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WAYS TO IMPROVE THE HEAT GENERATOR A. ROSSI

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ABSTRACT

Based on the test report of the heat generator by A. Rossi (2011, Lugano), the authors calculated that the summa of nuclear energy had been generated by the heat generator for 30 days exeeded 2900 MJ . To improve the operational characteristics of the device, it is proposed to use a high-frequency generator to heat the reacting mixture. The use of titanium instead of nickel in the heat generator can also be useful. An experiment was carried out in during which a nuclear reaction in a mixture of 5 g of nickel and 0.5 g of lithium aluminum hydride was initiated by heating in a household microwave oven. Gamma analysis of the mixture after it had cooled revealed the presence of a number of short-lived nuclides including ^{46}K (half-life 1.75 min.), ^{91m}Mo (half-life 1.077 min.), ^{168m}Lu (half-life 6.70 min.). At the moment of start of measurements, the activity of these nuclides ranged from 0.5 to 1 Bq.

Key words: low energy nuclear reaction; termogenerator A. Rossi; gamma spectrometry; nickel; titanium; high frequency heating

Introduction. The production of electricity at nuclear power plants and the processing of spent nuclear fuel are associated with the risks of man-made pollution of the environment. Therefore, the problem of searching for sources of environmentally friendly energy and conducting experiments on energy production based on low-temperature nuclear reactions is relevant.The idea of using cold transmutation of atoms (nuclei) to obtain clean and cheap energy was successfully implemented by Italian researchers S. Focardi and A. Rossi and became widely known [1]. At the same time, the achievements of the Russian inventor A.V. Vachaev, who created in 1994 an industrial installation in which a water flow was passed through the region of a high-frequency plasma discharge, and as a result, energy was created and new elements were synthesized at a rate of their formation of the order of kg/min [2], did not attract attention and went unnoticed by the world scientific public. This is probably due to the fact that after the death of A.V. Vachaev in 2000, his employees could not put the unit into operation, while the prototypes of Rossi's heat generator operate in many countries [3].

Analysis of the operation of the Rossi thermogenerator

As reported in [4,5], the heat generator is a ceramic tube, inside which contains a fuel - mixture of 1 g of nickel powder and 0.1 g of lithium aluminum hydride ($LiAlH_4$), with a heating coil wound on its surface. With the help of this spiral, the tube with fuel was heated up to 1260-1400°C. During testing, the amount of energy spent on heating, and the amount of thermal energy generated by the installation. It is indicated that during the 32 days of testing, the E-cat device produced 5800 MJ of heat, which is more than 3 times the energy used for electric heating. The spent fuel was subjected to mass spectrometric analysis, which revealed significant changes in the isotopic composition of the fuel, unambiguously indicating the origin of nuclear energy (Table 1).

Table 1.

Isotopic composition of the original and spent fuel (%) determined using an inductively coupled plasma mass spectrometer [1,3]

Nuclide	Initial fuel	Spent fuel
Li-6	6	58
Li-7	94	43
Ni-58	66	0.3
Ni-60	28	0.3
Ni-61	1.3	0
Ni-62	4	99

Let us calculate the nuclear energy obtained during the transmutation of 66% of ^{58}Ni nuclei into ^{62}Ni nuclei according to the (1)

$$E(62-58) = p\, N_A(\acute{\varepsilon}_{62} A_{62} - \acute{\varepsilon}_{58} A_{58}) / A_{58} (1)$$

where $E(62–58)$ is the energy obtained during the transformation of ^{58}Ni nuclei into ^{62}Ni nuclei;

p - the fraction of ^{58}Ni nuclei in the original fuel converted into ^{62}Ni (0.66 according to Tab.1);

N_A / A_{58} - the number of ^{58}Ni nuclei in 1 g of initial fuel; N_A is Avogadro's number;

$A_{58} = 58$, $A_{62} = 62$ - mass number for ^{58}Ni and ^{62}Ni, respectively;

$\acute{\varepsilon}_{58}$, $\acute{\varepsilon}_{62}$ - the binding energy per nucleon in ^{58}Ni and ^{62}Ni nuclei, respectively [6].

When substituting into (1) $N_A = 6.022*10^{23}$ 1/mol; $\acute{\varepsilon}_{58} = 8732$ keV, $\acute{\varepsilon}_{62} = 8795$ keV we get $E(62 - 58) = 0.154 * 10^{26}$ keV.

