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STF SIMULATION WITH PARKA AND APPLICATION TO DIAGNOSTIC INSTRUMENTATION EVALUATION*

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ABSTRACT

The PARKA critical assembly at LASL has been modified to serve as a driver for an array of 37 enriched UO_2 fuel pins. Utilizing good simulation of typical STF conditions, fuel motion diagnostic methods will be evaluated at low power for multipin assemblies. Initial experiments are to establish the capability of the neutron hodoscope and in-core detectors. Preliminary results are reported for the latter technique.

SUMMARY

The PARKA critical assembly at LASL has been modified to serve as a driver for an array of 37 highly enriched UO_2 fuel pins representing fast reactor fuel. PARKA is a Rover Project Kiwi reactor loaded with graphite-uranium fuel elements. These are one-hole bead loaded elements that were used for critical assembly studies for Rover reactor design. Four enriched uranium loadings of 100, 200, 300, and 400 kg/m^3 are distributed to give approximately flat fission density across the 0.89-m fueled diameter. Figure 1 is a photograph of the PARKA core with a 37 fuel-pin array at the center.

Onetran transport code calculations have been run for the 37 pin array at the center of PARKA and also for the case of a central subassembly (217 pins) surrounded by six half subassemblies. The 37 pin array calculations had Na, H_2O, or void in the region between fuel pins. Water was included since its density is the same as Na and its moderating properties

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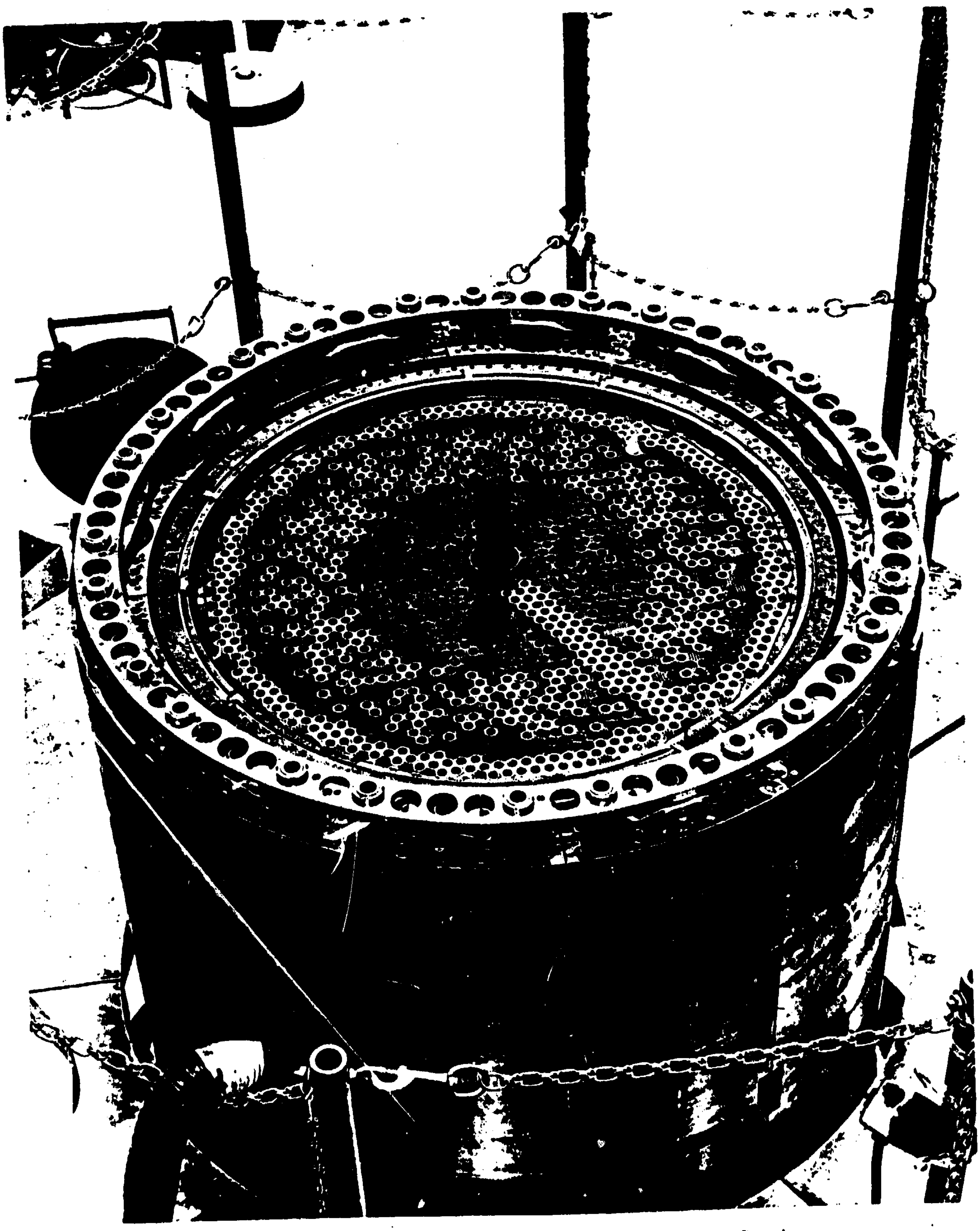

