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DEPT. & GROUP NO. 735-51		PAGE 1 OF 7	
AUTHOR <i>R. C. Barry</i> R. C. Barry		DATE 12/7/62 GO NO. 7573 7568	
TITLE <u>Radiographic Measurements of SNAP Fuel</u> <u>Element End Gaps</u>		S/A NO 2219 2215 TWR	RECOMMENDED FOR OUTSIDE DISTRIBUTION ☐ YES ☒ NO <i>J. J. [Signature]</i> SIGNATURE
PROGRAM SNAP 2 SNAP 8	SUBACCOUNT TITLE Fuel Element Development		
DISTRIBUTION USE AN ASTERISK (*) TO INDICATE THOSE WHO ARE TO RECEIVE COMPLETE COPIES * D. F. Atkins * J. K. Balkwill * R. C. Barry (10) * G. D. Calkins * D. C. Campbell * D. J. Cockeram * R. M. Dunlop * D. L. Henry * C. E. Johnson * J. R. Lewis * J. D. Masters * G. W. Meyers * A. R. Mooers * W. E. Nagel * M. E. Nathan * W. Sawicky * J. G. Spraul * J. Susnir * J. B. Vetrano * H. Wilson	STATEMENT OF PROBLEM <p>The spacings at the ends of SNAP fuel rods in assembled fuel elements are required to comply with applicable drawings and specifications. The problem was to develop a reliable nondestructive method for determining these spacings.</p> ABSTRACT: <p>A nondestructive method has been developed for measuring the spacings at the ends of fuel rods in completed SNAP fuel elements. A precisely aligned radiographic technique is employed to form an undistorted image on extra fine grain radiographic film. The end gap is then measured with a 20 x measuring microscope.</p> <p>The radiographic technique, alignment gages, and film reading methods are described for measuring gaps at the blend end and blind end of the fuel elements.</p> <p>The accuracy of measurements at the blend end ranges from ± 0.0005 inches for spacings up to 0.010 inches to ± 0.002 inches for spacings above 0.025 inches. The accuracy at the blind end is only about one-half that at the blend end.</p> <p>Future action will consist of using a 2000 KV X-ray source to improve the image detail of the gap at the blind end.</p>

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I. INTRODUCTION

A radiographic technique has been developed for measuring the spacing between the ends of the fuel rod and 1) the blind end cap and 2) the blend cup in assembled SNAP fuel elements. A radiographic image of this gap is produced by projecting vertically oriented 250-260 KVP X-rays through accurately leveled (horizontal) fuel elements as shown in Figure 1. Two alignment gages with predetermined gaps as shown in Figure 2 are included in each radiograph to determine, among other things, the accuracy of the X-ray beam alignment. Extra fine grain radiographic film (Kodak Industrial X-ray film Type M-single emulsion, or equivalent) is employed to achieve the greatest possible image clarity. The radiographic images of the end gaps, illustrated in Figure 3, are measured with a 20 X micrometer microscope which has 0.0005 inch graduations.

II. GAP MEASUREMENTS AT THE BLEND END

Normally, the radiographic image of the gap between the fuel rod and the blend cup at the blend end of a SNAP fuel element appears as a black line with well defined edges as shown in Figure 3, element No. 449. However, if the rod and the ceramic coating of the blend cup are touching, the image of the gap appears as a well defined grey line (cf. Figure 3, element No. 447). It has been demonstrated that the metal to metal spacing at the blend end of fuel elements and also the reference spacings of the alignment gages can be measured to the nearest 0.001 inches up to about 0.010 inches, to the nearest 0.002 inches from about 0.010-0.025 inches, and to the nearest 0.004 inches above 0.025 inches. These values will vary slightly depending on the skill of the inspector in aligning the microscope reticle lines with the edge of the radiographic images of the gap.

The above measurements refer to the metal to metal spacing. The radiographic image of the ceramic coating of the blend cup can only be seen and measured if the rod and coating are in intimate contact. When there is as little as 0.001 inches gas gap between the rod and the blend cup, the image of the coating is obliterated because of scattered radiation, and the measured gap represents the sum of the coating thickness plus the gas gap. Thus the gas gap must be calculated by subtracting the coating thickness from the measured gap.

