Establishment of the "Solid Fusion" Reactor

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Abstract

A gas-loaded fusion reactor operating at room temperature using ZrO_2 + nanoPd catalyst produced nuclear heat for hundreds of hours when pressurized with D_2 gas, but no measurable nuclear heat when pressurized with H_2. ^{4}He was produced during the D_2 run, and not during the H_2 run. No electrical power was supplied to the reactor during the runs, thereby demonstrating operation of an autonomous fusion "heater".

Introduction

About 50 Years ago (1955-1958), one of the authors (Y. Arata) investigated "solid-state plasma fusion" (simply "Hot Fusion") together with "thermonuclear fusion", he was the first researcher in the world to discover "Solid Fusion", as well as the first researcher in Japan to discover "Hot Fusion". Moreover, on Feb 6, 1958, he carried out large "open experiments" for the general public, which strongly impacted not only Japan but also the world, although he was at a young age (33 years old) at that time.

In addition, the authors continued to demonstrate experimentally the existence of "Solid Fusion" for the first time in the world, by publishing research reports in over 70 papers[1-53] presented in the Proc. Japan Acad., and other societies during about 20 years (1989~2007). In these experiments, many kinds of alloys, which include Pd and Pd-black etc. were developed and used as specimens. Recently, the authors started to develop the usefully practical reactor of "Solid Fusion" (Solid Reactor), and it was achieved some month ago at last. This reactor is a remarkable improvement over the many known models developed so far.

[Among many things that Arata learned during his hot fusion studies was that high temperatures occur when bulk Pd metal containing a large D/Pd ratio is exposed to air. When Fleischmann and Pons (F-P) reported high temperatures and the melting of a Pd electrode, he recognized that air likely had made contact with the test electrode and oxidized the dissolved deuterium. Since these F-P studies had not been carried out in an argon atmosphere, he resolved to convince himself whether or not "cold fusion" was real. As a result, considerable independence has characterized the Arata and Zhang (A-Z) program.]

"Solid Fusion Reactor" Experiment*

Figure A shows the principle of the "Solid Fusion Reactor" which is constructed with the following system. Firstly, microscopic solid fine powders are set inside the high vacuum, stainless steel vessel, and then pure D_2 gas is injected as "Streaming D_2 gas" into the stainless steel vessel. This "Streaming D_2 gas" penetrates instantly into the many solid fine samples as the "Streaming Deuterons"(=D^+-Jet stream") without storing inside the stainless vessel.

This was an amazing event. Moreover at this time, nuclear fusion reaction was generated inside the solid with synchronous creation of both much Helium (^{4}He) and large thermal energy under the equation:

$$^{2}\mathbf{D} + {}^{2}\mathbf{D} = {}^{4}\mathbf{He} + \textbf{thermal energy} \quad \text{(a)}$$

$$\mathbf{(4\ {}^{2}D = 2\ {}^{4}He} + \textbf{thermal energy)} \quad \text{(b)}$$

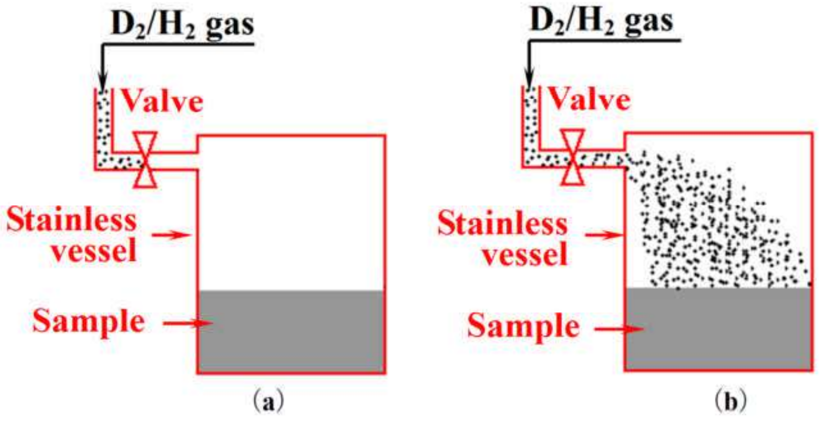

Figure A. Principle of "Solid Fusion" Reactor Vessel. (a): Reactor before introduction of D_2 or H_2 gas (only stainless steel vessel and sample (b): Introducing of D_2 or H_2 as the D_2 or H_2 -"jet-stream" into reactor vessel; and then D^+ or H^+ -"jet stream" penetrate into the sample)

(Note) : If D_2 or H_2 was introduced, D_2 or H_2 -"jet stream" immediately penetrates into the sample as D^+ or H^+- "Jet-stream: and Fusion Reaction", (^{4}He and thermal energy) immediately generated in the case of the "D^+-jet stream"; but in the H^+-jet stream" only chemical reaction heat is generated, (It will be explained in detail in Fig. 2, Fig. 3, Fig. 6 for D_2 and Fig. 4 for H_2).

Experiment and discussion

These experiments show the characteristics of "solid nuclear fusion reactor suitable for practical use".

