Introduction

Dr. Yoshiaki Arata is a professor emeritus of Osaka University, Japan. He is also a member of the Japan Academy. He was the first to develop a practical use "Solid Fusion" reactor in the world, which is expected to be an excellent energy source for the next 6 billion years. He reported a part of the experimental data at a board meeting of the High Temperature Society of Japan held on December 7, 2007. All members who attended the board meeting were very surprised and impressed to hear his report. Dr. Arata was the first researcher in the world to discover "Solid Fusion" about 50 years ago (1955-1958). He concentrated his efforts on the research of "Solid Fusion" during the recent 20 years after his retirement (1989). Finally, he has succeeded in developing a practical use "Solid Fusion" reactor and published the result in an article of the High Temperature Society of Japan. The "Solid Fusion" reactor essentially does not generate any pollution and makes it possible to fully supply the energy required for the existence of human beings. Further, the "Solid Fusion" reactor can accelerate the developments of new scientific fields and/or new industrial fields. It can also contribute greatly to various activities of society. Therefore, we believe that it would be very beneficial to create an opportunity for people other than the members of this Society to be informed of Dr. Arata's achievements in developing the "Solid Fusion" reactor. This is the reason why we have decided to issue a separate volume describing in detail Dr. Arata's achievements under his approval. We hope if this separate volume is helpful for many people in various fields.

It is our honor to distribute one of the best results in this century from Japan to the rest of the world.

Board meeting of the High Temperature Society of Japan

序

荒田吉明先生は大阪大学名誉教授であり、日本学士院会員です。このたび荒田先生が 12 月 7 日に開催された高温学会理事会で、世界で初めて人類 60 億年のエネルギー源とされている「固体核融合」の実用炉を研究され、その実験データの一部を報告されました。この成果に理事会では感嘆の声につつまれました。それで荒田先生が約 50 年前（1955-1958）世界で初めて開発されたもので、特に御退官（1989）以来この 20 年間は、“固体内核融合” 研究のみに集中され、遂に先日その「固体核融合実用炉」を達成され、今回本学会誌にその成果を発表されました。この核融合炉は本質的に無公害であり、人類生存に不可欠なエネルギーの供給を可能とするものであり、そして新しい学術・産業の発展を促すと共に、広く社会に貢献出来るものと判断し、「学会員」以外の多くの方々にも、その学術成果を広く知って頂くことは学会の使命のひとつと考え、荒田先生のご了解も得て、その別刷を適切に各分野の方々にも配布出来ればと判断した次第です。

日本から今世紀最大の成果のひとつとして世界に向けて発信出来れば、極めて有意義と考えております。

高温学会理事会

Establishment of the "Solid Fusion" Reactor

By Yoshiaki ARATA, and Zhang-Yue CHANG

Abstract: Fig. 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 ($^4_2$He) and large thermal energy under the following equation:

$$^2_1\mathrm{D}+{}^2_1\mathrm{D}={}^4_2\mathrm{He}+\text{thermal energy} \quad \text{-------------- (a)}$$

$$(4\,{}^2_1\mathrm{D}=2\,{}^4_2\mathrm{He}+\text{thermal energy}) \quad \text{-------------- (b)}$$

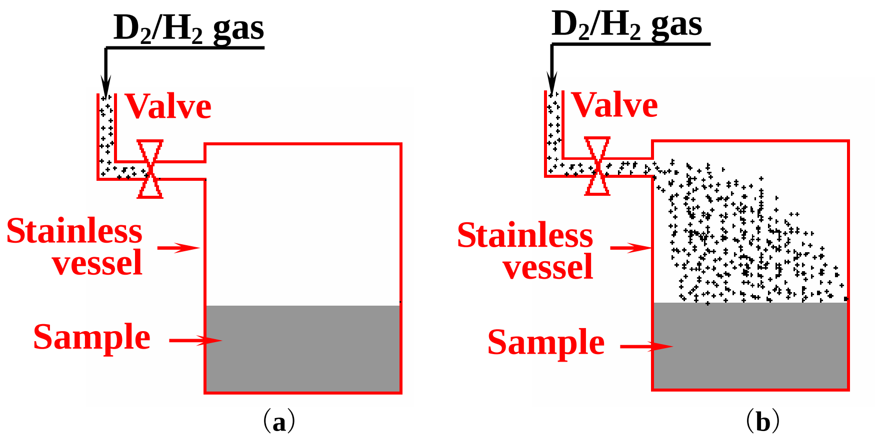


Fig.A Principle of "Solid Fusion" Reactor Vessel

(a): Reactor vessel before the introduction of D_2/H_2 gas (only stainless vessel and sample)

(b): Introducing of D_2/H_2 gas as the D_2/H_2— "jet stream" into the reactor vessel; and then D^+/H^+ — "Jet-stream" penetrate into the sample.

