

NEUTRON AND GAMMA RADIOGRAPHY STATION AT THE NUCLEAR RESEARCH REACTOR MARIA AT ŚWIERK

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Weak interaction of neutrons with typical metals, such as Fe and Al, combined with a strong scattering of the neutrons by hydrogen, allows them to penetrate macroscopic metallic objects and to reveal the internal distribution of hydrogen containing components, such as petrol, water, organic materials and corroded parts. The strong beam of gamma radiation, emitted from nuclear reactor, also can be used to provide an extra information on the interior of the object investigated. Having passed the investigated object, the neutron or gamma radiation reaches the fluorescent screen (converter), where it is converted into visible light (Fig. 1). The two-dimensional projection of the object on the screen is registered with the CCD camera and processed using computer methods.

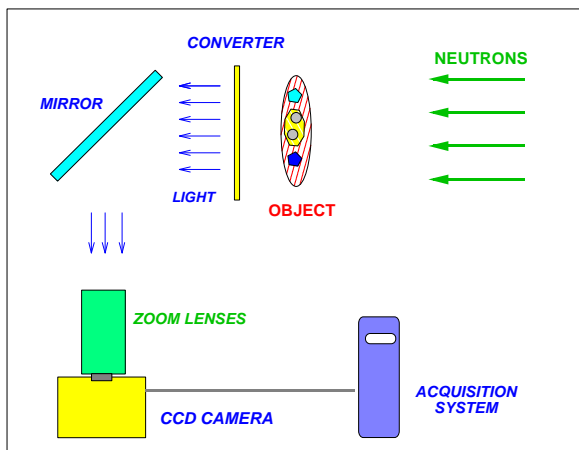


Fig. 1. The main parts of the neutron radiography station.

The neutron and gamma radiography (NGR) station at Świerk is situated at the horizontal beam H8 of the MARIA reactor. The station has started its operation in July 2001. The following investigations have been performed in 2005:

- Temperature dependence of water migration in rigid and loose porous materials.
- Nondestructive testing of technical objects.
- Kinetics of temperature changes in clay beds during imbibition.

The general layout of the NGR station is shown in Fig. 2. Due to the ample space by the channel H8 of the reactor MARIA and its relatively large neutron flux, this NGR facility has many advantages, especially for diagnostics of industrial objects. Remote-control support devices and modern analogue and digital registration equipment will allow us to scan and record the internal structure of large objects like engines, refrigerators, as well as some elements of their internal dynamics. The station is equipped with the mobile

sample support-carrier, enabling the remote control tuning of the position of the investigated object with respect to the radiation beam and converter screen. The sample support can hold objects with mass to 100 kg.

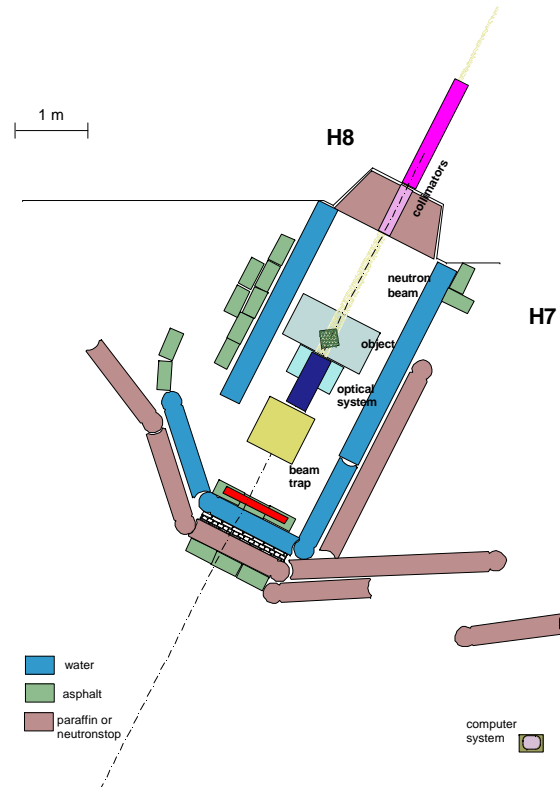


Fig. 2. General layout of the neutron and gamma radiography station at the research reactor MARIA.

The parameters of the station are: $100 < L/D < 200$. Cd ratio = 20, and the neutron flux density $1.1 \cdot 10^7$ n cm⁻² s⁻¹ at the sample position for $L/D=150$. The spatial resolution is usually of the order of 0.1 mm. The high quality images are produced with the exposition time of 2.5 s, but satisfactory quality of the full resolution radiograms was obtained for the exposition time of 0.6 s.

Good uniformity of the white field was confirmed and the linear resolution of 0.1 mm for the optical magnification used in most experiments was established. The result of the resolution test is presented in Fig. 3 containing the radiogram (Fig. 3a) of three 2 mm thick slabs made of cadmium, lead and Plexiglas with holes of 2 mm diameter. The edges of the holes are separated by gaps with widths decreasing from 1 to 0.1 mm upwards. The optical density plot (Fig. 3b) reveals distinct cusp on the left corresponding to the smallest separation gap (0.1 mm).

