Analysis of Normalized Power Productions Using the Low Energy Nuclear Reactions: Review of ICCF-24 (*a.k.a* International Conference on Cold Fusion) and USDOE's Funding

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1. Introduction

The lattice-confined energy production is investigated for the higher efficient power productions. Recently, it was held for the 24th International Conference on Condensed Matter Nuclear Science (ICCF-24) [1] in Silicon Valley which had been kept going on as the International Conference on Cold Fusion until 2006 after the amazing announcement in 1989 by Fleischmann–Pons experiment. Fig. 1 shows the classification by research topic in ICCF-24 where the Theoretical and Computational Studies topic has the most published area as 24 % [1,2]. Table 1 shows the research groups by nations in ICCF-24 [1,2].

The Defkalion Green Technologies S. A. was established in Greece to manufacture and make market products based on the energy catalyzer (E-Cat), which was invented by Andrea Rossi [3]. The product name is Hyperion. This company is undertaking a performance from invention to industrialization as the global standard. There is a simplified specification in Table 2. It is claimed of the nuclear fusion in a tabletop chemistry experiment [4] which is called as cold fusion reaction and also low energy nuclear reaction (LENR). It is suggested that the LENR is for the commercialization by the water heater which could be a possible energy production of the electricity generations. In this work, the regulated power production is analyzed for the commercialization. Hence, the coolant flow rate is utilized for the constant energy generations.

Although the evidence of fusion is described as the LENR, the hypothesis that a novel form of thermonuclear fusion was responsible for previous experimental results which is still controversial. However, there are several particular and profound research progresses. Dr. G. Miley, director of the Fusion Studies Laboratory at the University of Illinois, mentioned the LENR heavy element transmutation evidence has been reported by 15 independent laboratories [5-7]. Additionally, the significantly different group of experiments was performed in the 1990s by researchers at Siena University in Italy. S. Focardi and F. Piantelli used the hydrogen gas in combination with nickel rods [8]. They had reported several experiments with 18 and 72 Watts of excess heat. There were some interesting reports as some nuclear reaction that produced evidences of neutrons, gamma rays, charged particles, and the presence of anomalous elements. Significantly, S. Focardi and A. Rossi held a press conference at the University of Bologna. It was reported that the facility demonstrated a 10 kilowatt nickel-light water cold fusion reactor. Furthermore, the test employed a new, smaller device with a 50 cm^3 cell. It produced ~ 4.4 kW for 6 hours, or 25 kWh (90 MJ). Later, ambitiously, the 1st commercial company opened as Defkalion Green Technologies S. A. in Greece where they used the nickel based electrode [3]. According to the analysis, a special environment is required for LENR to occur and this is not a material such as PdD or NiH, regardless of its purity, dimension, or hydrogen content [9]. Nickel is a silvery-white metal with a slight golden tinge that takes a high polish. One of only four elements is magnetic at or near room temperature. Also, it is the transition metal with the hard and ductile material [10].

Considering the conventional fusion, the unsuccessful effort was made first in 1926 [11] to initiate fusion between deuterons. For fusion reactions, when enough energy was applied to the deuterons in plasma, it eventually resulted in a large research program [12] based on what is called a hot fusion. The studies have been done for over 70 years using over $ 25 billion [8]. Otherwise, the LENR has been studied for 23 years investing about $ 0.5 billion. There are some examples of the hot-fusion reactions as follows [9],

$$D + D = {}^4He + \text{gamma (23.9 MeV)} \quad (1)$$

$$D + D = \text{tritium} + \text{proton (4.03 MeV)} \quad (2)$$

$$D + D = {}^3He + \text{neutron (3.27 MeV)} \quad (3)$$

2. Methods

The science elements of Rossi's efforts have been fully documented and extensively discussed online, with scientific papers as well as online scientific exchanges. As the simplified configuration, Fig. 2 shows the configuration for reactor (A: body of E-cat, B: Hydrogen canister, C: Monitor and control equipment). Fig. 3 is the configuration for reactor and electricity generator, where the pump is used to control the coolant speed.

