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NEUTRONGRAPHY EXPERIMENTS AT THE IEA-R1 NUCLEAR RESEARCH REACTOR

Reynaldo Pugliesi; Marco A.P.V. de Moraes;
Ione M. Yamazaki and Clarice de F. Acosta

Instituto de Pesquisas Energéticas e Nucleares
Comissão Nacional de Energia Nuclear
Divisão de Física Nuclear - TFF
Caixa Postal 11049 - Pinheiros
05499 São Paulo - SP
Brasil

Abstract: Neutrongraphy of several materials have been obtained at the IEA-R1 Nuclear Research Reactor by making use of two experimental arrangements. The first one installed in a beam-hole tube and the second in the bottom of the reactor pool. The film and converter screens used were the nuclear solid state track detector (N.S.S.T.D.) CN-85-2B coated with a lithium tetraborate and the Kodak Industrex T-5 with a dysprosium foil. We have obtained good results and this work is the first step of the plan to develop the neutrongraphy technique in our Institute.

Introduction

Radiography with neutrons is a relatively new non-destructive technique employed in material analysis. It basically consists in registering the transmitted neutron pattern through the materials that are placed in a homogeneous neutron beam. This registering is made by means of converter screens in which a latent image is formed and can be direct or indirectly transfered to films. The transmitted pattern depends of the material thickness and of the total macroscopic cross-section that takes into account all the interaction processes between the neutron and the material, which impute to neutrongraphy special characteristics /1/. Several kinds of plastics, oils, explosives, adhesives and other hidrogeneous substances may succesfully be studied by this technique, in spite of being wrapped in metals. In some cases, structural differences among materials of neighbouring atomic numbers or between isotopes of a same element can also be seen. Neutrongraphy technique is particularly useful to inspect high radioactive materials.

The objective of this work was to verify the viability of the neutrongraphy technique at the IEA-R1 Nuclear Research Reactor (IPEN-CNEN/SP) due to the increasing industrial and nuclear technological development of our country.

Experimental Part

Lithium Tetraborate Converter Screen /2,3/

The neutron beam employed was extracted of the beam-hole tube 3 where a berilium filter-time of flight spectrometer is installed. Inside this tube there are: a lead filter to reduce the gamma radiation contribution and two berilium filters which permit that only neutrons with energy E<5,2 meV impinges the material studied. The neutron flux at the local of irradiation is ~ $10^5 n/s/cm^2$ and the beam geometric unsharpness is L/D = 25. The sample holder is an aluminium sheet in a "L" format as seen in figure 1. The film used was the Nuclear Solid State Track Detector N.S.S.T.D. CN-85-2B-Kodak type composed by cellulose nitrate, 100 µ thickness, coated with lithium tetraborate at the two faces. After an exposure time of 15 minutes the film is taked off from the sample holder, washed in water to remove the converter coating and is chemically etched in a NaOH solution (10%/w) at $(60 \pm 1)^{\circ}C$ during 30 minutes. These appropriate time conditions were determined by an image visual evaluation, after the film have been washed in water and dried in an air stream.

Dysprosium Converter Screen /1,4/

The experimental arrangement is located at the bottom of the reactor pool and contains a conical divergent collimator and a redoma where the sample-holder and the dysprosium converter screen are installed. The arrangement may be movable as far as the reactor core where the thermal neutron flux is ~ $10^{11} n/s/cm^2$. The flux at the materials studied is ~ $10^5 n/s/cm^2$ with a beam geometrical unsharpness L/D=250. The sample holder is an aluminium box dimensions 10 cm x 10 cm x 40 cm and the dysprosium screen is located behind it as seen in figure 2. Several types of films were tested and the best results were obtained by using the Kodak T-5. The exposure and image transfering times were 2 hours and 20 hours respectively. After a conventional etching process the optical density in the film was about 2 or 3.

By making use of photographic paper Kodak--Bromide F4 and F5, photographic reproductions of the results relative to both converter screens methods were made.

Results and Conclusions

Various radiographies were obtained in this work. Figures 3 and 4 show the summary of the imaged materials studied using the CN-85 and T-5 films and good contrast and resolution of images can be clearly recognized. Some of the radiographies such as the projectile or ink level into the steel tube and the nuclear fuel element were carried out in order to show the main characteristics of the technique relative to inspection of hidrogeneous substances and highly radioactive materials.