(Note): if D_2/H_2 gas was introduced、D_2/H_2—"Jet-stream" immediately penetrates into the sample as the D^+/H^+ — "Jet-stream", and "Fusion Reaction"、($^4_2$**He** and thermal energy) immediately generated in 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).

Introduction

About 50 years ago (1955~1958), one of the authors (Y.Arata) investigated "solid-state plasma fusion" (simply "Solid Fusion") together with "thermonuclear fusion" (simply "Hot 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 8, 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 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.

Key words: Solid Fusion, Solid Fusion Reactor/Solid Reactor, helium, thermal energy.

Experiment and discussion

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

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 high concentration (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 arranged on the central axis of the sample. The temperature T_s of the stainless steel vessel **2** is measured by a thermocouple arranged on the outer wall of the vessel **2**. The D_2 gas

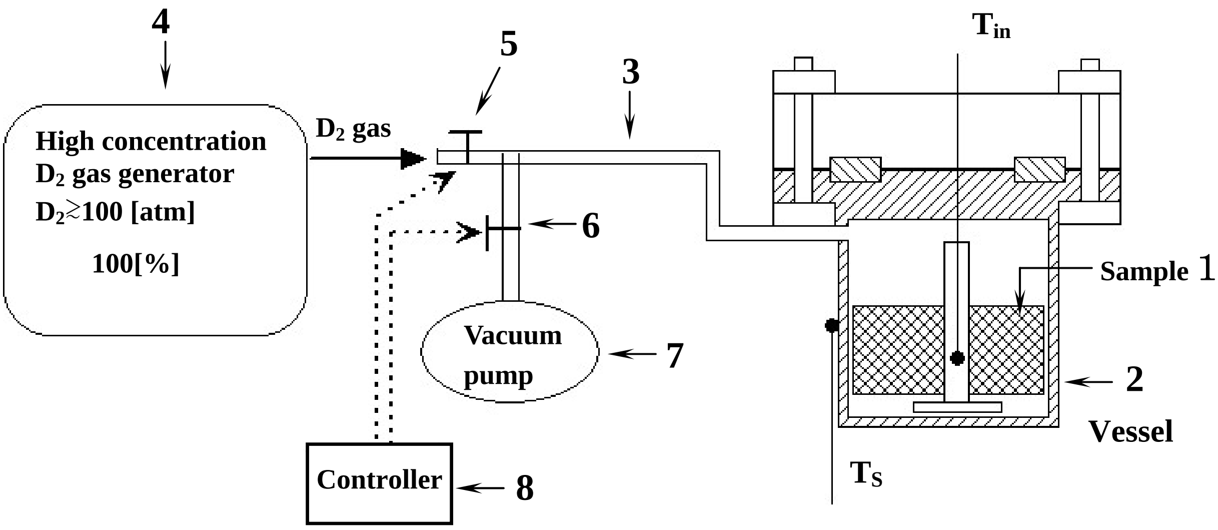


Fig.1 Experimental device

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 provided at the stainless steel pipe **3** and the open/close of the valves **5** and **6** can be 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 D_2 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 the clouds of electrons within the sample. In other words, where the supplied D_2 gas is converted into ${}^4_2He$ and thermal energy only in accordance with the following formula:

$$ {}^2_1D + {}^2_1D = {}^4_2He + \text{thermal energy} \quad \text{-------------- (a)} $$

$$ (4\,{}^2_1D = 2\,{}^4_2He + \text{thermal energy}) \quad \text{-------------- (b)} $$

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 a "${}^4_2$**He** 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.

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 the D_2 gas, and the thermal energy is generated (in which, chemical frictional reaction energy generated between “ D^+-jet stream and the sample atoms” is enclosed). Then, “D^+-jet stream” was stopped, in other words the generation of the 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 of the supplied D_2 gas enters as the “D^+-jet stream” into the sample without staying in the reactor, the nuclear fusion reaction and chemical reaction energy occurs inside the

