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Argonne National Laboratory

A PINHOLE CAMERA AUTORADIOGRAPHIC TECHNIQUE FOR ENCAPSULATED IRRADIATED FUEL SPECIMENS

by

W. N. Beck

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ARGONNE NATIONAL LABORATORY
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A PINHOLE CAMERA AUTORADIOGRAPHIC TECHNIQUE FOR ENCAPSULATED IRRADIATED FUEL SPECIMENS

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ABSTRACT

A gamma pinhole camera was devised to permit a nondestructive examination of irradiated specimens while still in sealed capsules. The camera was designed such that a complete experiment may be withdrawn from an irradiation facility, the specimen autoradiographed, and the experiment then reinserted if so desired. The pinhole aperture is 0.020 in., and the source to pinhole block is 4 ft. The image-to-source sizes are a one-to-one ratio. The resolution of the image is 0.03 in.

INTRODUCTION

In the development of fuel materials for reactors, it is essential to determine experimentally the characteristics of the material under conditions representative of actual in-pile operation. As a means of accomplishing these objectives, fuel specimens may be encapsulated, introduced into an operating reactor, and subjected to preselected periods of irradiation. Postirradiation examination and measurements of these specimens are used to establish the operational characteristics of the particular fuel. The capsule experiments are also frequently employed to determine the limits of burnup which can be achieved at various fuel temperatures.

The procedure generally applied is to perform several experiments with different capsules, each of which is irradiated at different times and temperature conditions. A subsequent postirradiation inspection of each of the specimens will determine if additional irradiations are required.

Because of the equipment and techniques required, irradiations of fuel specimens are inherently expensive and time consuming. In order to minimize the number of separate irradiations necessary to evaluate a fuel material, a pinhole autoradiograph technique has been developed, which permits a nondestructive inspection of the contents of the irradiated capsule. On the basis of the measured dimensional changes observed on the autoradiograph, the irradiation damage to the specimens can be evaluated, and a decision can then be made as to whether the irradiation of the specimens should be continued.

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INTRODUCTION

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PROCEDURE

The technique of utilizing gamma radiation and a pinhole camera to locate sources has been previously demonstrated.[1] In the proposed application, however, it was imperative that the resolution of the image be such that a quantitative measurement of the image be accurately representative of the actual size and shape of the sources.

An analysis of a pinhole aperture suitable for these requirements and at the proposed levels of gamma intensity indicated that an effective aperture could be maintained if the cone angle forming the aperture did not exceed 12°. Several experimental pinhole blocks were fabricated of tungsten having aperture sizes from 0.010 to 0.040 in. The apertures which were machined out of solid blocks were formed by 2 cones lying on the same axis, the base of the cones at the face of the blocks and the apexes overlapping at the center to the desired aperture. The pinhole blocks were evaluated with a source of known size and shape, located inside a hot cell. The pinhole blocks were mounted into 4-in. shielded plugs which fitted the access ports of the hot cell. The best resolution was obtained from a block having a 0.020-in. aperture, and a source-to-pinhole distance of 4 ft. The X-ray film holder was positioned an equal distance away from the pinhole block so that the image maintained a one-to-one ratio to the source size. Figure 1 shows a diagram of the construction of a completed pinhole block made of uranium.

The film found to be most suitable is Ilford Type G. The film holder is a cardboard cassette backed with 0.010 in. of lead.

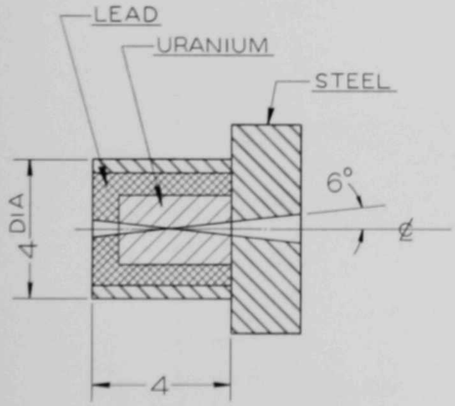

Figure 1

Diagram of a pinhole block. The aperture is 0.020 in.

PINHOLE AUTORADIOGRAPHIC FACILITY

A shielded camera was constructed which would accommodate an 11-ft irradiation capsule assembly in order to perform autoradiographs of instrumented capsules on top of or near a reactor. A drawing of the facility is shown in Figure 2. The shielded container is located over the vertical hole which contains the experiment. The experiment is then withdrawn into the shielded container to an elevation where the specimens in the capsule align with the pinhole block extension tube. The exposure time for the film is dependent upon the gamma intensity of the specimens, but generally varies from 1 to 1.5 hr. Satisfactory autoradiographs have been obtained from high-level gamma sources which were reading 20 r/hr through 8 in. of lead. As mentioned earlier, the location of the pinhole block is such that the image will have a one-to-one size relationship to the source.

