MAR 7 1990

Dr. Mastaka Mizushima, President
Mizu-Tech, Inc.
523 Theresa Drive
Boulder, CO 80303

Dear Dr. Mizushima:

This is in response to your and Mr. Plywaski's letter of February 12, 1990, transmitting a document "Research Proposal on Cold Fusion." The document does not satisfy the requirements of a grant application and, therefore, cannot be considered a formal proposal. Please check the enclosed brochure, DOE/ER-0249, for the requirements placed on grant applications.

Having said this, let me state that I cannot in good faith encourage you to resubmit the proposal in the required format, as I do not think that the approach offered is sufficiently original to stand a chance of passing a technical peer review.

I read with interest the attachments to your proposal. If you wished in the future to send us assorted cold fusion items from the Japanese press, that would certainly be appreciated.

Thank you for sharing your materials with the Department of Energy.

Sincerely,

Original signed by!
Ryszard Gajewski

Ryszard Gajewski, Director
Division of Advanced Energy Projects
Office of Basic Energy Sciences, ER-16

Enclosure

ER-16:RGajewski:mfr:3-5995:3-7-90:c:\Gajewski\Mizushima:wp

ER-16
R. G.
Gajewski
3/7/90

cold fusion

TELEPHONE MESSAGE FOR R H

M Bill Plywoski of Colorado

☑ Telephoned ☐ Visited Your Office Date / Time 2/13 9:50

☐ Return Call ☐ Will Call Again

MESSAGE Thanks you for Cold Fusion Report. Sent in mail translated Japanese Article, & Science article along with proposal.

303-494-0603

His associate - Mizushima (translator of Japanese articles)

Callers Telephone No. 303-444-2307 Area Code Extension

Call Taken By mr ☐ See Me For More Details

MIZU-TECH, INC.
523 Theresa Drive, Boulder, Colorado 80303, U.S.A.
Telephone and FAX: (001-1) • (303) 494-0603

Dr. R. Gajewski
Director, Advanced Energy Projects Group
Basic Energy Science Division
United States Department of Energy
Washington, D. C. 20545

February 12, 1990

Dear Dr. Gajewski:

Thank you for your graciously sharing with us the information on current status of cold fusion research, for forwarding your related report (DOE/S-0073), and for being receptive to review our research proposal in this field.

Accordingly we are sending our research proposal on cold fusion for your review. During our conversation, you mentioned that although your office was interested in receiving our proposal there were no research funds available until next fiscal year (Oct. 1990). However, in view of the ensuing development in current Japanese work in cold fusion, a long delay will represents a significant research drawback. We would like to check with you whether or not some contingent research support funds might become available prior to Oct. 1990 to start this work immediately and so not to lag almost one year behind, if our proposal is favorably reviewed by your office.

During our conversation you expressed an interest in receiving from us the latest related research work information from Japan. We enclose two newspaper articles and a paper by Arata and Zhang (translated by M.M.) and another paper by Wada and Nishizawa (originally in English) as appendix to the proposal.

Because of M. M.'s close association and frequent communication with Japanese scientists, we will be glad to provide a liaison function to your office on the Japanese cold fusion research effort and provide the related translations, as well as on any other scientific topics of interest.

Yours sincerely,

Masataka Mizushima and
President, Mizu-Tech, Inc.
and Professor of Physics Emeritus
University of Colorado,

William Plywaski
Vice-president, Mizu-Tech, Inc.

Research Proposal on Cold Fusion

by Masataka Mizushima and William Plywaski
Mizu-Tech, Inc.*
523 Theresa Dr., Boulder, CO 80303
Telephone and FAX (303)494-0603

Table of contents

Appendices (translated from Japanese by M.M.,except for 2.)

* Mizu-Tech, Inc is a SBA 8(a) physics research corporation.

Abstract

In view of the recent developments in Japan, it is now certain that we can achieve cold fusion reaction using deuterium saturated palladium. We propose to confirm the latest Japanese experimental results and seek ways to improve the reaction efficiency.

Keywords: cold fusion, deuterium, deuteron, palladium, electrolysis, electric discharge.

Historical Background

A muon catalyzed cold fusion $p+d+\mu \rightarrow {}^3He+\mu$ was seen by Luis Alvarez and others in a bubble chamber (Phys. Rev. 105 (1957) L1127). In the ordinary hydrogen molecular ion the probability of one proton tunneling through the Coulombic potential barrier to interact with another proton (or deuteron) is extremely small(about 10^{-64}/molecule-sec). But, if the binding is due to a muon the equilibrium inter-nuclear distance is reduced by a factor of 200, and that reduces the potential barrier sufficiently so as to make the probability of tunneling tremendously enhanced and the pd reaction can occur within the lifetime of the muon. However, since the muon lives only a very short time it was thought that one cannot sustain a sufficient number of such molecular ions to mass produce energy in this way.

C. DeW Van Sicken and S. E. Jones (J. Phys. G. Nucl, Phys. 12,(1986) 213-221) used the Morse potential to numerically show that the above stated change of the probability of tunnel effect is possible. They also predicted that a very high pressure could reduce the internuclear distance of the hydrogen molecule and that cold fusion could be made possible in the same mechanism, but the required pressure was so high that hydrogen might become metallic. While such high pressure is not available to us, they suggested that the known extra heating of Earth and Jupiter might be due to a cold fusion produced in this way.

It has been known since Fritz Paneth and Kurt Peters (Nature 118 (1926) 526) that palladium absorbs more than one hydrogen atom per each unit cell. They also asserted that titanium might absorb more hydrogen atoms. Such high density of hydrogen atoms might provide the required high pressure to produce cold fusion.

Stanley Pons and Martin Fleischmann pointed out that more deuterons can be absorbed in palladium than protons and tried Pd cathodes dipped in D_2O. On March 23, 1989 they had a press conference at the University of Utah and announced that they had sustained fusion in a test tube with the Pd cathode dipped in D_2O with a current density of about 500 mA/cm^2. They also published a "preliminary note" in J. Electroanal. Chem. 261 (1989) 301-308.

S. E. Jones and others (Nature 338 (1989) 526) used a titanium cathode dipped in D_2O, and measured an emergent neutron flux which was five times the background; much less spectacular result than Pons and Fleischmann, but still suggesting that a nuclear reaction of some kind was occuring.

Many scientists throughout the world tried to repeat the experiment of Pons and Fleischmann, but the results were mixed. Most of the established scientists remain skeptical and "Nature" refused to print Pons and Fleischmann's paper. The general opinion at present seems negative as one popular magazine (Discover 1990 January issue p.43) expressed it in a bitter way.

However, there are some positive results reported. A group at Texas A&M by May 25, 1989 reported that they did observe an excess neutron flux and a group at Stanford and a few others are said to have confirmed Pons and Fleischmann's result. The entire situation, including a long list of scientists who gave negative results or opinions is well reviewed by B. G. Levi (Physics Today June (1989) 17-19) and I. Goodwin (Physics Today December (1989) 43-45). DOE's Energy Research Advisory Board accepted the Huizenga-Ramsey report which concluded that "cold fusion is not persuasive" which implied that "that's not to say untrue".

Recent Developments in Japan

On November 30, 1989 a leading Japanese newspaper, "Asahi", reported that N. Wada and K. Nishizawa of Nagoya University, Nagoya, Japan, observed a neutron burst about 20,000 times the background under electric discharge between palladium electrodes which were previously exposed to the D_2 gas of about one atmosphere. Their paper was published (Jpn. J. Appl. Phys. 28, L2017 (1989)) shortly before this newspaper article.

H. Ikegami of the Institute of Nuclear Fusion, one of the largest federal research institutes in Japan, also located in Nagoya, performed an experiment similar to that of Wada and Nishizawa, but with better detectors and observed a neutron burst of about 1.7 million times the background, according to Asahi newspaper report of January 11, 1990.

Independently from the Nagoya group, Y. Arata and Y. Zhang of Kinki University and Osaka University, both in Osaka, Japan, observed over 10^8 neutron/sec emitted from a Pd cathode saturated with deuterium. They used a large cathode and observed that deuterium is extensively absorbed by Pd when the temperature is below 80°C, but that ordinary hydrogen does that below 110°C, and that above these temperatures neither element is absorbed by Pd. Arata and Zhang published their paper in "Study of Nuclear Fusion", 62 , November, 398 (1989), but that was published only in Japanese. These articles and papers are translated into English and included in this proposal as appendices.

Research Plan

It is certain now that one can induce at least some kind of a nuclear reaction, most likely a nuclear fusion, by means of electrical discharge on a deuteron saturated palladium. Our plan is to confirm and improve Wada's and Arata's experimental results.

In both Wada's and Arata's papers, it is emphasised that the surface of Pd has to be clean in order to produce the neutron bursts. The initial discharge for "activation" in Wada's experiment seems useful for that purpose. The Wada group has not tried mechanical or chemical polishing or any other methods to clean the surface. Wada assumes that the squeezing of deuterons at the surface of Pd as they try to migrate into the crystal has something to do with the initial step of the nuclear reaction. We will try the best techniques to prepare the surface of Pd.

If the surface is indeed where the initial reaction takes place, the use of a Pd powder, rather than a bulk crystal, might be more efficient. If that is the case, using an electric discharge may not be practical, but a high power laser, like a CO_2 laser, may work for that purpose. The Principal Investigator (PI) has experience in using CO_2 lasers at the National Institute of Standards and Technology (NIST), Boulder, where he and his students and colleagues are doing spectroscopy work.

Purity of the Pd rod has not been examined carefully in existing experiments, including that of Pons & Fleischmann. Yet the preparation of a high quality Pd material is most likely very important. The Arata group asserts that activation of Pd by means of what they call "on-off effect" is essential to prepare for cold fusion. It seems that in this effect deuterons go through the interstitial space of Pd a number of times, which probably means to correct for the crystal defects. If so, conventional methods like annealing for a recrystalization might work also.

Stimulation by a discharge was thought to be not very important in Wada's experiment, but subsequent experiment by Ikegami with better neutron detectors showed that this step was essential. Our opinion is that $e+d \rightarrow 2n+\nu$ reaction is important as an intermediate step of the whole process at least at the initial stage. Second order process with this weak interaction as the intermediate step, namely, $e+d+d \rightarrow 2n+d+\nu \rightarrow n+t+\nu$, may make the tunnel effect easier than the straight forward first order tunnel effect. If so, a high energy electron beam would also initiate the reaction. Also ordinary DC or AC currenct instead of a

discharge might be equivalently sufficient. (The bombardment by a proton or a deuteron beam may also help to stimulate the cold fusion.)

In this theory, we think that the second step of the process (nuclear fusion) can take place quickly if the neighboring deuterons are close by; that is, the higher the deuteron density the faster this process can take place. To sustain the fusion reaction it is obviously necessary to have deuterons in a very high density anyway. Arata group states that inside an activated Pd rod the deuterium pressure can be as high as 5000 atmospheres. If we use a larger Pd crystal, the pressure might be even higher to achieve a greater density of deuterons. Also a better shape of the Pd crystal might increase this inner pressure, or the density of deuterons. We will try a spherical shape of crystal, for example. (Arata asserted that larger Pd crystal was better, but Wada used wires with success. We will try both powder and a bulk crystal of Pd to see which is better.)

Arata-Zhang paper also indicates that a lower temperature (at least below 80°C) would increase the deuteron density, but they did not try any forced cooling. We will try freezing or lower temperatures to see if we can enhance the reaction efficiency.

Wada group used D_2 gas while Arata group used D_2O liquid. In the latter case one has to dissociate oxygen out with extra energy (electrolysis), but it is easier to handle D_2O than D_2 gas which is reactive. For future industrial applications the D_2O is probably better. Even with D_2O, electrolysis may not be necessary; for example, we might just immerse Pd in D_2O with some catalysis, and with current, cold fusion might work.

