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SEMI-AUTOMATIC BUBBLE COUNTING SYSTEM FOR SUPERHEATED DROPLET DETECTORS

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ABSTRACT

Neutron dose rate measurements are normally performed by means of PADC, CR-39 and TLD detectors. Although, none of these devices can give instant reading of the neutron dose, recently new kind of detectors are being developed, based on the formation of tiny drops in a superheated liquid suspended in a polymer or gel solution, called superheated droplet detector (SDD) or also as bubble detectors (BD), with no response for gamma radiation. This work describes the experimental setup and the developed procedures for acquiring and processing digital images obtained with bubble detector spectrometer (BDS), developed by Bubble Technology Industries, for personal neutron dosimeter and/or neutron energy fluence measurements in nuclear facilities. The results of the neutron measurements obtained during the F-18 production, at the RDS-111 cyclotron, are presented. These neutron measurements were the first ones with this type of BDS detectors in a particle accelerator facility in Brazil and it was very important to estimate neutron dose rate received by occupationally exposed individuals.

1. INTRODUCTION

Personal dosimeters, for all types of radiation, are essentials to ensure adequate protection of workers exposed to external sources. These are used to record the received doses as well as for evaluation of the effective dose, in order to make sure that the effective dose limits, specified by the regulatory authority, are not exceeded and also to demonstrate satisfactory working conditions or for safety assessment for optimization procedures and for radiation protection practices.

In a research establishment, in a nuclear facility or in any other devices used for the production of radioisotopes, neutron radiation is also produced. This radiation has no charge so it is extremely penetrating, produce indirectly ionization radiation and induce radioactivity in some nuclei by neutron capture process.

Normally, neutron dosimetry is usually done through Albedo and/ or with trace detectors such as PADC, CR39; or even with TLD (^{7}LiF/^{6}LiF) detectors [1-3]. However, these dosimeters have limitations, and all of them are passive dosimeters. In the last decade new devices known as "superheated droplet detectors" - SDD, or bubble detectors (BD) have been developed [4], with great advantage over the other ones, because they allow instantaneous visualisation of the exposure rate by counting the number of bubbles formed in the neutron interactions.

In 2008, the Nuclear Engineering Programme at COPPE/UFRJ, acquired a BDS36 kit and a RC-18 device for neutron detection from Bubble Technology Industries – BTI, Canada. The kit consists of a series of 36 tubes covering the energy range of neutrons from 10 keV to 20 MeV. These detectors can also be used for measuring the neutron fluence and energy distributions [5]. The RC-18 device allows recovering the used bubble detectors, for further measurements, so in this way this method is relatively inexpensive and can be used several times.

This paper presents the experimental setup for reading the bubble neutron detectors (BDS) at the Nuclear Engineering Institute (IEN), the Macro routine (in Visual Basic) for counting the bubbles with the computer programme Image Pro, and the results of dosimetric neutron measurements, during the F-18 production, in the IEN´s RDS-111 cyclotron.

2. MATERIALS AND METHODS

The BTI Inc. kit comes with six sets of BDS tubes with six different types of emulsions, uniformly distributed in an aqueous gel, to cover the neutron energy range from 10 keV to 20 MeV, with the following threshold: 10 keV, 100 keV, 600 keV, 1.0 MeV, 2.5 MeV and 10 MeV. Each tube comes from the factory with a certificate of calibration. To determine the dose of exposure is very simple, it needs only to count the number of bubbles formed during the irradiation (neutrons exposure) and divide this number by the factor shown in the tube label or in the certificate.

2.1. Experimental Setup

The experimental setup for counting the bubble on the BDS tubes is shown in Figure 1. It can be seen a digital camera (resolution of 3.34 mega pixels), a scaled rotation cylinder and a bubble detector tube. The images obtained in this system are processed through a routine developed (macro) for counting the bubbles using the Image Pro Plus Version 4 [6], according to the procedure described in section 2.2.

The rotary cylinder is used to obtain several images of the BDS tubes for three dimensions analysis (still under progress), or in the case when large amount of bubbles is formed in the BDS tube, due to a high rate of neutrons. In the last case, we normally get at least 13 images every 15 degrees, that correspond to 180^{o} scan of the BDS tube, around its vertical axis. This procedure is very useful to improve the counting of all the bubbles produced.

