5

A POSSIBLE ALTERNATIVE DESIGN

In this chapter, I will describe a new design for a Hot-Cat, but this time the description does not refer to a reactor designed by Andrea Rossi or Industrial Heat, but to an **independent "replication"** of the Hot-Cat, made by a 70 years old Russian physicist with a solid scientific curriculum – Alexander G. **Parkhomov** – which seems to have obtained results similar to those described in my previous chapter for Type IV reactor.

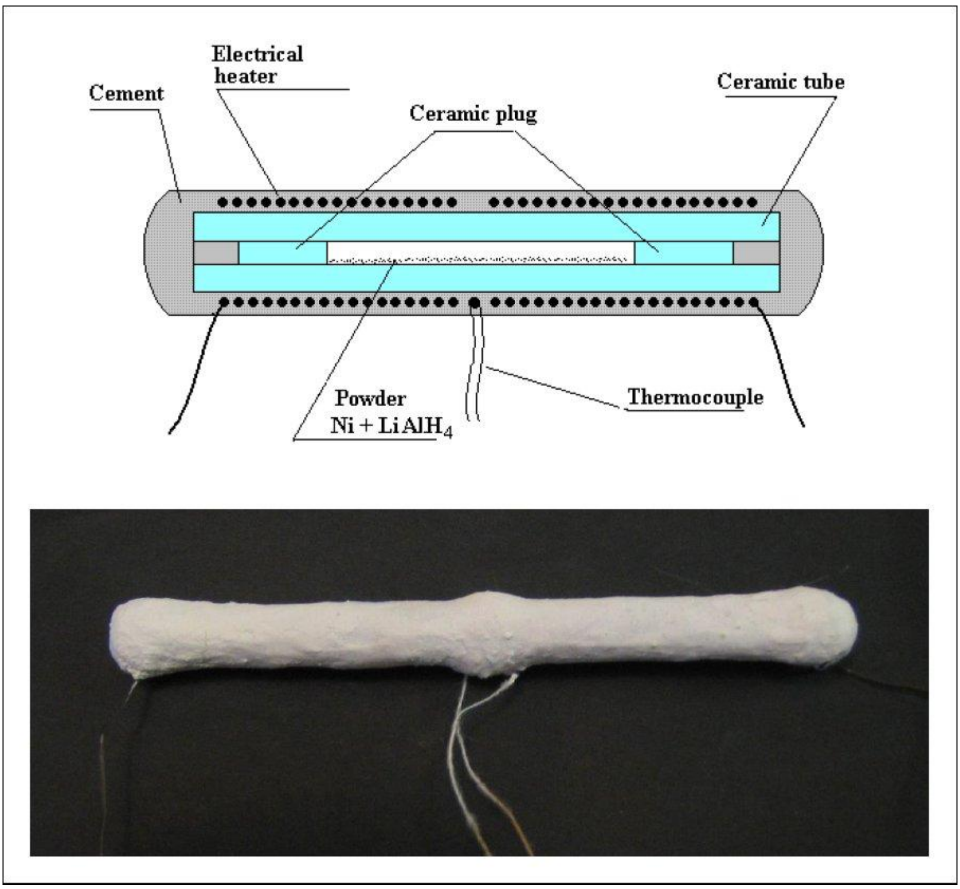

Fig. 5.1 - Design of the Parkhomov's reactor (above) and the reactor prepared for the experiment (below).

Alexander Georgievich Parkhomov, a disciple and colleague of Nobel Prize winner Andrei Sakharov, was born on January 31, 1945. In 1968 he finished his studies at the faculty of "Experimental and Theoretical Physics", at the **Moscow Engineering-Physical Institute**. In 1975, he earned a PhD at the faculty of "Physics of Radiation" of the same institute. In 1979-81 he worked as a senior scientific employee at the Vladimir Polytechnical Institute, and from 1987 to 1993 headed a **research group** at the Aviation Institute in Moscow. He's author of about 100 scientific papers, of which 45 with co-authors.

