

A new energy source from nuclear fusion

S. Focardi⁽¹⁾ and A. Rossi⁽²⁾

⁽¹⁾Physics Department Bologna University and INFN Bologna Section

⁽²⁾Leonardo Corp. (USA) - Inventor of the Patent

March 22, 2010

Abstract

A process (international patent publication N. WO 2009/125444 A1) capable of producing large amounts of energy by a nuclear fusion process between nickel and hydrogen, occurring below 1000 K, is described. Experimental values of the ratios between output and input energies obtained in a certain number of experiments are reported. The occurrence of the effect is justified on the basis of existing experimental and theoretical results. Measurements performed during the experiments allow to exclude neutron and gamma rays emissions.

1. Introduction

It is well known that in chemical reactions, and more specifically in processes used to obtain energy, as for example oil, gas and carbon combustion, only some electronVolts (eV) can be obtained for every couple of atoms involved. This depends on the fact that binding energies of external atomic electrons are in the eV range.

On the other hand, in nuclear transformations, the energy quantities that can be absorbed or released are of the order of mega-electronVolts (MeV) for every couple of nuclei involved in the process. As a consequence, for every given amount of energy obtained, the mass to be transformed by a nuclear process is about a millionth of that necessary for a combustion.

It is a general rule, valid for all stable compounds, that the mass for a compound is lower than the total mass of all constituents. In such conditions, the mass-energy conservation principle guarantees stability against the spontaneous disintegration into the components. As a consequence, for the nuclei, the mass of every stable nucleus turns out to be lower than the sum of the masses of all its components (protons and neutrons).

If we denote by m_p and m_n the mass values of free protons and neutrons, and by n_p and n_n the numbers of protons and neutrons belonging to a given (stable) nucleus N, the nuclear stability is insured by the always positive difference

$$\Delta = n_p m_p + n_n m_n - m_N \quad (1)$$

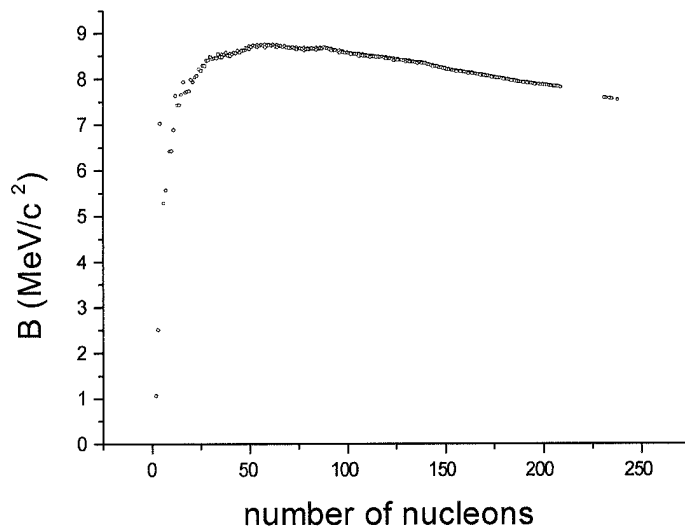


Figure 1: Binding Energy versus number of nucleons

where m_N represents the nucleus mass.

An important parameter, whose value is directly connected to the nuclear stability, is the binding energy for a nucleon B [1], defined as the ratio between Δ and the mass number, that is the total nucleon number $n_p + n_n$:

$$B = \frac{\Delta}{n_p + n_n}. \quad (2)$$

Fig.1 shows, for all stable nuclei, the binding energy B (expressed in MeV/c^2) versus the total number of nucleons (protons and neutrons) [2].

As is evident from the definition of B , nuclear stability is characterized by large values of the binding energy for nucleon. Nuclei having a mass number around 60 (as Fe, Co and Ni) are characterized as particularly stable.

Fig.1 shows clearly the two existing possibilities in order to obtain energy from nuclear transformations: they consist in producing more stable nuclei starting from low mass or from high mass nuclei. Such two processes are respectively referred to as fusion and fission.

Fusion processes occur naturally in the stars, where helium and other elements are produced, starting from hydrogen. Other similar phenomena, which lead to the production of heavier elements, occur in hydrogen rich stellar atmospheres, after supernovae collapse.

