RESEARCH STAND FOR CONCRETE SHIELDING TESTS

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Abstract : *A design of a stand for concrete shielding tests is presented. Studies of shielding of new concrete mixes are needed due to nuclear medicine dissemination and especially in the era of nuclear power development. This stand is designed in order to examine and select the best concrete mix for the construction of the first Polish fully operative, nuclear power plant. The examination of those concrete shielding mixes will be performed in the measuring room at the outlet of horizontal channel H2 at nuclear reactor MARIA (National Centre for Nuclear Research – NCBJ, Poland).*

Key words : *nuclear power plant, radiation shielding, heavy density concrete*

1. Introduction

In recent years, Poland is trying to develop the first fully operative, nuclear power plant. In order to do this, there is a need to perform a series of research. One of them is the need to examine and emerge the best concrete mix for the construction of this power plant with proper mechanical properties and satisfactory radiation shielding. This research stand is especially designed to test shielding for different concrete mixes.

2. Stand description

The stand designed for investigation concrete shielding will be located in the room I at the outlet of the horizontal channel H2 at nuclear research reactor MARIA (National Centre for Nuclear Research – NCBJ, Poland). The construction of this stand will be based on already existing in this room cast iron frame placed on the rails. The stand will be composed of: the cast iron frame on the rails, that allows the whole construction to move along the beam; detector (recombination chamber), cased in a shield preventing detection of scattered neutrons; linear guide system (consisting of 14 linear rails intended to move 14 concrete slabs) that allows changing the thickness of investigated shielding; and optional concrete block between the detector and linear guide system if the 14 concrete slabs would not be enough to achieve proper characteristics of attenuation. To each slab mounted on moving system it will be attached a line that allows for moving it without entering the room I (because of the radiation level – caused by scattered neutrons). All lines will be routed through conduit into room II, where there will be the possibility to set any configuration of the slabs at the beam (see Fig. 1). These are the necessary precautions to protect employees from high levels of radiation in the room I.

Linear guides, that are the part of the moving system, are placed to overlap in order to additionally collimate the reactor beam (in the case where the slabs are set in the off-axis beam end positions). Supervision of the positions of the slabs will be possible by using a vision system consisting of: IP cameras, router, and monitor or a computer in the room II, safe from the radiation protection point of view. Investigated slabs will have dimensions of 420x420x50 mm and will be made of heavy concrete with an average density of approximately 4 g/cm^3, which gives the weight of a single slab of about 35 kg.

Research stand will be located at the outlet of the beam in channel H2, the orientation shown in Fig. 1.

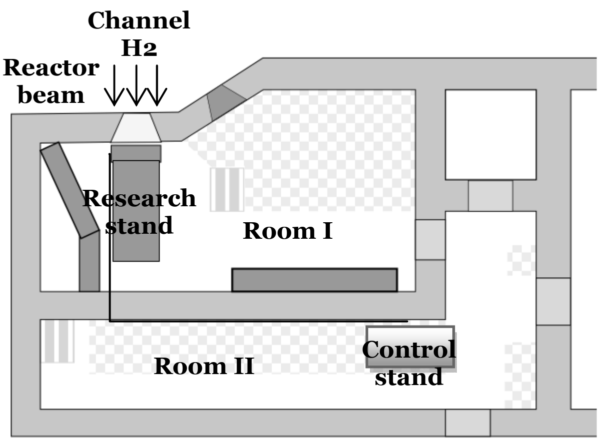

Fig. 1 The location of the research stand at the outlet of the channel H2

On the stand there will be placed consecutively from the beam entrance:

1) 14 concrete slabs mounted on the moving system

2) Stationary concrete block (consisting of ten, or if necessary more slabs) This block will be placed only after the measurement for concrete slabs mounted on moving system in the technological break of the reactor work.
3) Detector placed immediately behind the last slab cased in the PE (in order to minimize influence of the scattered neutrons) Adding a further concrete block will require to move the frame along the rails, so the position of detector relative to the reactor will remain unchanged.

