POST-INSTALLATION EVALUATION OF THE NEUTRON RADIOGRAPHY FACILITY OF ITU TRIGA MARK-II REACTOR

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ABSTRACT

The results of the experiments are presented., for determining the characteristics of the previously described neutron radiography facility, which has been designed and built in the Istanbul Technical University.

The thermal and total neutron fluxes and the gamma exposure rates have been measured inside and exit of the neutron beam collimator, and its surroundings. The ratio of neutron flux to gamma exposure rate at maximum power has been reported.The results have been compared to those measured in the absence of the collimator.

The neutron fluxes have been determined by using the foil activation method with gold foils enclosed in cadmium capsules. The gamma exposure rates have been measured by using LiF_7 (TLD_{700}) Thermoluminescent Dosimeters.

INTRODUCTION

The ITU TRIGA Mark-II reactor has three beam tubes. One of them, the Tangential Beam Tube (TBT) is equipped with a Neutron Radiography (NR) facility which consists of a divergent neutron beam collimator and an exposure room [1-4].

The neutron beam collimator which is placed into the TBT, has an outer aluminum cylindrical tube and an inner aluminum divergent tube. The gap between the cylindrical and divergent tubes is filled with powdered acid boric. Inner hole of the divergent tube is called collimator hole and filled with air.

Neutrons are allowed to enter the collimator hole only by passing through a pollycristalline bismuth gamma filter mounted in the collimator hole next to the reactor.

An exposure room is located at the outer face of the collimator next to the reactor shield. The wall blocks and the top block of the exposure room are made of a few heavy concrete blocks and, a water tank is mounted on the top of it.

DETERMINATION OF THE NEUTRON FLUXES FOR THE NEUTRON BEAM

The thermal and total neutron fluxes were determined experimentally by using the foil activation method at the exit of the neutron beam collimator and on the movable carriage table. The movable carriage table is situated 60 cm away from the collimator (Fig.1). Five different gold foils, which are 5.5 - 6.5 miligrams in weight, 0.0254 mm in thickness and 99.9918 % in purity, were used for each of these measurements. Two of the five gold foils were put into the cadmium capsules which were 12.7 mm in diameter, 1.016 mm in thickness and 99.9656 % in purity. Then all of them were mounted on a wooden apparatus and irradiated [5].

An HpGe detector, a spectroscopy amplifier and a Canberra 90 multichannel analyzer were used to measure the count rates of these irradiated gold foils. Each gold foil was counted for 1 hour using this system.

Gold foils, first, were irradiated at the power of 250 kW for 2 hours 15 minutes. After irradiation, it was realized that the foils were not irradiated long enough for the neutron flux was very low. Errors for the counts of the three bare gold foils irradiated at the exit of the collimator were found to be about 29 % and for the three bare foils irradiated on the movable carriage table were found to be about 57 %. Since these errors are considerably high, the results were thought having no practical value.

Then, irradiation was repeated at the same power for 3 hours 30 minutes. The count rates were obtained with errors about 20 % and 47 % for the foils at the above mentioned points respectively. These errors were also considered high.

Finally, the gold foils were irradiated at the power of 250 kW for 8 hours. Reactor cooling system was insufficient for irradiation more than 8 hours since the temperature and humidity in the air were too high during the summer time. These foils were counted to determine their activities after irradiation, and then the raw neutron fluxes, which are given in Table 1, were obtained via these count rates.

It was assumed that the epithermal and total neutron fluxes were obtained via the cadmium covered and bare gold foil activities respectively. The thermal neutron fluxes were obtained by subtracting the epithermal neutron fluxes from the total neutron fluxes.

During the evaluation of these experiment results, the neutron fluxes obtained by the counts of the foils numbered 1, 3, 5, 7 and 8 were considered accurate enough to calculate the total and thermal neutron fluxes since they have less error than the others which were irradiated under the same conditions. As a result, the total and thermal neutron fluxes were given in Table 3.

MEASUREMENT OF THE GAMMA EXPOSURE RATE FOR THE NEUTRON BEAM

Gamma exposure rate was measured by using LiF_7 (TLD_{700}) thermoluminescent dosimeters. The dosimeters were mounted inside and exit of the neutron beam collimator hole and, on the movable carriage table and then they were irradiated at the powers of 10 kW, 50 kW, 100 kW, 150 kW, 200 kW and 250 kW for 30 minutes.

