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Review Article

Future Green Energy Through Cold Fusion Nuclear Heat With Nickel Powder

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Abstract: Based on the principle of conservation of energy and from the well known nuclear fusion and fission reactions it is possible to guess that, the E-CAT hidden energy may be in the form of binding of protons and neutrons of the Nickel, Hydrogen and Lithium atomic nuclei. In view of the recently developed compact 1MW E-CAT power plant designed by the Leonardo corporation, Nickel can certainly be considered as the ultimate substitute of Coal, Oil and Uranium in near future.
Keywords: Cold Fusion, Low temperature nuclear reactions, E-CAT (Energy Catalyze)

INTRODUCTION

With reference to the current [1-6] and old [7] review reports, one can understand the current 'golden status' and old 'Pathetic status' of Cold fusion or Low energy nuclear interactions (LENR). Since 1989 many scientists proposed many interesting proposals for understanding the observed excess heat generation with various experimental setups[8-18]. Many researchers and scientists around the world have reported successful experiments at a number of international conferences, and selected articles are collected in an on-line data base. The results, however, have not been taken seriously by main stream science, even after full support by two Nobel laureates, Julian Schwinger and Brian Josephson. Julian Schwinger (1918-1994), a Nobel prize winner in Physics, 1965, who also worked with Oppenheimer, was a strong advocate of cold fusion [19]. Brian Josephson, a Nobel prize winner in Physics, 1973, is a discoverer of the Josephon effect in the field of superconductivity. He is presently a strong supporter of cold fusion [20].

These new interactions are exclusively based on 'excess heat generation' and are absolutely free from the currently believed alpha, beta and gamma radiations. Experts believe that, LENR could use 1% of the Nickel mined to produce current world energy at a price four times cheaper than coal. Joseph Zawodny, a senior research scientist with NASA 's Langley Research Center says: "It has the demonstrated ability to produce excess amounts of energy , cleanly , without hazardous ionizing radiation, without producing nasty waste". It is not a surprise to say that, very soon LENR will dominate all the current leading research areas of physics in the near future. Andrea Rossi says: "one gram of Nickel is equivalent to 5,00,000 liters of oil". As there is no emission of the alpha, beta and gamma radiation, as there is no emission of other gasses like SO2,CO2 etc, as Nickel is abundance is a high in the earth core and as the technical risk of power generation is less, E-CAT seems to be the best and ultimate green power generator in coming future. In this paper authors made an attempt to understand the working mechanism of heat generation in the E-CAT.

HISTORY OF THE E-CAT

Kanarev [21] and Japanese researcher Dr. T. Mizuno [22] provided measurable proof of fusion and fission products. In Italy, the cold fusion research pioneered by Francesco Piantelli in 1989 has been extended and supported by the local inter-university centers in Bologna (Focardi, Campari) and Sienna (Piantelli, Gabbani, Montalbano, Veronesi). A detailed report about this research was published by the Italian National Agency for New Technology, Energy and Environment in 2008. Piantelli filed two patents WO9520816 (1997) and WO2010058288 (2010), describing different methods, and published an article ITSI920002 about cold fusion of nickel with deuterium or hydrogen. Recently, interest in cold fusion as an alternative to nuclear energy was raised by the successful demonstration of the Rossi cold fusion device called E-cat. E-CAT (Energy Catalyzer) seems to be the most promising apparatus in this regard [1-6]. It is invented and being developed by Andrea Rossi. The Focardi-Rossi method of nuclear reaction Ni + H -> Cu is based on the preliminary research of Focardi and

