5.10 Development and Application of Neutron Diagnostics Based on Activation Method for Magnetic Confinement Devices*)

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Neutron measurements provide direct information on nuclear fusion reactions occurring inside high-temperature deuterium plasma. In practice, it is possible to measure the total neutron yield, energy spectra and neutron emissivity from such a plasma. Basing on these data one can estimate the total number of nuclear reactions, the released fusion power, and the relative contribution of thermal- and acceleration-mechanisms to the total neutron yield, etc. However, special neutron diagnostic tools are needed for tokamak studies to operate in the harsh radiation environment and to cover a broad range of neutron yields (from 10^{10} to 10^{19} sec^{-1}). In addition, the neutron measurements have to be made on a time-scale, which varies from 1 ms to several sec. The neutron activation technique seems to cope very well with these conditions. Therefore, it becomes recently to be of great importance.

To perform activation measurements small samples of suitable isotopes are placed close to plasma. After irradiation with neutrons from one or several plasma discharges, the samples are transported to a proper detector and activity of the produced radionuclide is measured. Taking into account geometry of the neutron source, the sample mass and its position, as well as the decay characteristics of the investigated isotope, one can estimate the total number of neutrons emitted from plasma. Moreover, activities induced in different isotopes (activators) permit the neutron energy spectrum to be determined. The activation methods provide also the calibration factor for other neutron detectors (e.g. for BF_3 or ^{3}He proportional counters, ^{235}U fission chambers, etc.) and they deliver valuable tests for neutron transport calculations.

In practice, different groups of isotopes are used to measure 14.1 MeV neutrons, originating from d(t,n)^{4}He reactions, as well as 2.5 MeV neutrons produced in d(d, n)^{3}He reactions. One can select isotopes with suitable energy threshold values (E_{th}) of their cross sections for activation reactions, and an adequate dependence of their cross sections on neutron energy. However, in order to avoid influence of scattered neutrons, the E_{th} energy value should be possibly high. Besides that, the nuclear reaction should produce a daughter nuclide that decays through the energetic gamma (Eγ) emission with a half-live ($T_{1/2}$) time in excess of a few minutes, but less than a few hours. Isotopes, which have too long decay half-lives, are rather unsuitable because they can not be reused in successive discharges, and the counting rate might be too low. Energetic gamma rays (e.g. 1.78 MeV γ-radiation from a decay of ^{28}Al) are preferred because such quanta are easily measured with a NaI detector, and they assure that the contamination of interfering (γ,γ') reactions is very low.

The first set of activators selected in our lab included: ^{58}Ni (E_{th}=1 MeV, $T_{1/2}$=70.8 d, E_γ=810 keV), ^{115}In (E_{th}=0.5 MeV, $T_{1/2}$=4.5 h, E_γ=336 keV), ^{197}Au (E_{th}=0.0 MeV, $T_{1/2}$=2.3 d, E_γ – 6 lines of energy from 97 keV to 411 keV). In 2006 this set was tested in experiments performed within the PF-1000 facility. For those tests the activators were fixed in a special holder shown in Fig. 1.

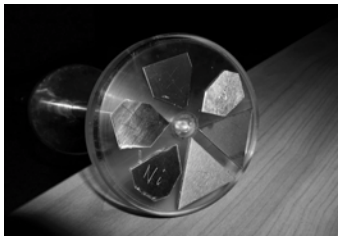

Fig. 1 Assembling of activators for PF-1000 experiment [1].

The set of the activators was placed in the PF-1000 axis at a distance of 5 cm from the electrode outlet. Each sample was activated with neutrons emitted from two discharges (Y_n varied from $2.2\cdot10^{10}$ to $1.0\cdot10^{11}$). The induced γ-activities of the samples were measured with a germanium detector. Numbers of activated nuclei was estimated on the basis of known characteristics of the isotopes decays. The estimated total neutron yields were comparable with those measured with the calibrated silver activation counters. The results obtained from the activated indium showed the largest difference. This discrepancy could be explained by the fact that indium is not a dosimetric standard and a cross section of the ^{115}I(n,n)^{115m}I reaction is poorly determined [1].

The preliminary activation measurements within the JET facility were performed in November and December 2006. The set of activators used previously in the PF-1000 experiment was supplemented by ^{180}Hf (E_{th}=0.1 MeV, $T_{1/2}$=5.5 h, E_γ=215, 332, and 443 keV) and ^{27}Al(E_{th}=0.0 MeV, $T_{1/2}$=135 s, E_γ=1179 keV). The obtained results are still being elaborated, but preliminary estimations revealed that the total neutron yield values inferred from the measured activities do not differ significantly from those obtained by means of fission chambers [2].

[1] B.Bienkowska, L.Karpinski, A.Szydlowski et al., Czech J. Phys. 56, Supp. B (2006) B377-382

[2] R.Prokopowicz, A.Szydlowski, M.Scholz, Report on the visit at JET (Oct.30–Dec.12, 2006)

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