DETECTION OF NEUTRONS IN ELECTROLYSIS OF HEAVY WATER

COLD FUSION

TECHNICAL NOTE

KEYWORDS: *cold fusion, heavy water electrolysis, neutrons*

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Neutron measurements are conducted during heavy water electrolysis in a glass cell equipped with a palladium cathode and a platinum anode set in separate electrode compartments. The electrolysis shows neutron emission peaks at 5 h (runs 1 and 2) and at 20 h (run 3) after start-up. The neutron emission peaks were clearly detected by independent A and B ^{3}He counter channels; the peak values exceed 3σ. The neutron emissions are confirmed to occur in bursts.

INTRODUCTION

Since Fleischmann and Pons[1] and Jones et al.[2] announced their experimental observations of cold fusion, fusion reactions at ambient temperatures have been a worldwide topic and experiments have been carried out at many institutions. Some research groups claim to have detected either neutron emission or excess heat generation in their cold fusion experimental apparatus[3-7]; the observed neutron emission rates, however, have been very small in most cases. Cold fusion has been characterized as a very rare phenomenon with poor reproducibility and it is still a controversial issue.

The neutron release process first suggested by Jones et al. is a nonsteady-state phenomenon. Many experimental results have suggested that the neutrons are released in bursts. Thus, the heavy water electrolysis in cold fusion experiments must continue over a long period before neutron emission is detected. The major obstacle to improved reproducibility of neutron emission has been the long experimental electrolysis time.

In this paper, we attempt to improve the reproducibility of neutron emission detection by shortening the electrolysis time. For this purpose, the palladium electrode is pretreated to ensure deuterium saturation in the electrode before electrolysis.

EXPERIMENTAL

Electrolysis

The electrolysis cell is shaped like an "H" with two separate electrode compartments and a connecting bridge. The anode is a platinum plate (10 × 90 × 0.2 mm thick) and the cathode is a palladium plate (50 × 50 × 0.2 mm thick, 99.95% pure with the major impurities being 20 ppm silver, 10 ppm gold, 50 ppm platinum, and 30 to 50 ppm silicon). The cell contains a 1 M (mol/dm^3) LiOD heavy water electrolyte solution prepared by dissolving lithium metal in heavy water. The heavy water was purchased from Nippon Sanso Company (originally supplied by ISOTEC Inc.). The cell is equipped with condensers at the tops of both electrode compartments to reflux the evaporated D_2O. The condensers were cooled by circulating water. The current of the electrolysis was 1 A (20 mA/cm^2), supplied by a stabilized power source.

Palladium Electrode

Before electrolysis, the palladium electrodes were pretreated in the following way:

1. annealing at 800°C for 3 h in vacuum (10^{-3} Torr)
2. cooling and then contacting with D_2 gas (at a pressure of 15 atm) at room temperature for several hours
3. evacuation of D_2 gas and then heating at 400°C for 2 h
4. cooling again and then contacting with D_2 gas (at a pressure of 20 atm) for >12 h.

Thus, the palladium electrodes were fully charged with deuterium before the electrolysis. This pretreatment was carried out in a tube-type vessel. In order to place the palladium plate into the vessel, it was wound around a small rod. This winding allowed the electrode plate to be set in the cylindrical electrode compartment of the cell as well. The shapes of the electrolysis cell and the palladium electrode are illustrated in Fig. 1.