Parkhomov described his reactor, almost a replication of Rossi's Hot-Cat – namely of the Type IV design described in TPR-2 – in the **slides of a presentation** published online, prepared for his seminar entitled "Cold Fusion and Light Balls", held at the People's Friendship University of Russia on December 25, 2014. He appears to have reached a **COP = 2.58** at a temperature ***T* = 1290 °C**, so its reactor deserves great attention.

Fig. 5.2 - The simple setup used in the Parkhomov's experiment.

The reactor built by Parkhomov in his home laboratory **differs** from the Rossi's "Dog Bone" in many aspects, of which the main ones are: (1) **geometry**, which is similar to the "Type IV design" but not identical; (2) the fact of not to use a three-phase electric power, but a normal **single-phase** power; (3) perhaps the **lack of one or more** chemical components of the catalyst used by Rossi, still secret for reasons of Intellectual Property.

For these reasons, we can speak of a sort of "Type V" design distinct from the previously described "Type IV" design of Rossi's reactor. In addition, Parkhomov's reactor uses a **very simple experimental setup**, especially as regards the measure of excess heat. Instead, little is known on how atmosphere was removed from the reactor. And there are no pictures of the fuel after the test was completed to see if it was sintered.

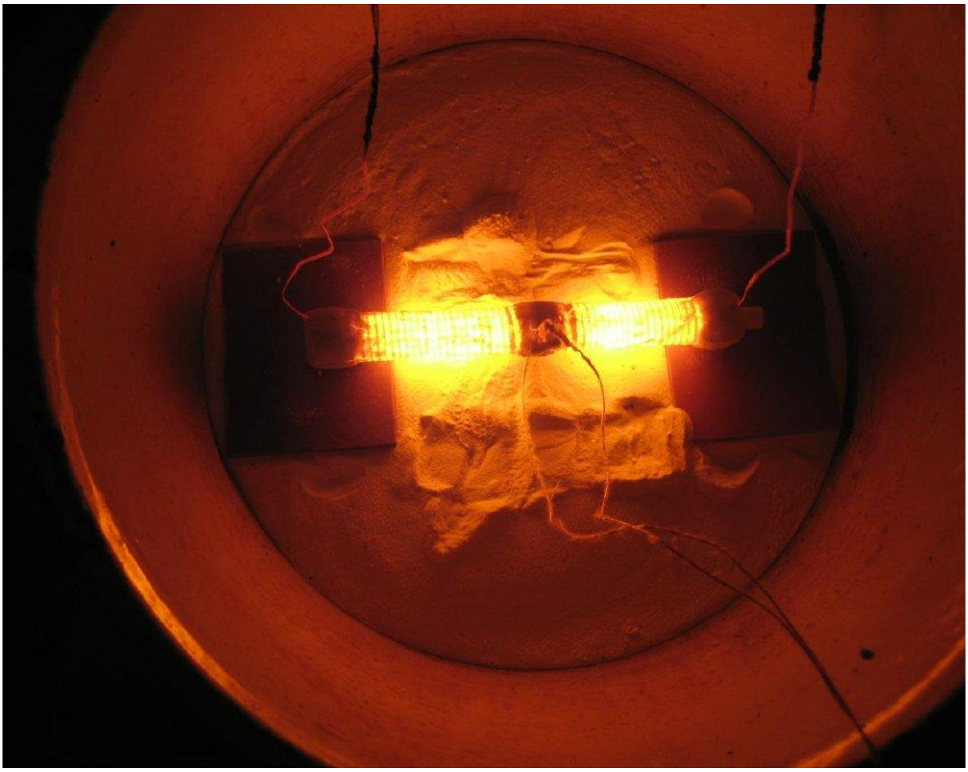

Fig. 5.3 - The reactor during operation. The covers of the thermal insulation and of the vessel have been removed.

We can see in the photo 5.2 the essential measurement equipment used by Parkhomov. From right to left of the image: **power supply** for heaters, **Geiger counter** display, **ammeter**, thermocouple amplifier, reactor temperature display, computer data logger, **digital voltmeter**. At the right side: Reactor in the calorimeter. On the top: Geiger detector. On the side surface: **radiation dosimeter**. A laptop computer is used for data logging of the reactor temperature and Geiger counter.