The heat productions could produce the electricity generator such as the conventional nuclear power plant (NPP). So, the mass flow rate of the coolant can regulate the power productions. The equation is described as follows;

$$\Delta\dot{Q} = \rho v A \, c_p \Delta T \quad (4)$$

where,

$$Q = heat$$
$$\dot{m} = \rho v A = mass\ flow\ rate$$
$$\rho = mass\ density$$

$$v = velocity$$
$$A = area$$
$$c_p = specific\ heat\ capacity\ at\ constant\ pressure$$
$$T = temperature$$

So,

$$\Delta\dot{Q} = \dot{m}\Delta T c_p \quad (5)$$

where,

$$\Delta\dot{Q} = heat\ production\ rate$$

Therefore, if one would like to make the constant temperature, the heat is variable to the mass flow rate. The coolant is glycol in the experiment. Heat capacity is assumed as 0.689 Btu/lb ºF at 240 ºF. The value is 2,884.7052 (= 0.689 × 4,186.8) J/(kg K) at 115.6 ºC. The ΔT is variable due to the hot leg is changeable. For a constant ΔQ, the mass flow rate should be changeable. When ΔT is 100 ºC and mass flow rate is 5 kg/sec, the ΔQ is 1.4423526 MW. The equations are as follows,

$$\frac{\Delta\dot{Q}}{\Delta T c_p} = \dot{m} \quad (6)$$

$$\dot{m} = \frac{\Delta\dot{Q}}{\Delta T c_p} = \frac{(1442352\ .6\ J/sec\ )}{(t-15.6)(2884\ .7052\ \ J/(kgK))} \quad (7)$$

$$\dot{m}(t-15.6)K = (5kg/sec\ )(115.6-15.6)K$$

$$= 500kg/\sec K \quad (8)$$

where t is changeable by random sampling in Monte-Carlo method. So, 5 kg/sec is a minimum value. The maximum values are shown in figures 4 and 5, where the Y-axis has the unit of kg/sec.

3. Results

The calculation with the generated random numbers of a variable t is performed. The Vensim is made for developing, analyzing, and packaging of high quality dynamic models [13]. These models are constructed graphically or in a text editor. Using the code system, the features include dynamic functions, subscripting (arrays), Monte-Carlo sensitivity analysis, optimization, data handling, application interfaces, and more [13]. The calculations are shown for mass flow rate of 1,000 and 10,000 minutes. The figures 4 and 5 show the trend of mass flow rates. Results show necessity mass flow rate for constant power productions.

4. Conclusions

It is analyzed for the constant power productions as the LENRs' possibility as an energy source. Since the LENR theory is not fully proved, it is very important to make constant energy generations. Generally, the heat is mostly generated by D + D + e fusion to give ^{4}He + e when deuterium is used and H + H + e fusion to give stable deuterium when normal hydrogen is used. When both isotopes are present, tritium is formed by the D + H + e fusion reaction [9]. If a stable power production is achieved with the coolant flows, the commercialization could be successful with a cheap equipment that makes a megawatt level electricity power. The non-hazard radioactive pollutions are expected compared to the conventional nuclear power plants. In fact, unreasonable skepticism and rejection of competent observation have severely handicapped the field and delayed the understanding and application [9]. In the early history of the first nuclear reactor, Chicago pile-1 (CP-1) [14] by Dr. Enrico Fermi at the University of Chicago, the regulated neutron transport was not known exactly. The scientists could moderate and block by carbon without leak of neutron in the reactor core. Similarly, one can just produce the heat of LENR in the crude type reactor of the E-Cat. Hence, the simulation of the possible scenarios of the heat production is very important. Fig. 6 shows the procedure of the new energy source production where a new kind of energy source is commercialized. Fig. 7 shows the yearly trend by research area in which 'Theoretical and Computational Studies' and 'Heat Production' are higher portions in 2021 and 2022. Fig. 8 is the yearly trend by nation where USA, Japan, and Russia have higher portions in 2021 and 2022. Recently, Following the research promotions of LENRs, U.S. DOE announced the ARPA-E (Advanced Research Projects Agency-Energy) in the field (Fig. 9), which reflects the governmental recognizing of the country [15].

Acknowledgments

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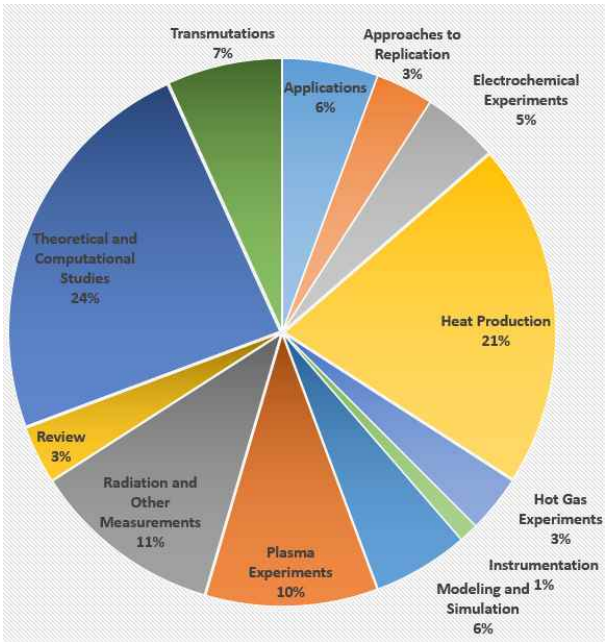


Fig. 1. Papers by topic in ICCF-24 [1,2].

