CONTROL ANALYSIS OF $^{235}\text{U}$ IN NUCLEAR FUEL
BY A NEUTRON ABSORPTION METHOD

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A non-destructive method based on a neutron absorption technique has been developed for the process-control analysis of $^{235}\text{U}$ in uranium-aluminium alloy components during the manufacture of reactor fuel elements. An account of the experimental stages leading to the design and construction of a process-control instrument is included, together with a description of the fully engineered neutron absorptiometer and the initial stages of its calibration.

Introduction

Fuel elements for materials-testing reactors of the design typified by the DIDO reactor at Harwell are manufactured at the Dounreay Nuclear Power Development Establishment in the form of coaxial assemblies of tubes of various diameters, fabricated from enriched-uranium/aluminium alloy. Each fuel tube is cold-extruded from a short cylinder of the alloy known as a “fuel insert”, and turnings removed from each end of the insert during machining are analysed routinely for $^{235}\text{U}$ as a basis for quality-control. The major uncertainty in this method arises from the notorious inhomogeneity of 20% uranium-aluminium alloy. The subsequent extrusion process renders the homogeneity of the tubular elements acceptable for reactor use, but frequent differences between the analyses of turnings removed from opposite ends of the same insert during manufacture lead to a high insert rejection rate, through lack of precision in the quality-control data. Periodic uprating of the materials-testing reactors, resulting in tighter fuel specifications has emphasised the need to find an alternative analytical technique with which to overcome the problems associated with obtaining a representative alloy sample.

Over a period of years, a number of possible non-destructive methods have been considered for insert analysis, including density measurement and passive gamma-counting. The density of such uniform items may be measured quickly, accurately and with good precision, and a great deal of data has been accumulated covering long insert production runs. If the extreme density figures for certain “rogue” in-
inserts are disregarded, the results appear to have a closer correlation with the expected uranium content of the inserts than those from the analysis of turnings, and this is confirmed by total dissolution and analysis of some whole inserts. However, the few rogue density results, attributed to a degree of porosity in the alloy not necessarily severe enough to warrant rejection before extrusion, give rise to too much uncertainty for density to be accepted as an entirely reliable quality control parameter. Passive gamma-counting appeared attractive at an early stage, since it offered the possibility of examining the extent of inhomogeneity by means of rotating each insert in front of a carefully collimated gamma-ray detector. The precision achieved in practice was disappointing however, owing to variation in the self-absorption of the relatively soft \( \gamma \)-rays from U-235 within the inhomogeneous alloy.\(^1\)

The measurement of neutron absorption has found application to control analysis for the determination of elements with high thermal neutron absorption cross-sections in well defined matrices of low absorption cross-section, and a number of laboratory instruments have been developed by the Analytical Research and Development Unit at Harwell for the control analysis of boron in aluminium alloys and other special metallurgical products,\(^2\) and in borosilicate glasses.\(^3\) Calculations based on thermal neutron absorption cross-section of \( ^{235} \text{U} \) (579.6 b), the degree of enrichment in the fuel for materials testing reactors (80%), and the dimensions of the range of inserts currently in production led to the conclusion that a neutron absorption technique might form the basis of a suitable non-destructive method for the control analysis of fuel inserts. A feasibility study was therefore begun, initially to calibrate an existing neutron transmission system using flat plate samples of uranium-aluminium alloy in order to establish a basis for further development of a suitable measurement geometry for the cylindrical inserts. This paper presents the results of this feasibility study, and describes an instrument developed and constructed at Harwell for use at the Dounreay Nuclear Power Development Establishment for routine insert analysis in a process-control laboratory.

**Experimental**

The neutron transmission apparatus used for the initial feasibility study was a manually operated laboratory system with similar neutron beam characteristics to that described in a previous publication,\(^2\) except for the diameter of the neutron collimator, which was reduced to 5 mm. Twenty samples of uranium-aluminium alloy were supplied by the Chemistry Support Group at Dounreay in the form of flat rectangular plates 26×13 mm\(^2\) weighing approximately 2 g each, the alloy