Each time up to 8 but not less than 4 dosimeters were irradiated together, then they were evaluated in the Çekmece Nuclear Research and Training Center. The variations of the gamma exposure rates as a function of power for three different points obtained from these measurements are given in Table 2.

The exposure rates at the power of 250 kW were measured to be 49.368 R/h at the exit of the collimator hole and, 10.646 R/h on the movable carriage table.

According to these results, at maximum power the ratios of the thermal neutron fluxes to the gamma exposure rates of the beam used for NR were obtained to be approximately

$$n/\gamma = 1.44 * 10^4 \ n / cm^2 \ mR$$

at the exit of the collimator hole and

$$n/\gamma = 5.30 * 10^4 \ n / cm^2 \ mR$$

on the movable carriage table.

On the other hand, it was estimated to be

$$n/\gamma > 10^5 \ n / cm^2 \ mR$$

at the exit of the collimator while the NR facility was being designed.[1, 2].

Relatively low n/γ ratios may be attributed to the following arguments.

1- Since the bismuth gamma filter is not monocyristalline, some of the neutrons passing through it into the collimator hole may be scattered out of the neutron beam.

2- The outer cylindrical aluminium tube and the inner divergent aluminum tube of the neutron beam collimator emit gamma rays as a result of the (n,γ) reaction. Therefore, aluminium has a role of an additional gamma source besides the reactor.

3- In Table 1, it can easily be seen that the gold foils which have less error give count rates higher and these count rates cause a higher neutron flux estimation. This suggests that higher neutron fluxes may be obtained if the error on the counts get lesser in case the duration of irradiation is increased under better cooling conditions of the reactor.

DOSE MEASUREMENTS IN THE SURROUNDINGS OF THE EXPOSURE ROOM

A portable surveymeter was used to measure the gamma dose rates in the surroundings of the exposure room. The average gamma dose rates were measured as 47 μR/h next to the shielding wall of the exposure room and 267 μR/h over the water tank at the top of these walls while it was 152 μR/h next to the shielding wall of the reactor in the reactor hole.

Additionally, a neutron monitor was used to measure the dose equivalents for neutrons. The average dose equivalents for neutrons were measured as 0.2 mRem/h next to the shielding wall of the exposure room and approximately zero over the water tank while the background was also measured approximately zero next to the shielding wall of the reactor.

As a result of these measurements, it can be concluded that total dose in the surroundings of the NR facility is under the maximum permissible dose limits.

CONCLUSION

In this study, the results of the experiments to determine the characteristics of the NR facility of ITU TRIGA Mark-II Reactor are presented. According to these results, the ratio of the thermal neutron flux to the gamma exposure rate of the beam at the exit of the collimator hole is somewhat less than the ratio recommended by literature. Therefore, in order to improve the quality of the neutron beam, a monocyristalline bismuth gamma filter was demanded to be bought by means of the financial support of the International Atomic Energy Agency (IAEA) . It was also measured that the total dose in the surroundings of the NR facility is under the maximum permissible dose limits [6, 7].