For measuring the consumed electric energy the "Mercury 201" electrical counter was used which allows the transfer of the information to the computer, also from the voltmeter and ammeter. During the first experiments the electric supply for heating the reactor was taken directly from the mains using **thyristors**.

Later experiments used a **changing transformer winding**. Both manual and automatic switching was used by the temperature controller. This allows us to provide continuous operation of the reactor at the given temperatures, improving the stability of functioning of the reactor. You can see the **circuit diagram** in the picture below.

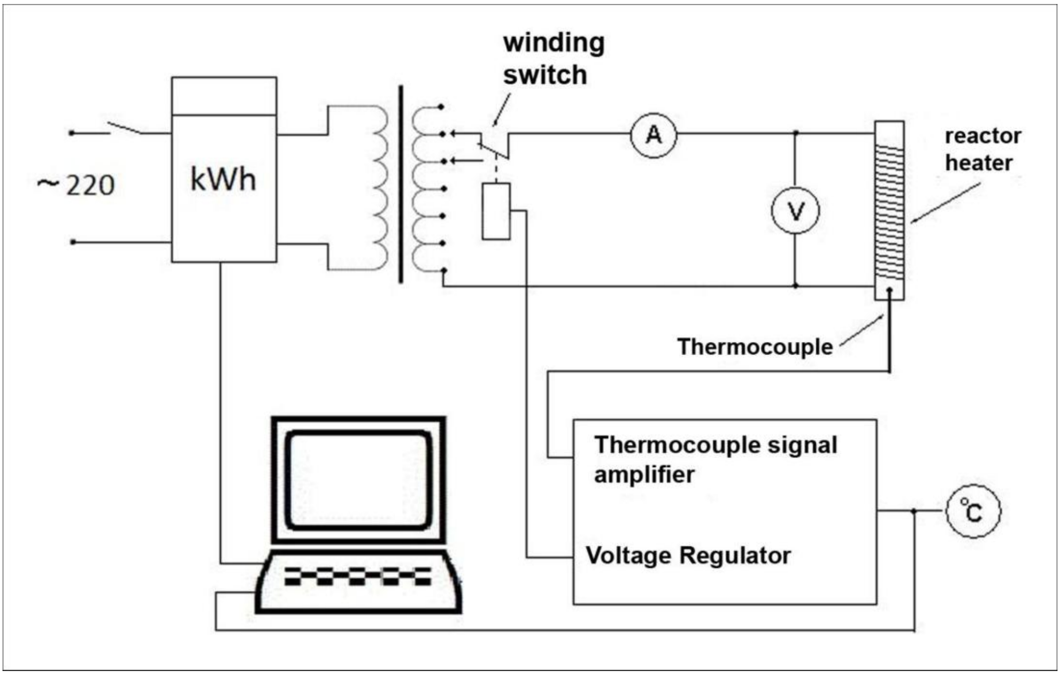

Fig. 5.4 - Circuit diagram of the power supply and control system used by Parkhomov.

Measurement technique of the liberated heat used by Parkhomov to check the performance of his reactor is simple: it is based on the amount of **vaporized water**, because that based on IR thermal images used in the Third Party Reports was too complex. The measurement method adopted by the experienced Russian physicist had been elaborated and experimentally verified multiple times by his colleague Yuri N. Bazutov.

How the **calorimetric measurement** is made? You can see in the picture 5.5 the simple calorimeter used by Parkhomov. The reactor is enclosed in a **metallic vessel**, which has a heavy cover. Thermal insulation is made of foam and on this cover a Geiger counter is placed. This vessel is **immersed in water** inside the outer vessel.

When the water boiling begins, part of it boils away in the form of **steam**. The released heat quantity is estimated by measuring the water quantity **before and after** the experiment. By measuring the decrease of water, and from the known **heat of vaporization** (2260 joules/kg), it is easy to calculate the generated heat. The correction for the heat lost through the isolation can be estimated from the heat cooling rate after reactor shutdown.