Similarly, we get $E(62 – 60) = 0.031*10^{26}$ keV, given that for ^{60}Ni p = 0.28 ; $\acute{\varepsilon}_{60}$= 8781 keV. The total energy from the transmutation of ^{58}Ni and ^{60}Ni will be $0.185*10^{26}$ keV.

Taking into account the fact that 1 eV = 1.602 * 10^{-19} J, this will amount to 2960 MJ. The total energy obtained by us is approximately two times lower than the test data (5800 MJ). Probably, the authors of the report [4] gave too narrow the uncertainty interval when estimating the excess energy (±10%).

Note that additional energy could be released during the transmutation of the elements that make up the ceramic tube (Al, K, O). Table 2 illustrates this possibility.

Table 2.

Possibility of energy release during neutron capture by aluminum and potassium nuclei

Nucleus	Binding energy per nucleon, keV	Half life	Content in natural mixture
Al - 27	8332	Stable	100,00%
Al -28	8310	2.245 min.	-
Si -28	8448	Stable	92.2 %
K - 41	8576	Stable	6.73 %
K - 42	8551	12.36 hour	-
Ca - 42	8617	Stable	0.647 %

The authors of [7] found, by means of emission analysis, the appearance in fragments of the ceramic tube (in which nickel powder saturated with hydrogen was located) of significant amounts of calcium after the operation of the heat generator for 7 months. When a neutron is captured by the ^{41}K nucleus, ^{42}K is formed, which, due to beta decay, turns into ^{42}Ca. The beta decay of ^{42}K is accompanied by the emission of a 1525-keV gamma-ray (yield 0.181), which can be detected [8]. From Table 2 shows that the process of transmutation of potassium into calcium is accompanied by the release of energy.

The number of neutrons required to produce excess energy during testing [4, 5] $0.33*10^{23}$ neutrons or $0.127*10^{17}$ neutrons/s.

One of the sources of neutrons required for the transmutation of ^{58}Ni to ^{62}Ni is the conversion of ^{7}Li to ^{6}Li. Let's consider a possible way of such transformation. The energy of free electrons in lithium increases with an increase in the temperature of the metal, and at a certain temperature, the energy of a part of the electrons (on the "tail" of the distribution curve) becomes sufficient to overcome the electron shells of lithium atoms. Such electrons are accelerated by the positive charge field of the nucleus and enter the nucleus.

$$^{7}Li + e^{-} ---> {}^{7}He \quad (2)$$

The binding energy of nucleons in the ^{7}Li nucleus is higher (by 10 MeV) than in the ^{7}He nucleus, and this excess can be compensated by the rest energy of the electron (511 keV), its kinetic energy, and the energy of the electron acquired during acceleration in the field of the nucleus.

Reaction (2) can be initiated due to the presence of muons in cosmic rays (CR), whose flux near the earth's surface [9] is $1.5\ 10^{-2}$ muons/cm^2·s. When muons hit a substance, they are captured by atoms and gradually descend to the K-orbital with the emission of photons.

The radius of this orbital is 200 times smaller than that of the corresponding electron orbital, so the muon spends a considerable time directly in the nucleus. Therefore, the muon is quickly captured by the nucleus, interacting with the proton according to the scheme: $\mu^- + p \dashrightarrow n + \nu_\mu$ [10],

for the interaction of a muon with lithium $\mu^- + {}^7Li \dashrightarrow {}^7He + \nu_\mu$

The ^{7}He nucleus turns out to be in a highly excited state (more than 100 MeV) and its decay can occur through many channels.

When ^{7}Li interacts with an electron (2), the formed ^{7}He nucleus, according to [6], ejects a neutron and turns into ^{6}He:

$$^7He \dashrightarrow n + {}^6He \quad (3)$$

Which in turn, passes through beta decay (half-life 0.807 s and the boundary energy of the beta particle is 3507 keV) into stable ^{6}Li: $^6He \dashrightarrow \beta^- + \tilde{\nu}_e + {}^6Li$, where $\tilde{\nu}_e$ is an electron antineutrino.

The calculation showed that when a nuclear reaction proceeds according to (2) and (3), the probability of the formation of high-energy particles (average energy 1568 keV) would be $3.09 * 10^{14}$ particles per second. The beta particle detector did not detect any beta activity when testing the heat generator. This was probably due to the fact that a certain number of beta particles swallowed by the walls of ceramic tubes and protective fittings, and some of them interacted with ^{7}Li nuclei according to reaction (2).

