



Standard Practice for Application and Analysis of Nuclear Research Emulsions for Fast Neutron Dosimetry¹

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1. Scope

1.1 Nuclear Research Emulsions (NRE) have a long and illustrious history of applications in the physical sciences, earth sciences and biological sciences (1,2)². In the physical sciences, NRE experiments have led to many fundamental discoveries in such diverse disciplines as nuclear physics, cosmic ray physics and high energy physics. In the applied physical sciences, NRE have been used in neutron physics experiments in both fission and fusion reactor environments (3-6). Numerous NRE neutron experiments can be found in other applied disciplines, such as nuclear engineering, environmental monitoring and health physics. Given the breadth of NRE applications, there exist many textbooks and handbooks that provide considerable detail on the techniques used in the NRE method. As a consequence, this practice will be restricted to the application of the NRE method for neutron measurements in reactor physics and nuclear engineering with particular emphasis on neutron dosimetry in benchmark fields (see Matrix E 706).

1.2 NRE are passive detectors and provide time integrated reaction rates. As a consequence, NRE provide fluence measurements without the need for time-dependent corrections, such as arise with radiometric (RM) dosimeters (see Test Method E 1005). NRE provide permanent records, so that optical microscopy observations can be carried out anytime after exposure. If necessary, NRE measurements can be repeated at any time to examine questionable data or to obtain refined results.

1.3 Since NRE measurements are conducted with optical microscopes, high spatial resolution is afforded for fine structure experiments. The attribute of high spatial resolution can also be used to determine information on the angular anisotropy of the in-situ neutron field (4,5,7). It is not possible for active detectors to provide such data because of in-situ perturbations and finite-size effects (see Section 11).

1.4 The existence of hydrogen as a major constituent of NRE affords neutron detection through neutron scattering on hydrogen, that is, the well known (n,p) reaction. NRE mea-

surements in low power reactor environments have been predominantly based on this (n,p) reaction. NRE have also been used to measure the ${}^6\text{Li}$ (n,t) ${}^4\text{He}$ and the ${}^{10}\text{B}$ (n, α) ${}^7\text{Li}$ reactions by including ${}^6\text{Li}$ and ${}^{10}\text{B}$ in glass specks near the mid-plane of the NRE (8,9). Use of these two reactions does not provide the general advantages of the (n,p) reaction for neutron dosimetry in low power reactor environments (see Section 4). As a consequence, this standard will be restricted to the use of the (n,p) reaction for neutron dosimetry in low power reactor environments.

1.5 *Limitations*—The NRE method possesses three major limitations for applicability in low power reactor environments.

1.5.1 *Gamma-Ray Sensitivity*—Gamma-rays create a significant limitation for NRE measurements. Above a gamma-ray exposure of approximately 3R, NRE can become fogged by gamma-ray induced electron events. At this level of gamma-ray exposure, neutron induced proton-recoil tracks can no longer be accurately measured. As a consequence, NRE experiments are limited to low power environments such as found in critical assemblies and benchmark fields. Moreover, applications are only possible in environments where the buildup of radioactivity, for example, fission products, is limited.

1.5.2 *Low Energy Limit*—In the measurement of track length for proton recoil events, track length decreases as proton-recoil energy decreases. Proton-recoil track length below approximately 3μ in NRE can not be adequately measured with optical microscopy techniques. As proton-recoil track length decreases below approximately 3μ , it becomes very difficult to measure track length accurately. This 3μ track length limit corresponds to a low energy limit of applicability in the range of approximately 0.3 to 0.4 MeV for neutron induced proton-recoil measurements in NRE.

1.5.3 *Track Density Limit*—The ability to measure proton recoil track length with optical microscopy techniques depends on track density. Above a certain track density, a maze or labyrinth of tracks is created, which precludes the use of optical microscopy techniques. For manual scanning, this limitation arises above approximately 10^4 tracks/cm², whereas interactive computer based scanning systems can extend this limit up to approximately 10^5 tracks/cm².

1.6 *Neutron Spectrometry (Differential Measurements)*—For differential neutron spectrometry measurements in low

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² The boldface numbers in parentheses refer to the list of references at the end of the text.