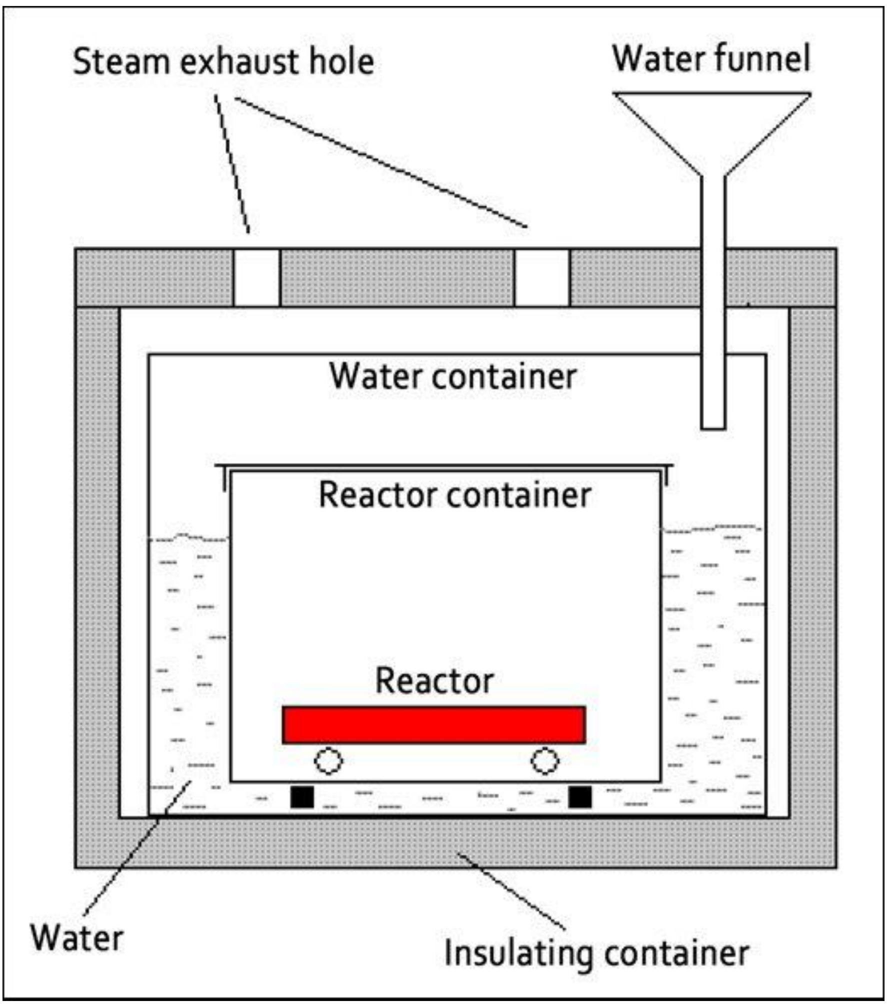

Fig. 5.5 - Design of the simple calorimeter used by Parkhomov.

Therefore, the measurement of the amount of water vaporized in the control and active runs is very simple. As Parkhomov explains: "During the experiment, after boiling of water began I kept **invariable** the top level of this water by **gradual addition** of fresh water. The mass of the evaporated water was considered to be equal to the mass of the added water".

The expert of LENR Michael McKubre commented positively this type of calorimetry: "The method has been employed accurately for well over 100 years. With simple precautions, it should be **accurate within a few percent** over a wide range of powers and reactor temperatures. One must be concerned to interrogate the heat that leaves the calorimeter by means other than as steam escaping at ambient pressure, that water does not leave the vessel in the liquid phase as splattered droplets or mist (fog), and to **accurately measure the water mass loss** (or its rate) to determine output power".

As revealed later by Parkhomov himself in a private communication to Frank Acland of *E-cat World*, measurements with a reactor **not containing fuel** and an electrical heater at the power up to 1000 W were taken. The quantity of consumed electric power after boiling of water, and the amount of heat necessary for heating and evaporation added for preservation of initial level, **coincided within 10%**.