Fig. 1. PARKA Core with 37 Fuel-Pin Array at Center.

significantly increase the Figure-of-Merit (FOM)*. For experiments that are based on neutron emission from the test region, when the presence of water may be undesirable, the fission distribution curves of Figure 2 show that void is a reasonable substitute for sodium. Addition of the test section in PARKA was computed to increase reactivity 3.2$ for the water filled cell and 0.9$ and 1.1$ for void and sodium respectively. The computations gave FOMs in the range of 10 to 20.

Calculations for four subassemblies inserted into the center of PARKA more nearly approximate proposed SAREF test geometries including appropriate sodium content and stainless steel containers. For this 868 pin array, fuel was also assumed to be highly enriched UO_2. Because of the large self-multiplication of four subassemblies, the PARKA system reactivity increases by 23$. The effect of the test assembly is to depress the fissions in the adjacent PARKA fuel by ~25%. The FOM is ~11 with a peak-to-minimum ratio in the fuel pins of 1.33 as shown by the dotted curve in Figure 3.

The 23$ of excess reactivity in PARKA can be reduced easily either by enlarging the central hole in the hexagonal fuel elements to increase core void fraction or by adding boron loaded graphite rods to the central hole. We concluded that boron would harden the PARKA spectrum to give both a smaller peak-to-minimum variation across the test assembly and an increased FOM. This was confirmed by calculations with boron uniformly distributed over the driver portion of the PARKA core. The boron required to reduce reactivity the required 23$ is equivalent to 6.3 g per PARKA fuel element. The computed fission ratio to the base case is shown as the solid curve in Figure 3. Although the boron poison causes a large perturbation in the driver fission profile, the resulting FOM is ~20 and the peak-to-minimum fission ratio in the fuel pins is only 1.10. Maintaining a flat fission density profile in

*FOM = ratio of minimum power density in the test fuel to maximum power density in the driver.