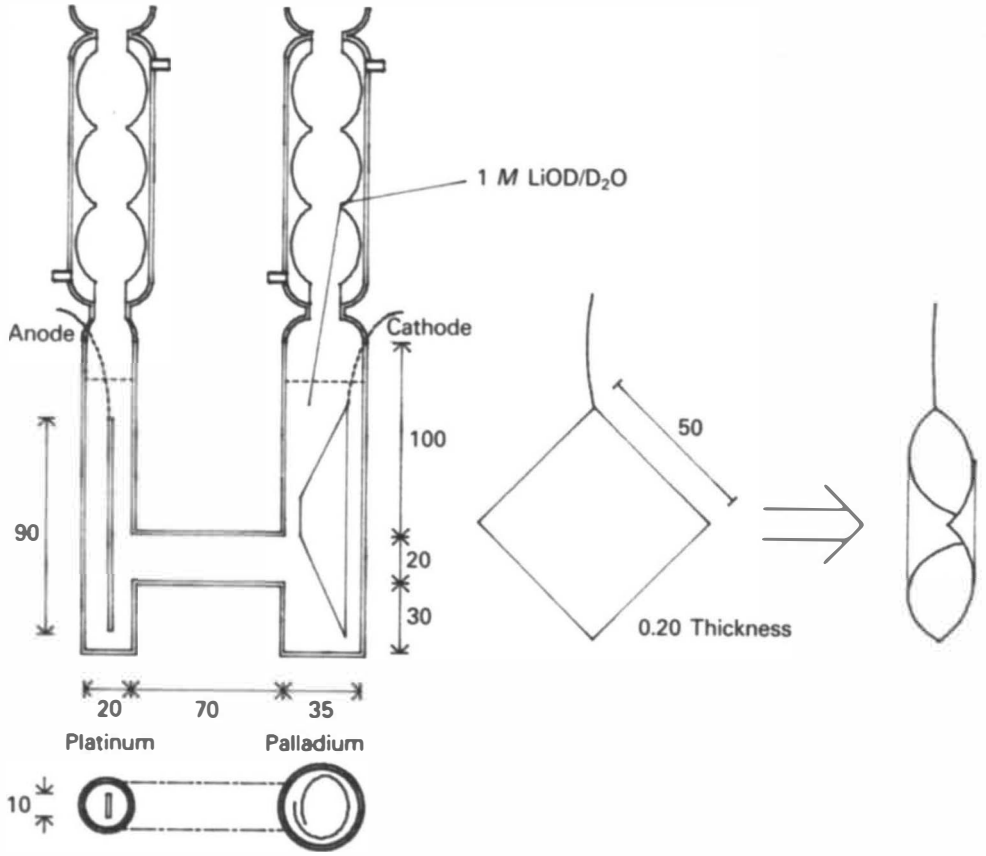

Fig. 1. Sectional view of the electrolysis cell and the winding of palladium cathode. Measurements are given in millimetres.

Neutron Measurements

Neutron measurements were conducted using nine ^{3}He neutron counters charged with ^{3}He gas. The neutron counters were divided into three groups: channels A, B, and C. Each channel consisted of three ^{3}He detectors. The detectors were embedded in polyethylene blocks surrounding the electrolysis test cell; channels A and B were in the right and left walls, respectively, and channel C was in the bottom. All the pulse-height discriminators of the three single-channel analyzers for channels A, B, and C were set at 4 V. The polyethylene blocks were covered with cadmium sheets and surrounded by 20-ℓ polyethylene tanks containing saturated boric acid solution (Fig. 2). The front side of the neutron measurement system was left open for the many electric cables for the ^{3}He neutron counters and the tubes for the electrolysis cell.

The signals from the neutron detectors of channels A, B, and C were accumulated in each channel for 2000 s and then printed out. The signals were also accumulated every 100 μs in each channel. The accumulated signals were transferred and stored in a personal computer for the analysis of burst neutrons. The efficiency of this neutron measurement system, which was calibrated by a ^{252}Cf neutron check source placed in the measurement system, was 7%. A schematic of the measurement system is shown in Fig. 3. The temperature of the experimental room was kept constant at 25°C.