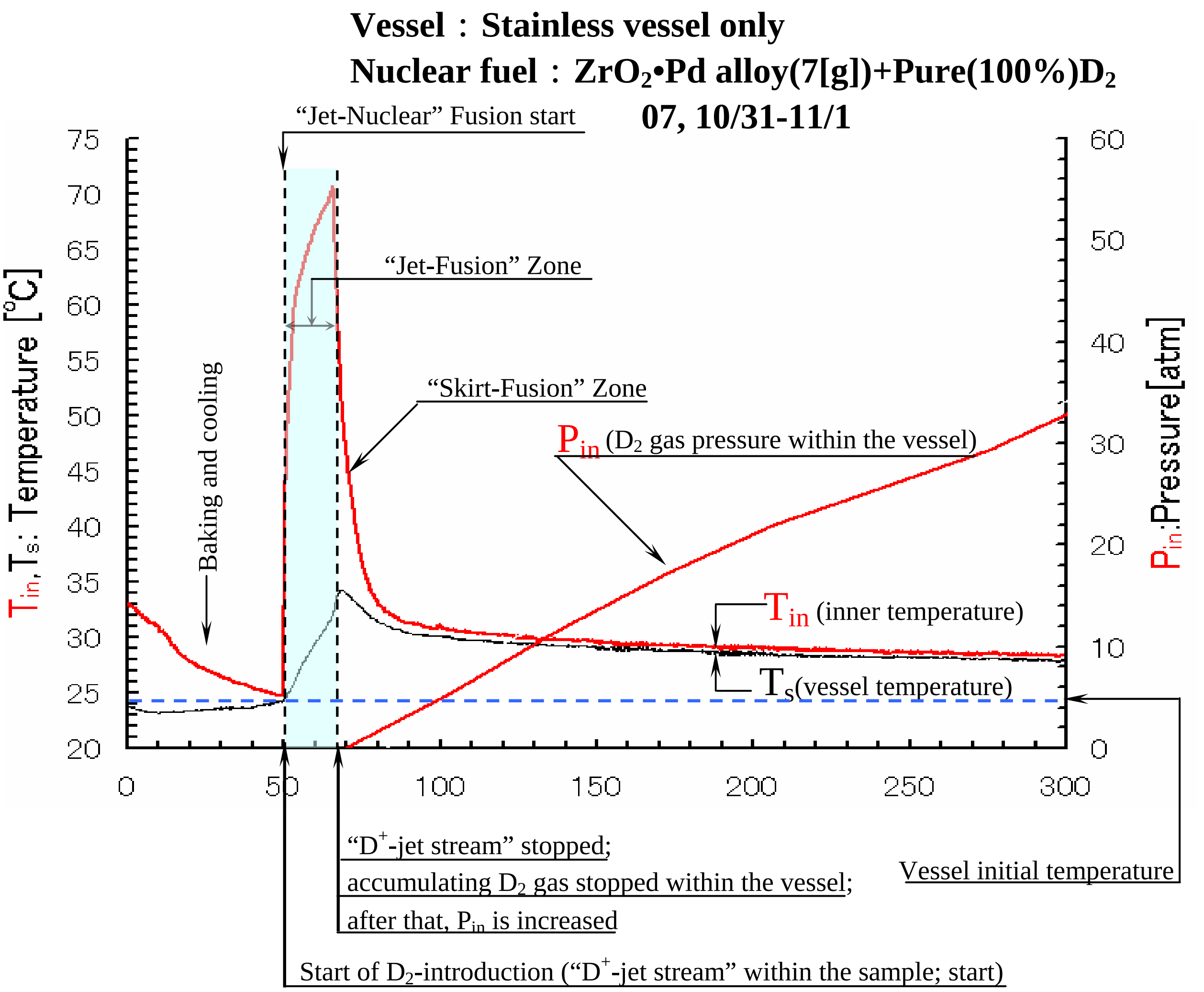


Fig.2 Simultaneous generation of thermal energy and ${}^4_2He$

sample. For instance, each 2~4 D-atoms of the “D^+-jet stream” are coagulated as the “clumpy 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” full fill 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.

This experimental result is a very epoch-making one which is beyond any expectation. This is an unexpected new phenomena. This new phenomena 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”.