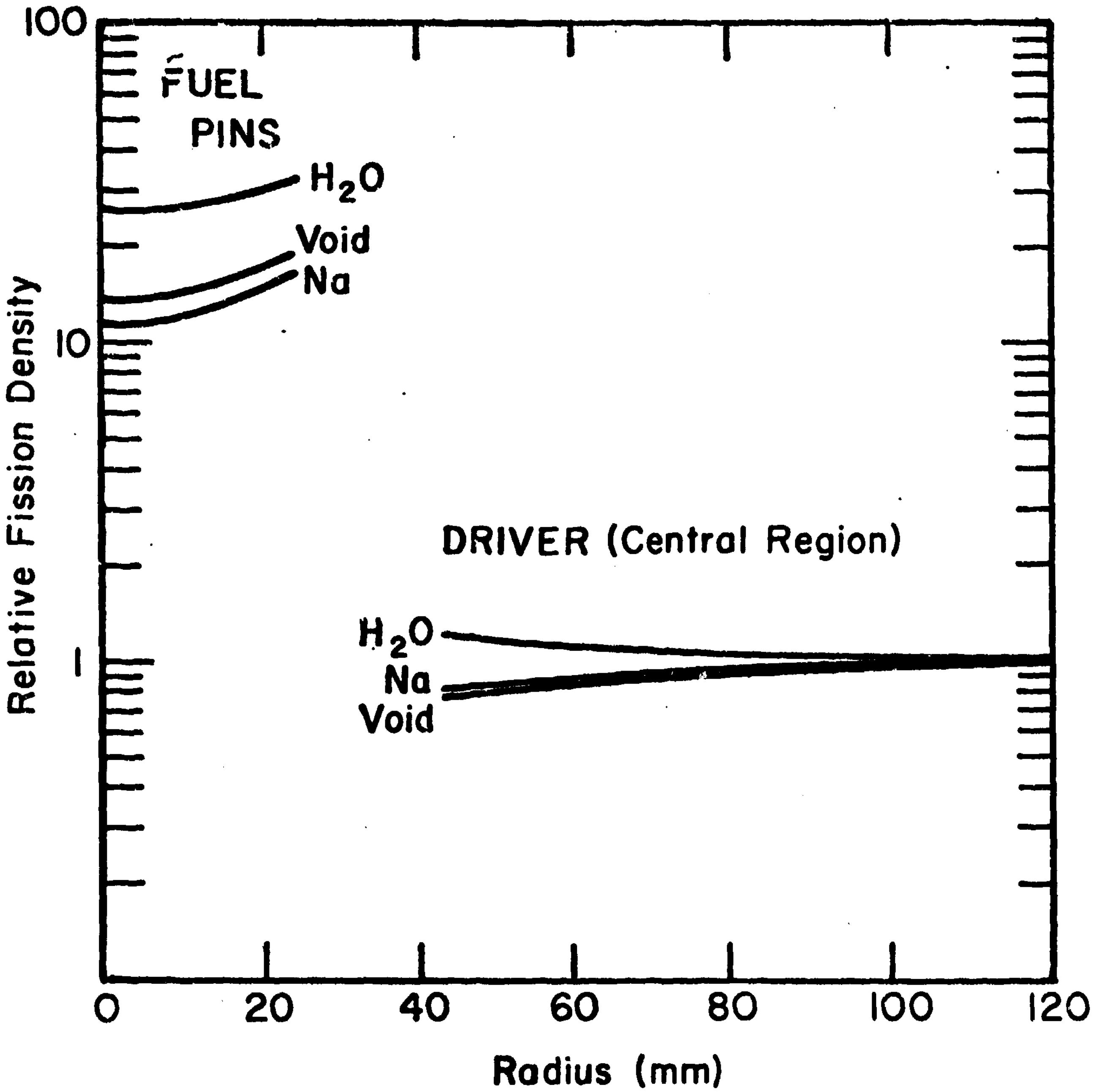

Fig. 2 Ratio of Fission Density for Modified PARKA to Unmodified PARKA for a 37 Fuel-Pin Array