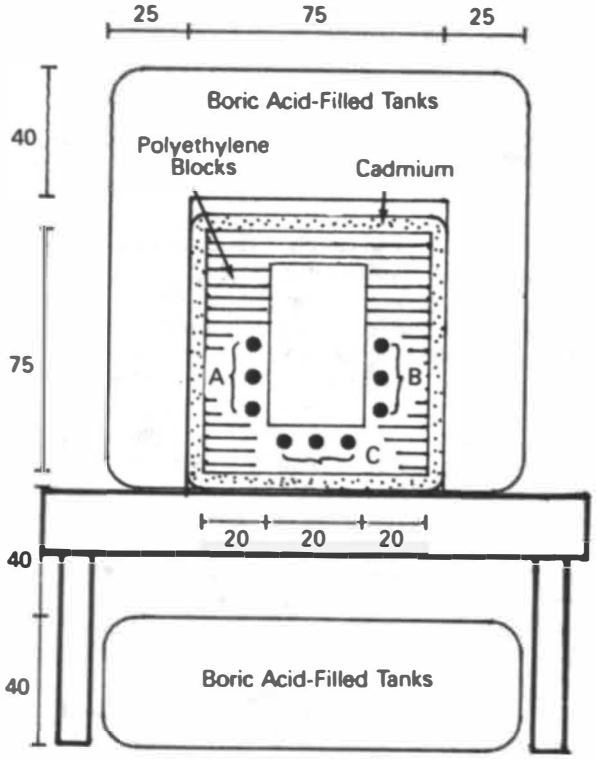

Fig. 2. Sectional view of the neutron measurement system. Measurements are given in centimetres.

RESULTS AND DISCUSSION

The experiments were conducted at the Atomic Energy Research Laboratory of Musashi Institute of Technology. The

laboratory operates a research reactor, TRIGA II (100 kW), daily except weekends from 9:30 (start-up) to 15:30 (shutdown). The reactor is not operated at night. The measuring room is located outside the reactor room, ~20 m away from the center of the reactor. The background neutrons originating from the reactor were negligible in the usual neutron counting experiments in the room; however, because these experiments deal with very low neutron fluxes, the background neutrons due to the operation of the reactor were clearly recorded by the neutron measuring system, as shown in Fig. 4.