Artificial fission processes are obtained in nuclear reactors by means of neutron interactions with Uranium or Thorium which induce nuclear breaking and neutrons release. There exist no natural fission processes, with the only exception of a flooded Uranium mine in Gabon [3] which reproduced, about two millions years ago, physical conditions similar to the ones occurring in a nuclear reactor.

2. Experimental results

In this paper we report the results obtained with a process and apparatus not described here in detail and protected by patent in 90 countries, consisting of a system whose heat output is up to hundred times the electric energy input. As a consequence, the principle of the conservation of energy ensures that processes involving other energy forms are occurring in our apparatus.

The system on which we operate consists of Ni, in H atmosphere and in the presence of additives placed in a sealed container and heated by a current passing through a resistor. The maximum temperature value can be set to a wide range of values and an external meter allows us to measure the electric energy input. The container is in thermal contact with an external tank full of water and thermally insulated in order to minimize outside heat exchanges. As consequence of the energy production of the system, water boils and the water pipe is under pressure. The steam pressure cannot exceed a limit, whose value can be changed in the range 3-6 bar, because of the opening of a valve. When the valve opens, new water, whose amount is measured by a meter, enters from the supply. These data allow us to calculate the power produced by our system.

In stationary conditions the power output turns out to be much greater than the input (measured with an electric power meter). Some examples of the results obtained with this system (method A) in brief periods ($\sim 1-1,5$ hours) are reported in lines 1-3 of the Table 1. The ratio between output and input power depends on changes occurring in the Ni-H system and on the time interval elapsed between the starting of the experiments and the measuring moments.

We have subsequently achieved a forced warm water movement through some radiators connected in series. In this case, the energy produced has been evaluated by measuring the power needed to obtain the same radiator temperature with a normal heating system (method B). In Table 1, lines 4 and 5, the results of these measurements are also reported. The patented apparatus is able of producing a constant and reliable amount of energy for a period of months

A third method (method C) based on a closed circuit in which water is forced to circulate by means of a pump was used in order to measure the power generated: a section of the circuit contains the energy amplifier opportunely insulated in order to minimize thermal exchanges with outside. Two thermocouples placed before and after the energy amplifier allow to detect continuously the water temperatures which are recorded on a computer. As a consequence the measured temperature difference allows to calculate the thermal energy transferred from the energy amplifier to the water. The electric input energy is measured by means an electric power meter. Similar results have been obtained in a test performed with ENEL spa on June, 25th 2009.

days	method	input energy	output energy	out/inp
2008-5-28	A	0,2	83	415
2008-6-11	A	0,806	165	205
2008-9-2	A	0,5	40	80(*)
2009(2-17 - 3-3)	B	5,1	1006,5	197
2009(3-5 - 4-26)	B	18,54	3768	203
2009-10-22	C	0,018	3,23	179

Table 1: Input and output energies, expressed in kWh, in some experiments.
 (*) The anomaly in this experiment is due to contamination of the fuel.

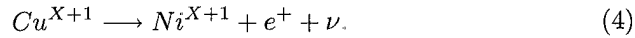
In all cases the energy production is too high for any chemical process. In fact, assuming that each Ni atom in sample can realise, in optimal conditions, a typical chemical energy of some eV, the amount of energy emitted in the long lasting experiments would required at least 10^{28} atoms. That is something like a million of grams, a quantity enormously larger than the sample we have employed. For such a reason, we believe that form of energy involved is nuclear, and more specifically, due to fusion processes between protons and Nickel nuclei. They are exothermic with an energy release in the range 3-7,5 MeV, depending on the Nickel isotope involved.

It is remarkable that similar results have been obtained in the factory of EON in Bondeno (Ferrara, Italy) in a test performed with ENEL (spa) on June, 25th 2009 and in another sery of tests made in Bedford, New Hampshire (USA) in a lab of LTI with the assistance of the DOE (November 19 2009) and of the the DOD (November 20 2009).