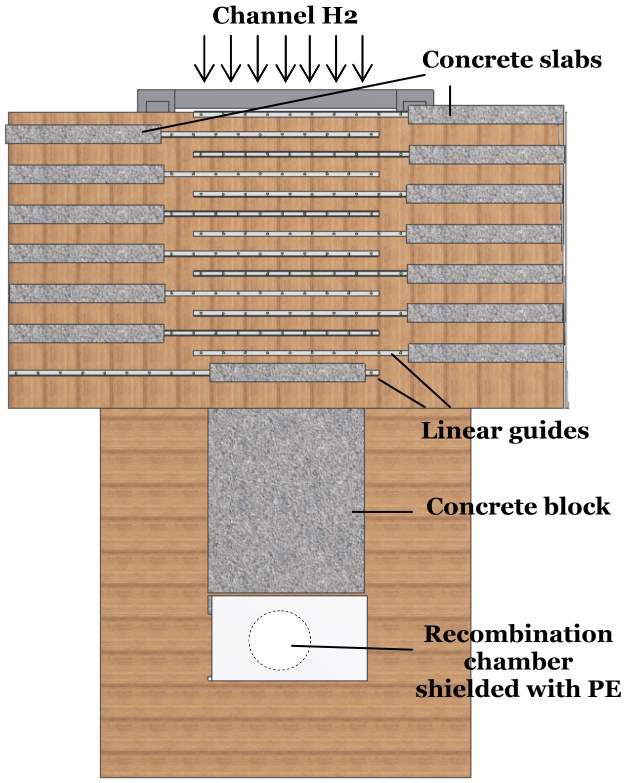

Fig. 2 Top view of the research stand with mounted linear guides, concrete block and shielded recombination chamber

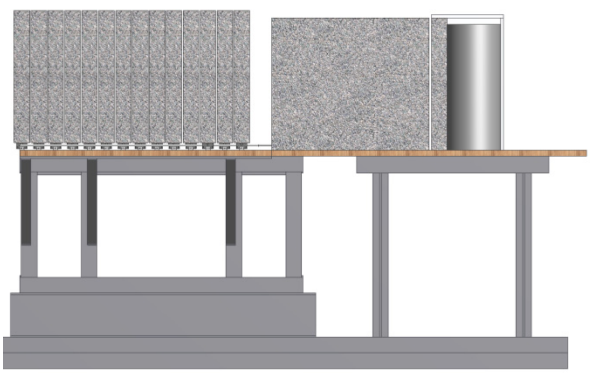

Fig. 3 Side view of the stand (assumed space between the slabs – 4 mm)

Any modifications to the existing iron cast frame will be made on the spot and during the reactor technological breaks. The whole construction was specially designed to hold equipment with 14 single slabs, concrete block with weight of from 350 - 700 kg, and detector shielded with PE, which gives a total carrying capacity of about 1.5 tones.

3. The measurement procedure

Measurement will be carried out with at least two ionization chambers: the first – measuring the dose rate, placed behind concrete slabs additionally encased by concrete, and the second – monitoring reactor power. It is planned to use recombination chambers as a detectors of gamma radiation (gamma attenuation) GW2 and neutron radiation (neutron attenuation) REM2-8. Distinguishing neutron and gamma component is also planned for obtaining in the radiation field radiation quality factor [3] what is crucial in the radiation protection point of view . For low level radiation the chambers containing boron [1] and high-pressure recombination chamber REM2-7 will be used [2].

The measuring procedure begins with the execution of measure only with front cover of the detector and with the concrete slabs placed in the end positions of the linear guide system, thereby collimating reactor beam. Next, successively slabs will be placed increasing the thickness of the concrete shielding. These slabs will be moved by a system of lines running through culverts to room II, where one can safely operate the setting of the slabs. Any change of the configuration will be controlled through the vision system.

After examining all the concrete slabs mounted on linear guide system it is necessary to wait for the technological break of the reactor, and then move the entire cast iron structure in such a way, that after the inclusion of a concrete block (understood as a set of fixed slabs) placed between moving system and cased detector, the distance between reactor and the detector remain unchanged. Then the measuring procedure is repeated.

During the technological break there will be also a possibility to change the whole concrete set to another sample of concrete type (different mixture) .

