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IMPROVEMENTS OF REACTOR NEUTRON FLUX UTILIZATION

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Toru KOHAYAKAWA, Toshio ISHII and
Minoru MOROZUMI

日本原子力研究所
Japan Atomic Energy Research Institute

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Toshio ISHII, Minoru MOROZUMI
Division of Research Reactor Operation, Tokai, JAERI

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In order to make a progress in research activities by utilizing research reactors, it was demanded to develop the techniques which made it possible to use more intense neutron beams or to increase more experimental spaces in high flux region. These were achieved only by introducing some ninor improvements of reactors and / or experimental facilities. This paper describes some of these achievements which have been performed on JAERI's research reactors. These are as follows :

1. Improvements of utilization technique in neutron spectroscopy.
2. Improvement of the fuel assembly as an in-core irradiation facility in JRR-2.
3. Improvements of neutron flux utilization in JRR-4.
4. Deformation of neutron flux distribution to make it fit for proposed experiment.

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* Prepared for the South East Asia and Far-East Regional Study Group Meeting on Problems and Experience in the Utilization of Research Reactors at Bhabha Atomic Research Centre, Bombay, India in March 1973.

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研究炉における炉内中性子の有効利用のための改善*

日本原子力研究所東海研究所研究炉管理部
高田　稔・深沢邦武・小早川透・
石井敏雄・両角　実

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研究炉を利用する研究活動を促進するために，より強い中性子ビームの利用や中性子束の高い領域における利用スペースの増加が要求されてきた。これらの要求は原子炉施設の部分的な改造や実験装置の改造により満たされてきた。本報告は，原研の研究炉で行なってきたこれらの改造について述べている。ここに述べられている改造は次のとおりである。

1. 中性子回折装置における改造
2. ＪＲＲ－２における炉心照射装置としての燃料体の改造
3. ＪＲＲ－４における利用施設の改造
4. 実験に適合させるための炉心内中性子束分布の変形

＊　本報告は，1973年3月にインド国ボンベイ市のバーバ原子力研究所で開催された「東南アジアおよび極東における研究炉の利用と経験に関する専門家会議」に提出したものである。

CONTENTS

I. INTRODUCTION

As techniques on utilization of research reactors make progress, it becomes necessary to use more intense neutron beams or to increase more experimental spaces in high flux region. The simplest way to satisfy these demands is to construct a higher neutron flux reactor or to perform major improvements of the research reactors. But it is very difficult from the economical point of view or others. Therefore, some minor improvements of reactors or experimental facilities have been experienced and planned to increase irradiation spaces or to get more intense neutron beams. Some typical examples of these improvements which have been performed or planned are described in this paper. These improvements are as follows;

1) To improve experimental facilities (for example, neutron diffract-meters, neutron spectrometers and others) which use neutron beams from the core.
2) To improve a fuel assembly which samples are able to be irradiated in.
3) To increase irradiation facilities inside or outside of the core.
4) To deform the neutron flux distribution in the core.

II. OUTLINES OF THE IMPROVEMENTS

1. Improvements of utilization in neutron spectroscopy[1)]

A lot of experimental facilities using neutron beams from the core (for example, neutron diffract-maters, neutron spectrometers, etc.) are installed with JRR-2 and JRR-3. Following the advantage of research programme on the neutron diffraction and neutron spectroscopy, experimenters would like to use more intense neutron beams. During a recent decade, the neutron spectrometers have increased the efficiency of experiments about 10 times larger than before only by the improvement in several parts of instruments.
Those are as follows;

1) Removement of graphite brock from the top of inpile plug.
2) Replacement of detection system with low noise circuit, which also decrease troubles for the maintenance.

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Those are as follows;

1) Removement of graphite brock from the top of inpile plug.
2) Replacement of detection system with low noise circuit, which also decrease troubles for the maintenance.

3) Improvement of neutron shielding.

4) Introduction of new monochromating crystals.

5) Introduction of single crystal filter for the removement of fast neutron and γ-ray contaminations from the direct beam in chopper instrument.

Table 1 shows the improved parts of the facilities and their merits.

2. Improvement of fuel assembly as in-core irradiation facilities in JRR-2 [2)]

Some users required that samples could be irradiated in higher fast neutron flux. So, we have provided fuel assemblies which have had irradiation space in the center. It is so called "In-core Irradiation Facility". The fuel elements of these facilities are concentric tube type, uranium and aluminum alloy. Figs. 1 and 2 show the In-core Irradiation Facilities and one of the irradiation capsules, respectively. A irradiation capsule is inserted in the concentric tube fuel assembly and the assembly is inserted in one of the fuel holes. The outline of the In-core Irradiation Facility is as follows;

1) Purpose : a. Testing for radiation damage of reactor materials by fast neutron.
   b. Testing of fissile materials.
   c. Radio-isotope production.