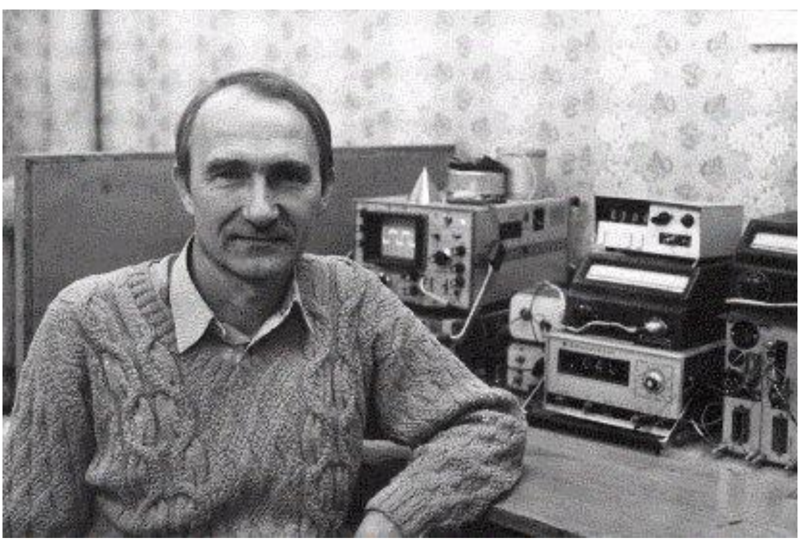

Fig. 5.6 - A young Alexander Parkhomov in his home laboratory.

The reactor consists of a ceramic tube **made of alumina** (Al_2O_3). Such cylinder has a length of 120 mm, an external diameter of 10 mm and an internal diameter of 5 mm. An electric heater is wounded around the internal tube thick 2.5 mm. The heater is made of a heat-resistant alloy **“nichrom”**. The wire was coiled directly on the corundum tube with intervals of 0.5 mm between rounds, and then was covered with heat-resistant **cement**.

As Dr. Parkhomov responded to an inquiry regarding the construction of the reactor he made: “The search of cement, which maintains high temperature, was **the most complex problem**, which should be faced preparing the experiment. You need not only the right chemical structure, but also a **process engineering** – for application of the cement – including some stages. The creation of the reactor lasted 3 days”.

Here below you can see the sizes analysis of the nickel powder used in the **fuel mix**, as provided by Parkhomov in reply to a specific question made by Frank Acland. We see that the **mean size of the grains is 12.85 μm**, and that less than 10% of the powder is smaller than 3.150 μm. Probably, Parkhomov used this **wide range distribution** to increase the likelihood that some Rossi-like effect was found.

Volume Statistics (Arithmetic) №4

Calculations from 0.017 μm to 2000 μm

Volume:	100%		
Mean:	12.85 μm	S.D.:	11.33 μm
Median:	8.724 μm	Variance:	128.3 μm^2
Mean/Median ratio:	1.473	C.V.:	88.1%
Mode:	7.083 μm	Skewness:	1.587 Right skewed
Specific Surf. Area:	1007 cm^2/g	Kurtosis:	1.953 Leptokurtic

d_{10}: 3.150 μm d_{50}: 8.724 μm d_{90}: 31.28 μm

<10%	<25%	<50%	<75%	<90%
3.150 μm	4.857 μm	8.724 μm	16.55 μm	31.28 μm

Fig. 5.7 - The sizes analysis of the nickel powder used by Parkhomov.

The outer surface of the cylinder is in contact with a thermocouple, which is placed in the central part of the tube, as shown in the design picture of the reactor, illustrating also the cables of heater and thermocouple. The **ends of the tube** are sealed with high temperature resistant ceramic cement. The whole **surface of the cylinder** is covered by the same cement (likely, alumina, already used for the ceramic tube).

The Parkhomov's "Hot-Cat" is loaded with a mixture of nickel and of so-called "lithium aluminum hydride" ($LiAlH_4$). More exactly, inside the tube there is **1 gram of a powder of pure Nickel + 10% $LiAlH_4$** (ten percent by weight). The quantity of lithium aluminum hydride was not chosen at random, but according to a precise quantitative evaluation.