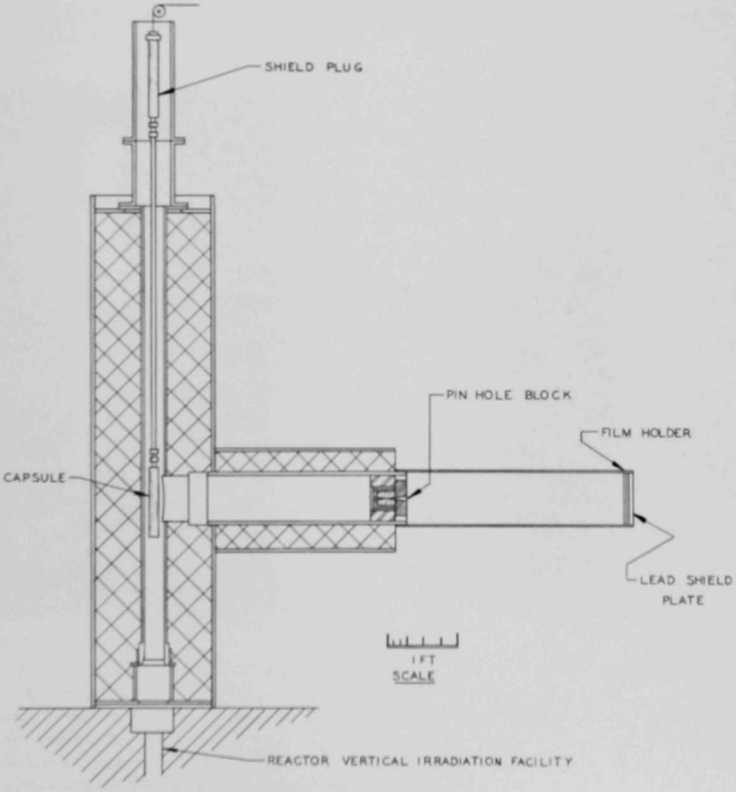

Figure 2. Shielded capsule container used for autoradiographing irradiated specimen

In addition to this, a measured length of tantalum metal is placed into the capsules prior to the irradiation. The tantalum rod becomes highly gamma active during irradiation, and thus serves as a dimensional standard to which the image of other sources appearing on the autoradiograph can be compared. For capsules not having an irradiated standard, measured cobalt sources are placed next to the capsule from which dimensions can be taken.

An evaluation of the dimensions of the irradiated specimens determines whether the experiment should be discontinued. If the irradiation period is to be extended, the experiment is simply reinserted into the reactor.

Typical photographs of specimens after they have been removed from the capsules as compared to a positive print of the autoradiographs are shown in Figures 3 through 6. The resolution obtained in the autoradiographs and by high contrast positive prints has been measured to be approximately 0.03 in.

32439 1X

Figure 3. Autoradiograph taken before the capsule containing the specimens shown in Figure 4 was opened. The orientation of the specimens is the same as in Figure 4. The radioactive material below the specimen is Al-0.5 w/o Co alloy originally adjacent to the specimens for neutron monitoring but which melted during irradiation and dropped to the bottom of the capsule.

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Figure 4. Uranium-fissium alloy specimens after irradiation while still in holder in which they were irradiated and oriented as shown in the autoradiograph in Figure 3. The object at the lower left is a length standard.

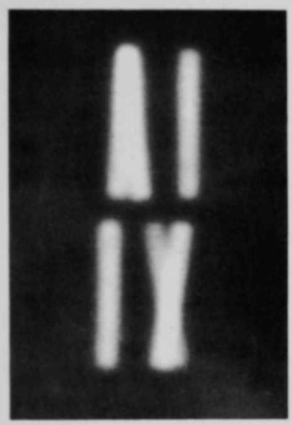

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Figure 5. Autoradiograph taken before the capsule containing the specimens shown in Figure 6 was opened.

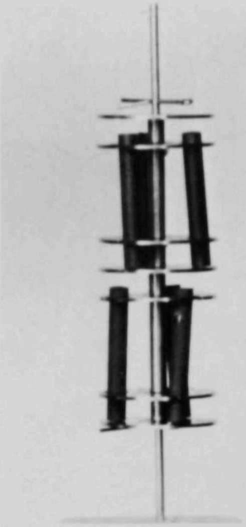

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Figure 6. Photograph of specimens in capsule oriented as shown in the autoradiograph in Figure 5.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of L. R. Heaton in the development of the pinhole block and of R. Fousek, who conducted the evaluation tests.

REFERENCE

1. Wiltshire, L. L., Locating Sources of Gamma Radiation with a Pinhole Camera, Technical Memorandum No. 124, U. S. Naval Radiological Defense Laboratory (1961).