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Biological shielding test of hot cells with high active source ^{60}Co (300 TBq)

P. Švrčula*, D. Zoul, M. Zimina, A. Petříčková, T. Adamíková, M. Schulc, O. Srba

Research Centre Rez Ltd., Hlavní 130, 25068 Husinec-Řež, Czech Republic

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A B S T R A C T

This article describes a method for testing of the efficiency of the biological shielding of the hot cell facility, which were constructed as a part of the project SUSEN. Ten hot cells and one semi-hot cell are present in the facility Radiochemistry II. The shielding is made from steel plates. In order to demonstrate sufficient efficiency of the biological shielding of the hot cells and a correspondence between measured and contractual values at selected points. The test was done using sealed high activity ^{60}Co sources. The results are also used as a proof of the optimization of radiation protection for the workplace of this type. The results confirm significant optimization of radiation protection at the workplace. The dose received by a staff do not exceed one tens of annual limit during active service. Obtained results fulfill general requirements of radiation protection and will be used for further active service of hot cells facility.

1. Introduction

Testing of the efficiency of the biological shielding of hot cells (HCs) was launched by the Research Centre Rez Ltd. on the 23rd of November 2015 in a cooperation with Chemcomex Inc. (coordinators), ÚJP, Inc. (transportation of sources) and VF Inc. (radiation protection supervisor). Testing of the effectiveness of the biological shielding lasted for four days. Eleven cells were successfully trialed in order to demonstrate a desired efficiency of the shielding of the HCs, a correspondence between measured values and contractual values as well as to prove the safety of the operation at the workplace of such a category.

Object Radiochemistry II is located at the Research Centre Rez Ltd. and is planned as a workplace of III. category with a presence of ionizing radiation sources. The facility is equipped with ten HCs, one semi-HC and one „dry pool". HCs and the dry pool are designed for maximum activity up to 300 TBq ^{60}Co. Semi-HC is designed for maximum activity up to 250 GBq ^{60}Co. The cells are equipped with experimental devices for diagnostics and testing allowing irradiated samples to enter the HCs, technologies for a complex samples processing (cutting, welding machining etc.) and a set of machines for mechanical testing (sample preparation area, tensile testing machine, fatigue machine, etc.). Moreover, the study of the local mechanical properties and microstructure of materials can be conducted using microhardness and nanohardness testers and scanning electron microscopy (SEM), respectively (Fig. 1). The workplace includes operator rooms as well as a technical support for the HCs.

All shielding parts are made of steel, an outer wall shielding is 500 mm thick, an internal wall between HCs is of 300 mm with the possibility of extension up to 500 mm (Fig. 2). The ceiling shielding is 400 mm thick and a floor shielding of HCs is 300 mm wide. The detail design of the shielding has been designed by a supplier. All blocks are made of steel plates (100 mm wide), every wall has 5 steps to prevent the penetration of gamma ray shots through the shielding.

The biological shielding is made of steel modules. Size of a single module is 2×4 m^2, the weight is about 25 t. Free spaces of about 20 mm wide were identified during the construction as is shown in Fig. 3. This spaces were filled up with steel pellets in order to increase the efficiency of the biological shielding.

The calculation of the shielding thickness is based on a predicted workplace time t_0, which is the time of an operator's presence at the workplace relative to his total working time. Controlled area is divided into 3 groups according to Table 1.

During the dosimetry test it was not allowed to operate with irradiated samples due to incomplete shielding. However, it will be equipped with the complete biological shielding, shielding windows, manipulators and one removable hermetic box as soon as an active service starts. Moreover, it has functional electric and data systems as well as a radiation protection system. The shielding test was done using sealed ionizing radiation source, thus, an active ventilation was not needed. Testing of the biological shielding is ensured by CHEMCOMEX Prague, Inc. VF, Inc. which arranges the necessary permission from The State Office for Nuclear Safety and provides a temporary workplace for work with sealed highly radioactive sources with defined controlled area. ÚJP Prague, Inc. ensures transportation of the sources. Research Centre Rez (RCR) provides a technical and support personnel, carries

* Corresponding author.
E-mail address: petr.svrcula@cvrez.cz (P. Švrčula).

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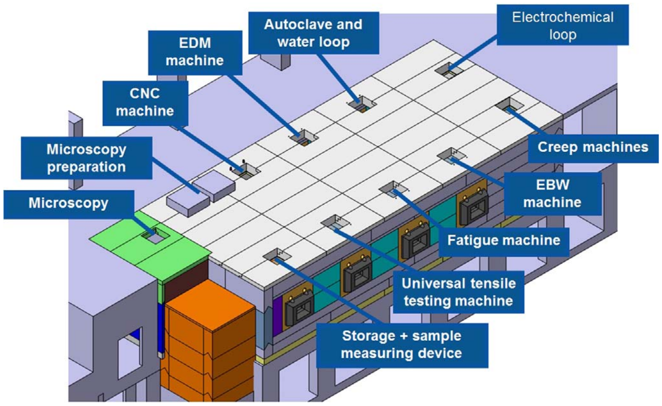

Fig. 1. Equipment of the HCs facility.