We plan to subcontract with the University of Colorado (CU), where the PI is a Professor of Physics Emeritus, to use its shop facilities for mechanical, glass blowing, and other laboratory work. Library, computer, and some office facilities of CU can be used under that arrangement. Student assistants will also be available from CU. We also plan to invite a Japanese physicist as a consultant at the beginning stage of the experiment. The PI can communicate with Japanese scientists through verbal and written Japanese using BITNET, FAX, and other communication methods.

The PI was in Physics Department, Nagoya University for three months in 1986. In fact, the president of that university, Sachio Hayakawa, is a friend since the days when both of us were physics students at University of Tokyo at the same time. The PI was also at Osaka University a number of times as a visitor.

Proposed Budget for the First Year

Masataka Mizushima (Pricipal Investigator)		400 hrs/$40/hr	$16,000.
William Plywaski (Associate Investigator)		700 hrs/$25/hr	$17,500.
2 Assistant Investigators		900×2 hrs/$15/hr	$27,000.
Consultant		200 hrs/$35/hr	$7,000.
Secretarial		100 hrs/ $8/hr	$800.
	subtotal		$68,300.
labor overhead	17%		$11,611.
travel(to Japan)			$6,000.
	subtotal		$85,911.
Neutron detectors			$50,000.
CO_2 laser			$12,000.
mass spectrometer			$8,000.
shop work including material			$20,000.
	subtotal		$175,911.
administrative expense	13%		$22,868.
	subtotal		$198,779.
profit	10%		$19,878.
	Total		$218,657.

VITA Jan. 1990

NAME: Masataka Mizushima

BORN: March 30, 1923, Tokyo, Japan

EDUCATION:

University of Tokyo, Degree Rigakushi (between B.A. and M.A.) in Chemistry - 1946.

University of Tokyo Rigaku-Hakushi (Sc.D.) in Physics - 1951.

EXPERIENCE:

Research Assistant in Physics, University of Tokyo, 1947-1952.

Research Associate in Physics, Duke University, 1952-1955.

Assistant Professor of Physics, University of Colorado, 1955-1958.

Associate Professor of Physics, University of Colorado, 1958-1960.

Professor of Physics, University of Colorado, 1960-1988.

Physicist, National Bureau of Standards, Boulder, 1955-1969.

Visiting Professor, University of Tokyo, Tokyo, Japan, 1962-1963, 1972.

Visiting Professor, University of Rennes, France, 1964.

Visiting Professor, Institute of Atomic Physics, Bucharest, Romania, 1969-1970.

Visiting Professor, University of Nymegen, Netherlands, 1972.

Visiting Professor, University of Tokyo, Japan, 1972.

Honorary Fellow, University College London, England 1979-1980.

Visiting Professor, University of Electro-Communications, Tokyo, Japan, 1980-1981, 1987, 1989.

Visiting Professor, Institute for Molecular Science, Okazaki, Japan, 1982.

Visiting Professor, Nagoya University, Japan, 1986.

Invited Researcher, ATR Optical and Radio Communication Research Laboratories, Osaka, Japan, 1987, 1988.

Professor Emeritus of Physics, University of Colorado, Jan. 1989-present.

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Resume of

William Plywaski, Ph.D. (Physics)
927 Mtn. Meadows Road
Boulder, CO 80302
(303) 444-2307

SKILLS OUTLINE:

My work skills are represented by successful interaction with people, broad teaching and curriculum development experience, technical management, marketing and planning, proposal writing and project evaluation.

My education and background in science, engineering, management, and business --all with extensive experience-- enable me to provide practical solutions to theoretical and design problems.

I am the director of the Seafarer Group, Inc.
I manage and operate assets in the $300,000 range.

This diversified background as a scientist, educator and manager, lets me present complex ideas to both technical and non-technical people.

EDUCATION:

Ph.D. (Physics), University of Colorado, 1972.

University of Houston, graduate studies (Fluid Dynamics), Department of Chemical Engineering.

B.S. (Chemical Engineering), Oregon State University.

Franklin High School (Academic), Portland, Oregon.

Numerous academic courses & seminars in physics, mathematics, and related topics.

USAF courses in flying, navigation, missile guidance & control, electronics, avionics, radar, communications, personnel & management.

USAF Command & Staff Course, Maxwell AFB, AL, 1978.

USAF Squadron Officer Course, Maxwell AFB, AL.

LANGUAGES:

Fluent Polish and German, plus several other ones at a conversational level (e.g.: Spanish, Italian).

MILITARY STATUS:

Major, USAF Reserve, Master Navigator with over 5,000 flying hours, Vietnam veteran, Secret clearance (DOD).

1978-1954 - USAF active and reserve military service - see appendix.

PUBLICATIONS:

CURRENT-CURRENT INTERACTIONS OF HADRONS IN RELATIVISTIC COMPOSITE MODEL (Ph.D. Thesis, University of Colorado, 1972. Theoretical & mathematical physics related to our understanding of the structure of matter).

THE VERY HIGH ENERGY LIMIT OF PROTON-PROTON SCATTERING (with Prof. A.O. Barut), International Atomic Energy Commission, International Centre for Theoretical Physics, Miramare/Trieste, Italy, 1969 (IC/69/106).

VERY-HIGH-ENERGY LIMIT OF PROTON-PROTON SCATTERING (with Prof. A.O. Barut), The Physical Review D, vol. 2, No. 3, August 1970.

QUANTUM STATISTICAL MECHANICS TREATMENT OF VIRIAL COEFFICIENTS, National Bureau of Standards (NOAA), Engineering Report (project #81151), 1963. (Study of properties of real gases at extremes of temperature & pressure via isomorphism with the Ursell Expansion (quantum statistical mechanics, cluster functions) theory of the Mayer cluster integral equation).

THERMODYNAMICS - A SKETCH OF THE NON-EQUILIBRIUM THEORY (University of Colorado, Department of Physics & Astrophysics project, 1969).

PROPAGATION OF ELECTROMAGNETIC WAVES IN PLASMAS (with Prof. N. Ashby, partial thesis project, University of Colorado, 1970).

QUANTUM MECHANICAL STUDY OF PLASMAS - Aerospace Research Laboratories, Office of Aerospace Research, United States Air Force, Wright-Patterson Air Force Base, Ohio. (W. Plywaski, P. Biagi, N. Ashby, three annual research progress reports - 1964, 1965, 1966).

MAGNETIC COMPASSES AND DIRECTIONS (Seafarer Group Publications Monograph, (SGPM), 1974).

SEAFARER MAGNETIC COMPASS ADJUSTING PROCEDURES (SGPM, 1981).

SEAFARING HISTORY AT A GLANCE (SGPM, 1982).

BASIC SAILING - THE EIGHTFOLD WAY TO EASY SAILING (SGPM, 1983).

BASIC MATHEMATICS USED IN NAVIGATION (PILOTAGE, ELECTRONIC, CELESTIAL), (SGPM, 1984).

THE HYDRODYNAMICS AND AERODYNAMICS OF SAILING CRAFT (SGPM, 1985).

SAILBOAT STABILITY & PERFORMANCE PARAMETERS (SGPM, 1986).

CELESTIAL NAVIGATION FOR MARINERS & PILOTS (SGPM, 1988).

WORK HISTORY:
Present: I am the **Vice President** of MIZU-TECH, Inc., 523 Theresa Drive, Boulder, CO 80303, a physics research, science applications, and consulting company.
Present - 1972: I am the **science consultant** for **Pragmatronics, Inc.**, 751 Left Fork Road, Boulder, CO 80302, (303) 444-4912, for physics oriented problems and their solutions.

I am the **founder, president and director**, of the **Seafarer Group, Inc.**, Sugarloaf Road, Boulder, CO 80302, (303) 444-2307, since its inception in 1972. I have management, public relations, teaching, fiscal and operational, as well as curriculum development responsibilities. We teach classes in sailing, seamanship, and navigation (pilotage, electronic, celestial), with emphasis on technical understanding. The classes are held in the Metro Denver area in conjunction with the University of Colorado (Boulder & Denver), on 25 ft. sailboats locally, and aboard 50 ft. sailboats in the Caribbean (St. Thomas, USVI), Mexico (La Paz, Sea of Cortez), and US West Coast (San Diego, Channel Islands). Salary: $28,500 p.a. & bonuses.

1973-1972: **Research Associate (post Ph.D.)**, Dept. of Physics and Astrophysics, University of Colorado. I continued theoretical research work in high energy physics and taught classes.

1972-1961: **Teaching Assistant**, as above. I taught & assisted with lower & upper division physics courses & their related laboratories. As part of this, I conducted lectures & recitation sections as well as delivered seminars, etc.: Basic Physics, Classical Mechanics, Statistical Physics, Electromagnetic Theory, Nuclear Physics, Electricity & Magnetism, Classical & Relativistic Quantum Mechanics.

1972-1961: **Research Assistant**, as above. I participated in diverse research work in the following areas:
Experimental work: nuclear spectroscopy, nuclear magnetic resonance, optical pumping & laser phenomena.
Theoretical work: S-matrix theory, classical, relativistic, & statistical quantum mechanics, statistical physics, thermodynamics of plasma, propagation of electromagnetic waves in plasma (Landau as well as collision damping), high energy and elementary particles' structure.

1965-1963: **National Bureau of Standards (NOAA)**, Research/Chemical Engineer; (while attending the University of Colorado, Graduate School, Department of Physics and Astrophysics).
Experimental/theoretical work: cryogenics, thermodynamics of gases and materials at extreme pressures and temperatures, wave propagation in plasma, & steady state phenomena.

1961: **General Electric Co.**, Johnson City, NY. Field Liaison/ Electronics Engineer; represented GE at Republic Aviation Co., Farmingdale, (Long Island), NY; worked on fire control system and all related interphases during the manufacture of F-105 aircraft and provided electronics liaison.

1960: **Martin-Marietta Co.**, Littleton, Co. Systems Engineer; worked in support & design functions related to the development and manufacture of the Titan rocket.

1959: **Iron Fireman Manufacturing Co.**, Portland, Or. Development Engineer; work performed on a subcontract with General Dynamics Co. related to gyros, gyro pickoffs, relays, sensors, servo drives, and inertial guidance.

1959: **Aerojet General**, Sacramento, Ca. Development Engineer/Research; work related to the development and stability of solid state rocket propellants.

INTERESTS AND HOBBIES:

Current affairs, literature, music, chess, science, travel, mountaineering, skiing, sailing, flying, and camping.

PERSONAL:

Married/no children; excellent health and good physical condition; height: 5' 6", weight: 143 lbs.; birthdate: October 24, 1931, in Lodz, Poland; US citizen; involved in grassroots politics & community.

REFERENCES:

Professor Wesley Brittin, Dept. of Physics and Astrophysics, University of Colorado, Boulder, CO 80309. (303) 492-7169.

Professor Asim O. Barut, Dept. of Physics and Astrophysics, University of Colorado, Boulder, CO 80309. (303) 492-7169.

Professor Igor Gamow, Dept. of Chemical Engineering, University of Colorado, Boulder, CO 80309. (303) 492-6969.

Professor Jay Wolkowisky, Dept. of Mathematics, University of Colorado, Boulder, CO 80309. (303) 492-7565.

Jack Beckner, Ph.D. (Chemical Engineering), Senior Financial Analyst, Merrill Lynch Pierce Fenner & Smith, Inc. 1965 15th St., P.O. Box 7120, Boulder, CO. 80306. (303) 938-3922.

Ms. Virginia McDermott, Assistant Director, University of Colorado/Denver, Division of Continuing Education, 1200 Larimer St., Campus Box 164, Denver, CO 80204. (303) 556-2735.