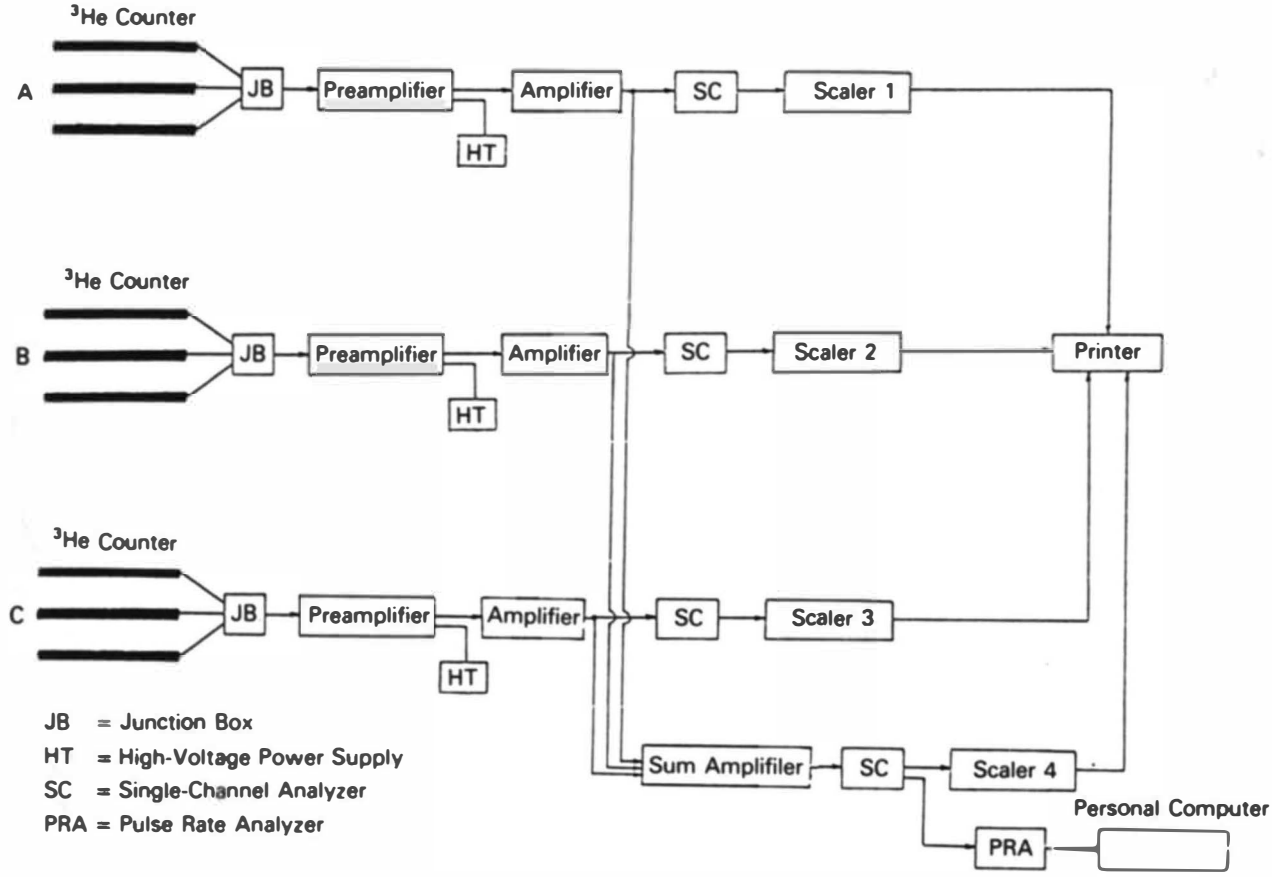

Fig. 3. Schematic of neutron counting system.

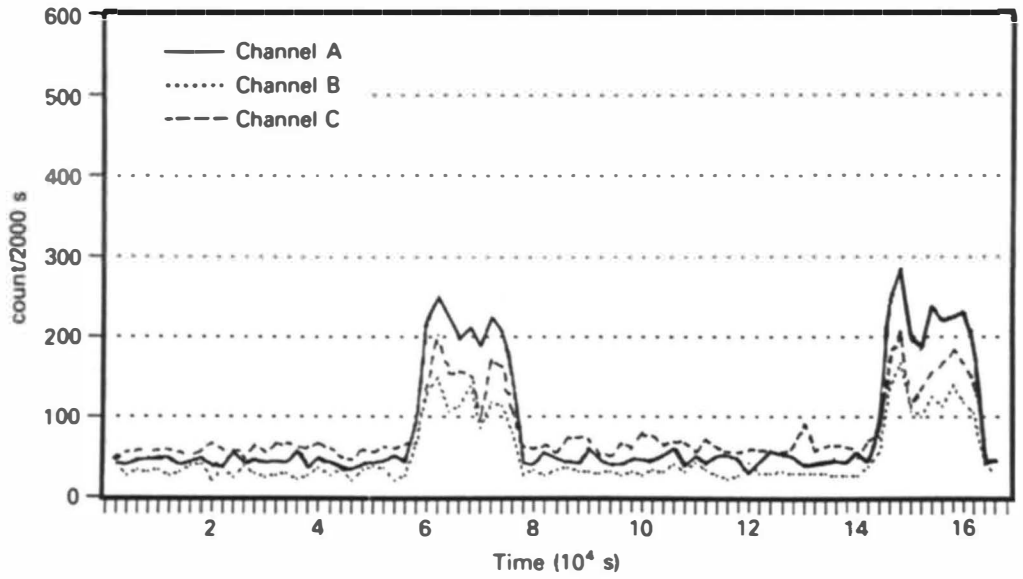

Fig. 4. Background neutrons: The two large peaks indicate the neutrons from the TRIGA II reactor.