The proton capture process performed by a Nickel nucleus produces a Copper nucleus according to the scheme



Copper nuclei, with the exception of the stable isotopes Cu^{63} and Cu^{65} , decay with positron (e^+) and neutrino (ν) emission in Ni nuclei according to the scheme



Subsequently, the positron annihilates with an electron in two gamma-rays according to the process



A process alternative to (4), electron capture, in abbreviated form indicated as EC, consists in the nuclear capture of an orbital electron which gives rise to the process



<i>Nucleus</i>	$\text{Ni}^A + p^1 \longrightarrow \text{Cu}^{A+1}$	$\text{Cu}^{A+1} \longrightarrow \text{Ni}^{A+1}$	$\text{Ni}^A \longrightarrow \text{Ni}^{A+1}$
Ni^{58}	3, 41	4, 8	8, 21
Ni^{59}	4, 48	6, 13	10, 61
Ni^{60}	4, 80	2, 24	7, 04
Ni^{61}	5, 86	3, 95	9, 81
Ni^{62}	6, 12		6, 12
Ni^{63}	7, 2	1, 68 (Ni) 0, 58 (Zn)	8, 22 + 2, 14
Ni^{64}	7, 45		7, 45

Table 2: Energy (in MeV) released by Ni->Cu and Cu->Ni transformations for different Ni isotopes.

As a consequence, in this case, the reaction (4) must be replaced by

$$\text{Cu}^{X+1} \longrightarrow \text{Ni}^{X+1} + \bar{\nu} \quad (7)$$

with emission of an antineutrino ($\bar{\nu}$).

The two decay processes (positron emission and EC) are alternative: their relative frequencies for the various copper isotopes are generally unknown with the only exception of Cu^{64} for which EC decay (7) is about twice as frequent as positron decay [4].

The capture rate of protons by Nickel nuclei cannot depend on the mass values of different isotopes: in fact they possess the same nuclear charge and the same distribution of electrons in the various atomic shells. In practice, starting from Ni^{58} which is the more abundant isotope, we can obtain as described in the two above processes, Copper formation and its successive decay in Nickel, producing Ni^{59} , Ni^{60} , Ni^{61} and Ni^{62} . Because Cu^{63} , which can be formed starting by Ni^{62} is stable and does not decay in Ni^{63} , the chain stops at Ni^{62} . In Table 2, for every Nickel isotope, we report, expressed in MeV, the energies obtained from the process $\text{Ni}^A + p^1 \longrightarrow \text{Cu}^{A+1}$ (column 2), those obtained from the process $\text{Cu}^{A+1} \longrightarrow \text{Ni}^{A+1}$ (column 3) and their total for the complete transformation $\text{Ni}^A \longrightarrow \text{Ni}^{A+1}$ (column 4). The data reported in columns 2 and 3, are obtained as differences between the mass values of the initial and final state: the ones reported in column 3 contain also the neutrino (or antineutrino) energy, particles which interact weakly with the matter and does not hand their energy locally. On the other hand we have to consider the energy equivalent of the electron rest mass due to the positron annihilation. Cu^{64} also decays in Zn^{64} with negative electron emission; the energies relative to both decays are reported in Table 2 (third column); the value (8,22) carried in column four takes into account the relative frequencies of both Cu^{64} decay modes.

Ni^{65} , coming from the decay of Cu^{64} , decays with electron emission, releasing 2,14 Mev: such a value must be added to 8,22 Mev reported in Table 2 (line 6, column 4). The two isotopes Ni^{59} and Ni^{63} are unstable, but because of their long lifetime (8×10^4 years and 92 years respectively for Ni^{59} and Ni^{63}) can be considered as stable in the times of our experiments.

For every nucleus in the mass range 58 – 64 amu, we have built Table 3 which contains

- the mass value expressed in amu (column 1)
- the total energy obtainable from all transformations (column 2)
- the percentage in natural composition (column 3)
- the product of columns 2 and 3

The sum of the energy releases in the last column gives ≈ 35 MeV, which represents the mean energy value obtainable for every Ni nucleus (in the hypothesis that all nuclei give rise to the whole sequence of events). Such a figure must be compared with $E \approx 200$ MeV for every U^{235} fission in a nuclear reactor [5] and ≈ 18 MeV for every reaction between deuterium and tritium in not still existing fusion reactor. For the same number of nuclei, the ratio between Ni and U masses is 0,25 and the ratio between the energies that can be obtained is $\approx 0,2$. Taking into account the world reserves of these elements, their extraction costs and the great investments needed for the building and maintenance of a nuclear reactor, the nuclear processes (based on Nickel) appear from the economical point of view very interesting.