Mr. Charles Corriere, President, Estimatic Corporation, and Corriere & Associates, 5350 S. Roslyn St., Suite 440, Englewood, CO 80111. (303) 779-1616.

Alan Nelson, Ph.D., President, Nelson & Associates, 41 Bridge Rd., Nederland, CO 80466. (303) 494-0183.

Mr. Leo Birkby, President, Monarch Energy Corporation, 1536 Cole Blvd., Golden, CO 80419. (303) 279-5536.

Mr. Robert Brown, President, Cable Investments Inc. 8400 E. Prentice Ave., Englewood, CO 80111. (303) 793-3344.

Col. Salvatore Villano, Commander, 142nd Tactical Control Group, Buckley ANG, Aurora, CO 80016. (303) 366-5363.

Brigadier General Floyd Snyder, Commander, 187th Tactical Transport Group, Wyoming Air National Guard, Cheyenne, WY 82001. (307) 772-6358.

APPENDIX/ACTIVE & RESERVE MILITARY SERVICE:

1979-1973:
154th Tactical Control Group, Colorado Air National Guard (COANG), Buckley ANGB, Aurora, CO.

Major, **Logistics & Maintenance Division,** Chief, Electronic Maintenance;
in charge of electronic maintenance, briefings, preparadness and operational status, training and support of the Group's subordinate units (Arizona, Colorado, Texas, etc.); liaison and planning with higher headquarters, Western Region HQ, Tactical Air Command, Bergstrom AFB, TX.
Operations Division, Weapons Director, Senior Director, operational/tactical control of airborne aircraft, air-to-air/ air-to-ground combat, theater air control and battle plans.

1973-1970:
305th Military Airlift Squadron (Reserve), Military Airlift Command, Tinker AFB, OK.

Major, C-124 Aircrew member, Master Navigator, navigator instructor, worldwide transport flights, assistant operations officer.

1970-1963:
187th Air Transport Squadron, Military Airlift Command, Wyoming ANG, Cheyenne Airport, WY.

Major/Captain, C-121, KC-97, KC-135 aircrew member, Senior Navigator, worldwide transport flights, including Vietnam, air-to-air refueling flights (Operation Creek Party), Rhein-Main AB, Germany; avionics instructor, assistant plans officer.

1963-1960:
HQ NORAD (Reserve), Ent AFB, Colorado Springs, CO.

Captain, **Directorate of Ground Environment/Electronics;** electronics maintenance, support, planning and analysis for ground radars, SAGE, BMEWS, special projects, liaison with major contractors, etc.

1960-1959:
137th Fighter-Interceptor Squadron, Oregon Air National Guard, Portland, OR.

1st Lieutenant, aircrew member, F-89H & J, radar navigator, weapons control officer, air training & electronics maintenance officer.

1959-1958:
655th Air Control & Warning Squadron, 655th Radar Squadron (SAGE), Air Defense Command, Watertown AFS, Watertown, NY.

1st Lieutenant (active duty), weapons controller, weapons director, senior director in charge of Weapons Control Center operations shift, tactical control of aircraft in air-to-air/air-to-ground combat.

1959-1957:
27th Fighter-Interceptor Sqdn., 465th Fighter Interceptor Sqdn. Air Defense Command, Griffiss AFB, Rome, NY.

1st Lieutenant, aircrew memeber F-94C, F-89D, & H, & J, radar navigator, weapons control officer, air-to-air operations, squadron intelligence officer, assistant electronics maintenance officer.

A New Method of Cold Fusion

Discharge on deuterium saturated palladium

Detected a large number of neutrons

A lecturer of Nagoya University and another person announced

Asahi shinbun (News paper) November 30, 1989

Lecturer Nobuhiko Wada of the Faculty of Science, Nagoya University and Associate Professor Kunihide Nishizawa of the Radioisotope Research Center, Nagoya University, announced that they were able to produce cold fusion by means of a new method in which a discharge is applied to palladium in which deuteriums are absorbed. Their paper was published in the Japanese Journal of Applied Physics which was published on the 29th. According to their paper a large amount of neutrons, 20,000 times that of natural background, were detected at one time and they were sure that they had a nuclear fusion.

After a report of cold fusion, in March this year in England, there were a few reports of neutron detection up to a few times its background, but this report of a very large number of neutrons is the first. It will be of interest to many people.

They placed two palladium wires, 2 mm in diameter and 2.5 cm in length, facing each other with a distance of about 4 cm, in a flask, 8 cm in diameter and 0.3 ml in volume. First, air was evacuated out of the flask and the surface of the palladium was cleaned by a discharge for 10 minutes; then the deuterium gas was injected to one atmosphere and the apparatus was sealed. They observed neutrons emitted to about a few times over the natural background in every hour.

After two days they applied a discharge between palladium wires for about ten minutes and observed neutrons of about 20,000 times over the natural background for one minute. After that, they observed neutrons up to about ten times over the natural background on and off for about 10 hours. They repeated this experiment three times, and observed the same result. When they replaced deuterium by ordinary hydrogen they did not see any neutron emission. Palladium absorbs about 800 times its own volume of deuterium gas. In this experiment, Lecturer Wada assumed that deuterium, as it comes out through the surface by the discharge, produces nuclear fusion because of its high density. This is quite different from the conventional method of electrolysis.

To detect neutrons they desensitized a detector so that it did not react to sources other than neutrons, such as gamma-ray. They think this made their detection of neutrons easier.

Mr. Wada said, "no paper with a clear description of experimental method has been published on cold fusion so far. I want our result to be tested by others."

A comment by Professor Noboru Oyama, Department of Engineering, Tokyo Agricultural and Engineering University (Electro-chemistry): "it is likely that nuclear reaction is taking place, since the neutron emission is as high as 20,000 times that of natural background. The number 20,000 is not ridiculous as I see from what I understand. It will be necessary to test the noise level of detectors and such by another independent group."

(The paper referred to in this article is in English, and a copy is enclosed

M. M.)

Jpn. J. Appl. Phys. 28, L2017 (1989)

Nuclear Fusion in Solid

Nobuhiko WADA and Kunihide NISHIZAWA†

Department of Physics, Faculty of Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-01
†Radioisotope Research Center, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-01

(Received August, 9, 1989; accepted for publication October 12, 1989)

Spontaneous neutron emissions were intermittently detected from activated palladium rods well soaked with deuterium gas in a closed glass bulb. By the stimulation of the palladium rods with a high voltage discharge between the rods, a burst of neutron flux 2×10^4 times larger than background was detected. Atoms or molecules of mass number 1, 2, 3, 4, 5 and 6 were found in the residual gas. Nuclear fusion in solid is interpreted in terms of the supersaturation of the solid solution of deuterium.

KEYWORDS: nuclear fusion, spontaneous emission, burst emission, deuterium gas, reaction bulb, activation, bombardment, solid solution, supersaturation, mass spectrum

Observation of nuclear fusion of deuterium (D_2) in the solid matter has been reported by a few authors.[1,2] They used the method of electrolysis of heavy water (D_2O) for the hydridation of palladium. We attempt the direct method of soaking palladium into deuterium gas in a closed shell.

The activation and soaking of the palladium rods were carried out in a reaction glass bulb of 300 ml with a pair of electrode stems, as shown in Fig. 1. The palladium 99.5% rods of 2 mmϕ × 35 mm were fixed to the Cu electrode stems. In order to activate the sample, AC voltage of 12 KV, 60 Hz was applied between the electrodes in vacuum of 1 Pa. In other words, the sample was bombarded. After the activation, the bulb was filled with D_2 of 1 atm. The purity of deuterium gas was 99.8% with a trace of tritium (T) less than about 10^{-11} mol/l.

The schematic arrangement of the experimental system is shown in Fig. 2. Neutrons were counted by using a BF_3 detector (Nuclear Enterprises Ltd. Neutron Monitor NM2B) and a multichannel analyzer (Inotec Inc. IT-5400). The neutron detector was calibrated with the neutron standard sources ^{241}Am/Be and ^{252}Cf at the National Electrotechnical Laboratory. The multichannel analyzer was used in the multichannel scalar mode and the integration time per channel was set for 9 or 0.9 seconds.

In order to raise the counting rates of the events, three reaction bulbs were set around the detector as shown. The pressure of deuterium in the reaction bulbs was measured by a pressure compound gauge ranging from 0 to 10^5 Pa (1 atm). The amount of deuterium gas absorbed into the sample was estimated by the variation of the pressure.

Figure 3 illustrates the time dependence of detected neutrons together with the pressure variation. The error bars for the points are not shown in Fig. 3 for simplicity, but they rang from ±100% (4 counts/hour) to ±3.8% (697 counts/hour). The average background of neutron flux (B.G. mean) was 1.99 counts per hour (CPH) and the standard deviation (σ) was 0.266 CPH. The counting rates of B.G. were distributed mostly in 0, 1, 2, and 3 CPH and occasionally 4 CPH and rarely 5 CPH. The counting rate greater than three times the standard deviation of B.G. (3σ) was counted as a significant event. But

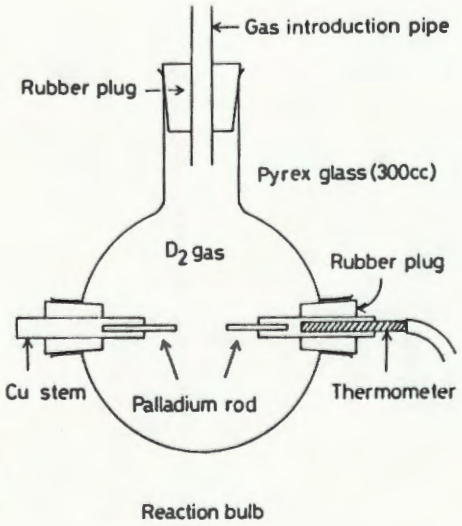


Fig. 1. Schematic diagram of the reaction bulb.