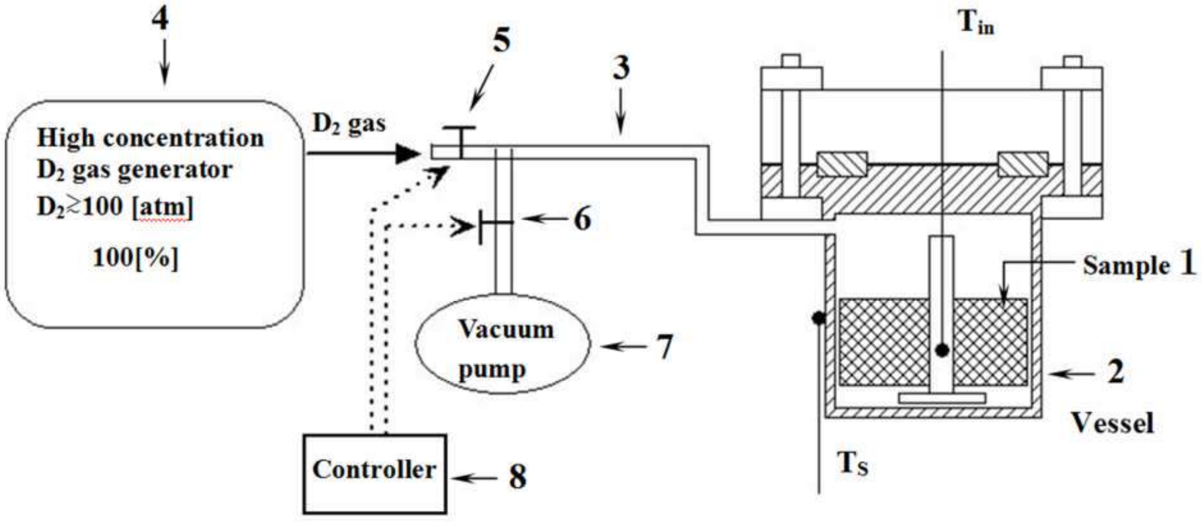

Figure 1. Experimental Device

Figure 1 is a diagram showing the principle of the "Solid Fusion Reactor" suitable for practical use. The fuel for the reactor is D_2 gas **4** having a high isotopic purity (almost 100%). The vessel **2** is made of stainless steel. A sample is provided within the high vacuum vessel **2**. The inner temperature T_{in} is measured by a thermocouple placed on the central axis of the sample. The temperature T_s of the stainless steel vessel **2** is measured by a thermocouple placed on the outer wall of the vessel **2**. The D_2 gas generator **4**, the vessel **2** and the vacuum pump **7** are coupled to each other via the stainless steel pipe **3**. The valves **5** and **6** are connected to the stainless steel pipe **3.** Opening and closing of the valves **5** and **6** is controlled by the controller **8**. The feature of the reactor is that once the D_2 gas is supplied to the vessel **2**, the supplied gas directly enters into the sample as the "D^+-jet stream" without staying within the vessel **2**. The reaction occurs between these streaming deuterons within clouds of electrons within the sample. In other words, where the supplied D_2 gas is converted into ^4He and thermal energy only in accordance with the following formula:

$$\mathbf{^2D + {}^2D = {}^4He + thermal\ energy} \quad \text{(a)}$$

$$\mathbf{(4\ {}^2D = 2\ {}^4He + thermal\ energy)} \quad \text{(b)}$$

Here, the thermal energy includes additionally the chemical energy generated between "streaming deuterons" (= D^+-jet stream") and "sample solid atoms". In other words, during the reaction period, the reactor serves as "^4He generation reactor" as well as a "thermal energy generation reactor". It can be understood that this reactor is an ideal reactor suitable for practical use.

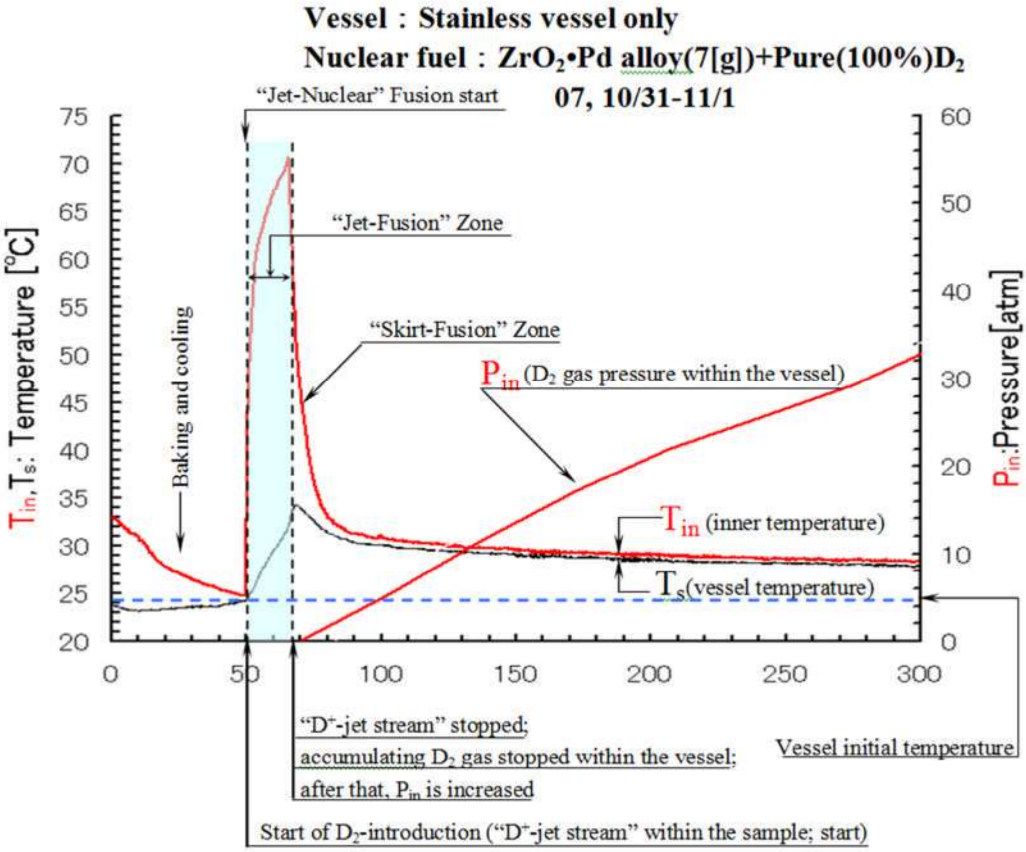

Figure 2. Simultaneous generation of thermal energy and ^4He

In the case where the sample is ZrO_2-Pd (nano Pd) alloy, as shown in Figure **2**, the nuclear fusion reaction rapidly occurs inside the sample simultaneously with the supply of D_2 gas, and the thermal energy is generated (in which, chemical reaction energy generated between "D^+-jet stream and sample atoms" is included). Then, "D^+-jet stream" was stopped, in other words the generation of thermal energy is stopped simultaneously with the completion of the nuclear fusion reaction, which is called as the "Jet-Fusion". During the "Jet-Fusion" reaction period, the gas pressure within the reactor is zero, and all the supplied D_2 gas enters as the "D^+-jet stream" into the sample without staying in the reactor, and chemical reaction energy occurs inside the sample. For instance, each 2~4 D-atoms in the "D^+-jet stream" are coagulated as the "lumpy solid-state deuterons" (simply "Solid-deuteron")(52) inside the innumerable each crystal lattice "space" ("electron box")(52) within the sample solid, and these "Solid deuteron" fulfill its function to create the "Solid nuclear fusion reaction". In other words, "Solid-deuteron" corresponds to the "Nuclear fuel"(52). And then, the generation of the thermal energy is stopped simultaneously with the completion of the "Jet-Fusion" reaction. Thereafter, the D_2 gas is accumulated within the reactor and the gas pressure P_{in} within the reactor is increased over time, unlike the reaction period during which P_{in} is equal to zero.