(The peak widths are ~6 h = 21 600 s and the time interval between the two peaks is 1 day = 86 400 s.) Because the background level was elevated by the operation of the reactor, the neutron measuring data were valid only when the reactor was shut down.

As shown in the background plotted in Fig. 4, channels A and B have good responses, while channel C shows higher values for the background and lower values for the reactor neutrons. This indicates that both the amplification level and the discrimination level of channel C were lower than those of the other channels.

Three electrolysis experiments were conducted; the same size palladium electrode (50 × 50 × 0.2 mm thick) was used in each experiment. The neutron counts (the sum of channels A, B, and C) during the heavy water electrolysis of runs 1, 2, and 3 are shown in Figs. 5, 6, and 7, respectively. The results are quite interesting. A coincidence in the neutron detection occurs at 5 h after start-up in runs 1 and 2, while a neutron peak was observed in run 3 at 20 h after start-up.

The counts of each channel around the observed peaks in runs 1, 2, and 3 are plotted in Figs. 8, 9, and 10, respectively. The operation of TRIGA II reactor was strictly controlled. It was confirmed that the reactor was operated during the time of the large long pulses shown in Figs. 5 and 6. It was

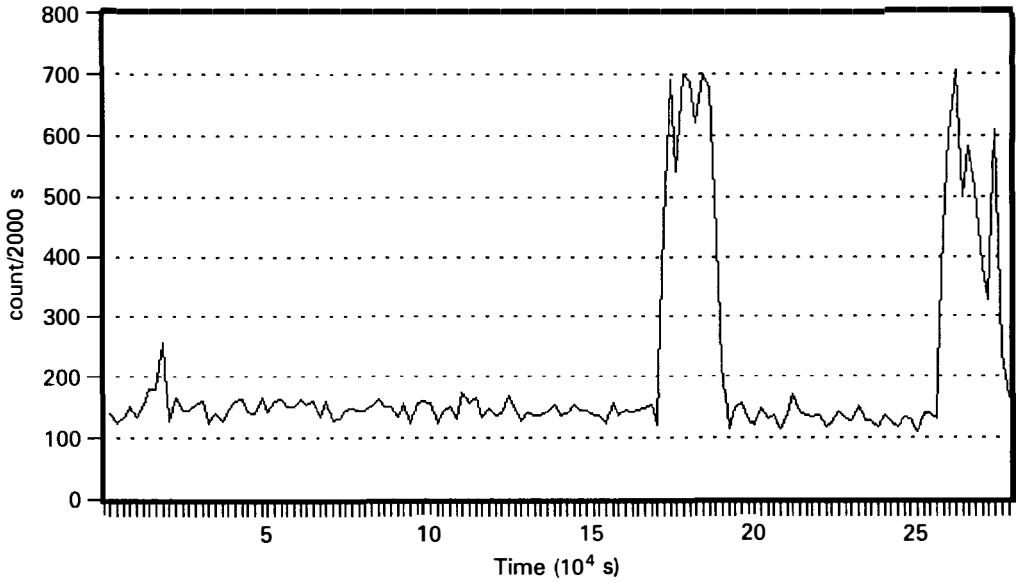

Fig. 5. Neutron measurement during heavy water electrolysis (1 mol/dm^3 LiOD with 50- × 50- × 0.2-mm-thick palladium cathode): total counts of channels A, B, and C in run 1. The two large peaks indicate the operation of TRIGA II reactor.