A digital camera Nikon CoolPix Model 995 [7], using a 5.3 aperture diaphragm, shutter speed 1/125, sensitivity ISO 400, operated in the function of MACRO AUTO mode at a distance of 24 cm from the BDS tube allows high quality images. The images are saved in TIFF format (Tagged Image File Format) with 16 million colours (24 bits) with a size of

2048 x 1536 pixels (9327 kB). Afterwards, the images are transfer to a hard disk of a computer (PC - IBM compatible) for further processing with Adobe Photoshop Version 6.0 software. With this program the images are manually filtered to correct the settings levels (to remove any noise), then the image is reduced to 256 in grey colour (8 bit), getting a file size with 3075 kB.

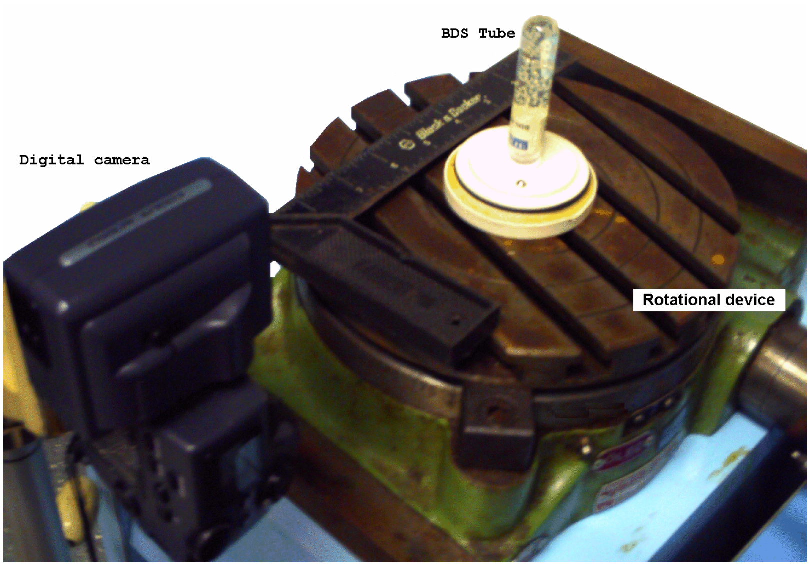

Figure 1. Experimental setup for bubbles counting.

2.2. Digital Image Processing

The Image Pro Plus is an image analysis software used for quantification and processing of 2D and 3D images, it has extensive tools to measure and customization features of closed polygons (bubbles). The Plus version allows to create macros for automatic programming analysis and counting.

The software provides through the Count/Size command, three option of analysis, with respect to intensity and size of the objects, these are: Manual Mode; Auto Bright Objects; and Auto Dark Objects. Firstly, it is necessary to select and define some parameters for evaluation of linear and spatial objects, providing its limits for lower and higher levels. The parameters chosen in this work are:

1. Area - area of each bubble represented in the image;
2. Aspect - the relationship between the major and minor axis of each bubble measure;
3. Diameter (max.) (mean) (min.) - maximum diameter, mean and minimum of the bubbles;
4. Margin - distribution on the optical density of the object far from the centre to the periphery, this is to diagnose the wall thickness with relation to its size;

5. Perimeter - perimeter of the bubble;
6. Roundness - measure of the roundness: $(\text{Perimeter}^2)/(4.\pi.\text{area})$.

In the following table the values of the mentioned parameters, for the bubbles analysis, are presented.

Table 1. Limits set for the bubbles analysis of the BDS tubes.

	Limits *	
Area	75	3700
Aspect	1	1.9
Diameter (max.)	10	146
Diameter (mean)	7	90
Diameter (min.)	9	60
Margin	0.2	0.4
Perimeter	30	265
Roundness	1	2

* The values are in pixels

In case of large number of images per sample, or for tubes with more than 130 bubbles, the developed macro (series of commands and instructions) written in Visual Basic for analysis in batches is used. This macro is based on the following algorithm:

1. Application of sequence of filters to unite possible discontinuities in the walls of the bubbles;
2. Application of grey scale filter for automatic recognition of bubbles;
3. Application of morphological filter for removal of overlapping bubbles;
4. Measurement and automatic counting of bubbles;
5. Manual mode for adding up more bubbles; and
6. Recording the results in formatted file.

The macro developed allows an interactive mode, in order to eliminate overlap bubbles and to set manually some bubbles that may have not been considered automatically, i.e., those that were rejected in the auto mode for not being in accordance with the parameter settings, see Figure 2. An important consideration of the method, is that the bubbles formed on the walls of the tube should not be counted. In the automatic counting around 80% of the bubbles are marked.