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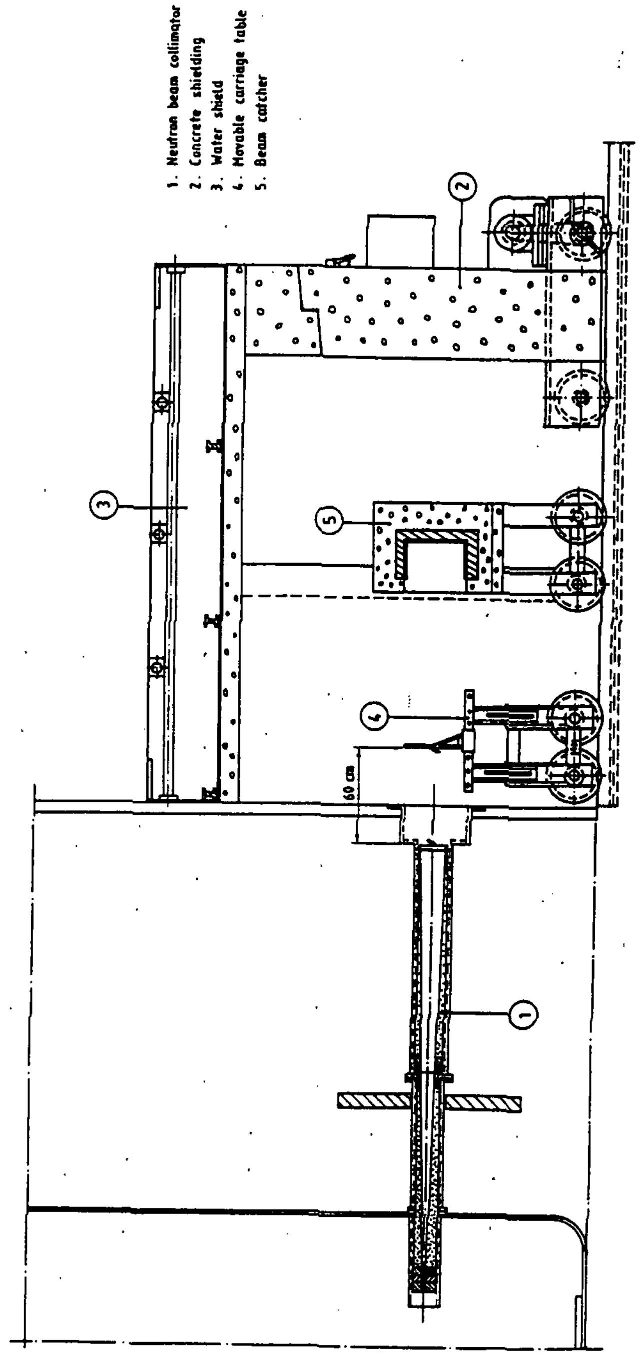

Figure 1. The neutron radiography facility of the ITU TRIGA Mark-II reactor [1,2].

	FOIL #	NEUTRON FLUX $n/cm^2\ s$	ERROR %	
At the exit of the collimator hole	1	$5.59 * 10^4$	14.12	(Cd covered)
	2	$3.70 * 10^4$	22.66	(Cd covered)
	3	$2.62 * 10^5$	5.51	
	4	$1.78 * 10^5$	7.29	
	5	$2.46 * 10^5$	5.77	
On the movable carriage table	6	$2.10 * 10^4$	47.55	(Cd covered)
	7	$3.12 * 10^4$	32.78	(Cd covered)
	8	$1.88 * 10^5$	7.52	
	9	$6.99 * 10^4$	14.88	
	10	$2.29 * 10^4$	26.09	

TABLE 1 The raw neutron fluxes as a result of irradiation at a power of 250 kW for 8 hours.

REACTOR POWER kW	GAMMA EXPOSURE RATE R/h		
	On the movable carriage table	At the exit of the collimator hole	In the middle of the collimator hole
10	0.446	1.769	22.172
50	1.858	9.475	100.824
100	4.893	19.605	199.954
150	6.848	30.506	311.696
200	8.458	40.328	341.174
250	10.646	49.368	342.539

TABLE 2 The gamma exposure rates.

	TOTAL NEUTRON FLUX n/cm^2s	THERMAL NEUTRON FLUX $n/cm^2\ s$	GAMMA EXPOSURE RATE R/h	n/γ n/cm^2mR
At the exit of the collimator hole	$2.54*10^5$	$1.98*10^5$	49.368	$1.44*10^4$
On the movable carriage table	$1.88*10^5$	$1.57*10^5$	10.646	$5.30*10^4$

TABLE 3 The neutron fluxes and the gamma exposure rates at the power of 250 kW .

	GAMMA DOSE RATE μR/h	DOSE EQUIVALENT FOR NEUTRONS mRem/h
Next to the shielding wall of the exposure room	47	0.2
Over the water tank	267	~ 0.0
Next to the shielding wall of the reactor in the reactor hole	152	~ 0.0

TABLE 4 Doses measured in the surroundings of the exposure room.