III. GAP MEASUREMENTS AT THE BLIND END

At the blind end, the radiographic image of the gap is characterized by a grey line with a well defined edge at the end of the rod, but the image of the surface of the end cap tends to be

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less well defined (cf. Figure 3, right side radiograph). This loss of image sharpness is caused by the inside radius in the end cap, the build-up of ceramic coating, and the limited energy (kilovoltage) of the available x-ray equipment at AI. The accuracy of gap measurements at the blind end is only about one-half that of the accuracy of gap measurements at the blend end because of the poorly defined internal surface of the end cap. This statement concerning accuracy applies only if the thickness of the coating is in the range of 0.003-0.005 inches and the coating thickness is known to the nearest 0.001 inches.

The relatively low energy radiographic technique presently used, coupled with the loss of image detail caused by the internal radius of the end cap, prevents the image of the coating thickness from being clearly defined. When the coating thickness approaches 0.010-0.015 inches, a faint image of the coating can be seen, but not uniformly clear enough for the thickness to be accurately measured. As was found at the blend end, an independent measurement of coating thickness is required, and this must be subtracted from the metal to metal spacing to obtain the gap spacing.

Two methods are presently being employed for measuring the coating thickness at the blind end of a tube before fuel element assembly. The first requires depth gage measurements inside the tube before and after coating. The second method employs an eddy current instrument with a probe coil attached to the end of a wand for insertion into the tube for measuring the coating thickness directly. It is estimated that the accuracy of end cap coating thickness as determined by the depth gage method is ± 0.002 inches and by the eddy current method is ± 0.001 inches. At present, no dependable nondestructive test has been developed which is generally applicable for measuring coating thicknesses in assembled fuel elements.

IV. FUTURE ACTION

Improved radiographic techniques for measuring the gap between the fuel rod and the cap at the blind end are to be developed using a 200 KV X-ray unit at the Los Angeles Cancer Clinic. The higher energy radiation is expected to 1) minimize the deleterious effects of the internal end cap radius and 2) provide sufficient radiographic latitude to permit a clear image of the glass coating to be recorded. Both single and double exposure techniques will be investigated.

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V. RECOMMENDATIONS

It is recommended that a record be maintained of the coating thickness on the end caps and on the blend cups of all fuel elements which are produced.

Figure 1 Radiographic set-up for measuring fuel rod spacings. The surface plate, parallel bars and fuel elements are carefully leveled. The fuel elements are aligned with a straight edge. The x-ray focal spot is centered directly over the end of the fuel rod, using a plumb attached to the x-ray tube. One alignment gage is placed at each end of the group of fuel elements with the spacing in the gage aligned with the end of the fuel rod in the elements. The radiographic film holder is located as shown above with suitable identification markings placed directly on the film holder. This procedure is used for each end of the fuel elements.

Design A: SNAP 8 Alignment Gage

NOTE A: Thicknesses of plastic spacers are 0.009 inches and 0.020 inches.

Design B: SNAP 2/10A Alignment Gage

NOTE B: Thickness of plastic spacers are 0.002" and 0.003".

Figure 2 - Alignment Gages Design A for SNAP 8 and Design B for SNAP 2/10A fuel elements. Two gages are required for each of the two designs, each with a different thickness of plastic spacer as per NOTES A and B. Spacer materials are a low density plastic material like polystyrene. A metal shim is placed under or wrapped halfway around the spacing in each gage to approximate the radiation absorption characteristics of the fuel element cladding. All materials are yellow brass except for the plastic spacer.

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Figure 3 Radiographs of the fuel rod spacings at the ends of SNAP 8 fuel elements. The radiograph at the left is a reproduction of the blend cup end, and the radiograph at the right is the corresponding blind end of this group of fuel elements. There has been a reversal of tonal values and unavoidable loss of image detail in the reproduction of these radiographs.