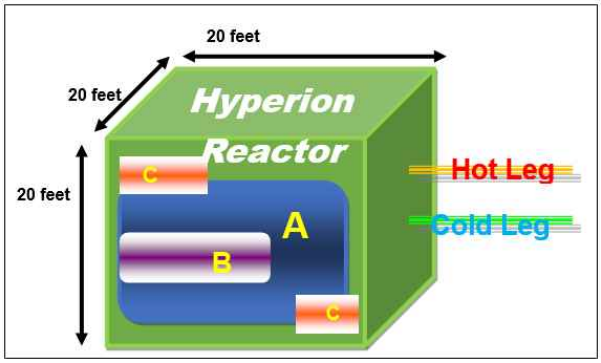


Fig. 2. Configuration for reactor (A: body of E-cat, B: Hydrogen canister, C: Monitor and control equipment).

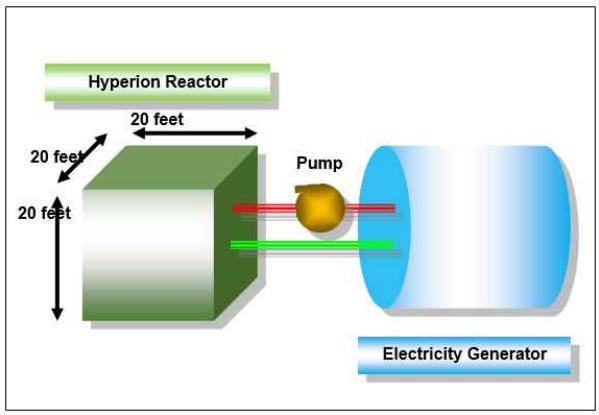


Fig. 3. Configuration for reactor and electricity generator.

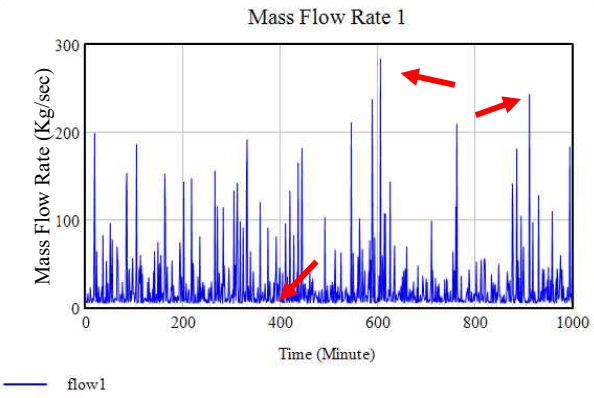


Fig. 4. Mass flow rate (kg/sec) for glycol coolant (Max. = 1,000 min.).

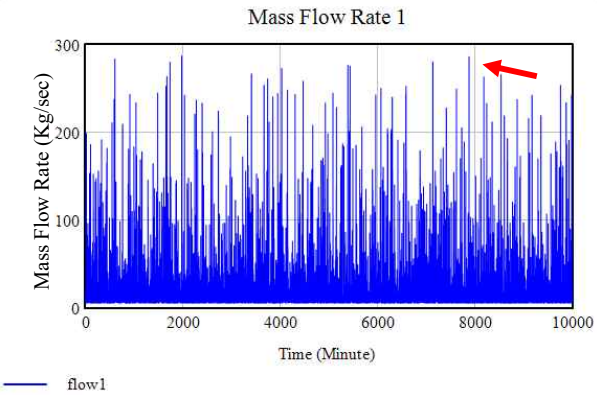


Fig. 5. Mass flow rate (kg/sec) for glycol coolant (Max. = 10,000 min.).

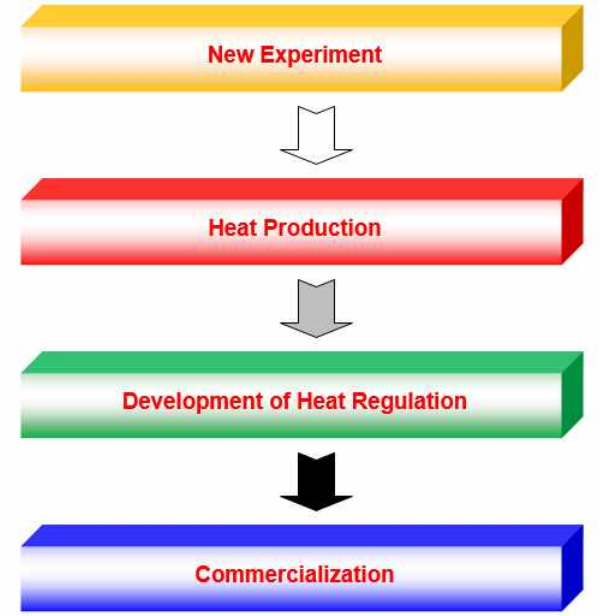


Fig. 6. Procedure of the new energy source production.