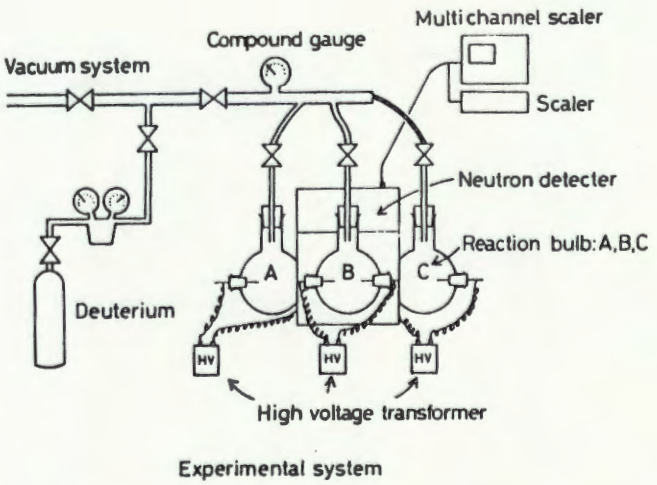
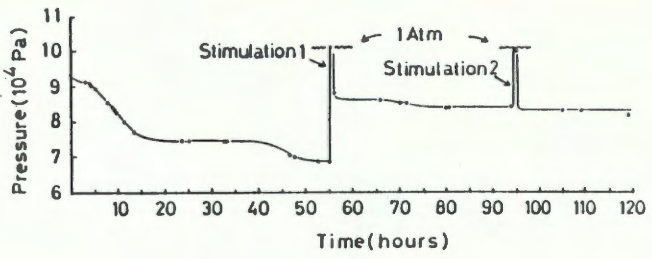
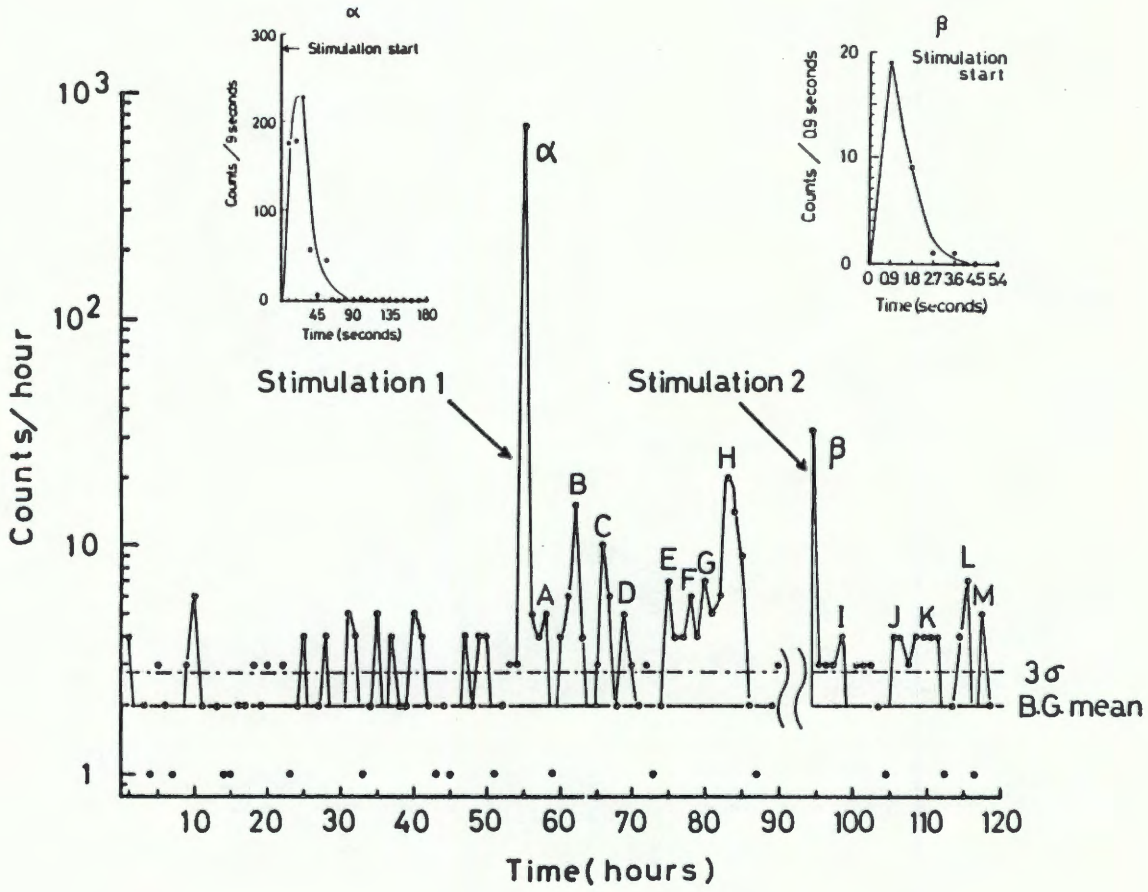


Fig. 2. Schematic diagram of the neutron measuring system.



(a)



(b)

Fig. 3. (a) Time variation of D_2 pressure in the reaction bulb. (b) Time dependence of neutron emissions and peaks after stimulation by high voltage discharge.

the events of three CPH were not counted even though they were larger than 3σ because they appeared often in B.G. The solid line and dotted line represent the levels of B.G. mean and 3σ respectively.

The activated sample began to absorb the deuterium gradually with time and the inner pressure of the bulb decreased as shown in Fig. 3(a). Very few emissions of neutrons were detected during this absorption process. The pressure showed a few plateau regions at different pressures. The spontaneous intermittent radiations of neutron were appeared in these plateau regions.

Stimulation of palladium rods with high voltage discharge was applied at 55 hours when the pressure was in the second plateau region. A burst of neutron emission just after starting of the 540-second stimulation. It co responded to the counting rate of 2×10^4 times larg than that of the background level (5.5×10^{-4} cps). The i ner pressure of the reaction bulbs rose by 2×10^4 Pa aft the stimulation, forming the 3rd plateau and the intermi tent neutron emissions were revived making several peak A, B, C, D, E, F, G, and H which showed higher rate o neutron emission than those of the 1st and the 2n plateau. The detailed α peak is represented by the left i sertion of Fig. 3(b). By the stimulation at 95 hour another burst β of neutron of 28 counts was detected in seconds but the counting rate was almost equal to that o the first (14 cps). The details are represented in the righ insertion. The periodical neutron emission peaks I, J, K

were detected by stimulation at the other plateaus of pressure which are not illustrated in Fig. 3 but their peak heights were weakened gradually. The used palladium never showed the emission of neutrons again, even though it was soaked with deuterium by the activation. The samples were consumed. Many cracks and holes were observed on the surface of the consumed sample by scanning electron microscope (SEM).

The same experiments were conducted with hydrogen gas instead of deuterium but no appreciable spontaneous neutron emissions nor the bursts of neutrons were detected, even though pressure variations similar to those for the deuterium were shown (Fig. 4). The possibility of detection of γ-ray emissions due to the nuclear fusion of hydrogen is thought to have been very small even if they were existed, because the detection of γ-ray noise of used detector was suppressed to low level deliberately.

After the experiment, the residual gas in the reaction bulb was analyzed by quadrupole mass spectrometer (ULVAC Co.). A substantial amount of atoms and molecules of the mass numbers 1, 2, 3, 4, 5 and 6 were observed (Fig. 5). The spectrum intensities of each number were very much influenced by the fractionation due to the character of the preferred evacuation of the ion pump used for the analyzing system. The molecular hydrogens (H_2, D_2, HD) should have been evacuated at the first step of injection of the residual gas into the system.

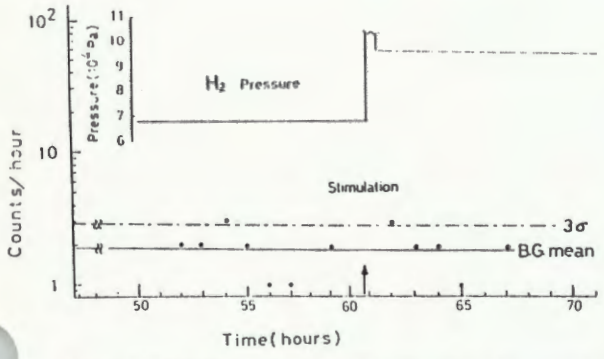


Fig. 4. Time dependence of neutron-detection for the experiment with hydrogen gas instead of deuterium. Stimulation is pointed by an arrow.

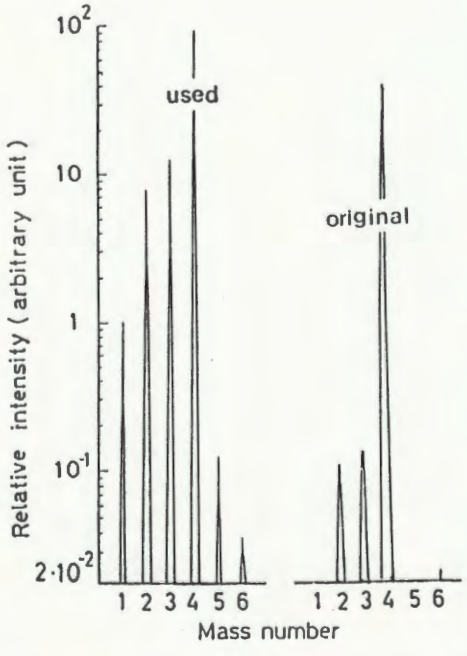


Fig. 5. Typical mass spectra of used gas in the reaction bulb and that of original deuterium gas.

The activation process used in the experiment was conventional procedures of the hydrogen storing technique in metals except that bombardment was used.

The emissions of neutrons were not detected during absorption and began spontaneously at the plateau region of the pressure variation curve. The burst of neutron was emitted accompanied by the burst of spouting absorbed deuterium gas in the sample. These facts suggest the following interpretations for the possibility of fusion in solids.

The well-saturated solid solution of deuterium will be supersaturated by raising temperature and the excess deuterium atoms in the solid should be exhausted as bubbled of deuterium gas. Thomson-Gibbs formula[3] of supersaturation of vapor pressure for the homogeneous nucleation is tentatively applicable to the nucleation of a deuterium bubble in solid.

$$\frac{P}{P_\infty}=\exp\frac{A}{rT}, \qquad (1)$$

where P is the equilibrium pressure of deuterium with solid solution; T, the temperature of the solid in Kelvin; A, the constant including atomic volume and surface energy of the solid; and r is the radius of the bubble. At the beginning of the nucleation, the radius of the bubble r is to be zero and the pressure P should be infinity. This means a very high rate of supersaturation should be created at the beginning of the nucleation of bubbles in the solid solution. It is very analogous to the bumping of bubbles in superheated boiling water. The high rate of supersaturation means a high density of deuterium atoms, which is just the condition for excitation of the nuclear fusions.

During absorption of deuterium into palladium, certain amounts of latent heat are to be released. If they exceed the natural dissipation, the temperature of the samples will be raised and the state of supersaturation of deuterium should be created. When the sample discards the excess deuterium gas, some neutrons will be emitted. The sample is cooled by the desorption of deuterium. At a certain desorption rate, the samples will cease desorption and begin absorption again. This alternating process of "breathing" of deuterium would explain the spontaneous intermittent emission of neutron at the plateau of the pressure variation. Application of high voltage between the sample rods will also work as an intense stimulation of abrupt supersaturation state that make instant bursts of neutron emissions.

The apparent ratio of absorbed deuterium and palladium rods D/Pd, was almost 1/3 at maximum. The most absorbed deuterium was distributed mainly in the surface layer of a certain thickness and not uniformly in

the whole sample at the beginning of absorption. As the time went on, the palladium became saturated layer by layer from the surface to the inside of the palladium rod. By the first stimulation, large amounts of deuterium in the first layer were exhausted instantaneously and the burst of neutron emission α was created. The small burst of neutron emission β stimulated 40 hours after the α might be emitted from the second inner saturated layer which absorbed smaller amounts of deuterium than the first one.

These mechanisms of fusion in palladium suggest similar results for the other metals. But the physical properties are different from the respective metals. The critical temperatures for the other metals are lower or higher than that of palladium. The latent heats for absorption are larger than that of palladium with positive or negative sign. This means that these other metals should be cooled or heated accordingly to allow absorption of deuterium. Palladium is the only metal that exhibits the nuclear fusion at room temperature except for some alloys used for hydrogen storing.

Acknowledgments

The authors express their thanks to Dr. H. Maekosh Nagoya University School of Medical Technology fc allowing use of his neutron detector and Mr. T. Goto for his electron microscopic observation of the sampl Mr. H. Mizuno for the optical spectroscopic analysis c the residual gas, Mr. M. Tani for the mass spec troanalysis and Mr. T. Satoh for making the instrumen in the Department of Physics. Also thanks are due to Mi N. Hamada, Y. Kameyama and Ms. N. Oguri for dat processing in the Radioisotope Center Medical Divisio

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Cold fusion is confirmed

Institute for Nuclear Fusion succeeded in confirming experiment of Nagoya University

Asahi Shinbun (Newspaper) Jan. 11, 1990

Professor Hideo Ikegami of the Institute for Nuclear Fusion* (located at Chikusa-ku, Nagoya), which is one of the facilities for all universities, announced on January 10 that he observed nucleons up to 1.7 billion times the natural background at one time in the cold fusion experiment by means of an electric discharge. In this way the cold fusion by means of a discharge, as announced by a group of scientists of Nagoya University last November and had been disputed pro and con, was finally confirmed by a third investigator.

