radiation from the screen had to penetrate only the black paper cover before reaching the radiation-sensitive material. If the screen was placed on the lens side of the packet, the radiation had to penetrate both the paper cover and the print paper before reaching the "negative material". The speed factor increase was relatively slight. Even when combined with the use of a lead screen on the opposite side of the film packet to serve as a back screen intensifier, the combined increase in speed was less than a factor of 2.

Although this Polaroid Packet method offered a great improvement over the previous X-ray film method in that a Polaroid neutron radiograph was available for viewing within 10 min. after the neutron exposure started, further increases in speed were desired.

Speed improvements can be obtained by opening the packet and inserting a fast fluorescent X-ray screen facing the radiation-sensitive material. The light emitted from this screen when the radioactive foil is placed on the packet intensifies the image sufficiently so that, with a rhodium screen, the image can be obtained in a total time of about 3 minutes, approximately split between neutron exposure and decay time.

This inconvenience of opening the packet before and after the radioactive screen exposure[a] to place and remove the fluorescent screen (it must be removed before the print can be developed) can be eliminated by using special Polaroid radiographic packets made to be used with X-ray fluorescent screens (Polaroid Type 3000X). Cassettes and developing apparatus for these radiographic packets are commercially available.[b] This radiographic Polaroid equipment has been described in the literature.[7]

The high-contrast resolution observed on these Polaroid radiographic prints is in the order of 0.020 in., as determined by neutron radiographs of of a cadmium test piece containing 0.020 in. holes whose spacing continually decreases.[8] Holes separated by about 0.020 in. could be resolved. In terms of radiographic contrast sensitivity, thickness changes in the order of 8 to 10 per cent were detectable in natural uranium in the thickness range of $\frac{1}{2}$ to 1 in. These capabilities are quite suitable for alignment procedures. Our experience has shown that the convenience of the Polaroid method has proved to be very useful.

Harold Berger
I. R. Kraska
R. E. Dickens

Metallurgy Division, Argonne National Laboratory,
Argonne, Illinois
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[7]J. A. REYNOLDS, *Nondestructive Testing,* 11, No. 1, 24 (1952).
[8]H. BERGER, *J. Appl. Phys.*, 34, 914 (1963).

[a]Another alternative approach is to perform the Polaroid exposure in the dark with the packet open. This permits the placing of the radioactive transfer screen immediately in back of the radiation sensitive material.

[b]Available from the Picker X-Ray Corporation, White Plains, N. Y.

The Effects of Coherent Scattering on the Thermalization of Neutrons in Beryllium

The problem of the effects of coherent neutron scattering on the neutron spectrum in finite assemblies has been studied theoretically[1,2,3,4] and experimentally.[5] We have obtained data on the time-dependent spectra in beryllium metal at 30 C by the phased-neutron-chopper/linear-electron-accelerator technique. We observe prominent crystalline effects at the Bragg energies of 0.022 eV and 0.0067 eV.

The primary neutrons are obtained from the RPI linear electron accelerator operated at 7 kW of electron beam power and 45 MeV; photo-neutrons are produced by electron converted bremsstrahlung in a thick water-cooled tungsten target. These neutrons are incident on a beryllium assembly, 4.31 in. × 11.9 in. × 12.0 in. (buckling $\sim 0.073/\text{cm}^2$), density approximately 1.7 g/cm^3, having a 0.5 in. × 0.5 in. reentrant hole to the center of the assembly from which the scalar neutron flux is extracted. The experimental set-up is shown in Figure 1. A mechanical disk chopper consisting of B^{10}-steel 3/4 in. thick, 1% by weight of B^{10}, samples the

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[4]S. S. JHA, *J. Nucl. Energy Part A: Reactor Science,* 12, 89-92 (1960).
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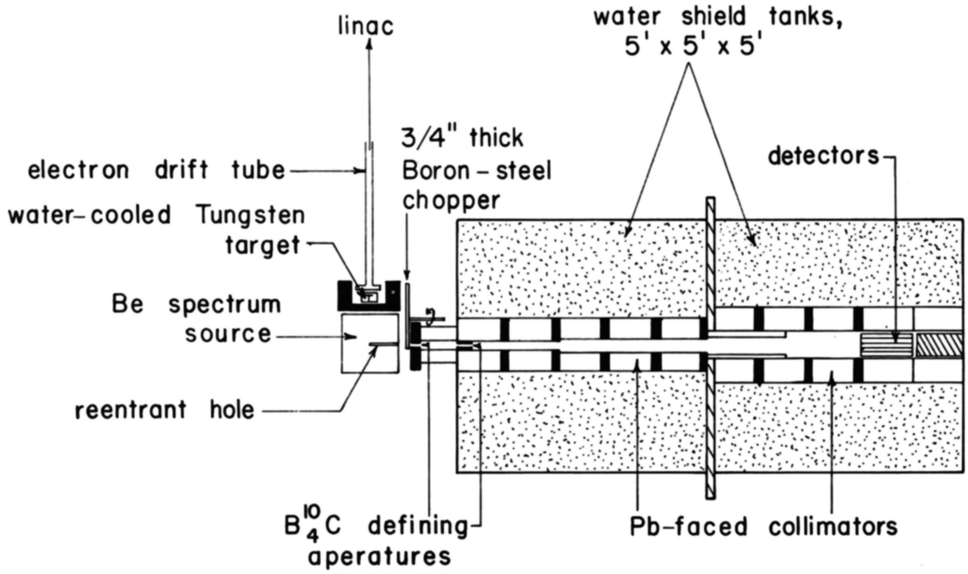