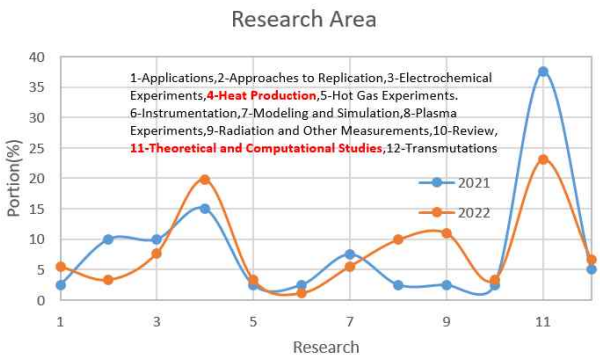


Fig. 7. Yearly trend by research area [1,2].

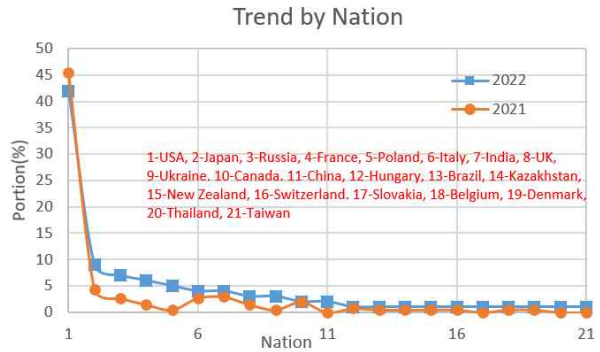
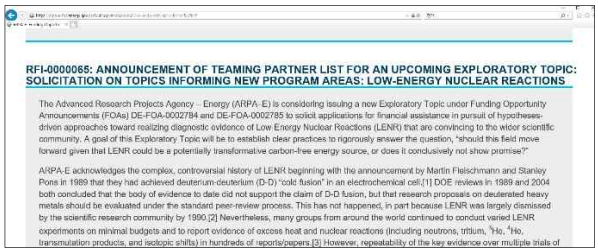


Fig. 8. Yearly trend by nation [1,2].



RFI-0000065: ANNOUNCEMENT OF TEAMING PARTNER LIST FOR AN UPCOMING EXPLORATORY TOPIC: SOLICITATION ON TOPICS INFORMING NEW PROGRAM AREAS: LOW-ENERGY NUCLEAR REACTIONS

The Advanced Research Projects Agency – Energy (ARPA-E) is considering issuing a new Exploratory Topic under Funding Opportunity Announcements (FOAs) DE-FOA-0002784 and DE-FOA-0002785 to solicit applications for financial assistance in pursuit of hypotheses-driven approaches toward realizing diagnostic evidence of Low Energy Nuclear Reactions (LENR) that are convincing to the wider scientific community. A goal of this Exploratory Topic will be to establish clear practices to rigorously answer the question, "should this field move forward given that LENR could be a potentially transformative carbon-free energy source, or does it conclusively not show promise?"

ARPA-E acknowledges the complex, controversial history of LENR beginning with the announcement by Martin Fleischmann and Stanley Pons in 1989 that they had achieved deuterium-deuterium (D-D) "cold fusion" in an electrochemical cell.[1] DOE reviews in 1989 and 2004 both concluded that the body of evidence to date did not support the claim of D-D fusion, but that research proposals on deuterated heavy metals should be evaluated under the standard peer-review process. This has not happened, in part because LENR was largely dismissed by the scientific research community by 1990.[2] Nevertheless, many groups from around the world continued to conduct varied LENR experiments on minimal budgets and to report evidence of excess heat and nuclear reactions (including neutrons, tritium, ^{3}He, ^{4}He, transmutation products, and isotopic shifts) in hundreds of reports/papers.[3] However, repeatability of the key evidence over multiple trials of

Fig. 9. ARPA-E's announcement [15].

Table I: Research group by nations in ICCF-24 [1,2].

No.	Country	Res. Group
1	USA	42
2	Japan	9
3	Russia	7
4	France	6
5	Poland	5
6	Italy	4
7	India	4
8	UK	3
9	Ukraine	3
10	Canada	2
11	China	2
12	Hungary, Brazil, Kazakhstan New Zealand, Switzerland Slovakia, Belgium. Denmark Thailand, Taiwan	1
Total	21 Countries	97

Table II: Specification of Hyperion reactor.

Material	Content
Power	~1 Megawatt(Thermal Power)
Coolant	Glycol
Size	20 feet × 20 feet × 20 feet