When lithium aluminum hydride is heated, there is a decomposition of such chemical compound and hydrogen is progressively released as a gas, so its pressure in the reactor increases. We can see, with a simple calculation, that **1 g of lithium aluminum hydride** allocates **0.105 g of hydrogen** or, going from weight to volume, delivers **1.17 l** of hydrogen (at normal air pressure and temperature).

$$2\,Li\,[Al\,H_4] \xrightarrow{125\text{ - }180\ ^{o}C} 2\,Li\,H + 2\,Al + 3\,H_2$$

$$2\,Li\,H \xrightarrow{>850^{o}C} 2\,Li + H_2$$

Fig. 5.8 - Decomposition of the lithium aluminum hydride releasing hydrogen.

Assuming that the interior of the reactor is a channel with a diameter of 4 mm, the **cavity volume** is approximately **2 ml**. From the previous calculation, we know that 100 mg of lithium aluminum hydride deliver about 100 ml of hydrogen (under normal pressure and temperature conditions). So, if 100 ml are compressed up to 2 ml, at typical air temperatures the pressure rises to **50 atmospheres**.

At the working temperature of Rossi's reactor, the nickel mixes with the liquefied aluminum and a gas environment of lithium and hydrogen appears. When the temperature exceeds 1,000 °C, residual air reacting with the hydrogen, lithium and aluminum, under a pressure that may reach **over 100 atmospheres**, makes a small quantity of nitrogen, ammonia, nitric oxide and oxides of lithium and aluminum.

The heating power supplied to the heater inside the reactor – through a standard 50 Hz AC with no other frequency stimulation, wave chopping or magnetic field – has been varied **stepwise from 25 W to 500 W**, and **after 4 hours** the external temperature of the reactor reached 1,000 °C. This is reflected in a stepwise increase shown in the picture below.

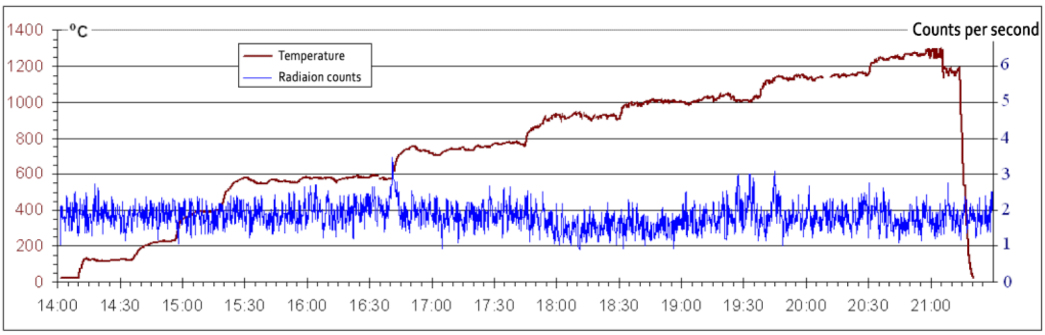

Fig. 5.9 - Temperature of reactor and counts from a Geiger counter during the experiment.

The same diagram shows the count rate (in counts/sec) provided by a **Geiger-Muller counter** – likely homebuilt and connected to a PC through a data logger – based on the Russian high sensitivity pancake probe SI-8B. This type of Geiger probe responds to **alpha, beta, gamma and X-rays**. It can be seen that, throughout the entire heating phase, the count rate is **not very different** from the background level (around 2 pulses/sec).

A small negligible increase in the background radiation is observed **sporadically**. Indeed, some spikes reaching a value of 3 counts/sec are noticeable at temperatures around 600 °C and 1000 °C. Further studies are thus needed to show if it was only an occasional occurrence or a sort of pattern. However, a **pocket dosimeter type DK-02** did not find a radiation in the limits of the errors of measurement (5 mR).

For neutron detection, Parkhomov used a **foil of Indium** immersed in the water of the calorimeter, however there was no observable activation of the foil during his experiments (so neutron flux density does not exceed 0.2 neutrons/cm^2). The **activity** of the Indium was measured using two Geiger counters. The impulses of the counters were recorded by a specialized computer. The same computer records the impulses from the Geiger tubes put above and below the dosimeter film and the metered electricity consumed.