colleagues. Sergio Focardi is an emeritus professor at the University of Bologna while Andrea Rossi is a skilled researcher and inventor. After years of successful collaboration, they gave on January 14, 2011, the first public demonstration of a nickel-hydrogen fusion reactor, called E-cat, capable of producing more than 10 kilowatts of heat power, while only consuming a fraction of that. In 2008 Rossi filed International patent application WO 2009/125444 A1 entitled Method and Apparatus for Carrying out Nickel and Hydrogen Exothermal Reaction. Ignoring the skepticism in the main stream science, Rossi proceeded further with the development and manufacturing of his E-cat generator. Public demonstrations of the E-cat reactor with some invited experts were made on January 14, March 29, April 19 and 28, September 7, October 6 and October 28, 2011. During the larger public demonstration on October 28, 2011, Rossi invited a few dozen people, including a group of engineers from an unnamed potential US customer, as well as a handful of journalists. According to Rossi, each module received an initial energy input of 400 watts and produced a self-sustaining, continuous output of about 10 kilowatts per hour for the next few hours.

E-CAT – RECENT TEST RUN OBSERVATIONS AND UNDERSTANDING ITS HIDDEN MECHANISM

In a third party inspection, the E-CAT subject to testing was powered by 360 W for a total of 96 hours, and produced in all 2034 W thermal [3]. In this context experts say:

1. Something "REAL" is happening and we are certainly dealing with a new source of energy.
2. There are efforts ongoing to explore the validity of the theories and the weak interaction theories suggest what the physics might be.

Proceeding further, authors of this paper request the readers to go through the detailed and interesting report of 50 pages carefully prepared by the third party, titled "Observation of abundant heat production from a reactor device and of isotopic changes in the fuel" [2]. In the report one can see the experimental setup, photos of the reactor, experimental data, observations, comments & opinions of the authors along with clear cut information on the non-emission of generally believed nuclear radiation. The utmost important point to be noted is that, as per the report, "The isotope composition in Lithium and Nickel was found to agree with the natural composition before the run, while after the run it was found to have changed substantially. Nuclear reactions are therefore indicated to be present in the run process, which however is hard to reconcile with the fact that no radioactivity was detected outside the reactor during the run".

After successfully conducting the 32 day test run with E-CAT, at Switzerland [3], authors concluded in the following way.

1. "A 32-day test was performed on a reactor termed E-Cat, capable of producing heat by exploiting an unknown reaction primed by heating and some electro-magnetic stimulation. In the past years, the same collaboration has performed similar measurements on reactors operating in like manner, but differing both in shape and construction materials from the one studied here. Those tests have indicated an anomalous production of heat, which prompted us to attempt a new, longer test. The purpose of this longer measurement was to verify whether the production of heat is reproducible in a new improved test set-up, and can go on for a significant amount of time. In order to assure that the reactor would operate for a prolonged length of time, we chose to supply power to the E-Cat in such a way as to keep it working in a stable and controlled manner. For this reason, the performances obtained do not reflect the maximum potential of the reactor, which was not an object of study here".
2. "In summary, the performance of the E-Cat reactor is remarkable. We have a device giving heat energy compatible with nuclear transformations, but it operates at low energy and gives neither nuclear radioactive waste nor emits radiation. From basic general knowledge in nuclear physics this should not be possible. Nevertheless we have to relate to the fact that the experimental results from our test show heat production beyond chemical burning, and that the E-Cat fuel undergoes nuclear transformations. It is certainly most unsatisfying that these results so far have no convincing theoretical explanation, but the experimental results cannot be dismissed or ignored just because of lack of theoretical understanding. Moreover, the E-Cat results are too conspicuous not to be followed up in detail. In addition, if proven sustainable in further tests the E-Cat invention has a large potential to become an important energy source. Further investigations are required to guide the interpretational work, and one needs in particular as a first step detailed knowledge of all parameters affecting the E-Cat operation. Our work will continue in that direction".

From current known physics point of view it is quite shocking, quite bitter and demands the need of review and revision of our known physical laws and concepts. Based on the principle of conservation of energy it is clear that, during LENR and Cold fusion some hidden and unknown energy is being coming out in the form of heat energy. From the well known nuclear fusion and fission reactions it is possible to guess that, the hidden energy may be in the form of binding of protons and neutrons of the Nickel and Lithium atomic nuclei.