The apparatus for this experiment was of about the same type as that of Lecturer Wada and others of Faculty of Science, Nagoya University: inside a flask of diameter 8 cm, volume 0.3 liter, were placed two palladium rods of diameter 3 mm, length 3.5 cm, facing each other with distance of about 4 cm. After pumping out the gas from flask, D_2 gas was injected to 1 atmosphere and sealed; let the whole thing stand for a few days so that the palladium was saturated by the deuterium.

In this experiment, within 1 second after a discharge by 12 kv, 450,000 neutrons, and within the next 1 second period 850,000 neutrons were detected. These were 9 million and 17 million times the naturally existing neutrons. In Wada's experiment, he detected neutrons about 20,000 times the background for the initial 1 minute period, and more than 10 times after the initial period for the remaining 10 hours, but in this case no such continuous emission of neutrons was detected.

In the experimental set up of Wada and others they could not distinguish neutron signals from electric and mechanical noises, but Ikegami had equipment to check for such noises, and he said that the resulting signal is certainly due to the neutrons.

In order to be useful as an energy source, it is necessary to have an emission of a few trillion neutrons per second continuously, or the Nagoya and present situations are not sufficient for practical purposes. Professor Ikegami, who is the chairman of the cold fusion research group, sponsored by the Ministry of Education and Research, composed of several cold fusion researchers of the nation, said: "now that cold fusion is confirmed, the research effort in our group will be given impetus. The next step is to find the mechanism of the nuclear fusion".

Lecturer Wada, upon hearing of the success of the nuclear fusion experiment said "I am delighted that they corrected the deficit in our experiment. We will make an efficient set up to produce a larger number of neutrons continuously, and try to find structure changes in palladium by electric discharge using an electron microscope."

(* This institute used to be the Institute of Plasma Physics, Nagoya University. Now it is independent of Nagoya University and directly supported by the Ministry of Education and Research. They are building a superconducting helical device. M.M.)

研究論文

強力な"Cold fusion"の達成

荒田吉明，張月嫦*

（近畿大学理工学総合研究所
*大阪大学溶接工学研究所）

(1989年11月6日受理／1989年12月7日改訂原稿受理)

Achievement of Intense "Cold fusion" Reaction

Yoshiaki Arata and Yue-Chang Zhang

(Received November 6,1989/Revised Manuscript received December 7, 1989)

Abstract

Intense generation of neutrons in "cold" fusion was achieved where "avalanche" phenomenon of neutrons emission was frequently observed by the deuterium forcedly penetrated into a palladium cathode (ϕ 2 cm × 5 cm). There found a very specific phenomenon of intense charge and discharge of deuterium in the Pd cathode during the continuous electrolysis of heavy water, and this was termed "on-off effect". While the Pd was strongly absorbing and exhausting deuterium, the thermal behavior of the Pd was examined in detail, and it was concluded that its feature and the generation of huge innerpressure of the Pd should be a necessary condition for the achievement of "cold" fusion reaction. It was clarified that a large amount of excess heat produced during the electrolysis was not due to "unobserved nuclear fusion" proposed by Fleischmann and Pons, but due to "reaction heat" which connected with intense absorption and explosive exhaust of the deuterium into and out of the Pd.

Keywords :

cold fusion, intense nuclear reaction, deuterium, heavy water-electrolysis, palladium-cathode, on-off effect, neutron,

緒　言

最近 Pd あるいは Ti にたいし，2種類の方法によって重水素が送り込まれ，いわゆる金属の存在によって，重水素による "Cold" fusion が発生したといわれている[1-3]．その1つは[1,2] 重水の電気分解によって金属の表面あるいは金属中に重水素を送り込むものであり，他の1つは[3] 高圧重水素中で金属の表面あるいはその

Research Institute for Science and Technology, Kinki University, Higashiosaka 341.
**Welding Research Institute, Osaka University, Ibaragi 567.*

Achievement of Intense "Cold Fusion"Reaction

Yoshiaki Arata and Yue-Chang Zhang*
Research Institute for Science and Technology
Kinki University, Higashiosaka 341
*Welding Research Institute, Osaka University, Ibaragi 567

Research in Nuclear Fusion, 62, 398-411 November 1989 (in Japanese)

(Translation of the text into English follows.)

Introduction

Recently reports[1-3] are published in which deuteriums were forced into Pd or Ti using two kinds of methods and resulted in a "cold fusion" of deuterons due to the existence of metals. One of them[1,2] is to put deuterons to the surface or bulk of metal by means of electrolysis, and the other[3] is to put deuterons to the surface or near area of metal under high pressure of deuterium gas. In both methods they observed only a small amount of neutrons emitted by the "cold fusion" of deuterons: up to or slightly above the background. Thus many scientists who tried the same experiments, particularly plasma physicists, denied the existence of "cold fusion".

For example the Caltech group (Lewis et al) [4] tried electrolysis "cold" fusion experiment for a long period of time under several conditions, using very sensitive detectors, but did not observe any "phenomena" (neutrons, γ-rays, triciums, ^{4}He, extra heat etc.), hence denied "cold" fusion completely. Many other scientists[5] had similar experiences. Nobody who had been supporting "cold fusion" by that time could refute that, because all they observed were neutron emission of near or slightly above background, and they had trouble in reproduceability and reliability of their experiments.

Thus the most important problem now is to prove that "cold fusion" really exists.

We, recently, obtained a positive result in response to that problem. We achieved intense "on-off effect" (to be explained below) on the Pd-cathode, activated by forcing deuterons in and out repeatedly, gave high "mobility" (increase of speed and freedom in direction of motion) and huge pressure on deuterons. Thus we investigated the thermal properties of Pd with large amount of deuterons inside, and found their important relations to the achievement of "cold" fusion. As a result we detected a remarkably large amount of neutrons in excess over the background. In some case they appear as avalanches; over 10^8 n/s in one case.

The phenomena were observed ten times during one month: for periods as short as 30 minutes and as long as 40 hours. Maximum of 10^{13} neutrons per case were observed, and it was difficult to attribute them to any other reaction than deuteron nuclear fusion.

All Pd-cathodes used by other scientists before us were much smaller than ours: they could not find characteristic heat properties of the Pd-cathode and strong "cold" fusion because of that. The unknown "nuclear fusion" with high yield of heat as proposed by Fleischmann and Pons[1] does not exist; the heat they observed must be the reaction heat produced when deuterons are absorbed into and emitted out of Pd-cathode explosively.

Experiment 1

Our experimental equipment is shown in Fig.1: bath is filled by D_2O+0.5%H_2O with small amount of LiOH or LiOD added. The cathode is mostly Pd, and compared with Ti. They are 20 mm in diameter and 50 cm in length. The anode is a platinum plate (width 50 mm, length 100 mm, and thickness 0.5 mm). The current density in electrolysis is 20 to 500 mA/cm^2, and 10 to 50 V is applied. The set up is kept in a temperature controlled water bath, at a given temperature T_o, outside which are 4 neutron detectors (BF_3 and ^{3}He), one multi-channel analyzer(1024 channels, connected to the BF_3 detectors and a display) and they are connected to automatic recorders, and one γ-ray detector.

Let the palladium which had strong "cold" fusion during the electrolysis be Pd●; an example of recorder chart of neutrons emitted from such Pd● is shown in Figs. 2 a) and b). In the case of Fig. 2a) the total intensity is about 10^3 mRem/h; the chart shown in the upper left is that of the "standard" nuclear source (^{252}Cf=10^5n/s, placed at the same location as the Pd●) observed by using the same detector, and the intensity is 0.8 mRem/h. Comparing the intensities for Pd● and ^{252}Cf we see that the number of neutrons emitted from Pd● is more than 10^8n/s. If nuclear reaction energy for 10^{10}n/s is 6 mWatt, the amount of energy produced in this case is 0.1 mWatt. Fig. 2b) shows maximum 10^7n/s continuous for 3 hours but with large fluctuation.

Next we analyzed the display of multi-channel analyzer during the emission of large amounts of the neutrons from Pd● and ^{252}Cf. Fig. 3 is the recorder chart (on logarithmic plot) of the neutron emission. A) gives that for neutrons from Pd● shown in the display through the BF_3 detector ($^{10}B+^1_0n\rightarrow{}^4He+^7Li$+2.78 MeV and $^4He+^7Li$+2.30 MeV), recorded during only 10 seconds. B) and C) are from standard neutron sources ^{241}AmBe(=2×10^6n/s) and ^{252}Cf(=10^5n/s), recorded for 10 minutes and 3 hours, respectively. D) shows background for 100 hours. B-1), C-1), and D-1) show those of AmBe, ^{252}Cf, and background, respectively, for

10 seconds. When we compare them to A) we see that the number of neutrons produced in 10 seconds in this experiment is comparable to that in 10 minutes by ^{241}AmBe shown in B), and that in 3 hours by ^{252}Cf shown in C). For the background we see that the noise increases with time, but no phenomenal change even after a long period of time. Fig. 4 is in linear plot with 10^3 as its full scale in contrast to Fig. 3 which is in log plot. A) is the record of neutrons produced by ^{252}Cf in 6 hours and B) is that of neutron burst produced by Pd● after producing neutrons for 40 minutes. In this photograph, ^{252}Cf gives 11 counts for 568 channels and a spread between 568 to 668; on the other hand, the Pd● count number is 143 for 40 minutes in channel 568, which is over the full s cale of 100, resulting in avalanche of count points in all channels in the display. We, therefore, took the photograph B) in a short period of time of points of count display at 40 minutes after a continuous neutron emission started. At least we see that Pd● emits by far a larger number of neutrons than ^{252}Cf. Patterns similar to Fig. 3 and 4 are obtained every time when recording similar to Fig. 2 is obtained. In other words, these recordings are obtained by different detectors simultaneously.

Thus we have shown that intense deuteron nuclear fusion appears with avalanche phenomena.

Experiment 2

Next we investigated the thermal properties of Pd-cathode which contains a large amount of deuterons. These properties are related to the production of "cold" fusion. Let the temperature near the center of Pd-cathode be T_2 and that of D_2O be T_1 (which has large local fluctuation), and that of thermal water bath which contains them be T_o (which is controlled to be constant); then we see that as we switch "on" and "off" the electrolysis current they change as shown in Fig. 5: when the current is "on" we see $T_2>T_1>T_o$, but when the current is turned "off" T_2 decreases much faster than T_1, and come to T_o almost simultaneously. If we "on" again at this situation T_2 increases faster than T_1 going back to the original situation. This phenomenon is reversible, and is an important thermal property of Pd-cathode. This is accompanied by Joule heat W_J and reaction heat W_R (due to absorption and emission of deuteriums by Pd), and their sum $W_1(=W_J+W_R)$. When heat emitted by Pd as it absorbs deuterons is R_{exo}, and that absorbed by Pd as it emits is R_{endo}, then $|R_{exo}|=R_{endo}(=W_R)$. In our experiment $W_1/W_J=1.5$, or $W_R/W_J=0.5$, showing that a large amount of heat appears and disappears inside Pd-cathode, and obviously the amont of heat depends on the

amount of deutriums contained. If that amount is large, T_2 increases or decreases more. We call this phenomenon "on-off", namely 「on-off of the current」. This phenomenon is reversible which is an important thermal property of Pd.

For the Ti-cathode we find $W_R=0$ and $W_1=W_J$. Thus Ti cannot absorb deuterons, or the deuterons penetrate only near its surface with a negligible reaction heat and a negligible change in T_2. This is a big difference from Pd, hence Ti-cathode is not suitable for intense "cold" fusion. This is because a deuterium -Ti compound is formed on the surface which prevents deuteriums from penetrating into the bulk of Ti. We see, for example, when current is turned "off" in the Pd-cathode tiny bubbles come out violently for a few minutes, but nothing like that seen in the Ti-cathode.