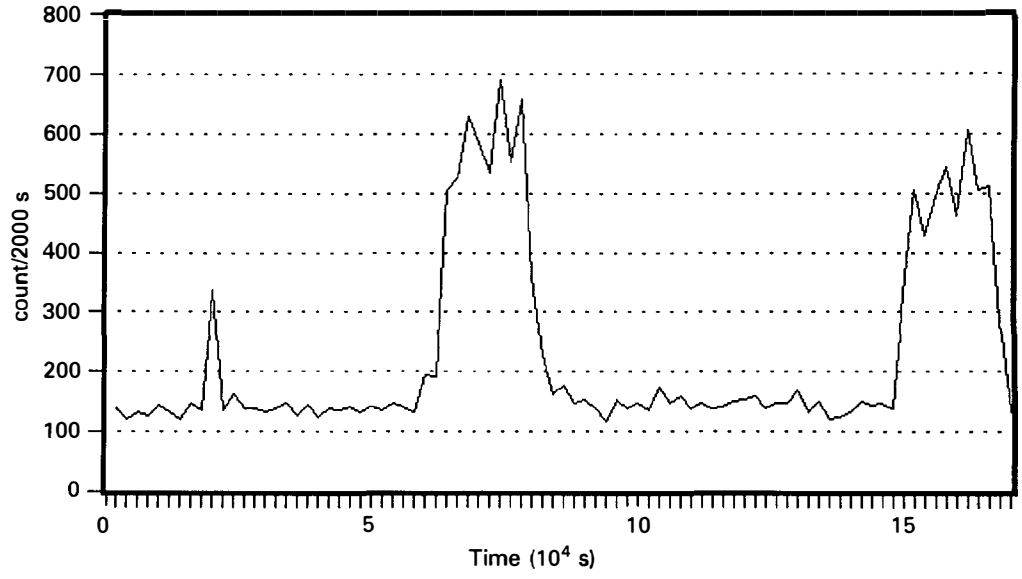

Fig. 6. Neutron measurement during heavy water electrolysis: total counts of channels A, B, and C in run 2. Experimental conditions are the same as run 1.

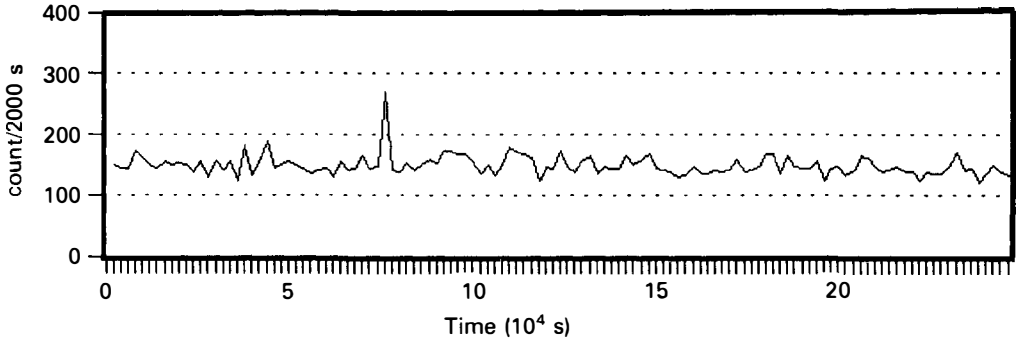

Fig. 7. Neutron measurement during heavy water electrolysis: total counts of channels A, B, and C in run 3. Experimental conditions are the same as run 1.

