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 ^{252}Cf Neutron Radiography at Battelle-Northwest

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Since 1969 Battelle-Northwest has been working on developing and applying ^{252}Cf to neutron radiography. The emphasis has been on development of portable ^{252}Cf radiography systems and on development of low-flux imaging techniques. A number of applications for neutron radiography have also been explored.

Exposure Facilities

During the investigations three facilities have been developed for use in neutron radiography. Two of these are portable systems housed in egg-shaped fiberglass shells. These facilities NC-1 and NC-2 are compared in Table 1 and are meant primarily for small sources ($< 200 \mu\text{gm}$). A large water tank was also developed for a $1.7 \text{ mgm } ^{252}\text{Cf}$ source. This facility is similar to others in use at various laboratories and will not be described extensively. The water tank is designed as a versatile source of neutrons and uses a unique stepping motor arrangement to remotely position the source (Figure 1).

Imaging Techniques

The imaging techniques explored at Battelle-Northwest have ranged in exposure time from 2-3 minutes to 40 hours for similar image contrasts in a flux of approximately $4 \times 10^2 \text{ n/cm}^2\text{-sec}$. The slowest technique used has been a standard gadolinium metal foil with Kodak AA film while the fastest technique has employed a high gain - low noise image intensifier to integrate the image from a scintillator for short periods. Resolution with the gadolinium foil has been limited by the system geometrical unsharpness while quantum mottle has limited resolution with the

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intensifier system. The use of gadolinium oxysulfide scintillation screens has been explored extensively and has yielded a technique intermediate in both speed and resolution compared to $^6\text{LiF-Zn-S}$ scintillators and gadolinium foils.

Indirect imaging has also been explored at low fluxes. It has been found that the use of europium screens and the use of scintillation screens during transfer (with both europium and dysprosium) improve the indirect imaging capabilities at low fluxes. Exposure curves for these techniques will be shown.

An imaging proportional counter has been adapted to neutron imaging for low-resolution applications. Neutron images produced by this counter had an unsharpness of 5.5 mm (3.3 mm FWHM) and a contrast of 55% when using a ^6LiF converter foil. Efforts have shown that an unsharpness of about 1 mm is possible; however, the efficiency would be undesirably low. Presently the efficiency is 0.25% and better resolution would require a lowered efficiency.

Applications

A number of applications for ^{252}Cf neutron radiography have been investigated. Neutron radiographs of both mixed oxide reactor fuels and of enriched uranium fuels have been made. In the forensic area, radiographs of tampered cartridges and of devices booby trapped with explosive charges have been made. Radiographs have been made to demonstrate the polymer loading of both rock and concrete samples.

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TABLE 7. Comparison of Portable Source Holders
(150 μ g ^{252}Cf source)

	NC-1	NC-2
Portable weight	350 lb	75 lb
Weight with moderator	350 lb	$\sim$ 320 lb
Moderator material	ZrH _x + others	H ₂ O
Typical collimation ratio	8:1	15:1
Source to object distance	69 cm	38 cm
Thermal flux	$2.8 \times 10^2 \text{ n/cm}^2\text{-sec}$	$9.4 \times 10^2 \text{ n/cm}^2\text{-sec}$
Cadmium ratio	1.4	1.8
Neutron-to-gamma ratio	$6.3 \times 10^4 \text{ n/cm}^2\text{-mR}$	$4.2 \times 10^4 \text{ n/cm}^2\text{-mR}$
Gamma filter	1.8 in. ZrH ₂ + 0.18 in. depleted U	0.2 in. Pb
Surface dose rates neutron	150 mrem/hr	170 mrem/hr
gamma	50 mR/hr	100-180 mR/hr