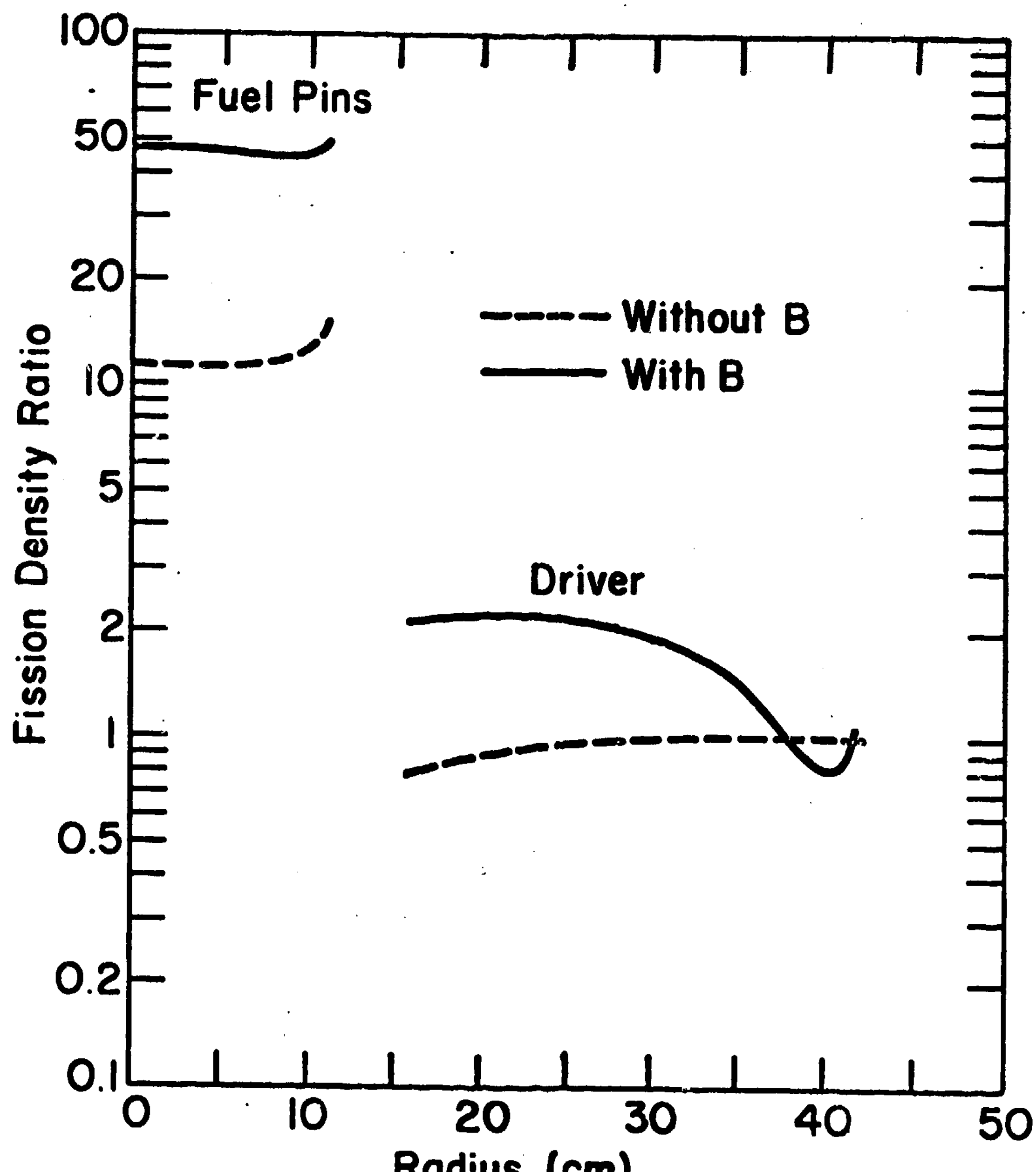

Figure 3. Ratio of Fission Density for Modified PARKA to Unmodified PARKA for a Four Subassembly Array

PARKA is of no particular concern for the driver application. It thus appears that PARKA can be adapted to serve as an excellent driver for a four subassembly array of fast reactor fuel pins.

Initial measurements made with the 37 pin array in PARKA show that the addition of the UO_2 fuel to the stainless steel cladding tubes increases reactivity by 1.1$. The UO_2 length of 0.91 m is centered relative to the 1.32-m long PARKA driver fuel. The measured relative fissions per fuel pin is plotted against radius in Figure 4 compared with the computed results.

A 100-mm long slot (shown in Figure 5) has been provided through the PARKA reflector and core to allow viewing of the fuel pin assembly with a hodoscope or coded aperture detector system. A four channel steel hodoscope collimator is shown in Figure 6 adjacent to the port extending into a shielded detector room where the hodoscope is to be installed.

The PARKA system is an excellent test bed for in-core detector studies. Initial in-core detector studies have been made with ^{235}U and ^{238}U fission chambers. These chambers, $\sim$5-mm in diameter, are designed to be inserted into one of the stainless fuel pin cladding tubes from which the UO_2 has been removed. Figure 7 is a cross sectional view of these detectors. The ^{238}U detector is sensitive to neutrons above 1 MeV and will thus respond primarily to neutrons from the test section. In contrast, the ^{235}U response weights the lower energy neutrons and is more sensitive to neutrons leaking into the fuel pin array from the driver.

Measurements have been made with the fission chambers located in the central fuel pin cladding. Detector response was determined when fuel pins were removed from each of the three hexagonal rings of pins surrounding the detectors. Results summarized in Table 1 show that the ^{238}U detector counts decrease as the fuel pins are removed whereas counts from the ^{235}U detector increase. The $^{235}U/^{238}U$ counting ratio