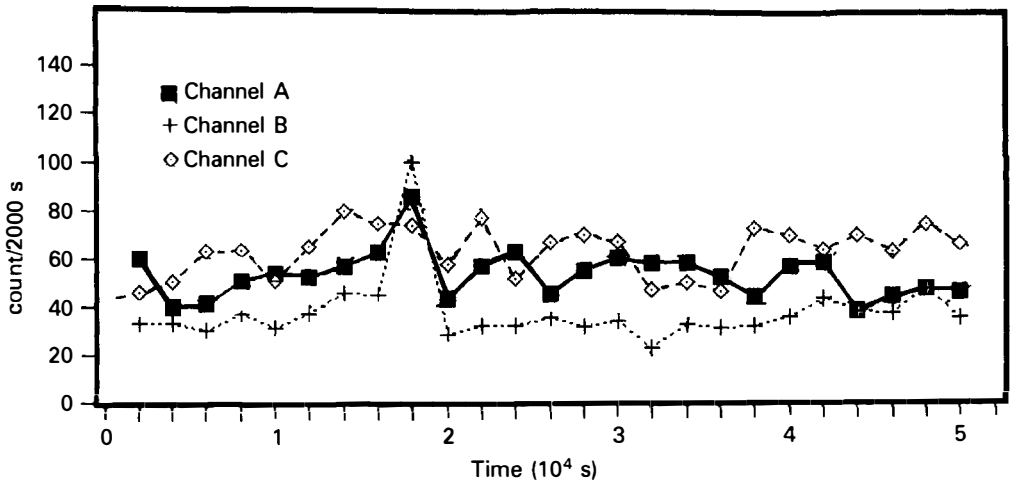

Fig. 8. Neutron counts of each channel in run 1.

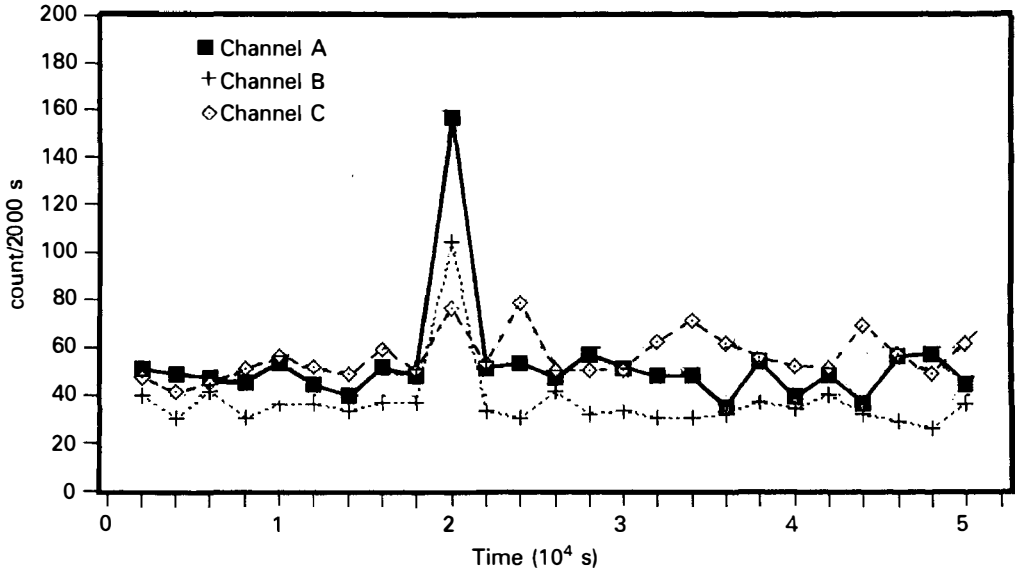

Fig. 9. Neutron counts of each channel in run 2.

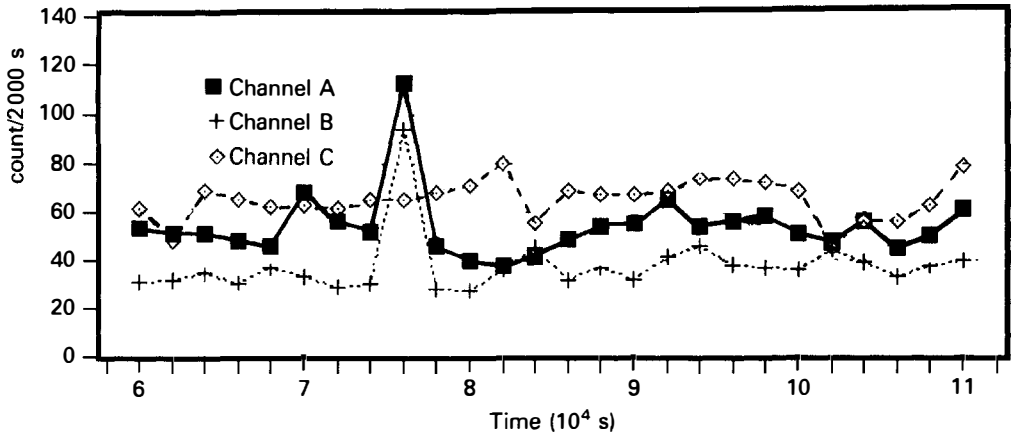

Fig. 10. Neutron counts of each channel in run 3.