Fig. 1. Experimental arrangement for measuring time dependent spectra in beryllium.

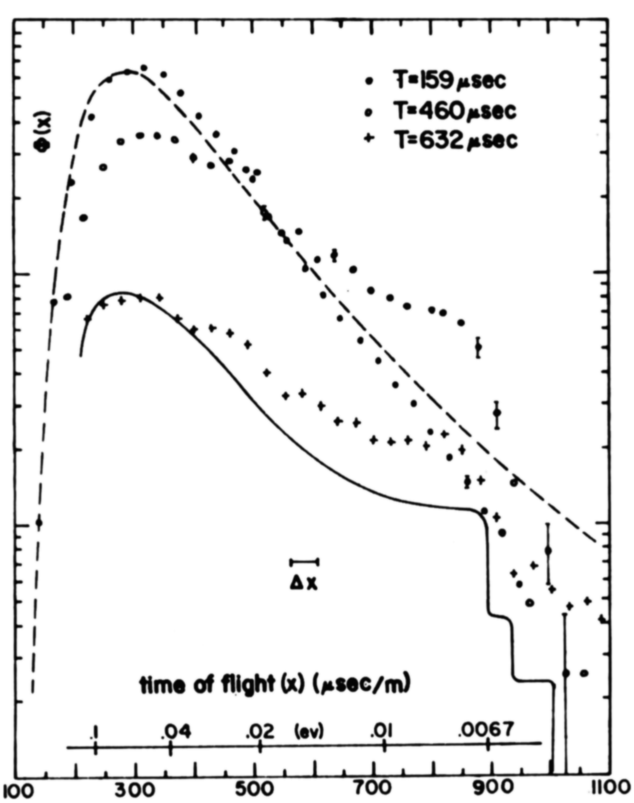

Fig. 2. Time-dependent neutron spectra in the center of a parallelopiped of Be metal buckling $0.073/cm^2$ for 30 C at times (T) after the primary burst from the linear electron accelerator. The curves are arbitrarily spaced for clarity . . . Solid Curve is Jha's theoretical curve for a buckling of $0.046/cm^2$. Dashed Curve is a Maxwellian, 30 C.

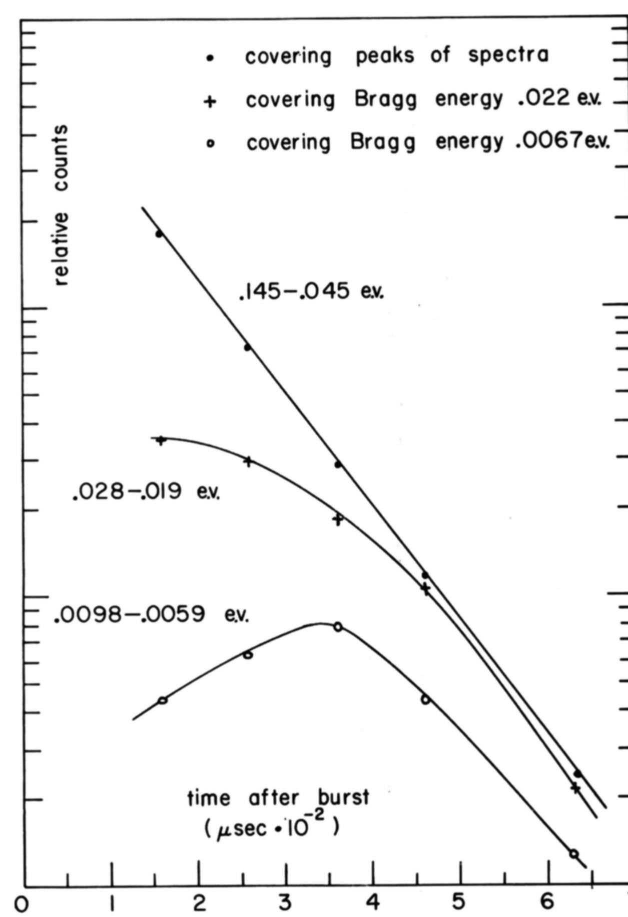

Fig. 3. Neutron die-away of several selected energy groups in beryllium.

neutron flux at times (T) subsequent to the primary neutron burst. The chopper opening has a half width of 130 μ sec. The energy spectrum of the neutrons emitted from the bottom of the reentrant hole is measured by time-of-flight over a 3-meter flight path. The neutron detector is a single 2-in. alumina-end-window BF_3 counter 6 in. long oriented with the detector axis along the neutron beam axis.

