MEASUREMENT OF MOISTURE AND HYDROGEN CONTENTS
BY INTERMEDIATE NEUTRON MODERATION

N. WADA

Radioisotope Center, Japan Atomic Energy Research Institute, Ōarai-machi,
Ibaraki-ken (Japan)

(Received January 4, 1974)

An intermediate neutron moderation method for measurement of moisture and/or hydrogen contents of small samples is presented. The sample is placed on the top face of a neutron howitzer, with a cadmium sheet between. Thermal neutrons resulting from intermediate neutron moderation in the sample are detected with a 3He proportional counter placed on the sample, by a cadmium difference method. With a 500 mCi Am-Be neutron source, the limit of moisture detection for a 10 x 20 x 1.8 cm³ asbestos plate in 1 min count time is 0.5 wt. %. The precision of measuring the hydrogen contents of 250 ml hydrocarbons containing 112 mg H/ml is 0.9% under the same conditions.

Introduction

G a r d n e r and K i r k h a m 1 first reported a theoretical model of the neutron moisture gauge based on fast neutron moderation, whereby rapid, non-destructive measurement is possible. It is applied for measurement of moisture and/or hydrogen contents in the civil engineering 2 and other industries. 3 A disadvantage of this gauge is that a large quantity of material is required for the measurement. Accurate moisture measurement, however, is possible by integrating over the large volume of material, even if the moisture distribution is heterogeneous. S e m e l and H e l f 4 reported results of the use of fast neutron moderation for moisture measurement in relatively small samples. In their work, a 5 Ci Pu-Be neutron source and special geometry conditions are used to obtain high sensitivity.

Besides the neutron moderation method, thermal neutron transmission techniques for small samples or plates have been reported by several workers. 5-7 In these techniques, a neutron source of about 5-10 Ci is necessary to obtain high accuracy within a reasonable count time, because the relative sensitivity is not too high.

In this report, a new method based on intermediate neutron moderation for measurement of the moisture and/or hydrogen contents of small samples is described, which uses a relatively low-level neutron source.
Experimental

Principle

The slowing-down powers of the elements which constitute asbestos or hydrocarbons are calculated from the average logarithmic energy decrement and scattering cross-section for intermediate neutrons of 100 eV. The results are shown in Table 1. The slowing-down power per unit weight of hydrogen is larger than those of the other elements by a factor of 1000. Below a few MeV, the scattering cross-section of hydrogen increases with decrease of the neutron energy, whereas those for the other elements are fairly constant. Therefore, hydrogen is the most effective in neutron moderation.

Assuming that the average energy of neutrons emitted from a radioisotopic neutron source is about 4 MeV, the number of collisions required to slow down to thermal velocity is then also calculated for the fast neutrons of 4 MeV and for the intermediate neutrons of 100 eV. From the data in Table 1, the number of collisions for intermediate neutrons is about half that for fast neutrons.

Therefore, a method based on intermediate neutron moderation can be applied for measurement of the moisture and/or hydrogen contents of small samples or plates, instead of a fast neutron moderation method.

Apparatus

The moisture and/or hydrogen measuring apparatus consists of a radioisotopic neutron source, a neutron howitzer covered with a cadmium sheet, a sample cell and a thermal neutron detector. It is shown schematically in Fig. 1.

A 500 mCi Am-Be neutron source emitting $1.2 \times 10^6$ n·sec$^{-1}$ is used. The howitzer is made by casting paraffin into an aluminium can, 30 cm in diameter and 30 cm high. The opening hole is 6.5 cm in diameter and 15 cm deep; these dimensions were determined from the experimental results on neutron absorptiometry. The top face is covered with a cadmium sheet 0.3 mm thick, to obtain a stream of intermediate neutrons in the direction of the opening. The sides of the howitzer are also surrounded by cadmium sheet for radiation protection.

The detector is placed on the sample. A cadmium difference measurement is made for each sample. For the neutron detector, three commercial slow neutron detectors, i.e. $^3$He proportional counter, BF$_3$ proportional counter and ZnS(Ag)-B polyester scintillation counter, were evaluated for detection efficiency.

A polyethylene neutron reflector is placed close to the neutron detector, to reflect back the fast neutrons which are scattered and lost into the outside; this is used to examine the effect in sensitivity of the hydrogen measurement.