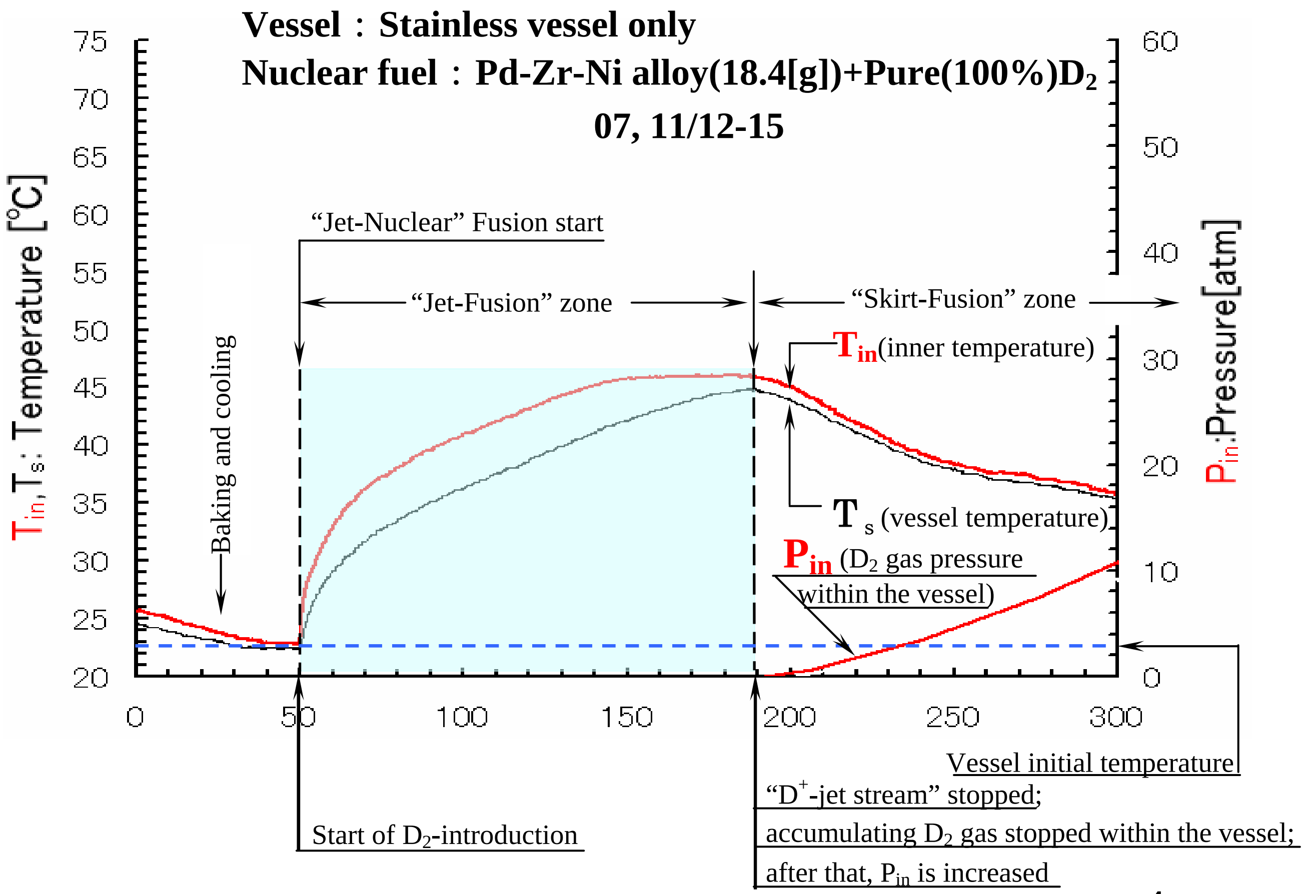


Fig.3 Simultaneous generation of thermal energy and ^4_2He

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 experimental results in reports. Up to now, the number of the reports is over 70, (Reference). One example of the "verification reactor" is a world-famous electrolysis-type reactor using D_2O/H_2O:"DS-Cathode"(="Double Structure Cathode"). According to 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, ${}^{4}_{2}\mathrm{He}$ and thermal energy is clearly generated. In the latter case where H is used, anything other than a small amount of chemical reaction heat cannot be recognized.

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 (${}^{4}_{2}\mathrm{He}$ 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 ${}^{4}_{2}\mathrm{He}$ is not generated at all.

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 incomparably 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