[The protocol for producing the ZrO_2-nanoPd catalyst is given in Ref. (54). The protocol for preparing the catalyst before use is different from that used with Pd-black. Prior to exposure to D_2 gas, the ZrO_2-nanoPd catalyst is first reduced by a controlled inflow of D_2 at about 20 cc-atm/min, next is outgased at 150°C until a vacuum of about 6 x 10^{-7} Torr is achieved, and then is cooled to room temperature. Ref. (58). Figure 2 shows the end of the cooling interval during run time interval 0 - 50 min, and the start of the Jet-Fusion period at time = 50 min.]

This experimental result is a very epoch-making one which is beyond any expectation. This is an unexpected new phenomenon. This new phenomenon can occur in the same manner in the case where another sample is used, as shown in Figure **3**. This should be called "historical phenomena"

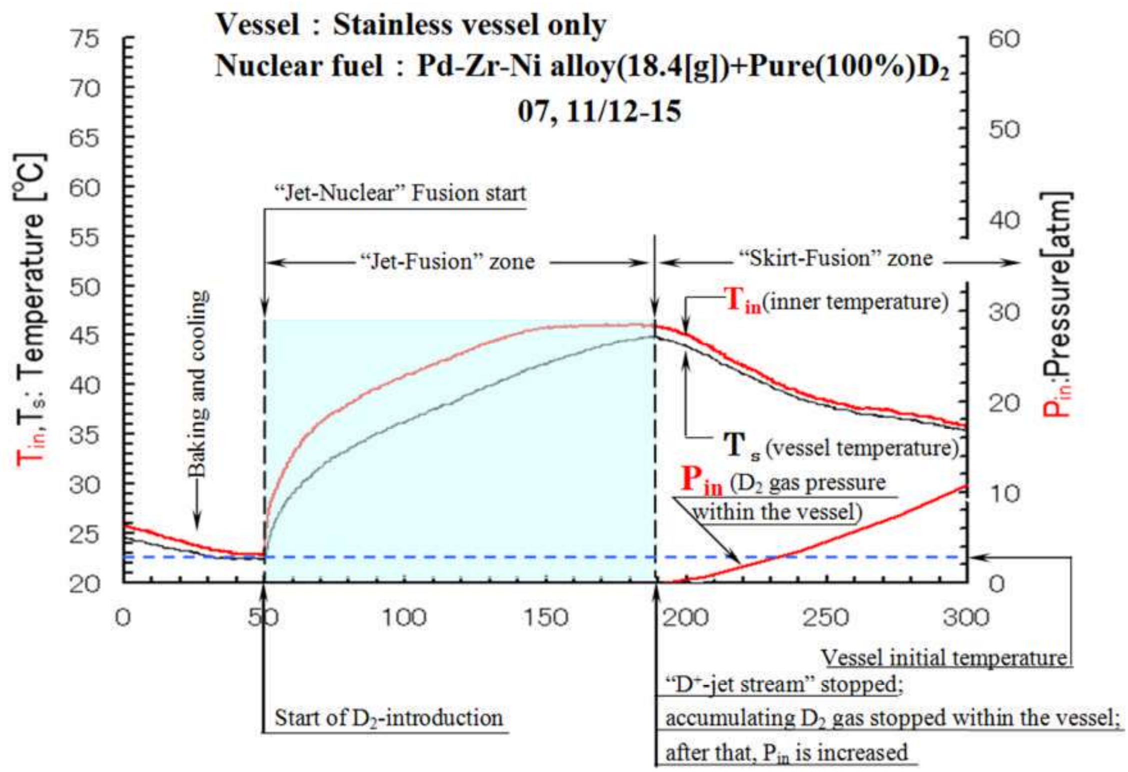

Figure 3. Simultaneous generation of thermal energy and 4He

In order to understand this new phenomena more deeply, another definitive experimental result will be presented based on the above conclusion. It is the comparison between D and H from the viewpoint of the nuclear fuel. In the past 20 years, it has been well known that the authors were far ahead of others and achieved brilliant success on "verification of solid fusion".[1-53] The authors named this device a "verification reactor". The authors continuously developed several kinds of verification reactors, not only one kind of verification reactor, confirmed the "verification of solid fusion", and published the results in reports. Fifty-five are listed at the end of this paper. One example of the "verification reactor" is a world-famous electrolysis-type reactor using D_2O or H_2O: "DS-cathode"(="Double Structure Cathode"). With the DS-Cathode, D/H is generated within the electrolytic solution of D_2O/H_2O, i.e., within the Cathode. The generation of D/H corresponds to the presence/absence of the solid fusion reaction. In the former case where D is used, anything other than a small amount of chemical reaction heat cannot be recognized.