During experimental tests, continuous controls on the radioactivity levels in close proximity to the apparatus suitably lead shielded, were performed by using a gamma ray detector [6] and three passive neutron bubble detectors BTbubble [7], one of which for thermal neutrons: no radiation was observed at levels greater than natural radiation background. No radioactivity has been found also in the Nickel residual from the process. The 10th of march 2009, during the run whose data are reported in Table 1, line five, measurements were performed, around the running Energy Amplifier, by the Bologna University Health Physics Unit which verified that emissions around the Energy Amplifier are not significantly different from the natural background. The water drawn from the Energy Amplifier has resulted to have the same concentration of natural radioisotopes of the tap water: therefore there is no difference between the tap water and the water from the Energy Amplifier.

Two different samples of material used in the experiments labelled in table 1 as method A (288 kWh produced) and method B (4774 kWh produced) were analysed at Padua University SIMS. In the long period sample, the mass analy-

Nickel mass	Energy	Nat. composition %	Energy x nat. comp.
58	41,79	68,08	28,45
59	33,58	0	0
60	22,97	26,22	6,02
61	15,93	1,14	0,18
62	6,12	3,63	0,22
63	17,81	0	0
64	7,45	0,93	0,07
Total			34,94

Table 3: Energy obtained by every Ni isotope due to all successive transformations.

sis showed the presence of three peaks in the mass region 63-65 a.m.u. which correspond respectively to Cu^{63} , elements (Ni^{64} and Zn^{64}) deriving from Cu^{64} decay and Cu^{65} . These allowed us the determination of the ratio $\text{Cu}^{63}/\text{Cu}^{65}=1,6$ different from the value (2,24) relative to the copper isotopic natural composition. The peak in the mass spectrum at a.m.u.=64, due to Ni^{64} and Zn^{64} (both coming from Cu^{64} decay) requires the existence of Ni^{63} which, absent in natural Ni composition, must have been in precedence produced starting by more light nickel isotopes. More details on this analysis will be given in a successive paper [8].

3. Theoretical interpretation

Proton capture by Nickel nuclei obviously requires the overcoming of an electrostatic potential barrier which opposes the process. For Ni^{58} (the more abundant Nickel isotope), the maximum potential energy V_{max} occurs at a distance R between Ni and proton nuclei centers equal to the sum of their radii, that is $R \approx 7,239$ fm. The V_{max} value is given (in MKS units) by the expression $V_{\text{max}} = \frac{1}{4\pi\epsilon_0} \frac{Ze^2}{R}$, where Ze^2 is the product of the two nuclear charges: it results in $V_{\text{max}} \approx 89 * 10^{-14}$ J $\approx 5,6$ MeV. The proton kinetic energy K_e can be easily estimated by the relation $K_e = \frac{1}{2}mv^2 = \frac{3}{2}kT$, where k is Boltzmann's constant and T is the temperature measured in Kelvin: also on assuming $T = 1000$ K, K_e is only $\approx 0,13$ eV. According to classical physics, a particle having a such an energy cannot overcome the very high potential barrier. Such an opportunity, in principle, is given by the quantum mechanical tunnel effect: in this case, the incoming particle can penetrate into the nucleus by getting through the potential barrier. The tunneling probability of a single particle colliding with an atomic target has been calculated by Gamow [9]. As shown by Evans [10], such a probability can be approximated as

$$P \approx e^{-(2\pi Zz/137\beta)} \quad (8)$$

where $\beta = \frac{v}{c}$ is the ratio between the velocity v of the incoming particle and the velocity of light c : in our case, we obtain $v^2 = \frac{2K_e}{m} \approx 2,77 * 10^{-7}c^2$, and then $\beta = \frac{v}{c} \approx 5,26 * 10^{-4}$. Z and z are the charge values of Ni ($Z = 28$) and H ($z = 1$).

The tunneling probability becomes, as a consequence, $P \approx e^{-2440} \approx 4,7 * 10^{-1059}$, so small to make the capture of a single proton by a Nickel nucleus impossible. Nevertheless we have an experimental evidence of a large energy that can only arise from nuclear reactions between Nickel and Hydrogen, the only two elements existing in our apparatus. Furthermore, other attempts [11-15] have been made with Ni and H, obtaining analogous results, even if in a much smaller scale and without an easy and clear reproducibility.

In an attempt to explain the observed experimental effects, our attention has been attracted by a statement reported in [16] relative to a stellar gas where the electrons tend to cluster into spherical shells around nuclei, at distance r_D known as Debye-Hückel radius. The first applications of the Debye-Hückel model [17] refer to electrolytic solutions for which it is possible to define a

Debye length [18] with the following characteristic: if the distance between two charged ions is greater than r_D , their electrostatic interactions are reduced by the presence of other ions attracted by the electric forces.

