NON-DESTRUCTIVE TEST METHOD FOR DETERMINING BORON CONTENT OF BASKETS INSERTED IN SHIPPING CASKS TO ENSURE SUBCRITICALITY

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Abstract

NON-DESTRUCTIVE TEST METHOD FOR DETERMINING BORON CONTENT OF BASKETS INSERTED IN SHIPPING CASKS TO ENSURE SUBCRITICALITY.

In order to ensure the subcriticality of spent fuel elements in shipping casks, the fuel elements are placed into an inserted basket with neutron absorber plates containing a definite amount of the boron-10 isotope. The paper describes a non-destructive test method which allows the specified boron-10 content to be detected by comparative neutron absorption measurements. The measuring apparatus is specified and criteria for the selection of the absorber plates to be tested are stated, with statistical aspects taken into account.

In compliance with the IAEA Regulations for the Safe Transport of Radioactive Materials [1], fissile materials must be so packaged and shipped that under all foreseeable circumstances no critical state can occur during transport. This nuclear safety can be reached in different ways. Normally the precautions to be taken are laid down by the competent authority in the approval certificate for a sample package. This approval prescribes at the same time measures of quality assurance which aim at guaranteeing compliance of the representative samples with the approved pattern. According to the instructions concerning measures of quality assurance valid in the Federal Republic of Germany [2], the applicant is responsible for the establishment and realization of quality assurance measures.

In the present case it has been proposed to ensure the subcriticality of spent fuel elements in shipping casks by using an inserted basket with neutron absorber

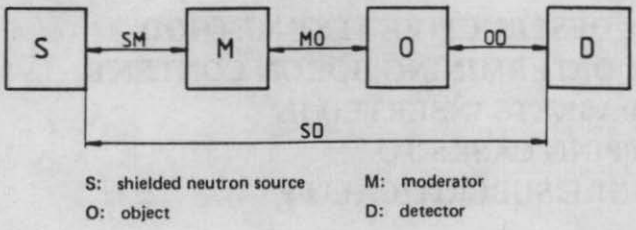

FIG. 1. Schematic diagram of the measuring arrangement and the essential distances.

plates containing a definite amount of the boron-10 isotope. In compliance with authorities, a non-destructive test method is described here which allows the specified boron-10 content to be detected by comparative neutron absorption measurements.

The measuring apparatus essentially consists of a moderated ^{252}Cf neutron source with an activity of 37 MBq (1 mCi), a ^{3}He counter tube and the electronic measuring equipment. Two kinds of plates are used as measurement objects; a sandwich-type structure with a pressed homogeneous Al–B_4C mixture surrounded by an aluminium cladding and plates from a homogeneously borated aluminium alloy.

Figure 1 is a schematic diagram of the measuring apparatus; it indicates the most important distances between the individual components. The source has the shape of a cylinder, 7.8 mm in diameter and 10 mm in height. It is embedded in one of the surfaces of a paraffin cube which serves as a shielding. The source neutrons are thermalized by a moderator consisting of plexiglass plates of different thickness. The plates to be tested, made of borated aluminium alloys, were of equal thickness (11 mm); their boron content differed. When the detector is selected it should be borne in mind that high sensitivity to thermal neutrons is of utmost importance. The distances indicated are important for statistical reasons to obtain high counting rates. In addition, they are to ensure good reproducibility.

Figure 2 shows an example of a basket containing absorber plates of this kind. This basket is inserted into a fuel element shipping cask.

Preliminary tests served to

- establish the thermal stability of the apparatus
- determine the counter tube characteristics
- determine the dependence of the counting rate on the moderator thickness and its influence on the steepness of the calibration curve
- define the optimum geometrical boundary conditions of the measuring apparatus
- test the qualitative and quantitative suitability of the apparatus by background determination.