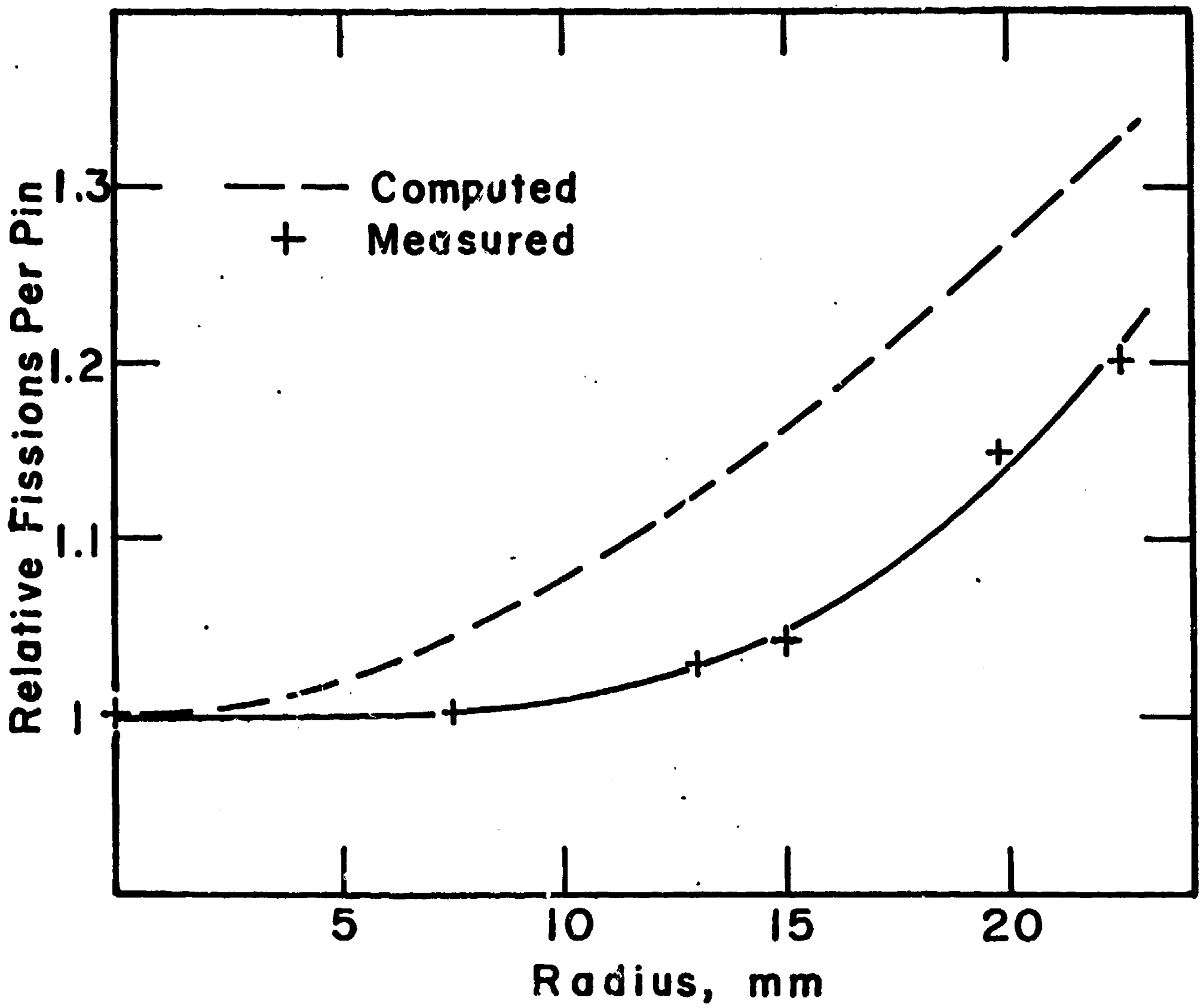

Fig. 4 Relative Fissions Per Fuel Pin for a 37 Pin Array in PARKA

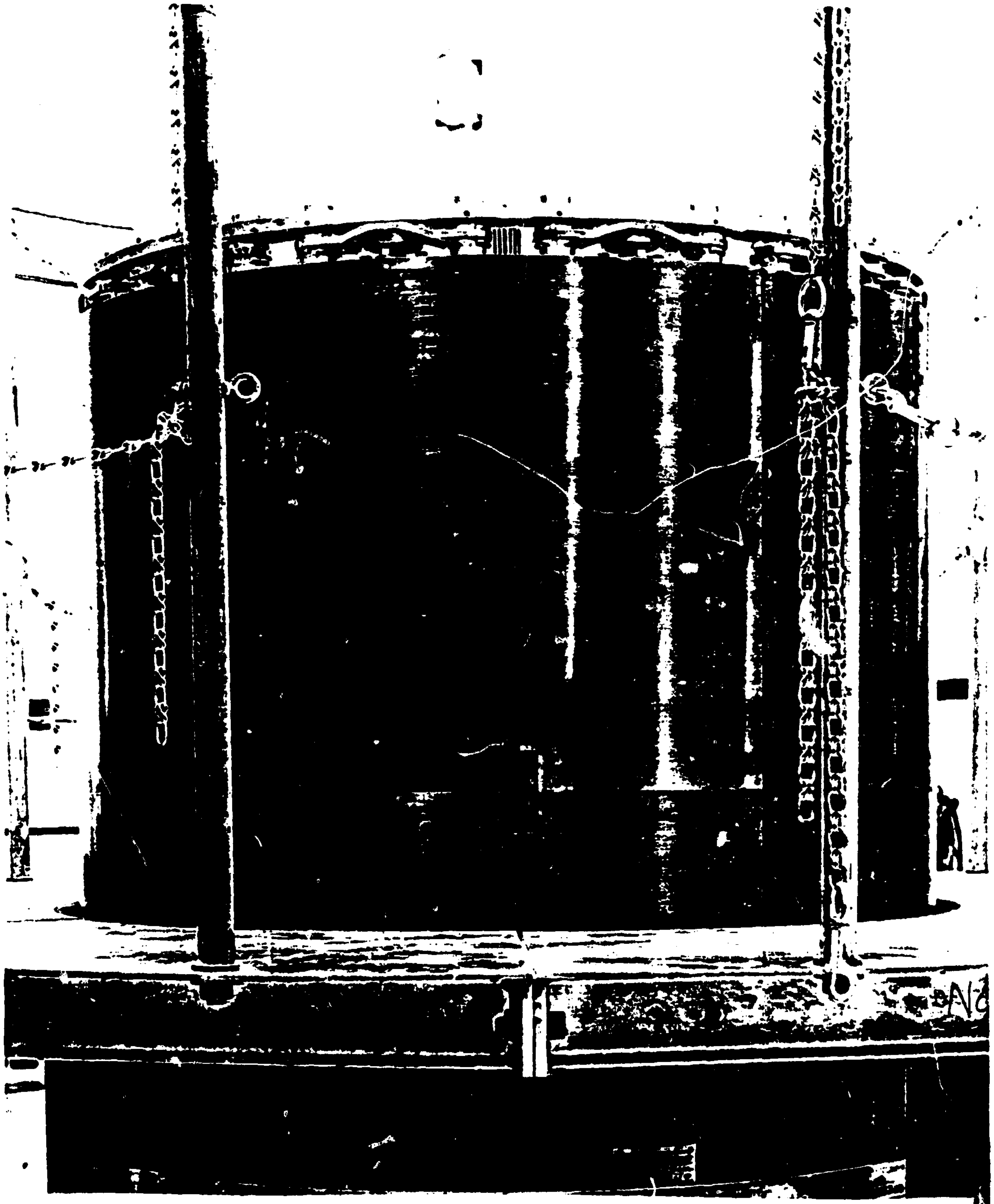