In our case, the proton-electron system might be shielded by the nuclear Coulomb potential, with the possibility of penetrating the Coulomb barrier. Shielding effect would also explain the anomalous situation observed since 1938 [19] in nuclear reactions, between accelerated protons and Ni^{63} occurring at 3 MeV, below the expected 4,6 MeV threshold.

The effect of electron screening on low-energy fusion processes has been investigated by Assebaum et al [20]: they report the increasing of the Coulomb barrier penetrability and calculate, for some reactions induced by protons ($p + \text{Li}^7$ and $p + \text{B}^{11}$) quantitative effects, that look very relevant, though probably not sufficient to interpret our experimental results.

More recently, in a series of interesting papers [21-23], Raiola et al confirmed experimentally the significant increase of nuclear reactions cross sections in metals due to electron screening.

4. Conclusions

In conclusion, our process and apparatus is the first and unique system, existing today, able to obtain energy from nuclear fusion reactions; furthermore, because the ingredients are Nickel and water (to obtain Hydrogen), this is an endless energy source for the planet, without emissions in atmosphere.

5. Bibliography

- [1] R.D. Evans, The Atomic Nucleus, McGraw-Hill, New York 1955, pag. 297.
- [2] nuclear mass values have been taken by Table of Isotopes, eight edition, march 1996, Wiley Interscience.
- [3] G. A. Cowan, "A Natural Fission Reactor," Scientific American, 235:36, (1976).
- [4] A.P. Arya, Elementary Modern Physics, Addison-Wesley publishing company, Reading Massachussets (1974), pag. 399.
- [5] D.J. Littler and J.F. Raffle, An Introduction to Reactor Physics, Pergamon Press London, 1957, pag. 51.
- [6] Gamma-Scout from Mineralium.com, Germany.
- [7] made by Bubble Technologies, Chalk River, Ontario, Canada.
- [8] A. Carnera, S. Focardi, A. Rossi, to be published on Arxiv.
- [9] G. Gamow, Z. Phys. 51, 204 (1928).
- [10] R.D. Evans, The Atomic Nucleus, McGraw-Hill, New York 1955, pag. 876.
- [11] S. Focardi, R. Habel and F. Piantelli, Nuovo Cimento, 107 A, 163 (1994).
- [12] S. Focardi, V. Gabbani, V. Montalbano, F. Piantelli and S. Veronesi, Nuovo Cimento A 111, 1233, (1998).
- [13] S. Focardi, V. Gabbani, V. Montalbano, F. Piantelli and S. Veronesi, 1997 Asti Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals, Conference Proceedings Società Italiana di Fisica, vol 64, 35 (1999).

- [14] A. Battaglia, L. Daddi, S. Focardi, V. Gabbani, V. Montalbano, F. Piantelli, P.G. Sona and S. Veronesi, *Nuovo Cimento A* 112, 921 (1999).
- [15] E. G. Campari, S. Focardi, V. Gabbani, V. Montalbano, F. Piantelli, E. Porcu, E. Tosti and S. Veronesi, *Proceedings of the 8th International Conference on Cold Fusion*, 21-26 May 2000, Lerici (Italy), pg. 69-74, Editrice Compositori, Bologna.
- [16] C. E. Rolfs and W. S. Rodney, *Cauldrons in the Cosmos*, University of Chicago press, 1988.
- [17] P. Debye and E. Hückel, *Z. Phys.* 24, 185, (1923).
- [18] K. A. Dill and S. Bromberg, *Molecular Driving Forces*, Garland Science, New York and London 2003, pag 433.
- [19] C. V. Strain, *Physical Review* 54, 1021 (1938).
- [20] H. J. Assenbaum, K. Langanke and C. Rolfs, *Z. Phys. A* 327, 468 (1987).
- [21] F. Raiola et al, *Eur. Phys. Journal A* 13, 377 (2002).
- [22] F. Raiola et al, *Eur. Phys. Journal A* 19, 283 (2004).
- [23] F. Raiola et al, *Eur. Phys. Journal A* 27, 79 (2006).

6. email address

Sergio.Focardi@bo.infn.it

AndreaRossi@journal-of-nuclear-physics.com