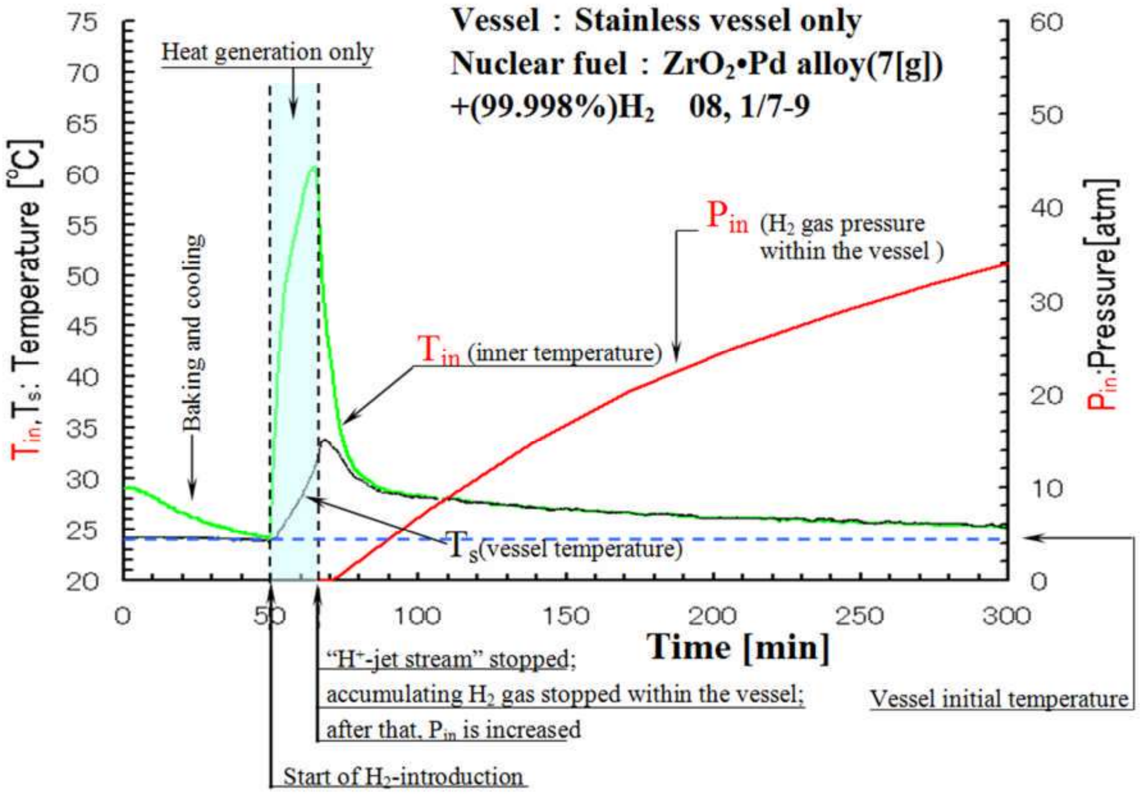

Figure 4. Heat Generation for H_2 Introduction

The comparison between D and H is made from the viewpoint of the nuclear fuel, using a newly developed "practical use reactor"("Solid Reactor"). In the case where D is used, an intensive reaction (^4He and thermal energy) due to the solid fusion occurs for both the "verification reactor" and the "Solid Reactor". On the other hand, in the case where H is used as shown in Figure 4 and Figure 7[A], [B], chemical reaction heat is generated, but ^4He is not generated at all.

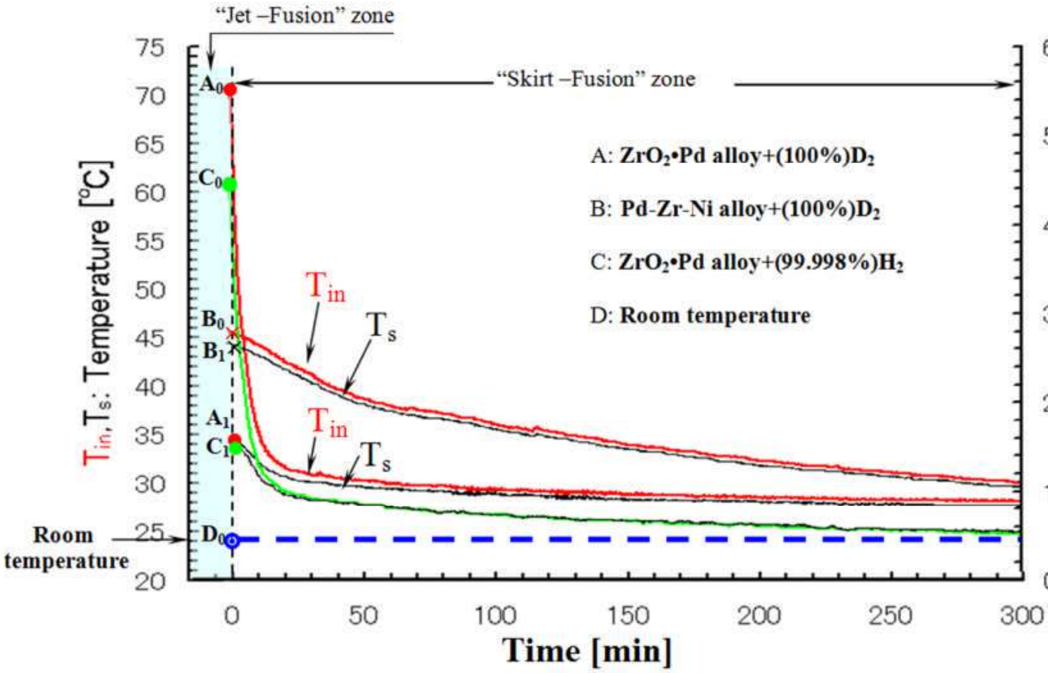

Figure 5A. Comparison of generation characteristics of Nuclear fusion during "Skirt-Fusion" zone for each fuel (0~300min)