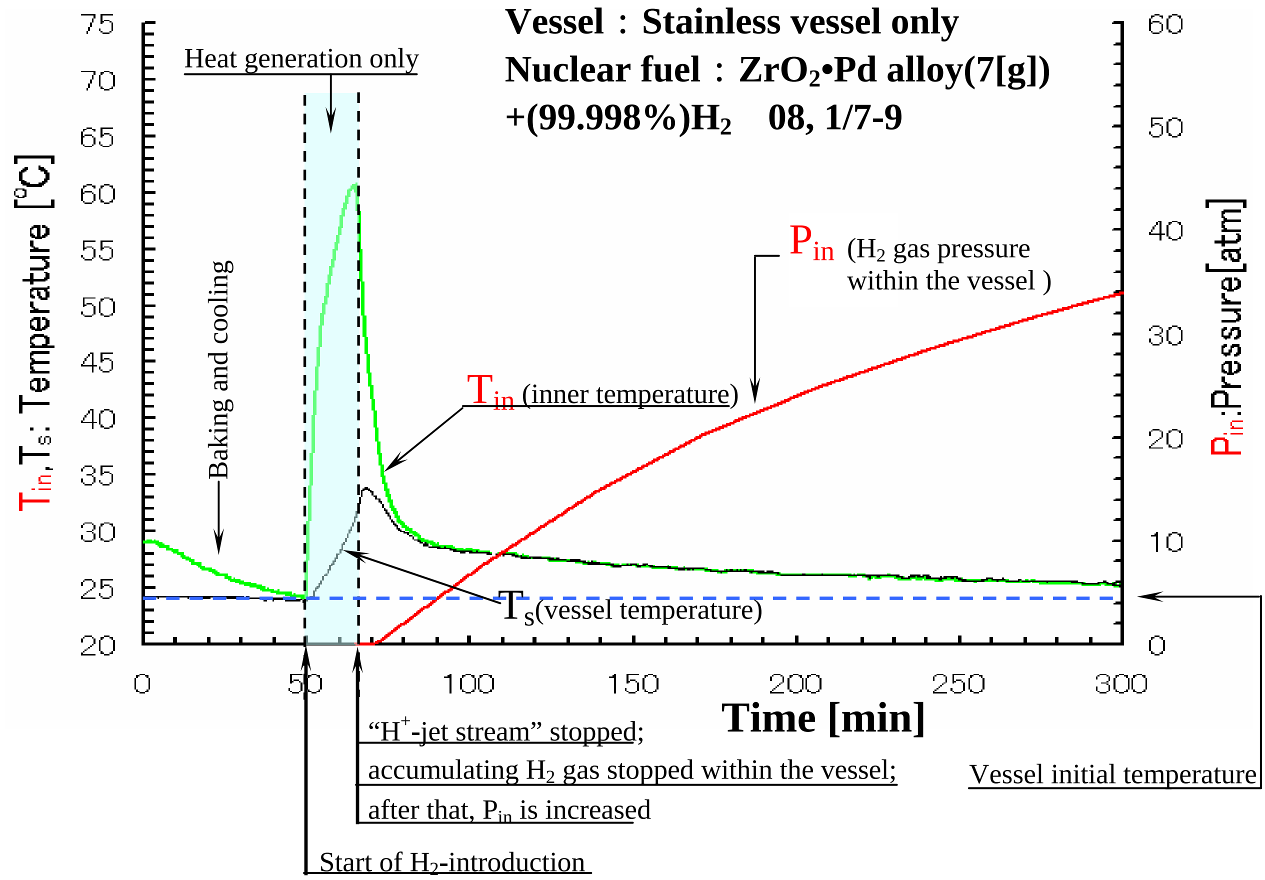


Fig.4 Heat generation for H_2-introduction

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 throughout 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 tempered compared with Fig.5A. It is clear that both gaseous and vessels temperature (C) in the H_2 gas drop into the room temperature (D-line) in 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 as "ΔT-characteristics"). These results depend on the continued