The figure below shows in detail the temperature change occurring at the electrical heating power of 300, 400 and 500 watts. You can see that, at a constant heating power, there is a **gradual increase in temperature**, particularly strong in the last part of the run at 500 W of constant heating power. At the end of the part with the highest temperature visible in this chart, some temperature **oscillations** begin.

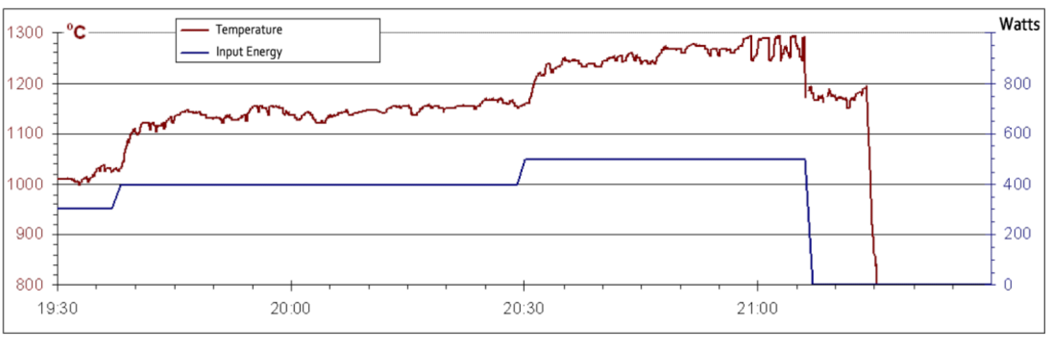

Fig. 5.10 - Changes in the heating process: zoom in the area of high temperatures.

The entire run of the Parkhomov's reactor ends due to the interruption of the electrical heating, as a result of a **burning of the heater**. After that, **for 8 minutes** the temperature stays at almost 1,200 °C, and then begins to fall sharply. This indicates that in the reactor, at this time, heat is produced at a high level **without** any electrical heating.

Thus, for this time duration (8 min) a heat **at kilowatt level** is produced inside of the reactor without electrical heating. So, the plot shows that the reactor is capable to generate a significant heat power that is greater than the electrical heating. According to the Parkhomov's report, during the total working time (90 minutes), the **excess heat energy** produced by the reactor has been about 3 MJ or 0.83 kWh.

A table published in the presentation prepared by the Russian physicist shows the extracted heat and the thermal efficiency calculations made for the **three "modes" of operation** corresponding to a temperature of about 1000 °C, 1150 °C and about 1200 to 1300 °C. You can see that, at temperatures of 1150 °C and in the range of 1200-1300 °C, the heat produced by the reactor is **much greater** than the consumed energy.

Average temperature of a "mode"	°C	970	1150	1290
Duration of a "mode"	min	38	50	40
Electring heating power	W	300	394	498
Electrical energy consumption	J	684000	1182000	1195200
Mass of vaporized water	kg	0,2	0,8	1,2
Energy spent for vaporization	J	452000	1808000	2712000
Heat leakage rate through thermal insul.	W	155	155	155
Cumulative heat loss through thermal ins.	J	353400	465000	372000
Cumulative net energy	J	805400	2273000	3084000
Output/input energy ratio (COP)	COP	1.18	1.92	2.58

Tab. 5.1 - Estimate of released energy as heat. Calculations are made for three modes of operation with a temperature of about 1000 °C, about 1150 °C and 1200-1300 °C.

The COP of the Parkhomov's reactor, as shown from the above table, at 500 W of power input (average effective power input = 1290 W) resulted equal to 2.58. As, from what Parkhomov said, the energy output in the **dummy run was within 10%** of the calculated baseline based on water chemistry (corresponding to a COP of 1.1 instead of COP = 1.0), you would need more than 200% error to get a COP of 2.5.

So, the calculated COP is **significantly above** the error margin and there are no doubt about the generated excess heat, and the Parkhomov's experiment has shown that this device actually produces more energy than it consumes. It represents the **first confirmation** of the main results obtained in the Lugano test described in TPR-2. This is also the first fully independent "replication" by "somebody skilled in the art".