ESTIMATING THE POSSIBLE LIBERATED HEAT ENERGY IN E-CAT

Authors of the recent E-CAT test run say [2] :

1. "The fuel generating the excessive heat was analyzed with several methods before and after the experimental run. It was found that the Lithium and Nickel content in the fuel had the natural isotopic composition before the

run, but after the 32 days run the isotopic composition has changed dramatically both for Lithium and Nickel. Such a change can only take place via nuclear reactions. It is thus clear that nuclear reactions have taken place in the burning process. This is also what can be suspected from the excessive heat being generated in the process".

2. "The unused fuel shows the natural isotope composition from both SIMS and ICP-MS, i.e. 58Ni (68.1%), 60Ni (26.2%), 61Ni (1.1%), 62Ni (3.6%), and 64Ni (0.9%), whereas the ash composition from SIMS is: 58Ni (0.8.%), 60Ni (0.5%), 61Ni (0%), 62Ni (98.7%), 64Ni (0%), and from ICP-MS: 58Ni (0.8%), 60Ni (0.3%), 61Ni (0%), 62Ni (99.3%), 64Ni (0%).We note that the SIMS and ICP-MS give the same values within the estimated 3% error in the given percentages. Evidently, there is also an isotope shift in Nickel. There is a depletion of the 58Ni and 60Ni isotopes and a buildup of the 62Ni isotopes in the burning process. We note that 62Ni is the nucleus with the largest binding energy per nucleon. The origin of this shift cannot be understood from single nuclear reactions involving protons".
3. "The Lithium content in the fuel is found to have the natural composition, i.e. 6Li 7 % and 7Li 93 %. However at the end of the run a depletion of 7Li in the ash was revealed by both the SIMS and the ICP-MS methods. In the SIMS analysis the 7Li content was only 7.9% and in the ICP-MS analysis it was 42.5 %. This result is remarkable since it shows that the burning process in E-Cat indeed changes the fuel at the nuclear level, i.e. nuclear reactions have taken place. It is notable, but maybe only a coincidence, that also in Astrophysics a 7Li depletion is observed".
4. "Our measurement, based on calculating the power emitted by the reactor through radiation and convection, gave the following results: the net production of the reactor after 32 days' operation was (5825 ± 10%) [MJ], the density of thermal energy (if referred to an internal charge weighing 1 g) was ($5.8 \cdot 10^6$ ± 10%) [MJ/kg], while the density of power was equal to ($2.1 \cdot 10^6$ ± 10%) [W/kg]. These values place the E-Cat beyond any other known conventional source of energy. Even if one conservatively repeats the same calculations with reference to the weight of the whole reactor rather than that of its internal charge, one gets results confirming the non-conventional nature of the form of energy generated by the E-Cat, namely ($1.3 \cdot 10^4$ ± 10%) [MJ/kg] for thermal energy density, and ($4.7 \cdot 10^3$ ± 10%) [W/kg] for power density".