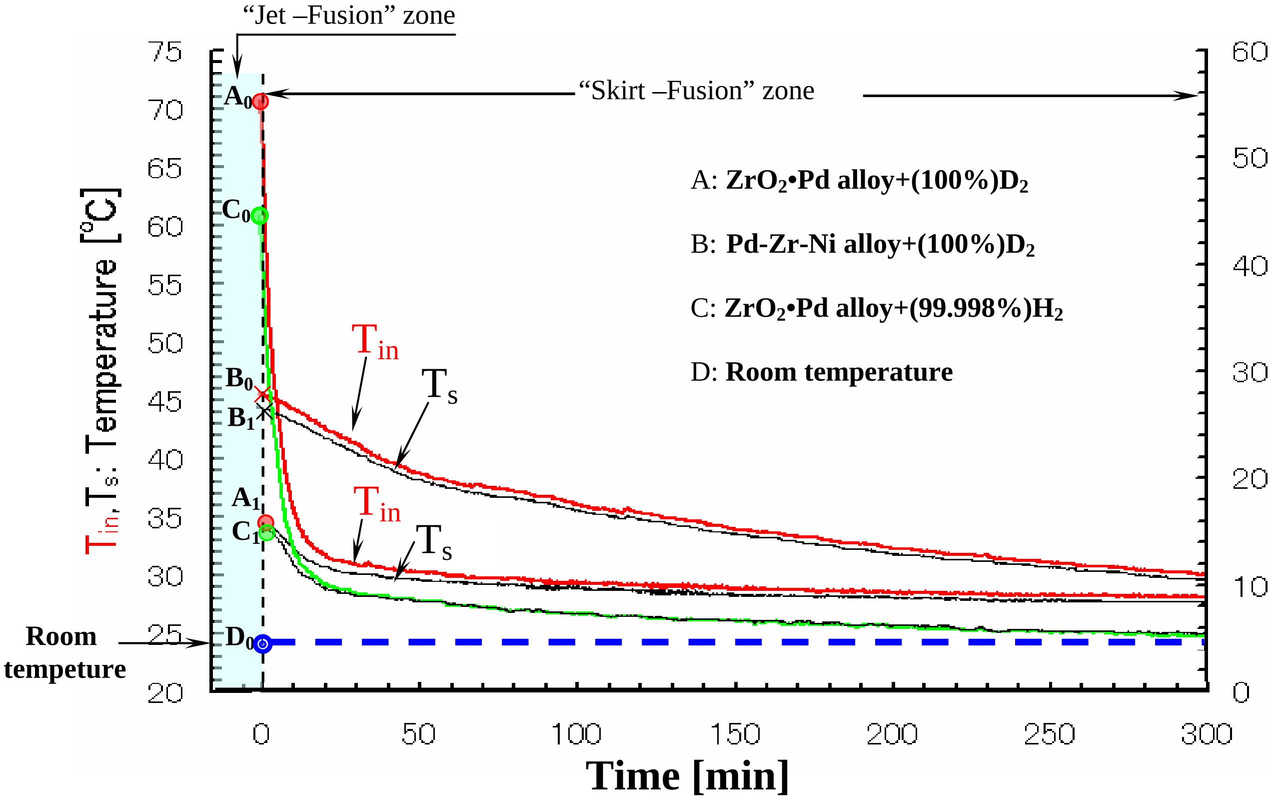


Fig.5A Comparison of generation characteristics of Nuclear fusion during "Skirt-Fusion" zone for each fuel(0~300min)

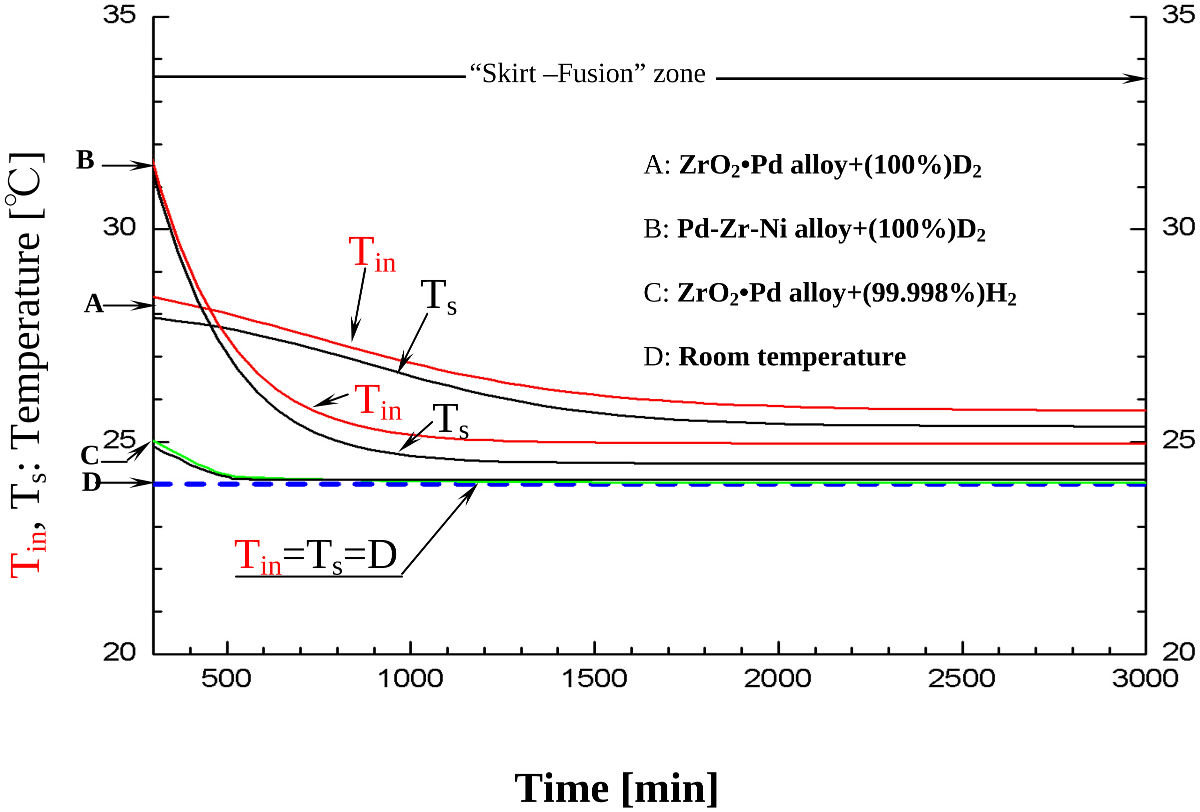


Fig.5B Comparison of generation characteristics of Nuclear fusion during "Skirt-Fusion" zone for each fuel(after 300min)

nuclear reaction of the “Skirt-Fusion”. This is the extreme very important result. This phenomena continue about several hundred hours.

