THEORY AND APPLICATION OF THE CODED APERTURE FUEL MOTION DETECTION SYSTEM

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ABSTRACT

A fuel motion detection system based on coded aperture [illegible] has been developed for the Annular Core Research Reactor. [illegible] evolved after [illegible] were carried out to determine the [illegible] system capabilities [illegible] reactor environment, [illegible] theory [illegible] radiation [illegible] compatibility with prototype [illegible] were [illegible]. [illegible] fabricated and [illegible] the ACRR [illegible] fuel motion from [illegible] accident conditions. In addition, [illegible] have shown that in the reactor environment [illegible], coded [illegible], particularly with [illegible] arrays, offers significant advantages over pinhole [illegible]. The extension of this technique toward [illegible] imaging with fast neutrons is also being investigated.

INTRODUCTION

A detection system has been fabricated to measure moving fuel in flowing sodium, pin-geometry tests to be conducted in the Annular Core Research Reactor, (ACRR). The [illegible] detectable fuel mass and temporal resolution requirements for these tests demand capabilities more advanced than those of fuel motion detection systems[1] at other facilities. This system, which is designed for tests involving one to seven LMFBR fuel pins, is presently undergoing proof tests in the ACRR. These tests include preliminary transient fuel motion experiments.

This paper contains a description of the apparatus and a brief summary of the proof tests in which fuel motion has been observed. Because of the encouraging progress in the adaptation of coded aperture technology to the fuel motion investigations, additional theoretical and experimental studies have been carried out on aperture design, reconstruction methods, filtering and neutron imaging.

DESCRIPTION OF THE FUEL MOTION SYSTEM

An artist's conception of the detection system assembled next to the ACRR core is shown in Figure 1. As an aid in meeting the test requirements, the recording instrumentation was placed close to the reactor core. Because of this proximity, a very effective shield and collimation system had to be constructed. The recording problem is made even more difficult because the viewing slot traverses only half of the core diameter, and the radiation from the back side of the test cavity contributes heavily to the background.

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The pulse simulated a loss of flow transient in which the reactor power history exhibited an initial pulse with a peak height of 150 MW and a FWHM of 100 msec. This was followed by a slowly decaying tail starting at [illegible] MW and lasting for about 4 seconds. It was predicted that a little less than 4 [illegible] joules/gram would be deposited in the fuel, enough to melt the pin and vaporize a portion of it. A similar pulse was recorded without the pin present to allow subtraction of the [illegible] in the image reconstruction process. For this rather [illegible] pulse, the [illegible] camera was operated at 50 frames/sec.

This experiment was conducted at the end of July, 1979 and analyses of the data [illegible] have [illegible] the raw data which consist of the [illegible] in the lower channel. The [illegible] and fuel motion has been observed. [illegible] to expand. Afterwards there is [illegible] of the pin cavity [illegible]. The latter [illegible] [illegible] and [illegible] [illegible] to scintillators.

[illegible]

[illegible]

[illegible]

In contrast [illegible] with the [illegible] code, the uniformly redundant array aperture [illegible] free [illegible] artifacts. This is a natural consequence of the [illegible] structure of the URA autocorrelation function. Although a linear Fresnel code similar to that shown in Figure 2 is used in the present fuel motion system, a URA has been constructed for imaging tests to be conducted in the near future.

Quantum noise [illegible] were performed for the URA aperture. The [illegible] of the URA aperture versus an equivalent pinhole aperture [illegible] a function of [illegible] integrals. It is important [illegible] which is modulated by the aperture, from stray background radiation, which is not affected by the aperture. [illegible] the scene background uniformly [illegible] the field of view, the [illegible] intensity [illegible] to the signal intensity. In contrast, [illegible] aperture will [illegible] over a [illegible] of how [illegible] the signal [illegible] aperture [illegible] origin [illegible] be [illegible] that the stray [illegible] in the [illegible]

[illegible]

[illegible]

[illegible]

[illegible] of [illegible] the linearity [illegible] signal [illegible], by [illegible] scattered [illegible] from the test fuel and its contai[illegible] signal [illegible] from [illegible] percent [illegible] Tantal[illegible] results as [illegible] and tilt [illegible] within the 1 to 2 percent statistical [illegible] of the calculation[illegible]

While the effect of reactor backgrounds and [illegible] well known, the [illegible] that [illegible] aperture [illegible] is potentially [illegible] experiment [illegible] will [illegible] these calculations [illegible] additional [illegible]

Because fission neutrons have a greater scattering [illegible] in the test fuel and contain [illegible] than fission gamma rays, they should be [illegible] useful in imaging

An off-axis Fresnel coded aperture made of tungsten alloy was used together with a static fast neutron detector consisting of a depleted uranium foil in contact with a Lexan sheet. The Lexan sheet effectively discriminated against [illegible] ray and [illegible] particle [illegible] because these radiations can't produce etch pits in the Lexan. A [illegible] resolution close to the [illegible] calculated [illegible] was achieved in these experiments. Concepts for transient fast neutron [illegible] which exploit the properties of coded apertures have also been investigated theoretically.

SUMMARY AND DISCUSSION

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ACKNOWLEDGMENT

[illegible]

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8. [illegible]

9. [illegible]