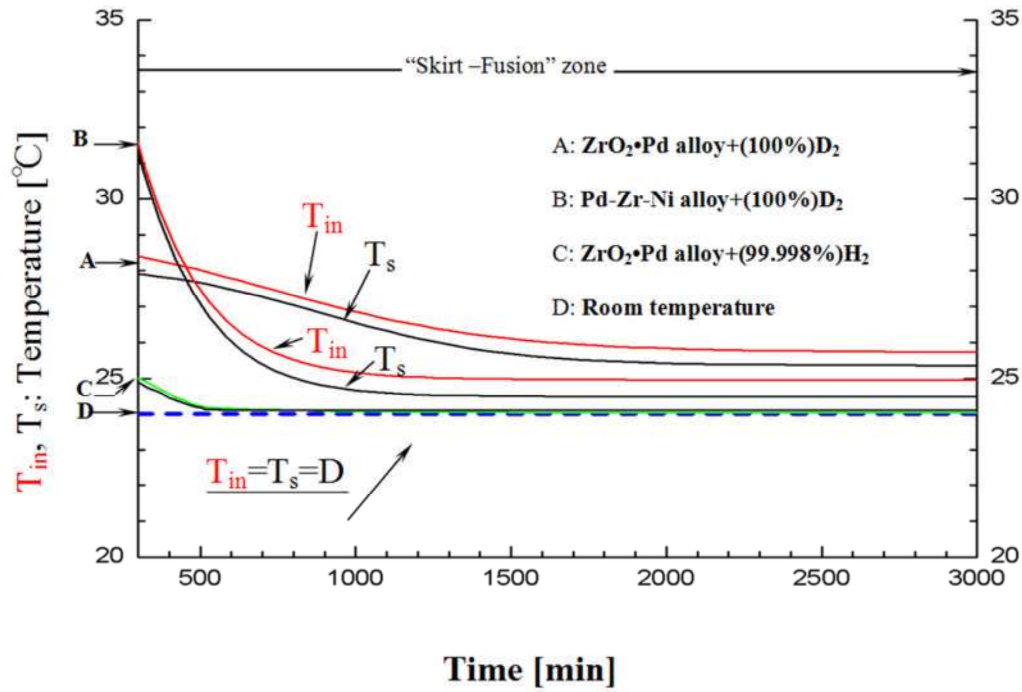

Figure 5B. Comparison of generation characteristics of Nuclear fusion during "Skirt-Fusion" zone for each fuel (after 300min)

The difference between the “Solid Reactor” and the “verification reactor” is that the structure of the “Solid Reactor” is much simpler than that of the “verification reactor”, and the reaction period of time of the “Solid Reactor” is in comparably shorter (10^{-2}~10^{-3} times) than that of the “verification reactor”, although the principle of these reactors is the same. In the “Solid Reactor”, the stream of D^+ (“D^+-jet stream”) directly and entirely enters into the sample for a very short period of time. On the other hand, in the “verification reactor”, this phenomena occurs indirectly, and therefore, a very long period of time is required for the reaction. For instance, D-atoms should be passing through the wall of Pd vessel in the “DS-Cathode” with a long period of time.

Based on this experimental fact and the comparison result between Figure **2** and Figure **3**, it can be clearly understood that this is a historical experimental fact.

Moreover, the relation of each gas temperature (red line/T_{in}) and vessel; temperature (black line/T_s) as shown in Fig. 5A and Fig. 5B; which indicated through long period with expanded scale in temperature compared with Fig. 5A. It is clear that both gaseous and vessel temperature (C) in the H_2 gas drop into the room temperature (D-line) is very short period. However, both A and B samples continue in long and long period at the separated state between red T_{in} and black T_s lines($\Delta T=T_{in}-T_s$: this is very important “ΔT-characteristics”). These results depend on the continued nuclear reaction of the “Skirt-Fusion”. This is the extreme very important result. These phenomenon continue about several hundred hours.

Finally, the D_2 pressure characteristic in the case where there is no sample within the vessel is shown in Figure **6**. In this case, once the D_2 gas is supplied to the vessel, the increase in the pressure P_{in} is started immediately as shown in the red line and then the pressure P_{in} is increased over time. On the other hand T_{in} (inner temperature) and T_s (vessel temperature) are not influenced by the supply of D_2 gas at the room temperature (i.e. T_{in} and T_s are not changed). Even though P_{in} is changed, T_{in} and T_s (always, $\Delta T=T_{in}-T_s=0$) are not changed as shown in Figure **6**. This is common sense in the conventional art, and conforms to the experimental result.

Consequently, “Skirt-Fusion” start immediately at the end of “Jet-Fusion”, and continue in long period (over 100 hours) as shown in Fig. 5B. Generated heat energy were about 4.4 kJ in “Jet-Fusion” ≅18 kJ/hour) and about 200 kJ in “Skirt-Fusion(≅250 kJ in “Skirt-Fusion”(≅4 kJ/hour). About 5×10^{15} ^4He were produced in “Jet-Fusion” and about 3×10^{17} ^4He in “Skirt-Fusion” zone. Sample is ZrO_2-Pd alloy (6.5 gram) in this case.

[Line Plots A are for ZrO_2-Pd alloy (6.5 gram sample) and Line Plots B are for ZrO_2-Ni,Pd alloy (18.4 gram)]

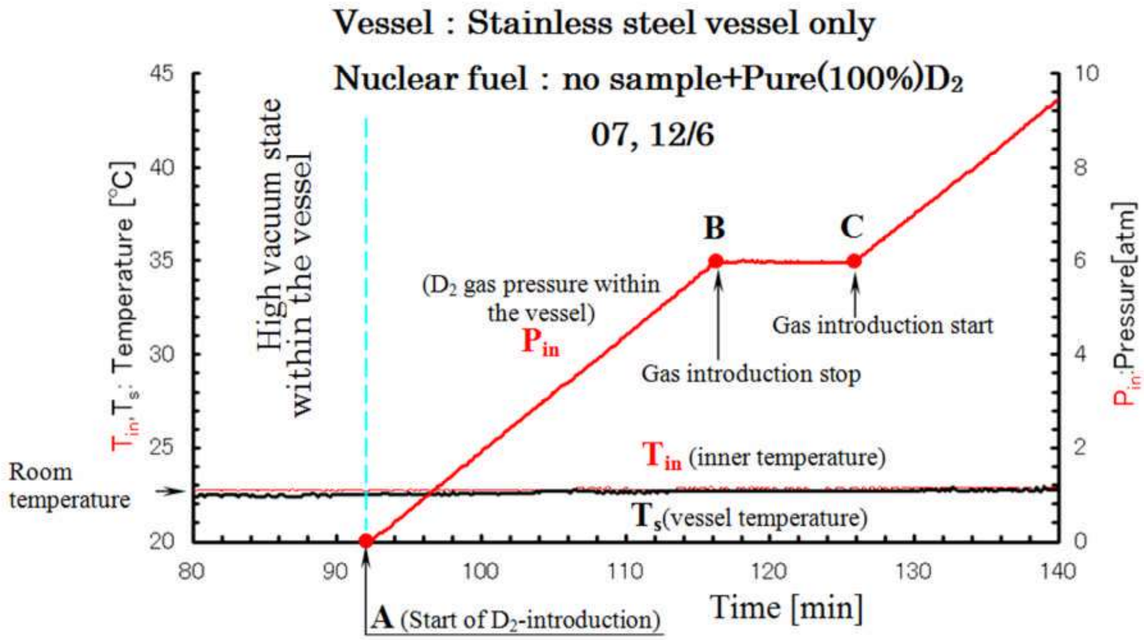

Figure 6. Gas pressure characteristics within vessel (no sample)

In order to further clarify this conclusion, Figure **7[C]**(within fuel gas) and Figure **7[D]** (within sample solid) are shown using Mass-spectrometer. In particular, it can be understood that a large amount of ^{4}He is generated within the sample solid as shown in Figure **7[D]**. It is well known as the characteristics of ^{4}He cannot enter into any solid and ^{4}He cannot egress from any solid under the temperature level from the room temperature to several-100°C. Figure **7[C], [D]** shows a situation in which a large amount of ^{4}He fully fills into the sample during a very short time. And then, it should be named as the Jet-nuclear Fusion Reaction (simply "Jet-Fusion"), because of these "Solid nuclear fusion reactions" generated like a jet cleaning extremely short periods as shown in Figures 2, 3 and 7. This clearly shows that this amazing phenomena results from the reaction within the sample.