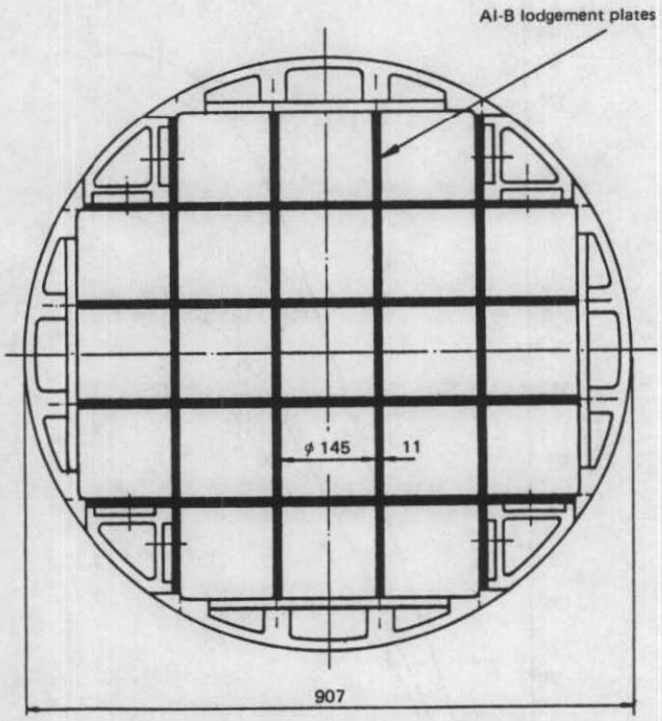

FIG. 2. Schematic cross-section of TN 900/1–21 basket with boronated aluminium lodgement plates.

Figures 3 and 4 show some measurement results of the preliminary tests. As can be gathered from Fig. 3, a counting rate maximum is obtained for a definite moderator thickness and a definite boron content which corresponds to that required for reasons of subcriticality. In the vicinity of this maximum, the slope of the curve indicating the dependence of the counting rates on the boron content as shown in Fig. 4 must be as steep as possible. This allows the optimum moderator thickness to be determined for the given boundary conditions (boron content, plate thickness).

To determine the calibration curve, a number of test specimens (plates) with stepped boron content were produced by the same method. For each test specimen the counting rate is measured several times; then the mean value and the standard deviation of the mean value as well as a confidence interval are calculated [3]. For the determination of the boron content some plates are chemically analysed to allow a calibration curve to be obtained. It is assumed that this calibration curve is valid also for the other plates of this series. With the aid of these other plates the calibration curve can be reproduced taking justified corrections into account (e.g. decrease of the source activity).

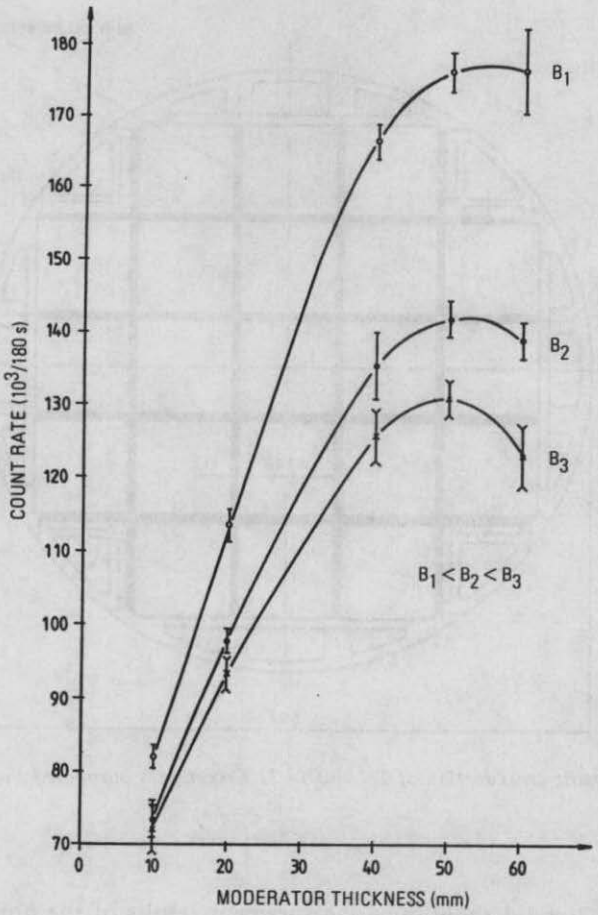

FIG. 3. Count rate as a function of moderator thickness with boron content B_i as a parameter.