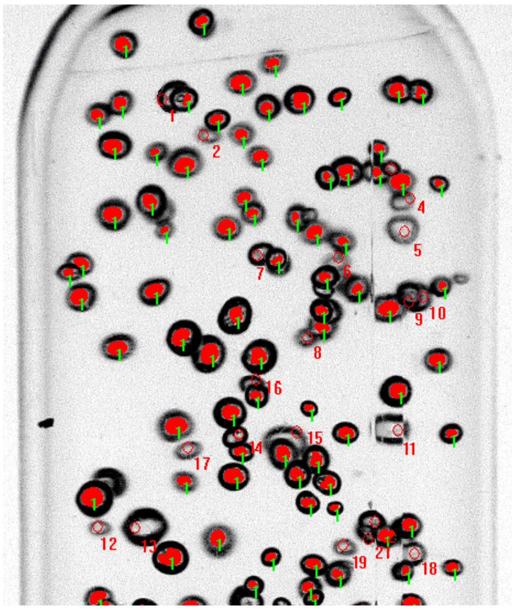

Figure 2. Counting of bubbles with the macro routine, the green lines shows bubbles counted automatically.

3. RESULTS AND DISCUSSION

The first dosimetric measurements with the new BDS bubble detectors, were made on 12 August and 03 September 2008, during the production of radioisotope F-18 in the RDS-111 cyclotron. The BDS tubes were placed approximately 90 cm from the target No.1, in the external shielding of the RDS unit.

1- Proton beam irradiation No. 660
The following tubes were used: BDS 10 (s/n 7341455 and 7341401); BDS 100 (s/n 735 4250 and 735 4246) and; BDS 600 (s/n 7344234 and 7344232). The beam current was 55 μA and the irradiation time was 180 minutes.

2- Proton beam irradiation No. 678
The tubes used were: BDS 1000 (s/n 7354335 and 7354324) and BDS 2500 (s/n 7354446 and 7354443). The current on the target was 51 μA and the exposure time was 150 minutes.

Since the nuclear reaction $^{18}O(p, n)^{18}F$ was carried out with proton with 11 MeV, the BDS 10000 detector was not used because only neutrons with lower energy than 8.6 MeV (Q value - 2, 44 MeV) were produced. In Table 2 are shown the results for the neutron doses using the routine macro on the exposed BDS tubes. For illustration purpose, the values reported by the Image Pro software, for the mentioned parameters, and the counts performed manually are also presented. In the manual counting, it was selected the best image of the tube and after its amplification, it was printed on paper and the bubbles were marked and counted for comparison. It can be seen that deviations were higher than 10% for the BDS tubes with more than 120 bubbles. Finally, to validate these results, other tests are being conducted at

Instituto de Radioproteção e Dosimetria (IRD) Neutron Calibration Laboratory – LNMRI, checking the certified values of the BDS kit.

Table 2. Performance of the developed method for counting bubbles of BDS tubes exposed to neutron field at the RDS-111 cyclotron.

File Name*	Area	Aspect	Diam. (mean)	Perimeter	Macro Counting	Difference (%)	Dose (mrem)
10_11_3146.tif	1850.2	1.0588	48.08912	153.16	123	11.4	124
10_14_3095.tif	2258.2	1.4338	53.50705	183.72	150	14.0	122
100_13_3185.tif	4217.8	1.8309	71.54741	254.45	104	-0.01	79
100_14_3198.tif	3826.7	1.2684	68.87144	220.48	94	-0.03	65
600_17_3211.tif	1340.9	1.5969	40.03605	135.93	111	0.07	70
600_20_3225.tif	4423.6	1.3867	73.25158	256.45	112	0.08	61
2500_14_3299.tif	3044.9	1.2734	61.46870	208.20	23	-0.09	15
2500_15_3313.tif	1632.4	1.5701	58.34614	394.14	21	-0.05	13
1000_13_3279.tif	3356.0	1.1794	64.69213	208.41	9	0.00	7
1000_17_3251.tif	839.56	1.6288	44.84942	359.46	26	0.00	15

* Energy Threshold _Dosimetric Factor_Image Number

4. CONCLUSIONS

The experimental setup and the procedure developed for BDS bubble detectors allowed neutron dosimetric measurements around the RDS-111 cyclotron. It also need further validation, but such implementation from now on will contribute significantly to the protection of individuals occupationally exposed to neutrons at the facilities in the Nuclear Engineering Institute.

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