We've described the experiment carried out by Parkhomov on December 20, 2014. On January 2015, he has performed **other experiments** on a reactor with fuel and on a dummy, i.e. heating the reactor without fuel. The table shows the results obtained in several experiments. In experiments with reactor models **having no fuel** as well as with reactors with fuel at a temperature below 1000°C, the COP is **close to 1**.

Reactor with Fuel

Date	Temp	Duration	Input	Output	COP
	°C	Min	Watts	Watts	
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	Duration	Input	Output	COP
	°C	Min	Watts	Watts	
02.01.2015	210	56	211	227	1.07
02.01.2015	470	00	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

Tab. 5.2 - The results obtained by Parkhomov in his several replication experiments.

The **COP vs. temperature relationship** emerging from all these experiments has been shown by the reader "Sanjeev" in a chart (see Fig. 5.11) posted on the blog *E-Cat World*. I've added to the chart the points corresponding to the Lugano test and to the second and third test described in TPR-1. We can see from the extrapolated curve that probably **no catalyst was used in the Lugano test**, whereas it was used in the other tests on the Hot-Cat.

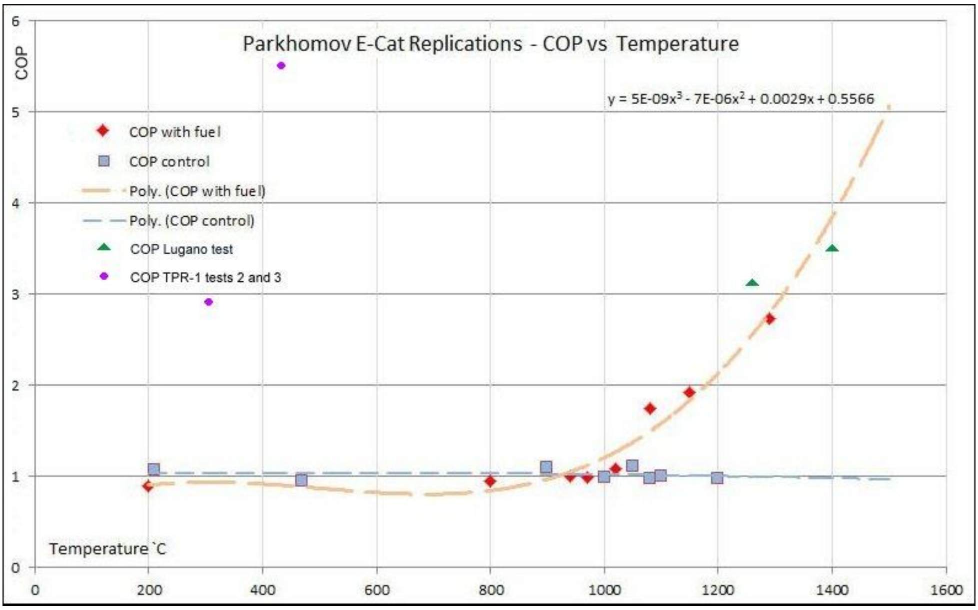

Fig. 5.11 - The many Parkhomov's tests vs. both Lugano test and TPR-1's test 2 and 3. We can see that probably no catalyst was present in Lugano test.

Sometimes, the reactor made of alumina powder was poured into a **metal envelope** to provide thermal insulation. This allows a 2-3 times reduction in the power necessary to heat the reactor; however, the operation in this regime is **less stable** than in case of the "naked" reactor. According to Parkhomov, many times in his experiments an uncontrolled **local overheating** resulted in destruction of the reactor.

Fig. 5.12 - Some reactors after the experiments carried out by Parkhomov.

In another experiment, the reactor was covered with a **further thermal insulation** of alumina powder instead of the metal envelope, then it worked for 38 minutes at a temperature near to 1080 °C, but when Parkhomov tried to increase the temperature the heater burned out. Thus, the main problem is **short-term operation** of the reactors, associated with the **destruction** caused by local overheating.