Fig. 2. Spaces in the joints of the biological shielding filled up with steel pellets.

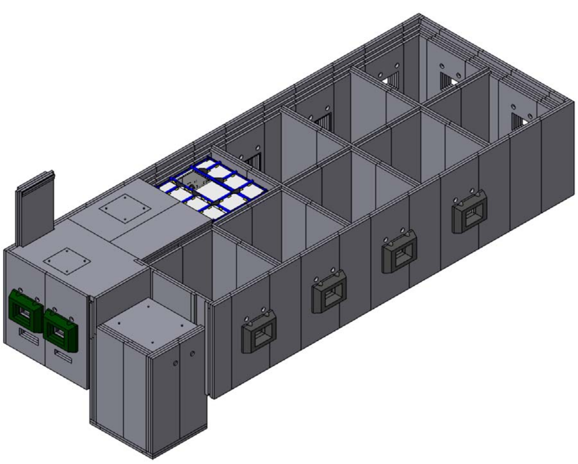

Fig. 3. Detailed design of the biological shielding.

Table 1
Categories of workplaces in controlled area depending on the working time.

Workplace	t_0 - the presence of an operator relative to its total working time
Permanent	$20\% < t_0 \leq 100\%$
Temporary	$1\% < t_0 \leq 20\%$
Occasionally	$t_0 \leq 1\%$

out necessary permissions, handling, and dosimetry measurements and documentation of the process, in a cooperation with employees of VF, Inc. VF, Inc. assigned a person responsible for the proper training of the staff involved in the test, for their introduction to the current state of workplace and every day planned activities.

All personnel involved in the test was equipped with personal dosimeters according to the Atomic Act (The State Office for Nuclear Safety, 1997) and was trained on health, safety, fire and radiation protection before the start of any operation. The protective equipment for each activity (gloves, protective clothing, helmets, etc.) was used during the whole testing. RCR provided RADOS −60 electronic dosimeters for everyone involved in the test. Official recordings of the training, movement of persons, times and received doses were stated in a special dosimetry diary. The maximum dose received by the person did not exceed 10 µSv for the whole duration of the test.

2. Measured values and measuring instruments used for their measurement

Radiation level monitoring was done by personal film dosimeters, electronic dosimeters, handheld dose equivalent rate (DER) meters and object radiation system. All values were measured at certain dosimetry points and were used for subsequent evaluation of the exposure of the personnel involved in the test. Certified handheld instruments GEORADIS RT 30 for measurement of the DER Hp (10) were used. The measurement was conducted in two ranges: 10 nSv / h −100 µSv / h with an uncertainty of 20%, and 100 µSv / h −10 mSv / h with an uncertainty of 30%. The results were simultaneously validated by handheld instruments THERMO FH40 with telescopic probe FHZ 612-10 with a range of 10 Sv/h. In order to monitor a technical hall under HC (dosimetric point 27 - in Fig. 4) a certified instrument UNIDOS with ionization chamber with of 1 dm ^{3} volume, respectively 1 cm^3 for higher dose rate, was used. A high DER is expected in this area due to the incomplete cable shielding. Ionization chamber was placed on the tripod allowing the height setting in a range from 1 to 3 m above the floor. The chamber was connected to the UNIDOS instrument using 10 m cable. It is allowed to read data in a safe area with low DERs.

DER in HC was measured by stationary MDG – 04 probe. All adjacent cells were also equipped with MDG-04 probe. These probes are installed in the building radiation protection system. The results were converted to the sum of DER from adjacent cells and after that were recorded.

3. Hermetic box

Hermetic box (HB) is a first and only barrier for radioactive aerosols. The box is independent on a shielding cell. Each HB is pressurized to about −150 Pa during a normal service. In case of emergency it is possible to increase the value up to −3500 Pa. HBs are made of stainless steel. Each box is 3000 mm high, 2550 mm wide and 2712 mm deep. The weight of a single box is 4 t and a carrying capacity is 4 t. Each box has removable feature, thus, it is possible to disconnect and remove it from the shielding cell. Box has a removable ceiling, which allows straightforward operation with the machines inside of the HB from the top using the crane, which is also used for the manipulation with the whole HB. All electrical and data cables, tubes supplying liquid and gaseous media and manipulators can be unmounted and the HB can be extract from the HC. Several types of boxes distinguished by color are available. Green HB is used for the transfer device, blue HBs are for the operation with gamma nuclides and red HBs are designated for operation with alfa nuclides (Fig. 5). Each HB is equipped with the second floor, which is designed 800 mm above the primary one.

4. Methods and monitoring range

The source of ^{60}Co with activity 300 TBq was used for the HCs test (Fig. 6). For semi-HC test ^{60}Co with activity 60 GBq was used as a source. DER values were measured directly, e.g. detector and source were in one plane. Dosimetry points were selected with regard to the weakest points in the biological shielding (holes, joints and bushings),