Finally, the D_2 gas pressure characteristics 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 of 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 the 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 with 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 kJ in “Jet-Fusion”(≃18 kJ/hour) and about 200kJ in “Skirt-Fusion”(≃3kJ/hour). About 5×10^{15} $^{4}_{2}He$ were produced in “Jet-Fusion” and about 3×10^{17} $^{4}_{2}He$ in “ Skirt-Fusion” zone. Sample is ZrO_2-Pd alloy (6.5gram) in this case.

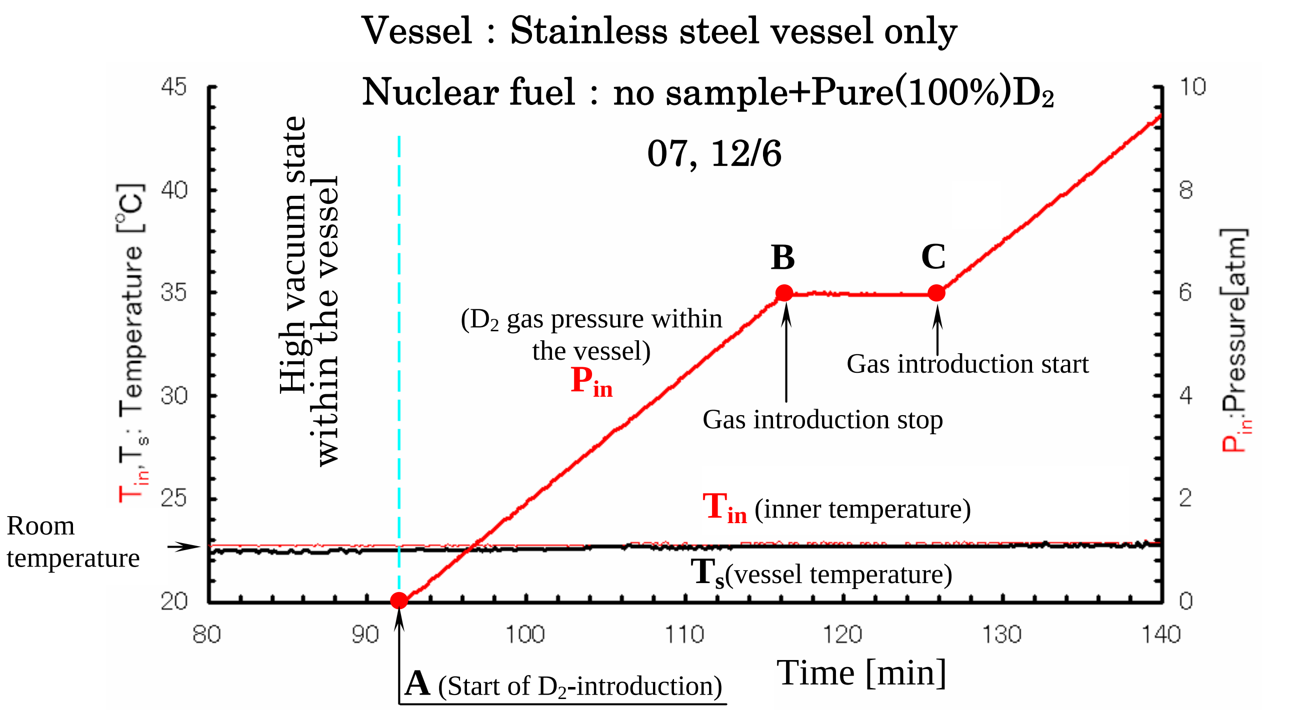


Fig.6 Gas pressure characteristics within the vessel (no sample)

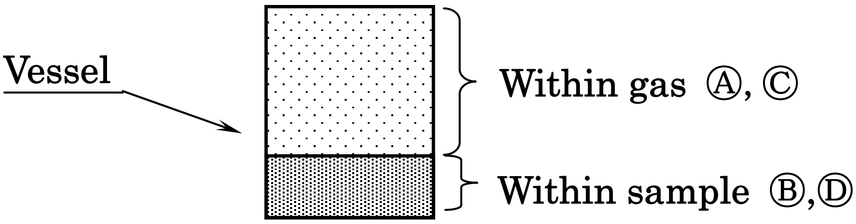
In order to further clarify this conclusion, Figure **7[C]**(within fuel gas) and Figure **7[D]** (within sample solid) are shown using Mass-spectrometer. In particular, it can be understood that a large amount of ${}^{4}_{2}He$ is generated within the sample solid as shown in Figure **7[D]**. It is well known as the characteristics of ${}^{4}_{2}He$ with respect to the metal that ${}^{4}_{2}He$ cannot enter into any solid and ${}^{4}_{2}He$ cannot egress from any solid under the temperature level from the room temperature to several-100℃. Figure **7[C]**、**[D]** shows a situation in which a large amount of ${}^{4}_{2}He$ 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 Figure 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 ${}^{4}_{2}He$ 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 (b) the solid nuclear fusion reactor 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 new 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.