We tried to improve the Ti-cathode by fusing Pd and Pd-Ti powders around the Ti-cathode to a few hundred microns. When the electrolysis is started, we see deuteriums are absorbed rapidly at the beginning as in the Pd-cathode, but that is only for the fused surface layer, not on the Ti-cathode itself, resulting in big cracks at the interface of the surface layer as shown in Fig. 6. Thus we need to change the properties of Ti fundamentally or continue the research of the surface layer, if we want to use the Ti-cathode

Experiment 3

We will state the thermal properties of Pd-cathode closely related to the "cold" fusion. The relation is stronger than that shown in experiment 2. Fig. 7 shows that as we increase T_o to some extent, the temperature of Pd-cathode T_2 increases rapidly and then goes up and down near a given temperature spontaneously; this is a "new phenomenon". It appeared about 50 times in 20 hours in our experiment. We measured such alternative temperature change every 2 hours, and let the maximum of T_2 during one 2 hours as T_M, the minimum of T_2 as T_L, and the temperature amplitude as ΔT_M ($=T_M-T_L$); they are illustrated in the upper part of Fig. 7. Fig. 8 shows experimental values of T_M, T_L, and ΔT_M. We see that $\Delta T_M=30^oC$, hence the reaction heat due to absorption or emission of deuterium, $\epsilon_{\Delta T}$($=MC\Delta T$) is 360 cal(=1.5 kJ) if M=200 g and C=0.06 cal/deg.g. Since the average time interval for this temperature change is about 80 sec, the average power is 20 Watts. This large average power is actually not due to an unknown nuclear reaction as Fleischmann and Pons[1] assumed, but simply due to the explosive absorption and emission of the deuteriums in and out of Pd. Next we will explain this "new phenomenon" in more detail. The ratio (D/Pd) depends on the temperature of Pd as shown in Fig. 9, which exhibits a characteristic hysteresis curve. Between 80^oC and 110^oC the ratio changes very much; from about

60% to 5%. If we take T_L=20°C and T_H=300°C the change is from 70% to 1%. Since the ratio is extremely small for $T_H \geq 110^\circ$, the deuterium is emitted explosively from the surface of Pd, and results in a rapid drop of T_2. When $T_L \leq 80^\circ$ deuterium is absorbed like an avalanche by Pd, resulting in a rapid increase of T_2. This is the reason of the spontaneous oscillatory appearance of ΔT_H.

Fig. 5 shows a phenomenon due to the "on-off" of current, as previously stated. We see, when Fig. 5 is compared with Fig. 7, they both have the same characteristics. However, the reaction shown in Fig. 7 is 10 to 100 times more intense than that of Fig. 5, so we call this new reaction an "on-off effect". We designate Pd which experienced this effect as Pd^*, and call the temperature range $\Delta T_{80\rightarrow 110}$ as "on-off range".

In order to understand these "on-off" states, we take the following two examples. In the first example we take Pd saturated by the deuterons at 30°C and put that into an oil of 150°C. Pd is oversaturated by the deuterons and emits deuteriums explosively to produce a strong upward stream of oil. This stream of oil is more violent than that in "Tenpura" of water containing food. Similarly when Pd prepared as before at 30°C is placed in a vacuum oven and heated to 110°C, it emits a large amount of deuteriums so rapidly that our vacuum pump cannot keep up (650 l/sec). As a result, the oven stays at atmospheric pressure for a long time. In other words, a high pressure appears instantaneously inside the Pd^*, which is deformed and pushes out deuterium explosively. For example, for 99.85% pure Pd the Vickers hardness index is V_H=38, and the maximum strength is σ_B=17.5 kg/mm^2, and Pd saturated by deuteron has about three times of this value, V_H~110, which implies σ_B~50 kg/mm^2 (=500 atmosphere). Thus when Pd is super-saturated to get about 4% plastic deformation, its inner pressure must be at least 5000 atmosphere, and probably more.

In the case of spontaneously oscillating "on-off effect", the inner temperature of Pd takes its maximum T_2, hence the above stated effect appears near its center axis first, resulting in bulging of both ends of the cylindrical cathode by about 1 mm, as shown in Fig. 11(a); this corresponds to about 4% plastic deformation. When maximum T_2 appears out of the central axis, the cathode is deformed like a bent-nail, as shown in Fig. 11(b). This phenomenon is proof that the inner temperature of Pd is higher than the boiling point of the electrolysis liquid, or higher than 110°C. However, because of the "on-off effect", the increase of the inner temperature T_2 of Pd^* is strictly limited, to prevent melting or evaporation. The reason is that, due to $T_H(\geq 110^\circ)$, the deuterons cannot stay in Pd^*, resulting in explosive emission to

emphasize cooling effect. No one so far has measured the temperature of Pd itself. Instead people measured that of the electrolysis liquid or the surface of the cathode, but the measurements do not reflect the thermal properties of Pd, and this leads to wrong conclusions such as of Fleischmann and Pons; hence one has to be careful. We heard an explosion, heating, and ignition a few times near the surface of the Pd, but they must be outside the Pd, not due to an inner reaction. As very active deuteriums come out of the Pd surface as minute bubbles, the current must decrease rapidly inducing a high voltage locally which produces ignition with spark, or burning some impurities. In these cases, the increase of Pd temperature is only 1 to 2 degrees, thus it is not due to any inner reaction of Pd, nor due to an unknown "cold" fusion reaction [1]. The "on-off effect" of Pd cathode is, therefore, the most important property among others.

After an explosive emission of deuteriums from the Pd surface, we polished the surface as we do for a microscope preparation, and after 1 to 2 hours sealed it in a vinyl bag with small holes for 3 days. We observed that the surface was wet with D_2O and the bag contained about 3 cc of D_2O. This must be the active deuterium which has reacted with oxygen in the air. No such phenomena were observed with respect to Ti-cathode, but we saw some microscopic small powder pieces as shown in Fig. 12. They must be some compounds of Ti and deuteriums as stated in experiment 2.

Discussions

We used a much larger Pd-cathode and Ti-cathode than anyone else. Many scientists used a very small cathode, such as 1 mm thickness of string or foil, but with such small cathodes there are a few causes to prevent "cold" fusion. One cannot measure temperature or its change of the cathode. Even when exo- or endo-thermic reaction appear, any extra heat will be absorbed quickly by the electrolysis liquid, making it difficult to detect them, and the temperature of liquid cannot exceed its boiling temperature. Particularly, the Pd-cathode will be rapidly saturated by the deuterium rapidly to form a stable PdD_x, and cannot expect to have the strength to endure the very high inner pressure. Under such condition, the mobility of deuterons necessary for the nuclear reaction is lost; one cannot have "cold" fusion forever in electrolysis.

Nobody previously noticed that smallness of the cathode is a fatal mistake. We realized that from the beginning and designed the cathode to have diameter 2 cm and length 5 cm. In this way we can measure the temperature of its center, T_2, accurately, and independently from its surface temperature, T_1, which is also the temperature of the liquid electrolyte. Thus we can find its change due

to exo- or endo-thermic reactions. Only in this way we find the appearance and properties of "on-off effect". We think that the size of our cathode happens to be appropriate for the "cold" fusion.

We want to emphasize this: scientists both pro and con on the existence of "cold" fusion have only tried electrolysis for a long time. For example, those who denied the phenomena used high precision detectors and tried electrolysis for days and months, but could not find any phenomenal change, while those who were for the "cold" fusion insisted that even if it were so low that one needs to have statistical treatments, one should be able to detect some results if the electrolysis were continued for a long time. They both had electrolyses with the same conditions, but extracted opposite conclusions to our surprise. We feel that both of them had implicit mutual understanding that only if one is patient enough, electrolysis would produce "cold" fusion someday. We, however, think that simple electrolysis will never, even for months or years, produce strong "cold" fusion. Actually electrolysis for a longer period than a critical value would make it worse.

We think that the minimum condition for strong cold fusion is to activate the Pd surface and push deuteriums into Pd as quickly as possible. An electrolysis for a long period of time renders the surface inactive and sometimes prevents deutrons from penetrating it. Also, it is necessary to polish the surface now and then. Another important point is to make the density of deuterons inside the Pd as high as possible and give them intense pressure and mobility (both in speed and direction of motion).

To satisfy these conditions, we applied deuteron saturated Pd to the "on-off effect", making Pd into Pd^*; then kept "current-on" this Pd^* for 2, 3 days to produce deuteron saturated Pd^*, still keeping "current-on" for about 3 hours to polish the surface, and again kept "current-on" for 2, 3 days to have strong avalanche of "cold" fusion, namely achieved the transformation $Pd^* \rightarrow Pd_{\bullet}$.

Among the two Pd-cathodes we used, successful results were obtained with the Pd which is shown in Fig. 11a); we obtained above stated results 10 times during one month. For the one shown in Fig. 11b), as shown in Fig. 13, measured by high sensitivity enclosed BF_3 neutron detector (NPC-101.Aloka) and in Fig. 14, measured by ^3He neutron detector modified as enclosed form (TPS-451 S.Aloka), only a weak but true neutron emission, a few times stronger than that of the background. In Fig. 15 upper limit of background noise of each detector is shown for this case. We thus found many of the necessary conditions for "cold" fusion, but we have to find differences for the case of Figs. 2, 3, and 4, and case of Figs. 13 and 14. We also have to learn more about when the reaction appears and disappears. We are going to investigate the necessary and sufficient conditions for "cold" fusion. It will also be important to measure neutron energies and other reaction products.

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Note added in proof (received on Dec. 19, 1989.)

Strength of "on-off effect" varies. We gave insufficient "on-off effect" on the cathode two times, on Dec. 6 and 7, and investigated resulting neutron emissions. In both of these cases, we obtained results similar to each other: the following Figure shows their results as obtained using ^{3}II modified as enclosure type (TPS451S.Aloa) and more sensitive enclosedBF_3 (NPC-101.Aloka), both connected to the same pen-recorder, as in the case of Fig. 15 of the text, and recorded on the same paper. Strong neutron pulse emitted by Pd● is recorded by both detector simultaneously; peaks A-A, B-B, C-C, D-D, and E-E correspond to each other. These pairs shift by 3 mm in each case, but that is because pens were separated by that amount.

In this way, we see that Pd● emits neutrons intensely, and that is closely related to the "on-off effect".

Fig. 1 Experimental set up.

A glass beaker contains 300 cc of D_2O with 0.03, 0.05, and 0.1 units of LiOH and LiOD. These are made from Li metal. The cathode is suspended by a gold plated Ti rod of diameter 5 mmϕ, and positioned 2 to 3 mm below the top of the liquid. The electric current and potential are 2 Amp and 15 volt, and 25 volt in most cases.

Fig. 2 a) Recorder chart for neutrons emitted from Pd● (BF_3 detector 2202D, made in Sweden.)

Recorder chart at upper left is the one for a "standard neutron source" ^{252}Cf ($\sim 10^5$ n/s), placed at the same position as Pd●, by the same detector, showing intensity of 0.8 mRem/h. The neutron emission from Pd● was observed 10 times in one month. The intensity was over 10^3 mRem/h twice, was about 10 mRem/h three times, and was in between them at other times. Comparing with ^{252}Cf, we see that the maximum intensity was found to be 10^8 n/s.

Fig. 2 b) Another recorder chart for neutron emission from Pd●.

In this case maximum neutron emission intensity was 10^7 n/s and lasted for three hours.

Fig. 3 Display (log-display) of neutron emission from Pd● by multichannel analyzer (BF_3 type, number of channels is 1024).