Detectors will be in advance calibrated in the Laboratory (Secondary standard) and the slabs will be also examined in the laboratory radiation fields (certificated isotopic sources).

4. Safety considerations

Because of high level of dose rate in the room I during reactor operation, there is no possibility to enter that room in that time (radiation levels shown in Fig. 4).

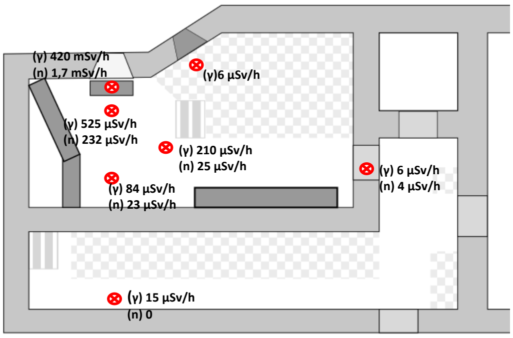

Fig. 4 Radiation levels at the outlet of the channel H2 measured at specific points showing gamma and neutron dose rate

All the operations must be done from the room II. There will be a possibility to apply modifications to the research stand, or to carry out some minor repairs, but only during the reactor operation break (a few days every week or dozen of days).

All measurements will be watched by radiation protection inspector and the radiation levels will be monitored in both rooms. In some emergency situation (blocking of a slab) there is a possibility to enter the room I quickly, for couple of minutes (only if there is no other possibility).

5. Numerical Modeling

On the basis of the technical drawing of the stand a numerical model of the room with the stand was developed using MCNPX code [4].

The main objective of this investigation was to examine the effect of different configurations of the stand on the level of radiation in the measuring room and in the hallway. To quantify the level of radiation, we calculated the average neutron flux on the surface of the room wall located opposite the outlet of the channel and adjacent to the corridor. The greatest impact on the outcome was from the neutrons scattered at the measured slabs and the walls of the room. We sought a configuration that would allow for a reduction in their number.

The first parameter tested was the distance from the outlet of the measuring channel H2. It has been shown that the neutron flux on the back wall of the room is the smallest, when the measuring position is as close as possible to the channel outlet. Placing in the channel outlet a polyethylene collimator 10 cm thick also significantly improved the situation - such an element is available, it was made as part of the filter/moderator system designed to obtain epithermal neutron beam. Other elements which affect the level of radiation was studied were: polyethylene plate, 10 cm of thickness directly protecting the rear wall of the room and rectangular tunnel with an edge length of 42 cm and 7 cm thick walls, made of polyethylene, extending from the channel outlet to the first concrete slab measured. The dimensions of the tunnel were exemplary, increasing the thickness of its walls, and the plate thickness will increase the efficiency of shielding. These parameters can be changed depending on the technical possibilities.

In the present investigation we also tested gamma radiation level in the room and the effect of lead shielding placed around the polyethylene tunnel. For this purpose, we calculated photon flux in the vicinity of the geometric center of the room. Calculations showed only a minor impact of the lead shield, photon flux was reduced by half, while the shielding itself represent a significant burden and placing it in the desired location is a big technical challenge.

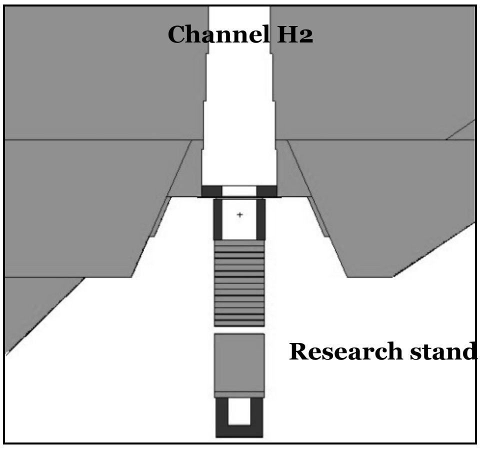

Fig 5. Fragment of the test room model together with the stand for concrete shielding tests, with the full load of concrete slabs, top view. Light grey elements are made of concrete (the slabs and the room walls), dark grey ones are made of PE (collimator at the outlet of the channel, and additional shielding of the detector.

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