Fig. 5. View of PARKA Reflector Showing Slot for Diagnostics Experiments.

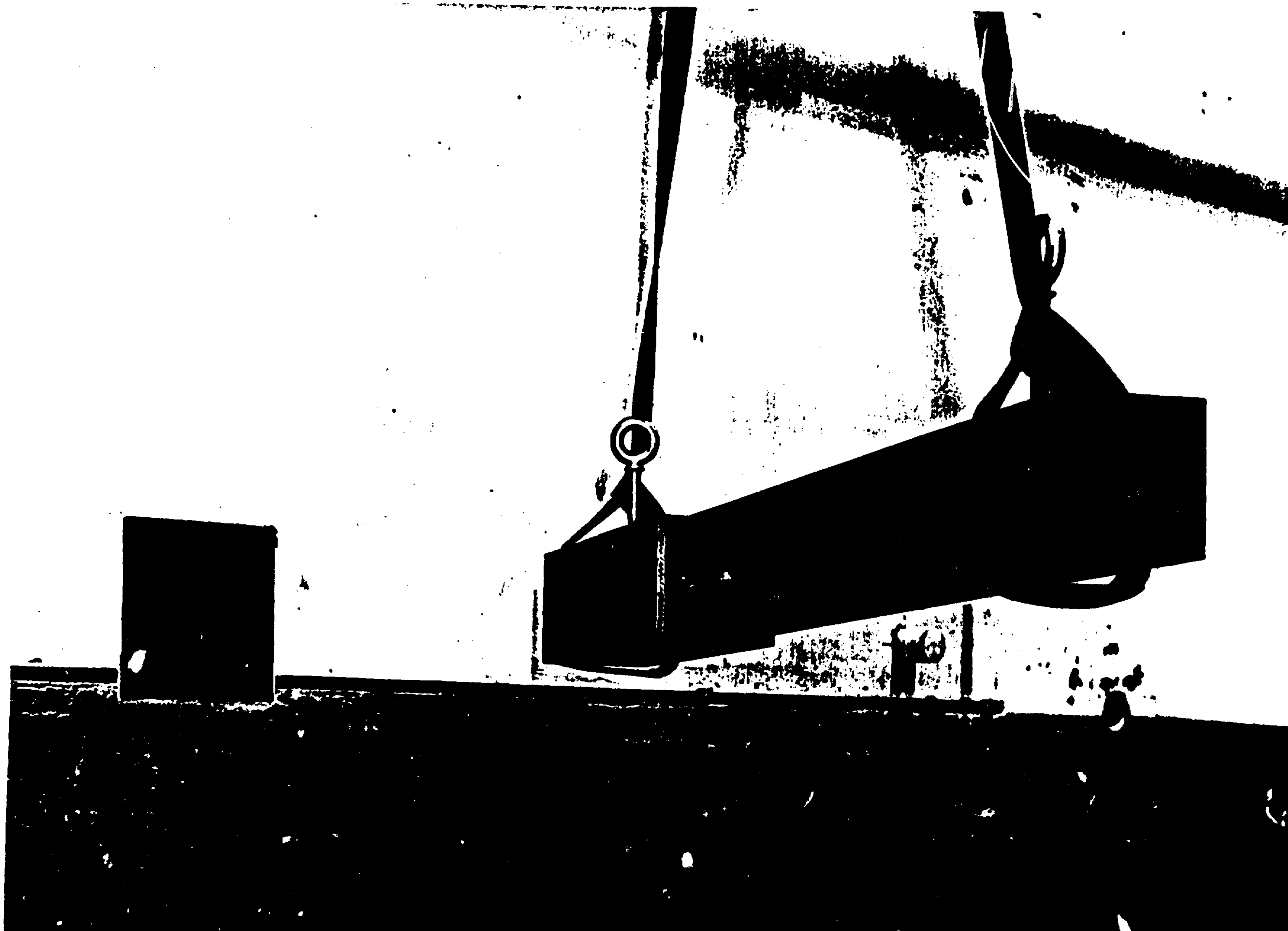

Fig. 6. Photograph of Four-Channel Hodoscope Collimator.