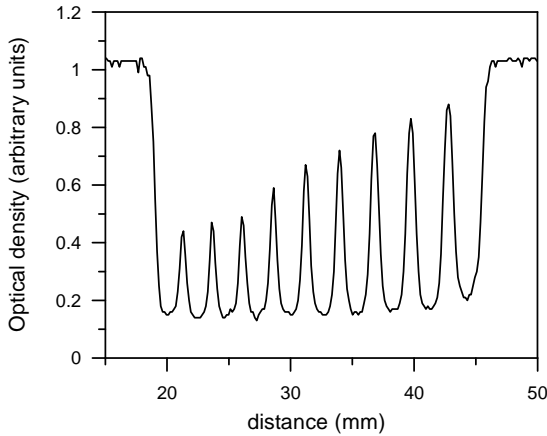
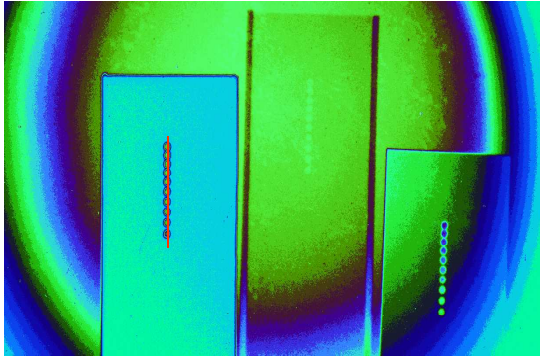


Fig. 3. The artificially colored radiogram of three sheets of (from the left) cadmium, lead and Plexiglas with 2 mm diameter holes separated by gaps of width from 0.9 to 0.1 mm (a), (b) – the plot of optical density distribution along the line across the holes' centres in the cadmium sheet.

Radiograms of objects with separated regions containing ordinary and heavy water demonstrate the strong incoherent scattering of neutrons by hydrogen nuclei. The strong effective absorption of neutrons by ordinary water produces dark regions in the images. As an example the radiogram of the aluminium double container with ordinary and heavy water is presented in Fig. 4. The thickness of both liquid layers was 1.3 mm.

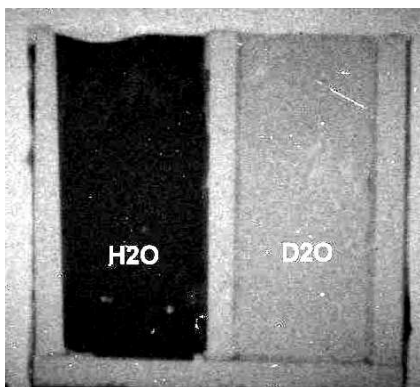
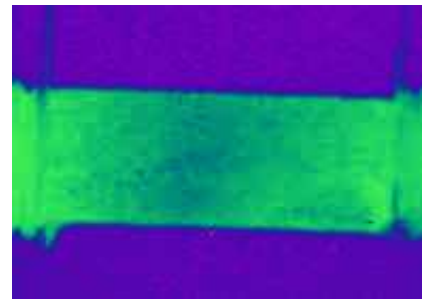


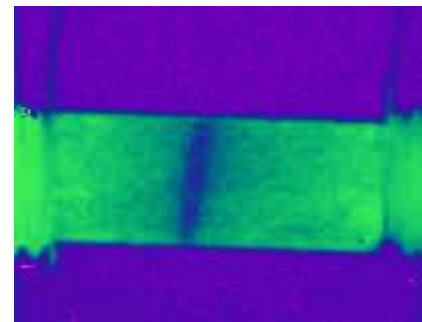
Fig. 4. The radiogram of flat double container filled with ordinary water (left part) and heavy water (right side) of 1.3 mm thickness.

Attempts were made to observe processes induced by various external factors, mainly the electric field. One of the most interesting processes observed was the evaporation of water from the wetted sample of aerated concrete when heated by the electric current. The sequence of images from this process is presented in Fig. 5. The process was observed during approximately 60 s after switching the voltage supply on. The sample was covered with three layers of acrylic paint and wetted for 24 h with 10% NaCl water solution. The sample is 35 mm long with the cross section 10 mm \times 10 mm and the ac voltage of 70 V was applied through the gold electrodes. The water evaporation through the damaged paint cover was very rapid leaving the dry region (visible in the radiograms as the light tilted strip) in the middle of the sample.

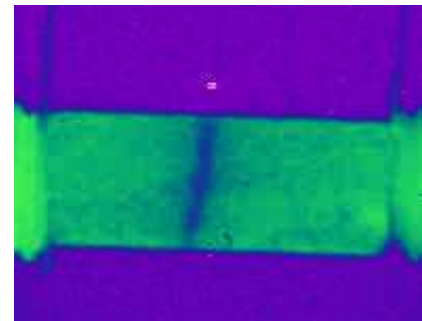
The merits of NR are inaccessible within standard X-ray or optical methods, supporting the expectations of interest in NR from many researchers of industrial, agriculture, medical and other roots.



(a) t = 5 s



(b) t = 10 s



(c) t = 55 s

Fig. 5. The process of the water evaporation induced by heating of the wet porous sample with the electric current. The time is counted from the switching the voltage supply on.