To emphasize the importance of the display for neutron emission from Pd● A), it is compared with B), C), and D), which are for standard neutron sources, $^{241}AmBe$ ($\sim 2\times 10^6$ n/s), ^{252}Cf ($\sim 10^6$ n/s), and the background, respectively. In order to show that neutrons are really emitted from Pd● we pick up the 568th channel, which is suitable to show neutrons from standard sources, $^{241}AmBe$ and ^{252}Cf, indicated with a horizontal bar in the display, and compare them with the patterns which appear in the 100 channels between this and the 668th channel. Thus we can compare the patterns in these 100 channels for the duration time τ to find the neutron emission. For example, A) is the display pattern for neutrons emitted from Pd● for only 10 sec (τ =10 sec), and is comparable to B) which is from $^{241}AmBe$ for τ =10min, and C) which is from ^{252}Cf for τ =3hrs. Also compared with B-1), C-1), and D-1), which are τ =10 sec like A), we see remarkable differences. Thus we see how a large number of neutrons are emitted as an "avalanche" from Pd●.

Fig. 4 Display (linear display with full scale 10^2) of neutron emission from ^{252}Cf compared with that from $Pd_{\bullet}$.
A) Neutrons from ^{252}Cf ($=10^5$n/s) for 6 hours.
B) Neutrons from $Pd_{\bullet}$ ($=10^8$n/s) for a short period of time after 40 minutes of emission.

Fig. 5 Relations between T_2, temperature inside the Pd-cathode, T_1, temperature of liquid which depends largely on location, and T_o, which is the controlled temperature of the thermal bath when the electrolysis current is on and off. When the current is "on", we see $T_2>T_1>T_o$; this is because deuterons are absorbed by Pd as an exothermic reaction. When the current is "off" deuterons are emitted from Pd as an endothermic reaction. In this experiment the reaction heat was about half of the Joule heat. In the case of the Ti-cathode such reaction heat was negligible compared to the Joule heat.

Fig. 6 Cracking of fused layer on the Ti-cathode.
Deuterons are absorbed by the layer of Pd and Pd-Ti powders fused to the thickness of a few hundred microns, as by the Pd-cathode, but they are not absorbed by the Ti-cathode itself, resulting in the cracking at the interface. The Ti-cathode is not suitable for "cold" fusion.

Fig. 7 Thermal property of the Pd-cathode during the "on-off effect". It looks similar to the "on-off" of the current shown in Fig. 5, but in this case it is independent of the current "on-off". Explosive deuterium emission and absorption appear spontaneously while current is on, and a large amount of heat is given off to the liquid. This is not due to the unknown "nuclear reaction" as proposed by Fleischmann & Pons. This effect of deuterium emission and absorption is 10 to 100 times stronger than that for Fig. 5. The driving force to produce this phenomenon is due to the characteristic hysteresis (Fig. 9) of the temperature dependence of the deuteron saturation amount in relation to Pd.

Fig. 8 Variation of the inner temperature of the Pd-cathode due to the "on-off effect"; T_M is the maximum, T_L is the minimum, and ΔT_M is the amplitude for a given two hour period.
This ΔT_M appears spontaneously by the "on-off effect", and is about 30°C on average; but this large reaction heat is not due to the unknown "nuclear reaction" as stated with regard to Fig. 7.

Fig. 9 The temperature dependence of the ratio deuteron/Pd.[6] There is a characteristic hysteresis at 80°C and 110°C for deuterium, and that is the cause of the "on-off effect" and ΔT_M of Fig. 8. For the hydrogen, however, the hysteresis loop is above 100°C, (120°C to 150°C), hence no "on-off effect" or ΔT_M appears under one atmosphere unless something is done. This makes a large difference between deuterium and hydrogen with respect to Pd.

Fig. 10 An example of "on-off effect".
When Pd is saturated at 30°C is heated in a vacuum oven, an explosive emission of deuterium appears at around 110°C, and that disrupts the work of the vacuum pump.

Fig. 11 Deformation of the Pd-cathodes under the "on-off effect".
In (a) the maximum inner temperature T_M appeared along the center axis of the Pd-cathode; due to a very large internal pressure induced by the "on-off effect" both ends of the cathode bulged up by more than 1 mm, giving 4% plastic deformation. In (b) T_M appeared off the center axis, and is bent by about 15°.

Fig. 12 Powders which came out of the Ti-cathode.
After a long time of electrolysis, we placed the Ti-cathode in a vinyl bag for 2, 3 days. These powders came out automatically; they were shiny silver white, probably they were deuterium-titanium compounds. Their thickness was about 100 microns, length was as long as a few mm, and most of them were spiral in form. The unit shown is 1 mm.

Fig. 13 An example of weak neutron emission (A).
The Pd-cathode shown in Fig. 11 (b) was used. In this case only a few times of background neutrons were emitted. The detector used was a highly sensitive enclosed BF_3 neutron detector (NPC 101.Aloka).

Fig. 14 An example of weak neutron emission (B).
This time a ^3He detector(TPS 451S.Aloka), modified to be an enclosed form, was used.

Fig. 15 Measurements of background of each detector.
The upper limit of the background of detectors we used are shown and compared to each other.

Fig. for the note added in proof.
Simultaneous measurement of a neutron emission by ^3He and BF_3 detectors.

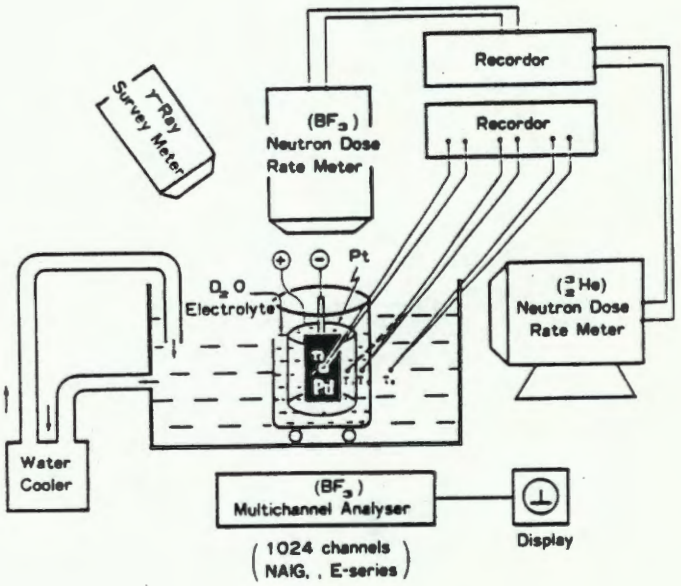
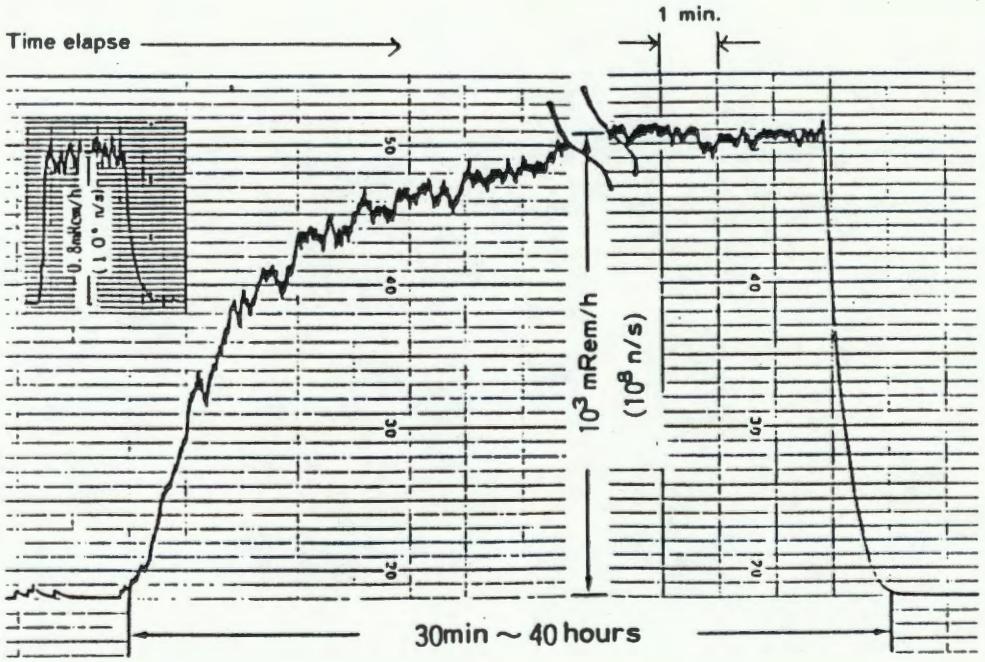
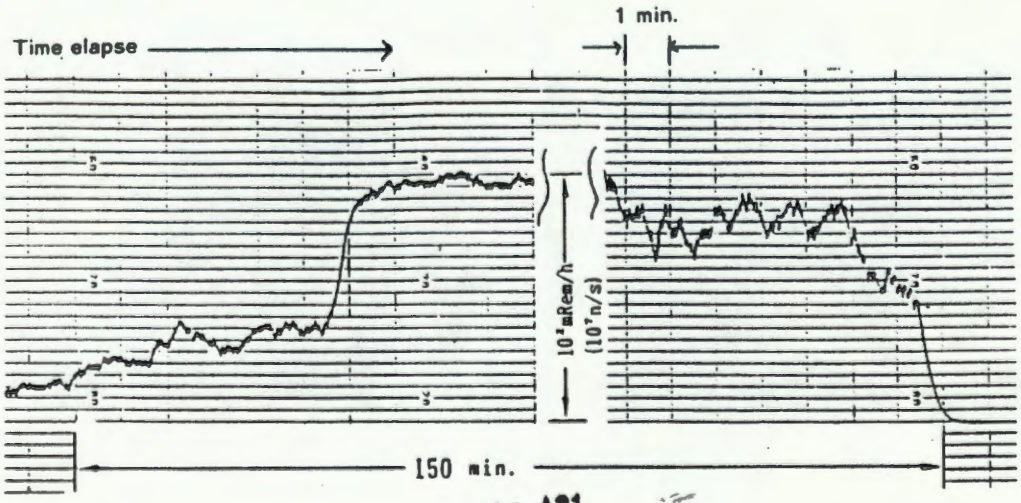


Fig. 1



a)

Fig. 2a



b)

Fig. 2b

A21

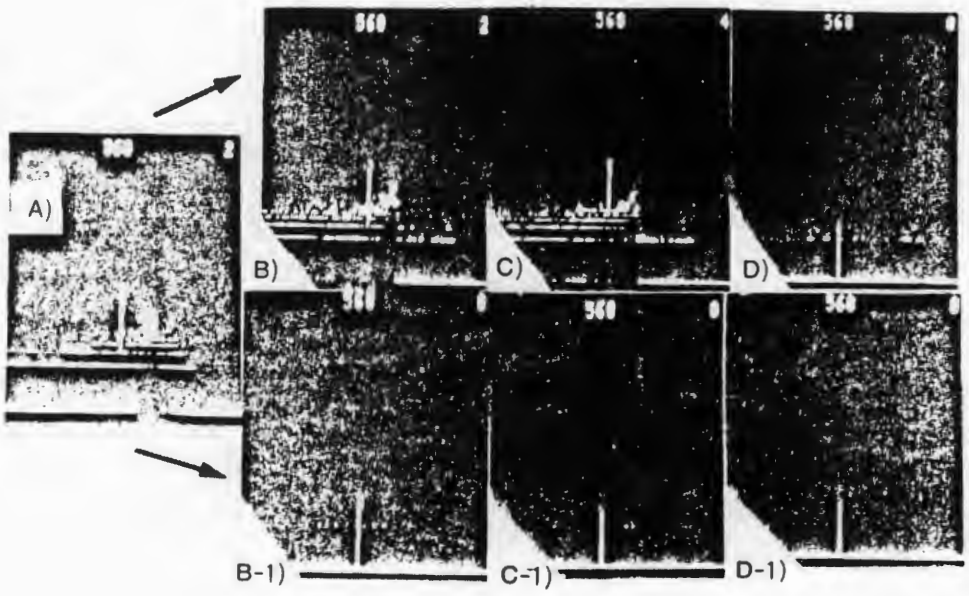
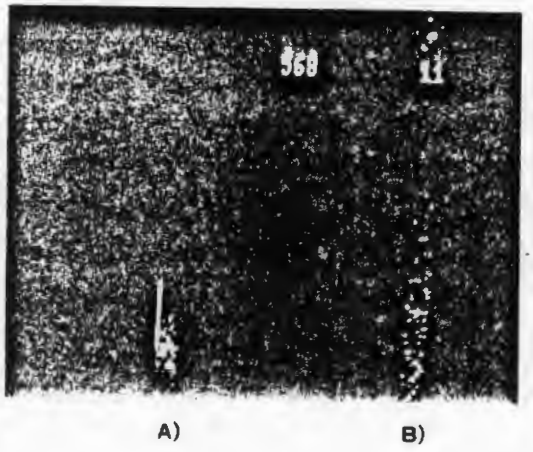