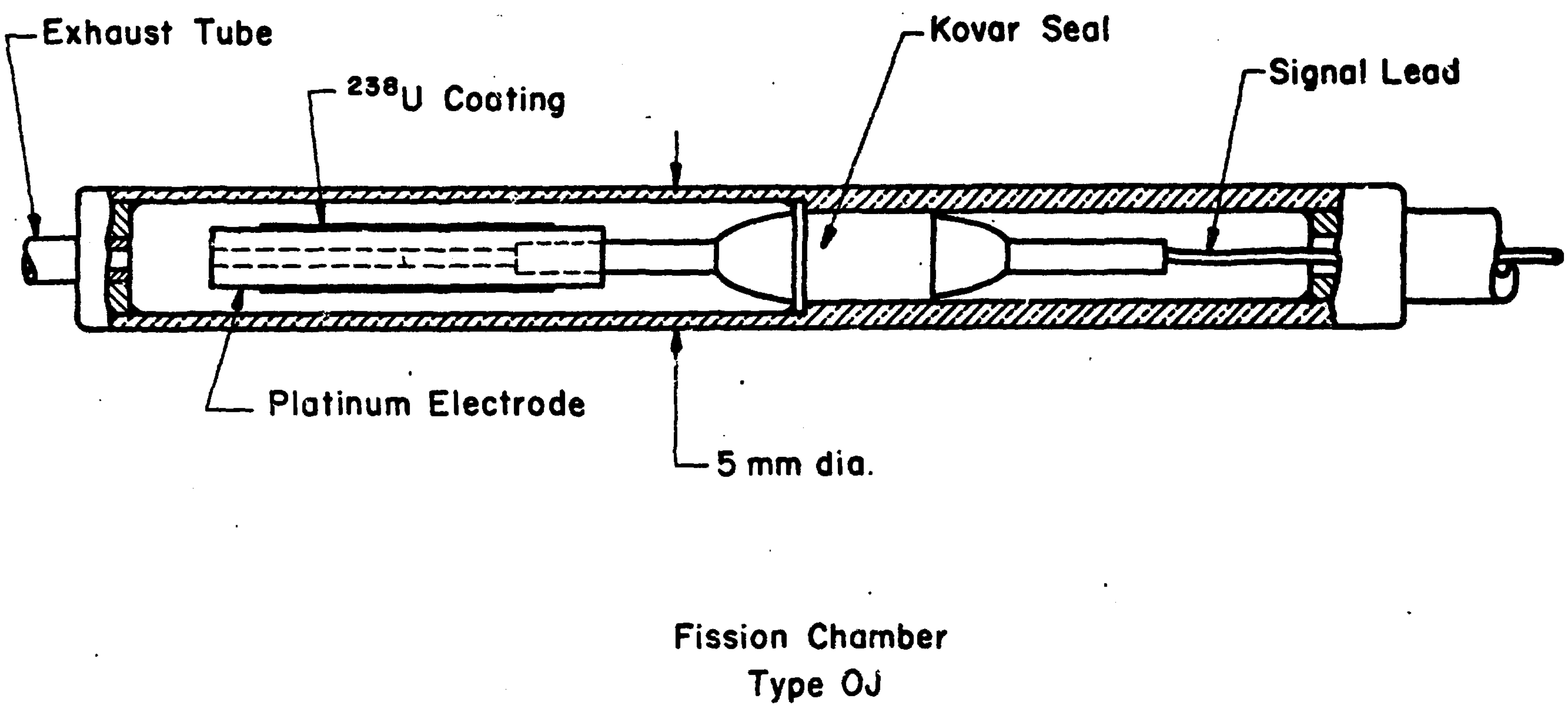

Fig. 7. Cross Sectional View of In-Core Fission Detector.

can be seen to be more sensitive to fuel loss than either detector separately. For these experiments, entire fuel pins

TABLE 1

Detector Response For Removal of Fuel Pins

Geometry	Relative detector counts ^{235}U	^{238}U	$^{235}U/^{238}U$
Reference	1	1	1
Six pins from ring 1	1.098	0.892	1.23
Six pins from ring 2	1.093	0.928	1.18
Six pins from ring 3	1.058	0.970	1.09

were removed, however, it is expected that similar results will be obtained if short lengths are removed in the vicinity of the 10-mm long fission detectors.

Results indicate that in-core detectors are capable of providing diagnostic information in multipin STF tests. For SAREF we would propose that one or more fuel pins be replaced with "hardened" channels enclosing a line of alternate ^{235}U and ^{238}U fission chambers cooled by flowing argon gas. The ^{235}U detectors then serve as monitors of local neutron flux driving fuel pins, while the ^{238}U detectors are sensitive to the proximity of fuel. For the high power levels in SAREF tests, ion current signals as a function of time would be preferable to counting rates.