The neutron spectra for delay times (T) of 159 μ sec, 460 μ sec and 632 μ sec are shown in Figure 2; additional spectra for intermediate delay times have also been obtained. The spectra have been corrected for background and normalized to the primary-neutron-production rate; they have been corrected for neutron decay in the beryllium assembly during the time the neutrons traverse the distance from the bottom of the reentrant hole to the chopper. The neutron-detector response has been corrected by comparison with a $1/v$ detector in the same flux; the error involved in this correction may be as large as 20% for inverse velocities less than 270 μ sec/meter. The horizontal error bar gives the timing uncertainty, due mainly to the burst width of the chopper. The vertical error bars are statistical errors only and do not include systematic errors.

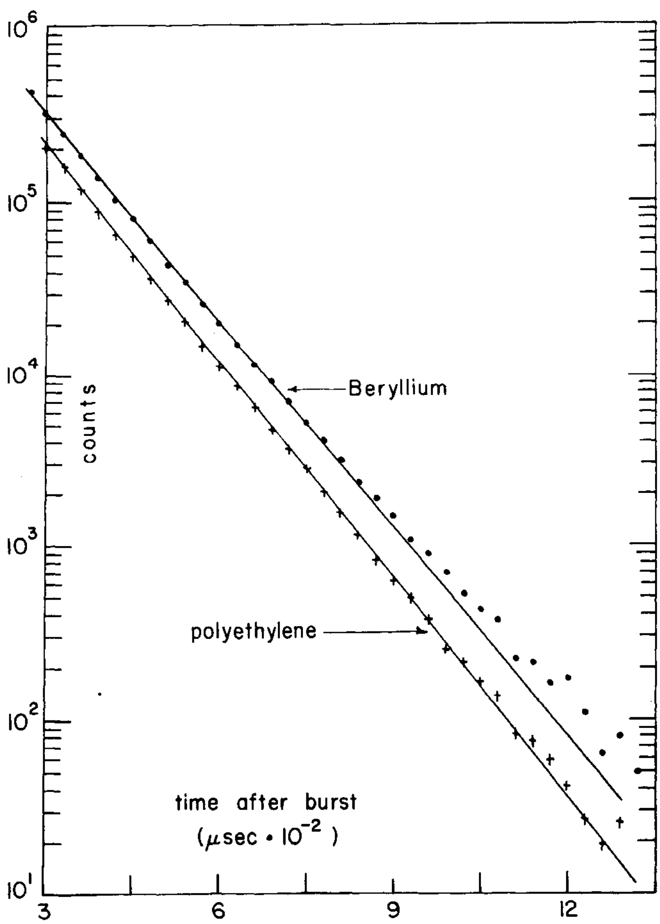

Fig. 4. Neutron die-away in beryllium and in a test assembly of polyethylene selected to give approximately the same decay time.

Three energy groups taken from these data have been replotted against time after the primary neutron burst; the curves of Figure 3 result. The energy group near the peak of the curves (0.145 - .045 eV) has been normalized to a single exponential decay. The other two groups .028 - .019 eV and 0098 - 0059 eV (which bracket the Bragg energies .022 eV and .0067 eV) indicate an initial build up and a subsequent decay approaching that of the first group.

In a different experimental set-up, using a B^{10} shield about the beryllium assembly, a conventional die-away experiment has been performed, the results of which are presented in Figure 4. Also presented are the results of a measurement performed on a polyethylene (non crystalline) assembly for the same decay time in the same environment. The polyethylene data, in contrast to the beryllium data, show no apparent change of slope.

Additional measurements are in progress on beryllium in the buckling range B^2 = 0.1 to 0.01/cm^2 and will be reported upon completion.

R. R. Fullwood
R. E. Slovacek
E. R. Gaerttner

Department of Nuclear Engineering and Science
Rensselaer Polytechnic Institute*

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Expediting Danger-Coefficient Measurements by Measuring Two Samples at Once*

In danger-coefficient measurements, whether by autorod[1,2] or pile oscillator, the required

*Work performed under the auspices of the U. S. Atomic Energy Commission.

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