When the calibration curve is established, the pairs of variates, i.e. the measured mean counting rate and the mean boron content determined by chemical analysis, are plotted in a diagram.

The suitability of the measuring apparatus and the confidence interval can be determined, for example, according to [4], the probability of the error of first and error of second kind being specified.

The variance of the boron content is estimated on the basis of the standard deviation of the results of the chemical analysis, the mass and the geometrical dimensions of the plates to be chemically analysed.

In the diagram mentioned above the standard deviations of counting rates and boron content give a rectangle whose area is allowed for with respect to the appropriate pairs of variates to fit the calibration curve (see, for example, Ref. [5]). With the aid of the counting rates of the reference plates and the

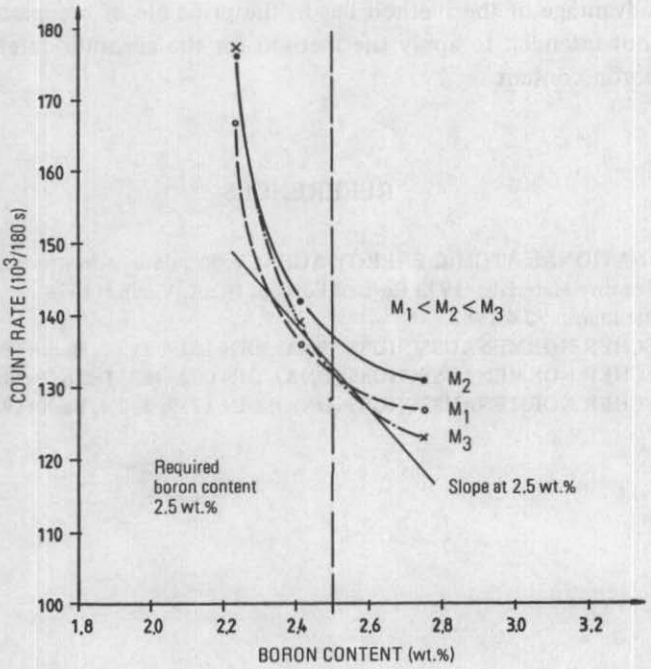

FIG. 4. Count rate as a function of boron content with moderator thickness M_i as a parameter.

calibration curve, the boron content of each individual plate is determined, the counting rate and the boron content being shifted to the safe side by k times the standard deviation. In addition, the required boron content is increased by k times the standard deviation, entered into the diagram and the appropriate counting rate determined which must not be exceeded by any test specimen. The factor k can be determined after the confidence level has been specified; in this case it should not be smaller than 2. When a repeat test of a reference plate shows that the counting rate lies outside the confidence interval, another calibration curve must be established.

The method – though in a somewhat modified form – was applied as a quality assurance measure in the manufacture of the TN 1300 shipping casks which were loaded in June 1984 within the scope of a handling and measurement programme. The above-described method will be applied to the TN 900 cask and possibly also other casks.

In summary, the following can be stated:

- The method described allows the boron content to be checked;
- The method allows the specified boron content to be complied with as it is based on conservative evaluation methods;

- The advantage of the method lies in the principle of comparative analysis;
- It is not intended to apply the method for the absolute determination of the boron content.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Materials: 1973 Revised Edition, IAEA, Vienna (1973).
[2] PIB-Mitteilungen **92** 6 1982.
[3] DEUTSCHER NORMENAUSSCHUSS (DNA), DIN 1319, Teil 3, Berlin (West) (1983).
[4] DEUTSCHER NORMENAUSSCHUSS (DNA), DIN 0025482, Teil 6, Berlin (West) (1985).
[5] DEUTSCHER NORMENAUSSCHUSS (DNA), DIN 1319, Teil 4, Berlin (West) (1983).