Accordingly, this reactor is a thermal energy generation device as well as a ^{4}He production device. It is obviously clear to us which one of the following is more important to human beings: (a) the thermonuclear fusion device of the "era"; or the solid nuclear fusion described above.

It is considered that the solid nuclear fusion described above is useful for an energy source for homes, cars, ships airplanes and the like. Quickly implementing measures is desired in view of the current air pollution problem. It is possible that a further science and new industry are to be developed.

In the last word, in very important for "Actual Nuclear Reactor" that the solid nuclear fusion reaction does not generate any pollution, whereas a hot nuclear fusion reaction is commonly known to generate a considerable amount of harmful pollution.

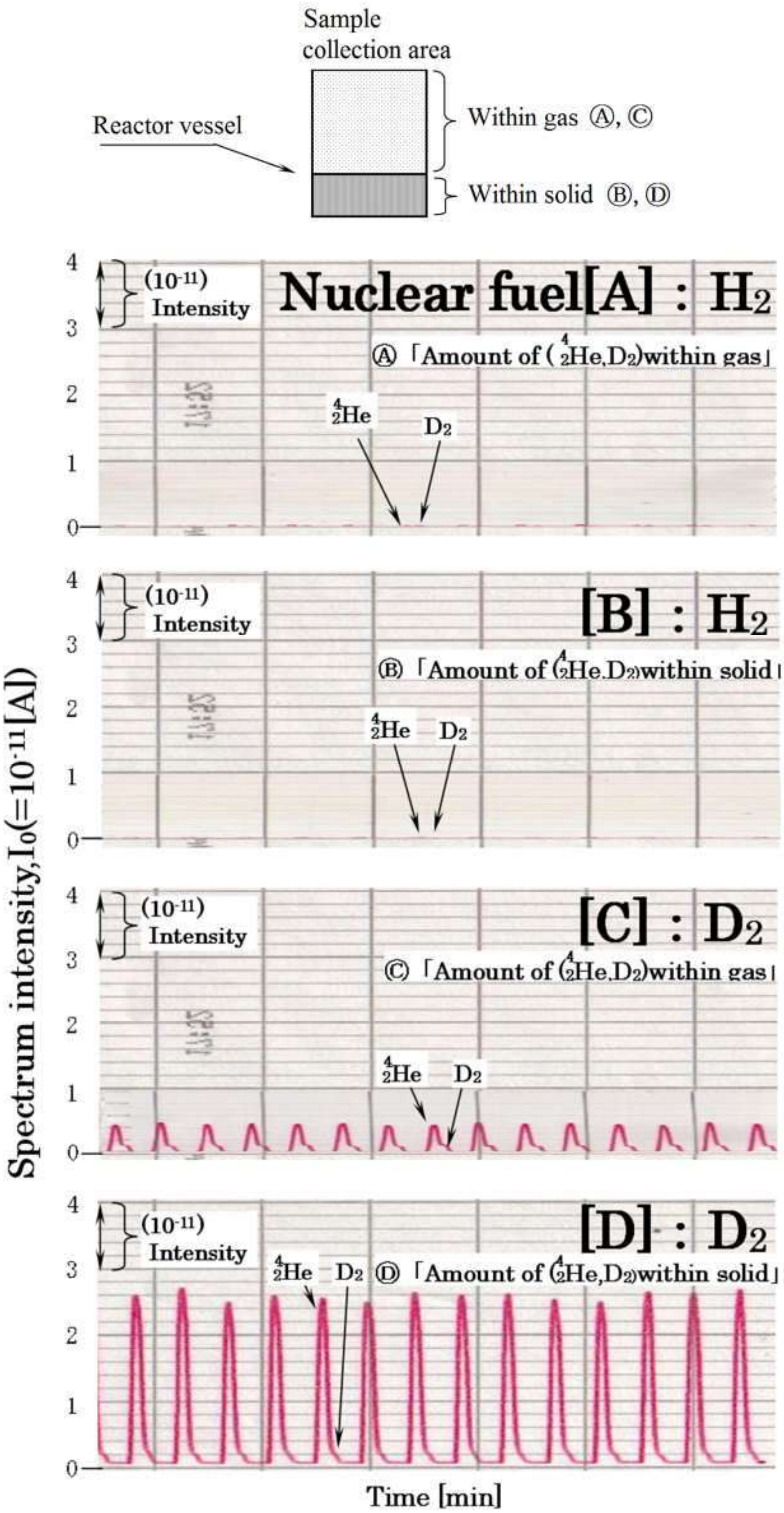

Figure 7. Mass analysis result for fuel (H_2 or D_2) and reaction product (^4He)

Note on Sources

The Abstract is a rewritten version of a statement on the Cover of his Arata Award lecture at ICCF14[(54)]. Explanations by editor (Talbot Chubb) based on References (52-55) are enclosed in square brackets. Text used in the Abstract is based on a presentation made by Arata and Zhang on May 22, 2008 in Osaka, Japan[(53)].