Sample's locations for QMS-measurement



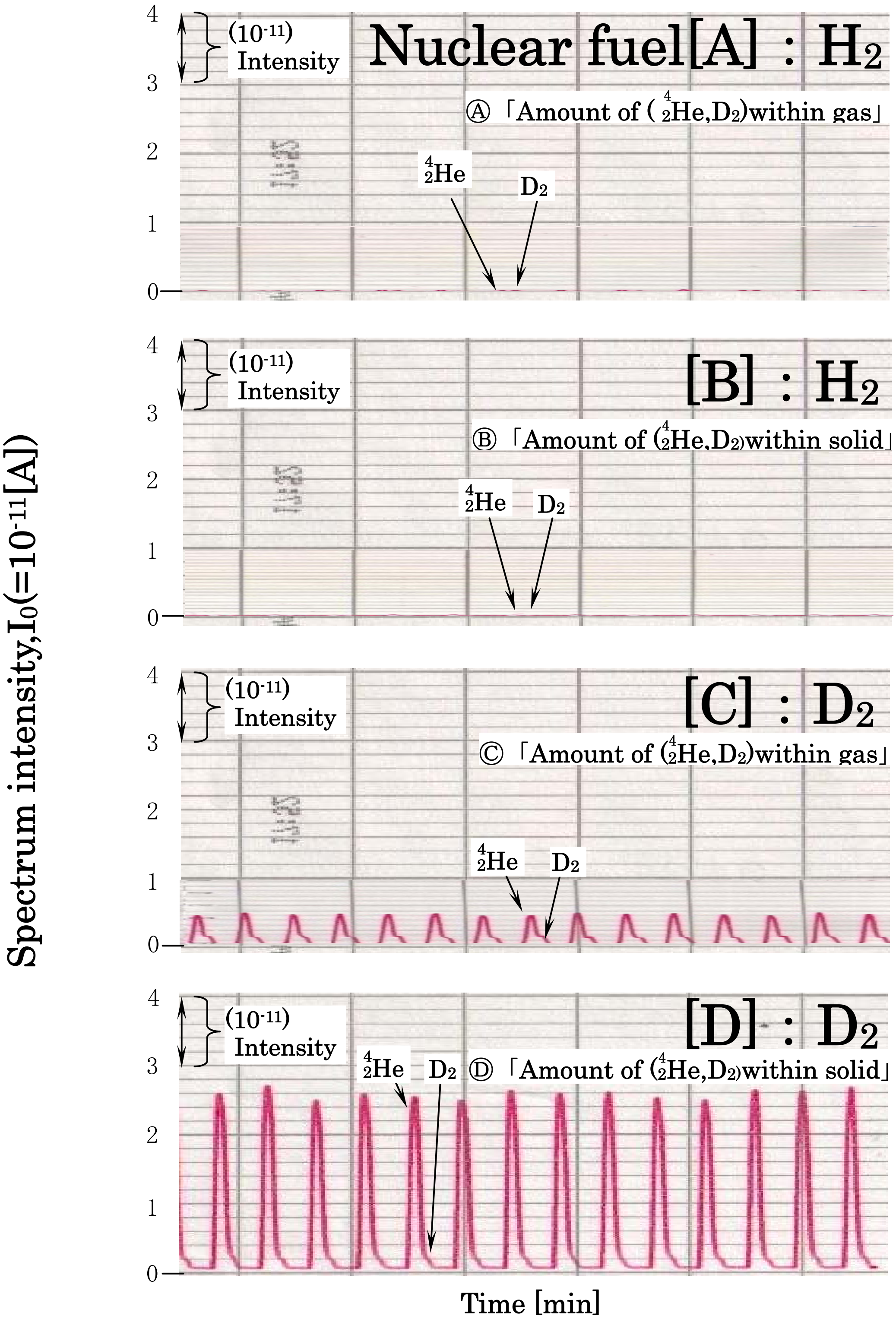


Fig.7 Mass analysis result for fuel (H_2/D_2) and reaction product (${}^{4}_{2}He$)

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