TABLE I

Standard Deviations and Peak Values (count/2000 s)

Run	Channel	Average Value (a)	Standard Deviation (σ)	$a + 3\sigma$	Peak Value (p)	$\frac{(p-a)}{\sigma}$
1	A	49.8	8.27	74.6	85	4.3
	B	35.9	8.75	62.2	99	7.2
	C	61.9	8.45	87.1	73	1.3
2	A	49.8	15.3	95.7	157	7.0
	B	37.1	10.3	67.9	104	6.5
	C	59.2	8.86	85.8	80	2.3
3	A	49.9	9.25	77.6	113	6.8
	B	36.7	7.62	59.5	94	7.5
	C	63.2	8.33	88.1	65	0.2

also confirmed that not any radiation sources were handled in and around the measuring room at the time when the small neutron peaks appeared.

The standard deviations were calculated for all the data taken except for the time of reactor operation in each run. The statistical treatment of the observed data in each experiment is presented in Table I. In each experiment, sufficiently large counts exceeding 3σ were observed at the peaks detected by channels A and B: $\sim 7\sigma$ was obtained in channels A and B in each run. The counts of channel C at the corresponding peaks, on the other hand, indicated that the values were larger than average but not large enough to exceed 3σ values.

Pulse rate analyzers were installed in the neutron detection system to analyze the burst neutrons. The pulse rate analyzer counts the number of neutrons detected in 100 μs and sends these data to a personal computer. The results of burst neutron analysis done in background runs are presented in

TABLE II

Results of Pulse Rate Analysis for Background Runs

Neutrons Detected (n/100 μs)	Number of 100-μs Time Units			
	TRIGA II Reactor			
	In Operation		Shutdown	
0	99 997 126	99 995 958	99 998 732	640 002 694
1	2 626	3 534	662	4 521
2	2	0	0	12
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
8	0	0	0	0
14	0	0	0	0
21	0	0	0	0
28	0	0	0	0
29	0	0	0	0
Measuring time (s)	10 000	10 000	10 000	64 001

TABLE III

Results of Pulse Rate Analysis of Background and Foreground

Neutrons Detected (n/100 μs)	Number of 100-μs Time Units			
		Foreground (Heavy Water Electrolysis)		
	Background Total[a]	Run 1	Run 2	Run 3
0	939 994 510	1 639 914 220	610 268 495	759 950 894
1	11 543	11 722	4 245	5 620
2	14	25	10	12
3	0	0	0	1
4	0	0	2	1
5	0	1	0	1
6	0	0	1	1
8	0	1	0	0
14	0	0	1	0
21	0	0	1	0
28	0	1	0	0
29	0	1	0	0
Measuring time (s)	94 001	164 001	61 033	76000

[a]Total values of the background runs in Table II.

Table II. At the background level, the number of neutrons detected within the short period of 100 μs is limited to a maximum of 2.

The results of burst neutron analysis made in the foreground runs, runs 1, 2, and 3, are presented in Table III. There are several cases in which a large number of neutrons are detected in 100 μs. This suggests that neutrons were emitted in bursts at the monitored peak. However, the reason for and mechanism of the neutron generation are unknown.

After the experiments described here, the neutron measurement system was rearranged to include a large (8-in.) NE-213 liquid scintillator. The NE-213 neutron counting system is expected to improve the counting efficiency and to provide information on the energy of the neutrons emitted.

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