References

1. Arata Y, Zhang Y-C; Kaku Yugo Kenkyu 62 (1989) 398. Cited in Chem. Abstr. 112: 224669 [1990]. (in Japanese). "Achievement of intense 'cold fusion' reaction".
2. Arata Y, Zhang YC; proc. Jpn. Acad. 66, Ser. B (1990) 1. "Achievement of intense 'cold' fusion reaction".
3. Arata Y, Zhang Y-C; proc. Japan Acad. 66, Ser. B (1990) 33. "Cold' fusion caused by a week'on-off effect'".
4. Arata Y, Zhang Y-C; proc. Japan Acad. 66, Ser. B (1990) 110."Corroborating evidence for 'cold' fusion reaction".
5. Arata Y, Zhang Y-C; Fusion Technol. 18 (1990) 95. "Achievement of an intense cold fusion reaction". But see; "Corrigendum",FT 19 [1991] 196.
6. Arata Y, Zhang Y-C; Fusion Technol. 22 (1992) 287. "Reproducible 'cold' fusion reaction using a complex cathode".
7. Arata Y, Zhang Y-C; Kaku Yugo Kenkyu 67 (5) (1992) 432 (in Japanese). "'Cold' fusion in deuterated complex cathode".
8. Arata Y, Zhang Y-C; Koon Gakkaishi(J.High Temp.Soc.). 20(4) (1994) 148(in Japanese, Engl.abstr.). "A new energy generated in DS-cathode with 'Pd-black' ".
9. Arata Y, Zhang Y-C; proc. Japan Acad. 70 Ser. B (1994) 106. "A new energy caused by 'Spillover-deuterium' ".
10. Arata Y, Zhang Y-C; Proc. Japan Acad. 71 Ser. B (1995) 304. vol. 71, No. 8, 304-309, (1995). "Achievement of Solid-State Plasma Fusion ("Cold Fusion")".
11. Arata Y, Zhang Y-C; proc. Japan Acad. 61, Ser. B (1995) 98. "Cold fusion reactions driven by 'Latticequake'".
12. Arata Y, Zhang Y-C; Koon Gakkaish (J. High Temp. Soc.). 21 (6) (1995) 303 (in Japanese, Engl. abstr. & Fig. captions). "Achievement of solid-state plasma fusion ("cold fusion")".
13. Arata Y, Zhang Y-C; Koon Gakkaishi (J. High Temp. Soc.). 21 (1995) 130 (in Japanese, Eng. abstr.); "Peculiar relation between hot plasma fusion and solid-state plasma fusion ("cold fusion")".
14. Arata Y, Zhang Y-C; Koon Gakkaishi (J. High Temp. Soc.). 21 (1995) 43 (in Japanese, Engl. abstr.). "Cold fusion caused by 'lattice quake'".
15. Arata Y, Zhang Y-C; Koon Gakkaishi (J. High Temp. Soc.). 22 (1) (1996) 29 (Japanese, Engl. abstr.) "Generation and mechanism of solid-state plasma fusion ("cold fusion")".
16. Arata Y, Zhang Y-C; proc. Japan Acad. 72 Ser. B (1996) 179. "Deuterium nuclear reaction process within solid".
17. Arata Y, Zhang Y-C; proc. Japan Acad. 73, Ser. B (1997) 62. "Presence of helium (4/2He, 3/2He) confirmed in deuterated Pd-black by the "vi-effect" in a "closed QMS" environment".

18. Arata Y, Zhang Y-C; J. High Temp. Soc. 23 (1997): (special volume pp 1-56). "Solid-state plasma fusion ('cold fusion')".
19. Arata Y, Zhang Y-C; J. High Temp. Soc. 23 (1997) 110 (in Japanese, Engl.abstr.). "Presence of helium (4/2He, 3/2He) confirmed in highly deuterated Pd-black by the new detecting methodology".
20. Arata Y, Zhang Y-C; proc. Japan. Acad. 73, Ser. B (1997) 1-6. "Helium(4/2He, 3/2He) within deuterated pd-black".
21. Arata Y, Zhang Y-C; Jpn. J. Appl. Phys. 237 (1998) L1274. "Anomalous difference between reaction energies generated within D2O-cell and H2O-cell".
22. Arata Y, Zhang Y-C;Kaku Yugo Kenkyu 69 (1998) 963 (in Japanese). "Excess heat in a double structure deuterated cathode".
23. Arata Y, Zhang Y-C; proc. Japan. Acad. 74, Ser B (1998) 110. "Anomalous 'deuterium-reaction energies' within solid".
24. Arata Y, Zhang Y-C; Proc. Japan Acad. 74 Ser. B (1998) 201. "The importance of sono-implantation".
25. Arata Y, Zhang Y-C; proc. Japan Acad. 75 Ser. B (1999) 71. "Definitive difference between [DS-D2O] and [Bulk-D2O] cells in 'deuterium-reaction'".
26. Arata Y, Zhang Y-C; proc. Japan Acad. 75 Ser. B (1999) 76. "Critical condition to induce 'excess energy' within [DS-H2O] cell".
27. Arata Y, Zhang Y-C; proc. Japan. Acad. Ser. B 75 (1999) 281. "Anomalous production of gaseous 4He at the inside of 'DS cathode' during D2O-electrolysis".
28. Arata Y, Zhang Y-C; Jpn. J. Appl. Phys. 38 (1999) L774. "Observation of Anomalous Heat Release and Helium-4 Production from Highly Deuterated Palladium Fine Particles".
29. Arata Y, Zhang Y-C; Genshikaku Kenkyu (Anomalous Nuclear Fusion Reaction). 45(2)(2000). vol.45, No.2, July 2000; and ICCF8 (Lerici, Italy, May 2000). "Definitive Defference among [DS-D2O],[DS-H2O] and [Bulk-D2O] cell in the Deuterization and Deuterium-reaction".
30. Arata Y; Kotai Butsuri 35 (1) (2000) 67 [in Japanese]. Cited in Chem. Abstr. 132: 128508 (2000) "Developmental challenge in new energy source; 'Solid state plasma fusion'".
31. Arata Y, Zhang Y-C; Appl. Phys. Lett. 76 (2000) 2472. vol.76, No.17, 2472, (2000). "Sono Implantation of hydrogen and deuterium from water into metallic fine powders".
32. Arata Y, Zhang Y-C; Jpn. J. Appl. Phys. 39 (2000) L4198. "Deuterization and Deuterium Reactions in the Electrolyses of D2O with the Double Structure Cathode and the Bulk Cathode".
33. Arata Y, Zhang Y-C; Proc. ICCF 8, Italy (2000) 11 and 293. "Definitive Difference among [DS-D2O], [DS-H2O], [Balk-D2O] cells in the Deuterization and Deuterium-reaction" (pp. 11-16), and "Sonoimplantation of hydrogen and deuterium from the water into metallic fine powders", (pp. 293-298).
34. Arata Y, Zhang Y-C; Proc. Japan Acad. 77 Ser. B (2001) 43. "Intense sono implantation of gases into metals".
35. Arata Y, Zhang Y-C; proc. Japan. Acad. 78 ser. B (2002) 57. "Formation of condensed metallic deuterium lattice and nuclear fusion".
36. Arata Y, Zhang Y-C; Proc. Japan Acad. 78 Ser. B (2002) 63. "Nuclear fusion reacted inside metals by intense sonoimplantion effect".