Fig. 3

Fig. 4



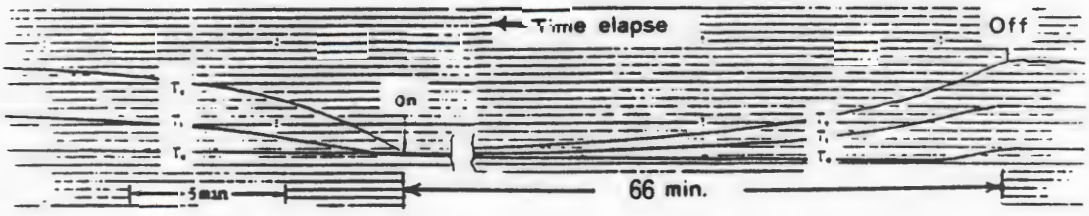


Fig. 5

Fig. 6

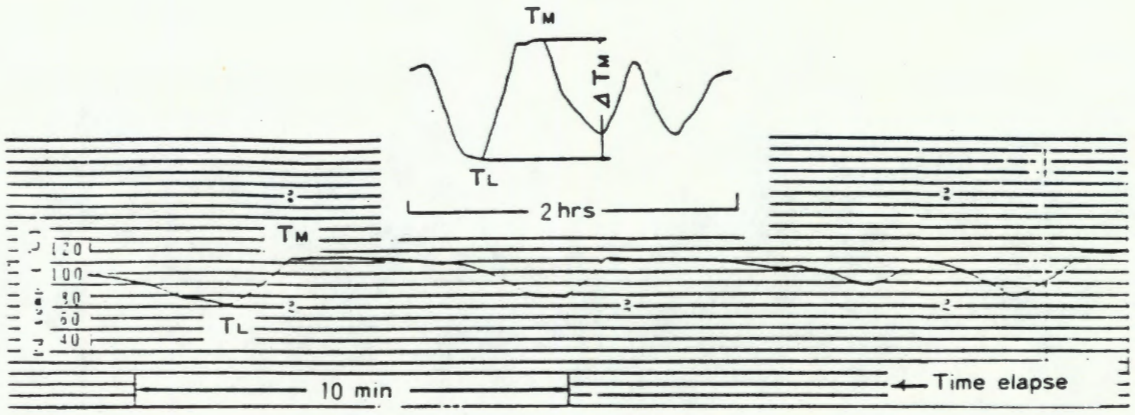


Fig. 7

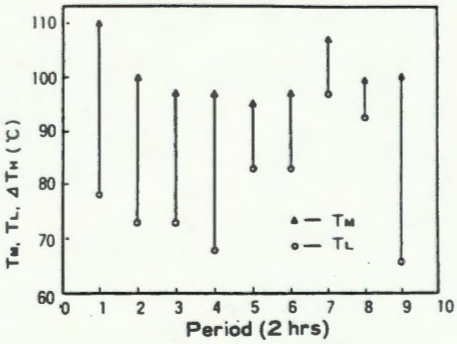


Fig. 8

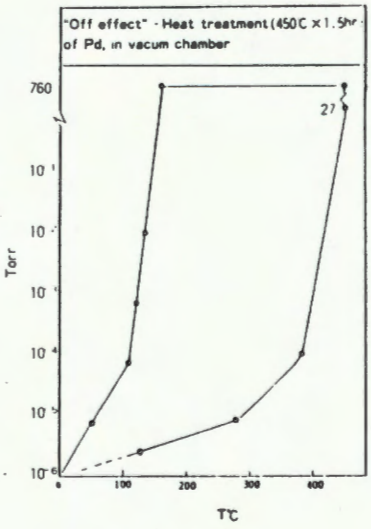


Fig. 10

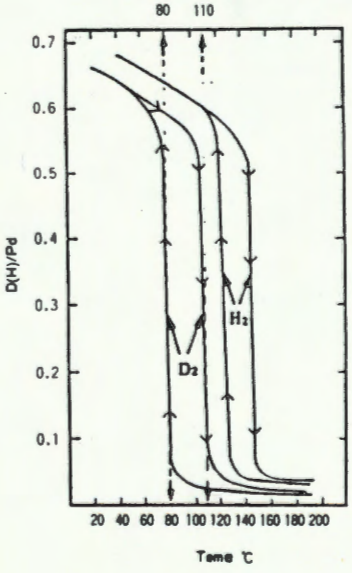


Fig. 9

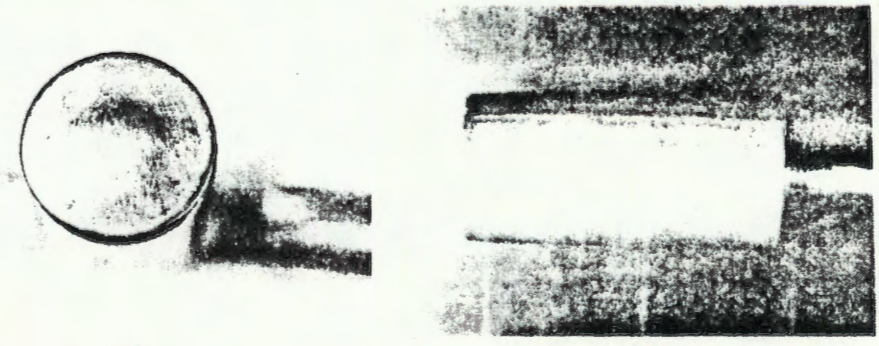


Fig. 11

Fig. 13

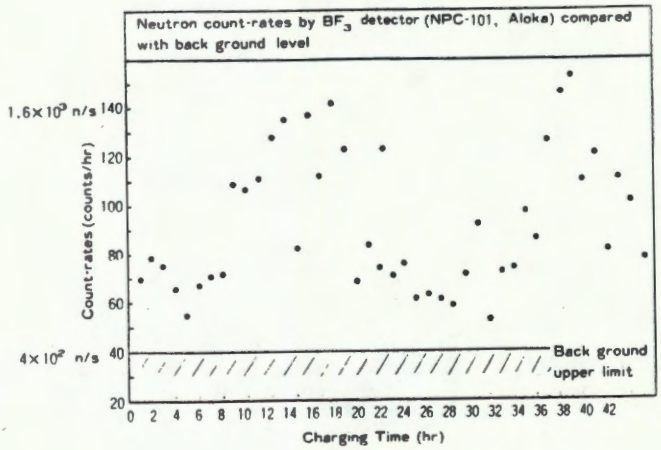


Fig. 12

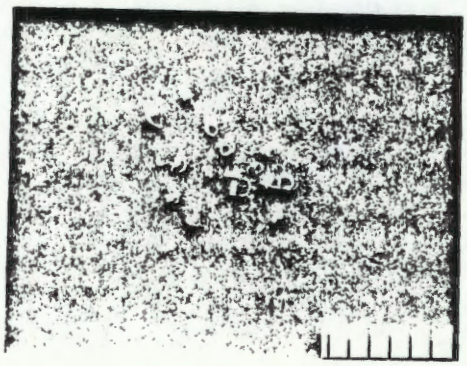


Fig. 14

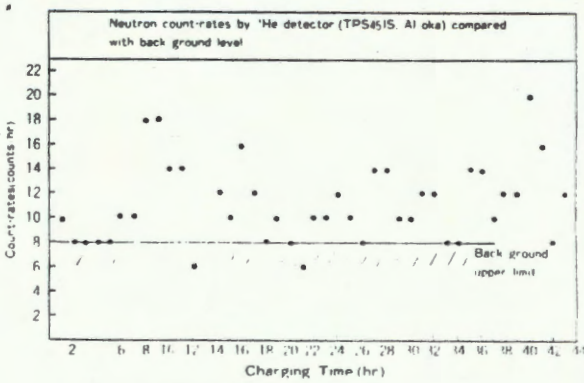
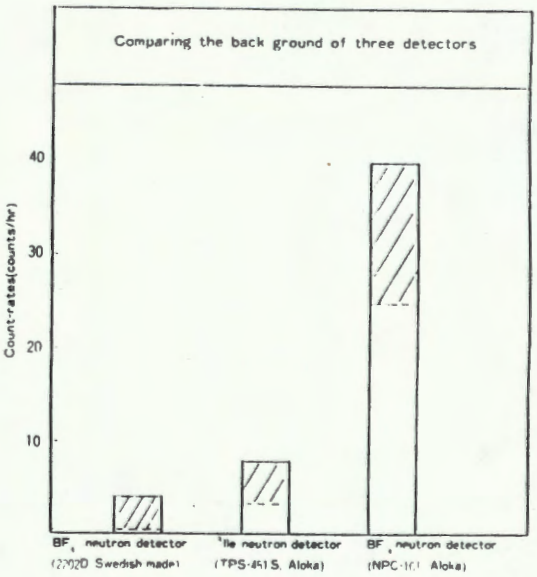


Fig. 15



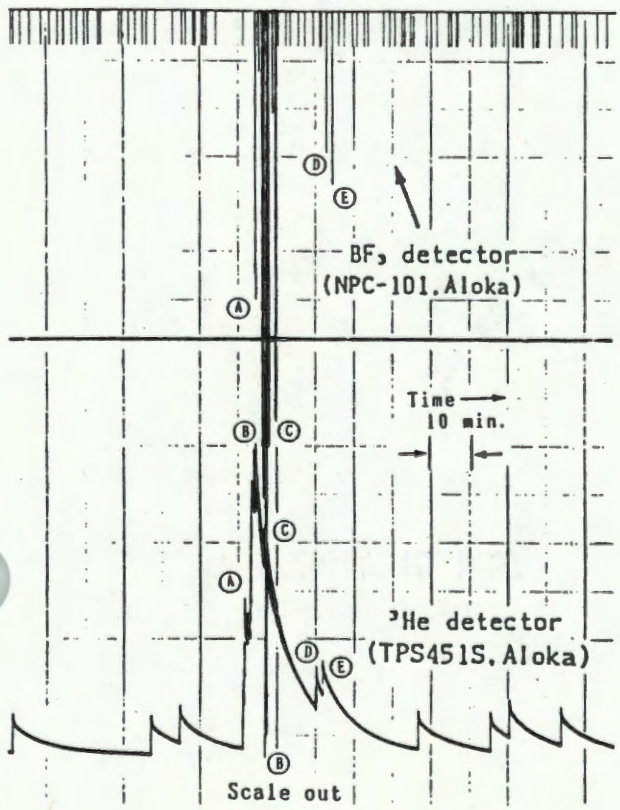


Fig. for the note added in proof