Possible ways to improve the heat generator A. Rossi

The use of a high-frequency (HF) generator for heating the reacting mixture (Ni + $LiAlH_4$), in our opinion, will improve the performance characteristics of the heat generator, since the thermal effect of the HF generator is not inertial and is easily controlled by changing the characteristics of the modulating voltage. In addition, by changing the frequency of HF radiation, it is possible to optimize the process of transmutation of nickel nuclei.

The author of this work used radiation from a household microwave oven to initiate the transmutation process in a nickel-hydrogen heat generator. A mixture of nickel powder (PNK-UT3 brand) weighing 5 g and $LiAlH_4$ powder weighing 0.5 g was placed in a crucible, which, in turn, was placed in another larger crucible. The crucibles with the drug were exposed to microwave radiation at a power level of 700 W. A minute later, the mixture was heated to a temperature of approximately 1000 °C, then the effect of HF radiation was stopped by opening the furnace door, but the reaction probably continued, because the temperature of the preparation remained high for another 3 minutes. After the mixture has cooled to room temperature, which lasted 7 minutes, the preparation was transferred into a standard cuvette with a diameter of 46 mm and placed on the end face of a GEM-30185 gamma detector, EG@Ortec, USA. The detector was placed inside a protective chamber - a lead shield to reduce the external background from external radiation. The thickness of the lead walls of the protective chamber was 10 cm. The registration of pulses from the detector was carried out using a single-board amplitude analyzer of the SBS-75 brand, Green Star Instruments, Russia.

Identification of the detected gamma emitters was carried out by the energy of gamma lines and the half-life by the method described in [11]. In table 3 shows the activities of short-lived nuclides found in the preparation (at the start of measurements), as well as their half-lives, quantum yields, and energy of characteristic gamma lines. The activity of the identified nuclides did not exceed 1 Bq, and the uncertainty of the results was 50–70% and it was due to a small number of pulses recorded during gamma analysis.

Table 3.

Results of the identification and calculation of the activity of nuclides in the nickel preparation after exposure to RF heating. The cooling time of the preparation before the start of measurement is 7 minutes

Nuclide	Type decay	Period half-life, minutes	Energy of the used gamma	Quantum. output	Activity at the moment start of measurements, Bq
P-35	β^- 100%*	0.788	1572	0.995	0.2
K-46	β^- 100%	0.750	1345	1.000	0.5
Fe-61	β^- 100%	5.980	1205	0.420	0.4
As-68	ε 100%**	2.530	1016	0.774	0.4
Mo-91m	ε 50%	1.077	1508 1208	0.242 0.186	1.0
Cd-102	ε 50%	5.500	481 1036	0.600 0.138	0.2
Sb-133	β^- 100%	2.340	979	0.582	0.4
Tb-148m	ε 100%	2.200	785 395	0.995 0.96	0.2
Lu-168m	ε 100%	6.700	979 984	0.21 0.13	0.5

* beta decay; ** – K capture

The use of titanium instead of nickel as a fuel in the development of heat generators, in our opinion, is promising. From Table 4, built on the data of [6,8], it can be seen that the addition of a neutron to the nucleus for most titanium isotopes leads to the release of

nuclear energy. In addition, the melting point of titanium

1668 ° C is higher than the melting point of nickel + 1452 ° C, therefore, the titanium crystal lattice, which plays a significant role in the transformation of protons into neutrons, is more stable at high temperature.

Table 4.

Content of titanium isotopes in a natural mixture and energy nuclear bonds

Nuclide	Content in natural mixes, %	The bond energy on one nucleon, keV
Ti-46	8.25	8656
Ti-47	7.44	8661
Ti-48	73.72	8723
Ti-49	5.41	8711
Ti-50	5.18	8755

Conclusion

Using the data from the report on the test of the A. Rossi heat generator in March 2011, the author calculated the nuclear energy obtained by transmuting nickel nuclei, which amounted to 2960 MJ, which is two times lower than the test data (5800 MJ). The author believe that electrons play an essential role in the process of the nuclear transmutation.

To improve the performance characteristics of A. Rossi's heat generator, it was proposed to use the heating of the reacting mixture with the help of an HF generator. It was proposed to use titanium instead of nickel as fuel.

For the first time, it was found that during the operation of the Rossi heat generator, radionuclides appear, which are characterized by short half-lives (minutes) and low activity.

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