37. Arata Y, Zhang Y-C; Proc. Japan Acad. 78 Ser. B (2002) 201. "Intense deuterium nuclear fusion of pycnodeuterium-lumps coagulated locally within highly deuterated atom clusters".
38. Arata Y, Zhang Y-C; Appl. Phys. Lett. 80 (2002) 2416. "Intense sonoimplantation of atoms from gases into metals".
39. Arata Y, Zhang Y-C; Proc. ICCF 9, China (2002) 5-16. "Pycnonuclear Fusion Generated in "Lattice-Reacter" of Metallic Deuterium Lattice within Metal Atom-clusters".
40. Yamamura T, Shiokawa Y, Inoue A, Zhang Y-C, Arata Y; J.High Temp. Jpn 28 (2002) 144. "Neutron Activation Analysis of Pd Atom Clusters Caused Pycnonuclear Fusion".
41. Arata Y, Zhang Y-C; ICCF10 (Boston (2003); "Development of Compact Nuclear Fusion Reactor Using Solid Pycnodeuterium as Nuclear Fuel".
42. Arata Y; Kotai Butsuri 38 (1) (2003) 83 [in Japanese]. "Discovery of Pycnodeuterium-lumps and Intense Solid-state Nuclear Fusion in Highly Deuterated (Nano-particles)".
43. Arata Y, Zhang Y-C, Fujita H, Inoue A; Koon Gakkaishi 29 (2) (2003) 68. "Discovery of solid deuterium nuclear fusion of pycnodeuterium-lumps solidified locally within nano-pd particles": English translation (Il Nuovo Saggiatore, 20 (2004) 66 in Italy phys. soc.).
44. Arata Y, Zhang Y-C; J. High Temp. Soc. Jpn 29 (2003) 171. "Deuterium Absorption Characteristics of Peculiar Composite Powder (Zr3NiO・NiO)".
45. Arata Y, Zhang Y-C; J. High Temp. Soc. Jpn 29 (2003)(special vol: pp 1-44). "The Basics of Practical Nuclear Fusion Reactor Using Solid Pycnodeuterium as Nuclear Fuel".
46. Arata Y; Il Nuovo Saggiatore 20 (5-6) (2004) 66. "The formation of 'solid deuterium' solidified inside crystal lattice and intense solid-state nuclear fusion ('cold fusion')".
47. Arata Y, Zhang Y-C; Progress of Theoretical Phys. (Supplement), No. 154 (2004) 241: Fusion 03. "The Basics of Nuclear Fusion Reactor using Solid Pycnodeuterium as Nuclear Fuel".
48. Arata Y; Special Volume, IIW (Osaka), July 11st (2004). "Relation between Welding Science and Nuclear Fusion".
49. Arachi Y, Emura S, Omura A, Nunogaki M, Asai T, Yamamura S, Inoue A, Arata Y; Solid State Ionics (2006). "Structural Analysis on High Density H (D) Absorbed Nano-sized-Pd/ZrO2 Composite for Hydrogen Storage Materials".
50. Arata Y, Zhang Y-C; ICCF12 (Yokohama, Jpn; (2006)). "Development of "DS-Reactor" as the Practical Reactor of "Cold Fusion" based on the "DS-Cell" with "DS-Cathode".
51. Arata Y;IL NUOVO SAGGIATORE, (2004)6, "The formation of 《solid deuterium》 solidified inside crystal lattice and intense solid-state nuclear fusion (《cold fusion》) ".
52. Yamaura, S., Sasamori, K., Kimura, H., Inoue, A. Zhang, Y-C, and Arata Y. (2002) J. Mater, Res. 17,.1329. “Hydrogen absorption of nanoscale Pd particles embedded in ZrO2 matrix prepared from Zr-Pd amorphous alloys”.
53. Arata, Y and Zhang, Y-C. (2008), J. High Temp. Soc. 34, 85. “Establishment of Solid Fusion Reactor”, English version.
54. Yoshiaki Arata, “Toward the Establishment of Solid Fusion as a Perpetual Energy for Humankind, Book distributed at ICCF14 (2008).
55. Yoshiaki Arata, ICCF14 Award Lecture (2008). “History of 'Solid Fusion'“.

Glossary

Cold fusion as used in this paper means dd fusion in bulk Pd as studied by F-P and followers, also referred to as F-P effect

D+-Jet Stream means Jet-Fusion deuterons adsorbed onto nanoPd catalyst where metal electrons provide charge neutralization

DS-Cathode means same as Double Structure Cathode: hermetically sealed vessel with Pd cylinder and ss welded end pieces, filled with nanoPd catalyst

Electron box is envisioned cubic volume containing 4 electrons + 4 deuterons in octahedral site of fcc lattice[(51,57)]

Hot fusion is the same as plasma fusion

Jet-Fusion reaction means nuclear fusion occurring during Jet-Fusion zone

Jet-Fusion zone means run-time interval during which D_2 or H_2 gas is flowing onto sample and back pressure in reactor is too low to record on mechanical gage.

Sample means catalyst bed material

Skirt-Fusion zone means run-time interval starting at end of Jet-Fusion zone and continuing thereafter. The verb "skirt" means "to form edge of" (Oxford Dictionary)

Solid-state fusion is same as solid fusion

Solid fusion means nuclear fusion in a solid containing nanometal Pd: sometimes called "metal catalyzed fusion", also referred to as A-Z effect

Solid Reactor means same as Solid Fusion Reactor: gas-loaded reactor producing heat and 4He without using any applied electrical power

Streaming D2 gas is same as Streaming Deuterons: long mean free path D_2 molecules enter reactor against negligible back pressure before impacting nanoPd

Thermonuclear fusion is same as plasma fusion, as sought in ITER program

Verification reactor means electrolysis-loaded DS-Cathode containing nanoPd catalyst and producing excess heat