2) Fuel type : Concentric tube plates, uranium and aluminum alloy (4 tubes). 600 mm in active length. 120 gr of U-235 per one assembly.

3) Neutron flux : $\phi_f = 4 \times 10^{13}$ n/cm^{2}sec.
   $\phi_f : \phi_{th}$ 1 : 2
   Distribution is nearly flat.

4) Irradiated capsule : 34 mm in diameter, 680 mm in length with monitoring instruments.

3. Improvement of neutron flux utilization in JRR-4

JRR-4 is a swimming pool type reactor with open core tank and forced coolant. Originally, none of irradiation holes reached to the core had been prepared in JRR-4. Because JRR-4 had been constructed for shielding experiments only, especially had been used for mock-up tests of shielding materials on the First Nuclear Ship of Japan. Thereafter, this reactor had to be used for other experiments and irradiations. Therefore, some irradiation facilities and tools are used and will be used for these experiments and irradiations in JRR-4. Those are as follows;

1) Irradiations by using water proof capsules
   We have made many kinds of water proof capsules. Generally, irradiation samples are put into these capsules and the capsules are hung with chain. It is easy to set the capsules in suitable neutron flux and to handle the capsules during the reactor operation.
2) Installation of irradiation tubes
   Some long irradiation tubes are installed from the reactor bridge to the core. It is easy to set the tubes in any position where is in the reflector region or outside of the reflector. These tubes are mainly used for the functioning test of neutron detector, sample irradiation with monitoring instruments, etc.
3) Installation of pneumatic tube
   We have a plan to install a pneumatic tube in JRR-4. It will become easy by using this pneumatic tube to perform irradiation experiments and activation analysis of short lived elements in JRR-4.

4. Deformation of neutron flux distribution

Neutron flux will be able to be changed remarkably by moving up or down the control rods in the reactor core, which has a large volume core and heavy water moderator such as JRR-3. Then we will be able to supply more intense neutron beams to some experimental holes by deforming the neutron flux in the core. But we have never performed this plan. We will have to investigate many kinds of safety evaluation of this plan before it is performed.

III. CONCLUSION

As above mentioned, we have performed and planned some kinds of improvements especially had been used for mock-up tests of shielding materials on the First Nuclear Ship of Japan. Thereafter, this reactor had to be used for other experiments and irradiations. Therefore, some irradiation facilities and tools are used and will be used for these experiments and irradiations in JRR-4. Those are as follows;

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III. CONCLUSION

As above mentioned, we have performed and planned some kinds of improvements of neutron flux utilization in order to use research reactor more effectively. However, before the improvements are performed, we believe, we should investigate the safety of these improvements sufficiently. When some improvements were planned, the sufficient safety evaluation of these improvements have been performed by the technical group in the operation section, chief engineer, safety committee at JAERI, before their performance and in case of the more sufficient safety evaluation required, licensing by National Committee on Examination of Reactor Safety is to be provided.

IV. ACKNOWLEDGEMENTS

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Table 1 Improved Parts of Spectrometers and Their Merits

PART OF INSTRUMENT	IMPROVED PARTS	MERITS	MACHINE
Detector	Change the BF_3-counter with new one, that has no heavy supporter at the end of counter	Intensity increases about 30 %	TNS
	He-3 gas filled counter	Counter shield is lighter than glass scintillator	TOF
Measuring techniques	Optimum combination of monochrometer and analyzer crystal	Intensity increases about two times	TNS
	Choise of focusing condition	Increasing of intensity and resolution	
Crystal	We have several crystal monochrometers that is, copper, hot pressed Ge, Al, Be and pyrolytic graphite	Best selection for the purpose of experiment	TNS
	We are using three neutron filters Bi, SiO_2 and Si. Bi is 22.5 cm in length SiO_2 is 10 cm in length Si is 10.5 cm in length	Bi crystal transmission for 1 - 2 MeV neutrons is about 0.01, thermal neutron is about 0.1 SiO_2 crystals for fast is about 0.1 for thermal is about 0.7 Si crystals for fast is about o.5 for thermal is about 0.95	TOF
Shielding material	B_4C, boric acid and light water It was felt that these materials represented some of the best compromises between cost, availability, and attenuation per unit length	Low background 1/10	TNS TOF
Circuit	Detector signal amplifier, Machine controller and memory of data circuit constitute a I.C.	Decrease in number of troubles	TNS TOF

Remark. TNS ; Triple axis neutron spectrometer. TOF : Neutron spectrometer with triple rotors