The N.S.S.T.D. are intrinsically insensitive to gamma radiation but damage by intense gamma radiation may be expected. Therefore, the effect of the intense gamma radiation on the track production or other factors of the films will be examined when proper equipment is available. Much useful informations about the radiography with neutrons were obtained from this work to its future implantation in our institution which basically has demonstrated its viability and powerful for our purposes by using the IEA-R1 nuclear research reactor.

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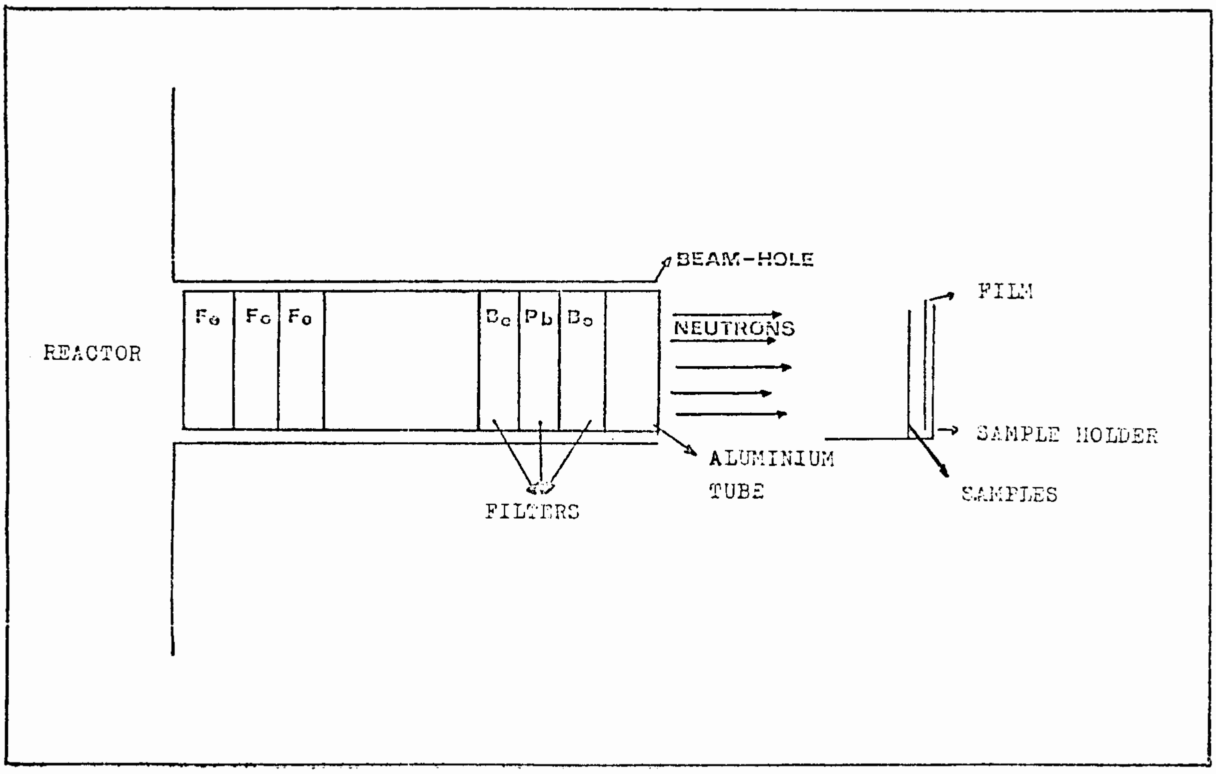


Figure 1 - Experimental Arrangement in the Beam-Hole 3.