As an alternative to in-core detectors, directional detectors located just outside the fuel pin array, have been suggested. We are investigating small proton recoil chambers for this application and a potential design is shown in Figure 8. We will investigate proton recoil counters of this general type including characteristics such as directional response, sensitivity, discrimination against spurious signals,

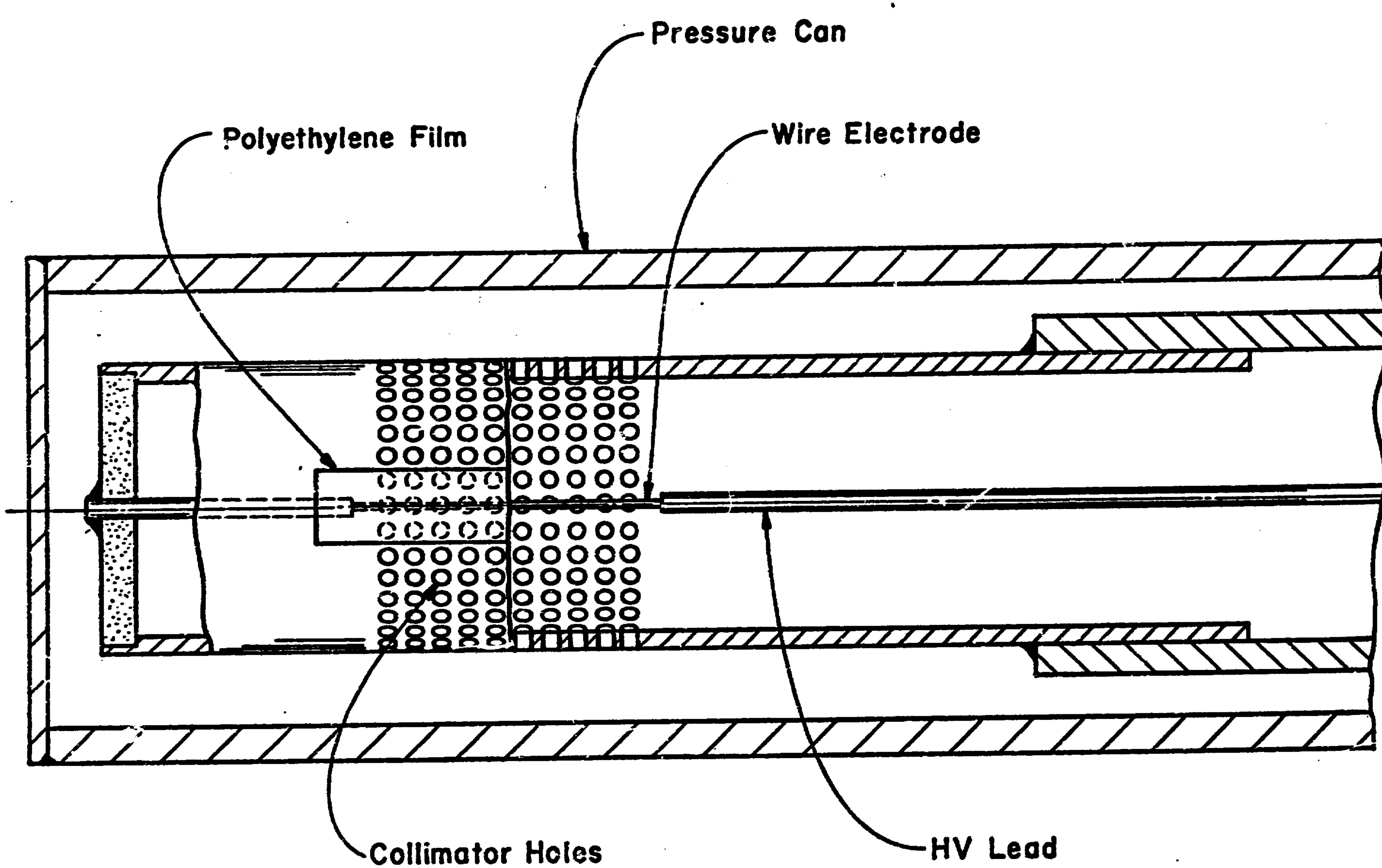

FIGURE 8. DIRECTIONAL PROTON RECOIL COUNTER.

signal-to-noise ratio, and vulnerability. It should be noted that proton recoil detectors are much more difficult to construct and operate than fission chambers.

The PARKA experiments planned for the immediate future will be run at relatively low power, using sensitive detectors and long counting times. At a later stage, high power transients may be initiated, if justified, in order to conduct imaging experiments. In any case, PARKA will provide the capability of evaluating diagnostic instrumentation application to large fuel pin arrays. This capability is not currently available at any other facility.