From above points and with reference to the net energy production (5825 ± 10%) MJ (of the reactor for 32 days run with one gram of Ni) - quantitatively it can understood in the following way. Binding energy of $^{58}_{28}Ni$ is 506.6 MeV and binding energy of $^{62}_{28}Ni$ is 544.41 MeV. Similarly binding energy of $^{7}_{3}Li$ is 41.45 MeV. For a moment guess that, $^{7}_{3}Li$ joins with $^{58}_{28}Ni$ forming $^{62}_{28}Ni$ and emits 3 hydrogen atoms. Clearly speaking, $^{7}_{3}Li$ transforms to 4 neutrons and 3 hydrogen atoms. 4 neutrons joins with $^{58}_{28}Ni$ forming $^{62}_{28}Ni$. To have stability $^{62}_{28}Ni$, must gain an effective binding energy (544.41-506.6)=37.81 MeV [23,24]. It can be gained from the binding energy 41.45 MeV of $^{7}_{3}Li$. If so the remaining binding energy of $^{7}_{3}Li$ is [41.45-(544.41-506.6)]=3.64 MeV and it may be liberated out in the form of heat energy. For every transformation of $^{58}_{28}Ni$ to $^{62}_{28}Ni$ via $^{7}_{3}Li$, liberated heat energy is 3.64 MeV and for one gram of $^{58}_{28}Ni$ liberated energy is 5984 Mega Joules. This can be compared with the observed E-CAT's 32 day output energy with one gram Ni fuel. If it is possible to design the E-cat to have mole transformations of $^{58}_{28}Ni$ to $^{62}_{28}Ni$ via $^{7}_{3}Li$ for second, then for every second, 0.3512 Tera Joules of energy can be liberated.

In general, the number of successful transformations $^{58}_{28}Ni$ to $^{62}_{28}Ni$ will depend on the quantity of Ni powder, fineness of the nickel powder, working temperature, working pressure and volume of the E-CAT, kinetic energy of Nickel and Hydrogen, melting points of nickel and lithium, unknown catalyst, efficiency of the E-CAT etc. Keeping all these parameters, instead of mass of Nickel, it is possible to consider number of $^{58}_{28}Ni$ to $^{62}_{28}Ni$ transformations per second. Design capacity of E-CAT can be fixed in this way for different large scale, medium scale and small scale applications. So, number of transformations, $n \cong f \cdot N_A$ where $f \approx 10^{-6}$ to 1 and can be called as the working factor. Now in a simplified view, proposed mechanism can be expressed in the following way.

If chosen time unit is One second,

$$\text{Energy liberated/sec} \cong f \times N_A \times 3.64 \text{ MeV/sec} \cong f \times 0.3512 \text{ Tera J/sec}$$

where $f \approx 10^{-6}$ to 1.

If chosen time unit is One hour,

$$\text{Energy liberated/hour} \cong f \times N_A \times 3.64 \text{ MeV/hour} \cong f \times 0.3512 \text{ Tera J/hour}$$

where $f \approx 10^{-6}$ to 1. E-CAT reactor speed can be defined as the number of transformations of $^{58}_{28}Ni$ to $^{62}_{28}Ni$ per second. Note that for one gram of Ni fuel, number of transformations can be understood as follows.

$$n \cong \frac{1 \times 10^{-3} \text{ (kg)}}{58.69334 \times 1.66053892 \times 10^{-27} \text{(kg)}} \cong 1.02603 \times 10^{22}$$

$$\Rightarrow f \cong \frac{n}{N_A} \cong \frac{1}{58.69334} \cong 0.01703768$$

Note that, energy liberated for one gram of $^{58}_{28}Ni$ in cold fusion is 1.66 MWh and energy liberated for one gram of $^{235}_{92}U$ in nuclear fission is 22.6 MWh. Clearly speaking, energy released in E-CAT is just 13.6 times less than the energy released in $^{235}_{92}U$ fission.

UNDERSTANDING NICKEL–HYDROGEN FUSION IN E-CAT

Andrea Rossi's stimulating experiments and inventions [5,6] on cold fusion suggest and confirm that under pressure and temperature, Hydrogen atom's proton joins with 62Nickel nucleus and electron joins with 62Nickel electronic orbits forming stable 63Cu atom and liberates heat energy of the order of MeV. It can be understood as follows.