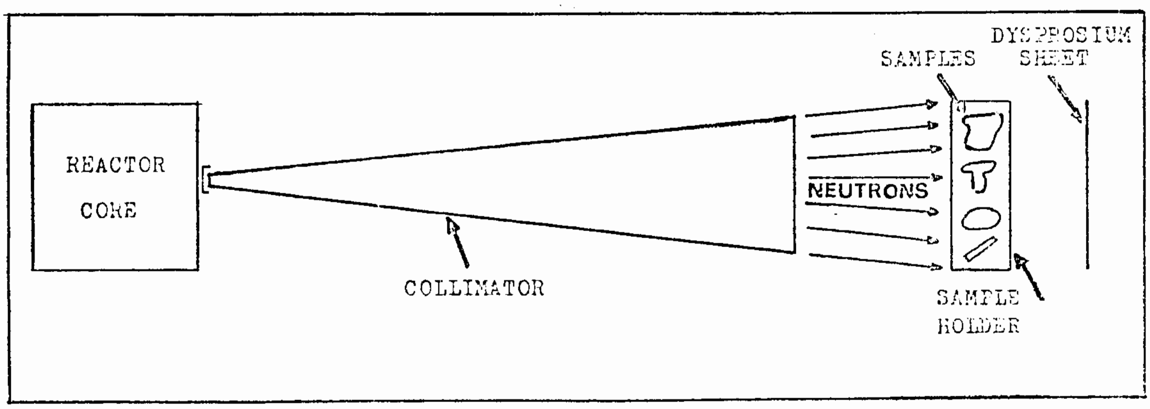
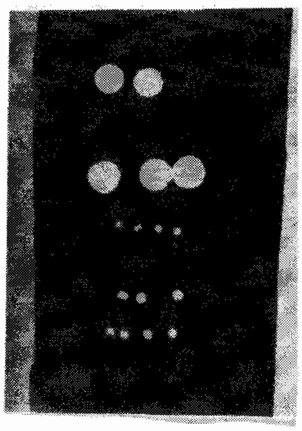
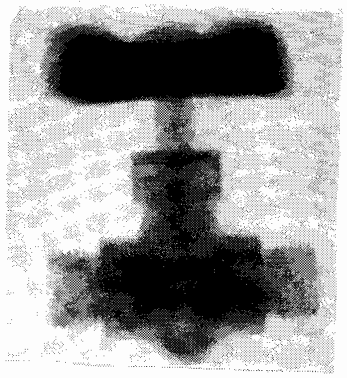


Figure 2 - Experimental Arrangement Installed in the Bottom of the Reactor Pool.

a) Cd sheet



b) Brass air valve



c) Iron screw

d) Projectile

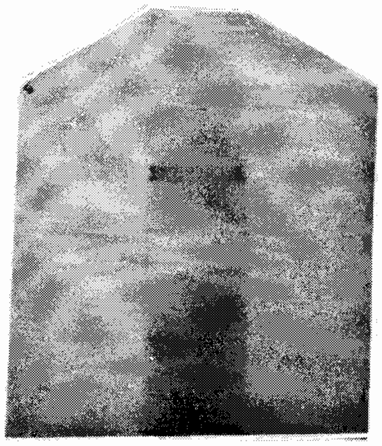
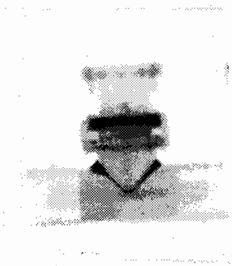
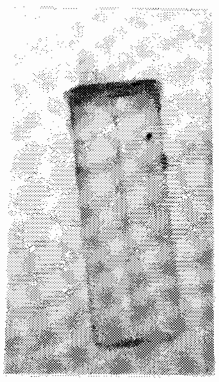


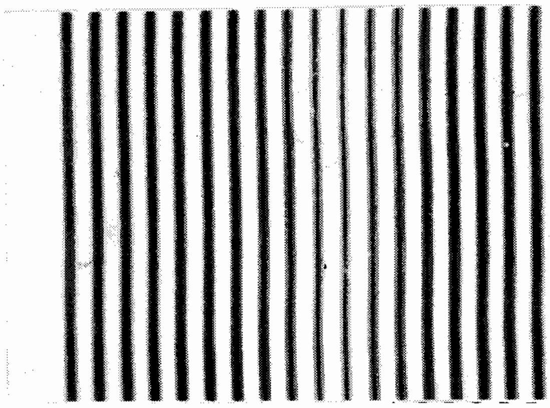
Figure 3 - Lithium tetraborate converter screen / CN-85-2B film



a) BNC conector



b) G-Muller Detector



c) Nuclear Fuel Element Section

d) Ink level into a steel tube

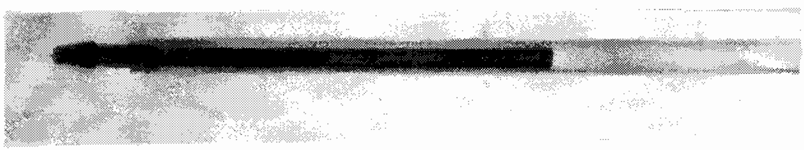


Figure 4 - Dysprosium Converter Screen/T-5 Film.