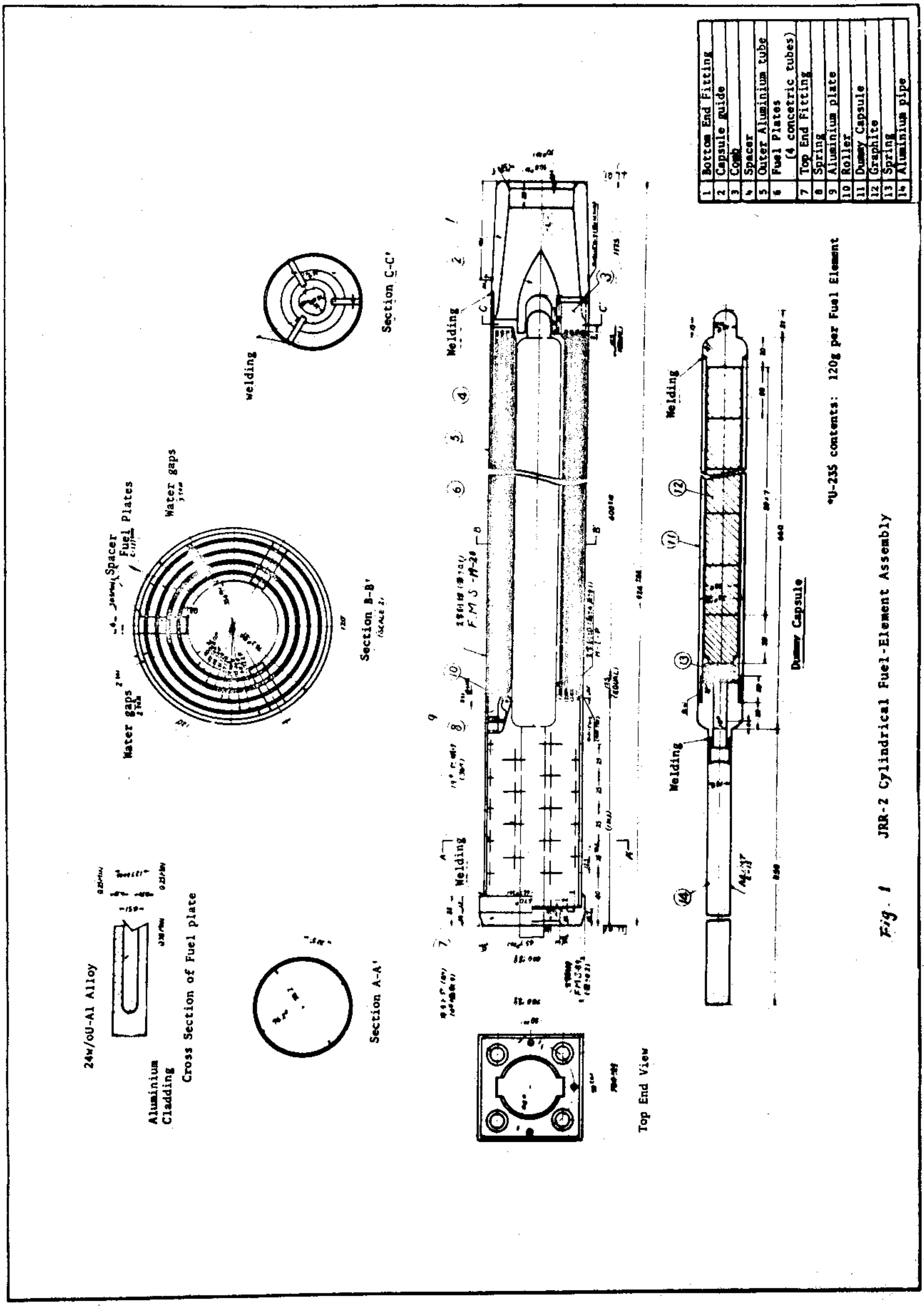

Fig. 1 JRR-2 Cylindrical Fuel-Element Assembly

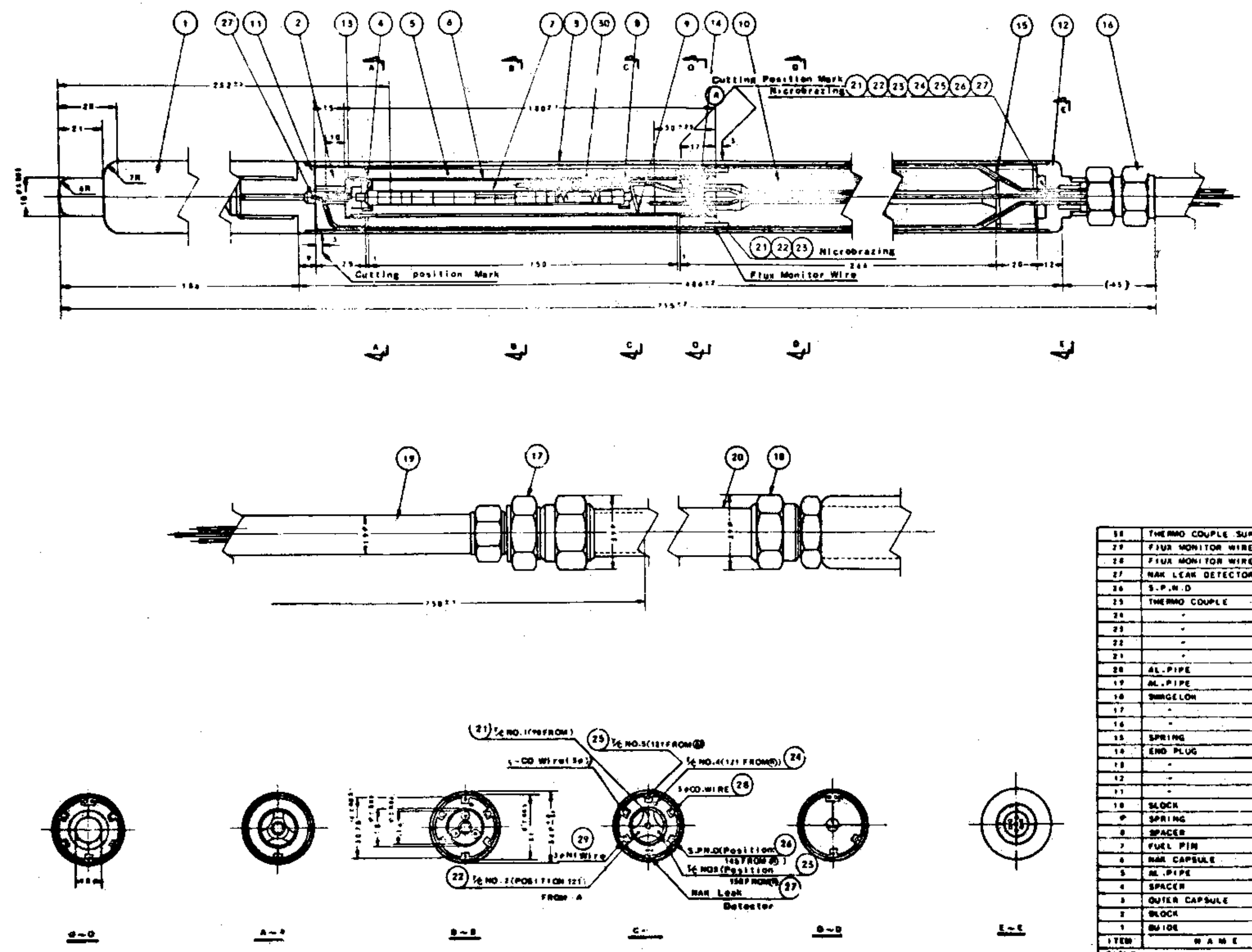

Fig. 2 JRR-2 High Power Irradiation Capsule

ITEM	NAME		MATERIAL
30	THERMO COUPLE SUPPORTER		316S.ST
29	FLUX MONITOR WIRE		Ni
28	FLUX MONITOR WIRE		Ti-Co
27	NaK LEAK DETECTOR		
26	S.P.N.D		
25	THERMO COUPLE	-5	
24	〃	4	
23	〃	3	
22	〃	2	
21	〃	1	
20	AL.PIPE		52 S
19	AL.PIPE		52 S
18	SWAGELOK	(C)	1610-1-16-316
17	〃	(B)	1610-6-12-316
16	〃	(A)	1210-1-12-316
15	SPRING	(2)	INCONEL-X
14	END PLUG	(D)	304 S.ST
13	〃	(C)	304 S.ST
12	〃	(B)	304 S.ST
11	〃	(A)	304 S.ST
10	BLOCK	(2)	2S-ALUMINIUM
9	SPRING	(1)	INCONEL-X
8	SPACER	(2)	316 S.ST
7	FUEL PIN		
6	NaK CAPSULE		316 S.ST
5	AL.PIPE		
4	SPACER	(1)	316 S.ST
3	OUTER CAPSULE		304 S.ST
2	BLOCK	(1)	2S ALUMINIUM
1	GUIDE		52S ALUMINIUM

TITLE	DWG. No.
JRR-2 HIGH POWER IRRADIATION CAPSULE	JRR-2-1
P.N.C	