1) Binding energy of 63Cu is 549.96 MeV and binding energy of 62Ni is 544.41 MeV. To have stability, 63Cu requires 549.96-544.41=5.55 MeV.
2) With reference to 'average binding energy per nucleon' and unified atomic mass unit, (within the nucleus) effective mass of each nucleon can be assumed to be 931.5-0.511 = 931.0 MeV. When proton joins with 62Ni nucleus, 938.3-930.0=7.3 MeV seems to be excess. 63Cu takes 5.55 MeV from 7.3 MeV and releases 1.75 MeV in the form of heat.
3) For 63Cu, average biding energy per nucleon is 8.73 MeV and for 62Ni, average biding energy per nucleon is 8.78 MeV. When suddenly 62Ni transforms to 63Cu, 8.78-8.73=0.05 MeV per nucleon will be liberated. Thus for 63 nucleons, 63*0.05 =3.15 MeV will also be released.
4) Thus a total of 1.75+3.15=4.9 MeV may be coming out in each Ni-Hi fusion of E-Cat. If so for one gram of 62Ni, liberated energy may be close to $7.625.10^9$ J.
5) Based on the above point-2, fusion of four protons (into a stable 4He) may liberate of 4*7.3=29.2 MeV and this can be compared with currently believed PP chain reactions in astrophysics.

CHARACTERISTIC APPLICATIONS OF E-CAT

1) Mini power plants for 5 to 10 Villages or two Towns or one City
2) Medium scale industrial power generation
3) Power generation for Busses, Lorries, Trucks, Cars and Bikes
4) Power generation for Trains, Ships, Submarines and Aero planes (if possible)
5) Power generation for medium and big residential and commercial apartments
6) Cold room heating, hot water generation and direct food cooking with hot water.
7) Farm field mini alternators for 2 to 3 successful crops per year with high yield.
8) Hose hold and special purpose laboratory mini alternators
9) De-centralized, Uninterrupted, Pollution free and Risk free power supply
10) Slow and gradual stopping of coal and oil usage for power generation and minimizing their transportation charges.
11) Based on the Environmental safety, Economical conditions and Safe& ease operating techniques, in future,
    A) Closed and intermittent running biomass based power plants,
    B) Coal based thermal power plants and
    C) Uranium based nuclear power plants can be converted to Ni based E-CAT power plants.
12) Transportation and travelling charges can be minimized.

DISCUSSION

From the 32 day experimental run of E-CAT, (measured) liberated energy for one gram of Nickel-58 is 5825 MJ with ±10% error. With the proposed method, (estimated) liberated energy for one gram of Nickel-58 is 5984 MJ. This is an excellent fit. If one is willing to consider the proposed methodology, E-CAT working mechanism and isotopic change mechanism both can be understood. Not only that, by considering the number of transformations of $^{58}_{28}$Ni to $^{62}_{28}$Ni per hour it is possible to decide the design capacity of E-CAT. Thus it may be helpful in designing the future E-CAT with all possible controls like E-CAT reactor volume, E-CAT working temperature, E-CAT working temperature, frequency of addition quantity of Nickel, frequency of addition quantity of Lithium etc.

On the E-CAT's recent third party test run, one can see various positive and appreciating comments in Andrea Rossi's blog, http://www.journal-of-nuclear-physics.com/. Andrea Rossi personally appreciated authors current approach on E-CAT mechanism and published the basic idea of this paper as a comment in the blog. No doubt, E-CAT can be considered as the most promising equipment for future power generation with plenty of available nickel, low working temperatures, no nuclear radiations, no pollution and no risk. Currently Andrea Rossi is seriously concentrated on developing E-CAT in all respects. Mean while Indian government, scientists, professors, industrialists and engineers may focus their attention on E-CAT design for fulfilling the infinite demand of electric power generation in India.

CONCLUSIONS

So far no model is successful in understanding and estimating the energy liberated in Cold fusion phenomenon. Considering the proposed concepts, with ease and efficiency, it is possible to fit, estimate and design a cold fusion based high power density apparatus like E-CAT for different energy level applications. With further research and analysis basics of 'cold fusion' can be established. In view of the recently developed compact 1MW E-CAT power plant designed by the Leonardo corporation, Nickel can certainly be considered as the tomorrow's best resource of green energy.

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