Hodoscope Collimator for 122-cm Viewing Height at TREAT*

by

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*This work supported by the U. S. Energy Research and Development Administration.

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The fast neutron hodoscope at TREAT contains major subsystems for collimation, detection, pulse processing, data storage, and support facilities. The collimator was designed to measure fuel motion in experiments containing typically 34-cm EBR-II fuel pins. Now, transient tests with active fuel length of 91 cm are beginning to be performed. A new collimator system has been designed, fabricated, and -- at this time -- partially installed at TREAT to satisfy requirements for extended fuel surveillance.

Functional Requirements

Functional goals for the new design were formulated with two major constraints: existing detectors and electronics were to be reused, and modification of the reactor was to be minimized. In order to provide coverage of fuel dispersal above and below active zones of FTR fuel, the total height viewed was set at about 122 cm. The viewing width was expanded to 6.6 cm, corresponding to a 61-pin FTR bundle.

Based on the above functional requirements, it was necessary to modify the viewing matrix at the object plane. The existing collimator views a height of 51 cm and width of 5.7 cm with a 23 x 15 array of detectors viewing 0.38 x 2.25 cm rectangles at the object plane. (Actual "resolution" for fuel motion is about an order of magnitude better than inter-detector spacing.) The new collimator has spacings of 0.66 by 3.45 cm. Although there are 360 slots slots in the 36 x 10 array collimator, instrumentation is restricted to the 334 detectors available from the original system.

Design Features

The new collimator design is similar in principle to the original collimator, yet incorporates many improvements intended to increase its usefulness as a research tool and facilitate the preparation process prior to the performance of experiments.

The seven major components of the collimator subsystem are as follows:

(1) Front Collimator: high-density material to minimize background and cross-over neutrons.

(2) Rear Collimator: primary-fast-neutron channeling component, including 20 slotted steel plates 181 cm in length.

(3) Rear Collimator Base and Shielding: to provide adjustments for alignment and shielding to minimize hazard during operations.

(4) Lead Filter Assembly: to have capability of inserting up to six lead plates in front of neutron detectors in order to reduce perturbations from gamma rays.

(5) Detector Plate: mounting for 360 neutron detectors.

(6) Detector Enclosure: light- and dust-tight enclosure around the detectors.

(7) Source Locator: remote positioning of higher intensity (30 Ci Pu-Be) neutron calibration source for greater reproducibility and reduced personnel hazard.

In addition to the major components of the collimator, reactor facility modifications are required:

(1) Existing Collimator: disassembly, removal, modification, and relocation to opposite end of TREAT slot. Also, addition of a shield and beam shutter.

(2) Slotted Elements: fabrication of unfueled elements to provide a clear viewing path for full-length pins.

(3) Cable Trenches and Cables: extension of existing trench and routing of a new trench to the relocated collimator and new cables to both collimators.

(4) Front Collimator Installation: Support plate installation at the North face reactor cavity.

The old collimator is to be placed on a standby basis for possible use primarily in single-pin experiments for which the better resolution may be needed.

In order to accomplish the requisite expansion of viewing region and still meet physical constraints, the collimator channels are "cross-focussed," that is, the image is inverted with respect to both vertical and horizontal axes of symmetry in the object plane. The crucial parameter which was maximized in design was the minimum path length through steel for radiation from one channel crossing over to an adjacent channel; this was held to a minimum of 100 cm, although the present collimator has a 150 cm path.

Specific Features

The seven major components are illustrated in Fig. 1. The front collimator is open horizontally but restricts vertical entry of neutrons not focussed directly upon target detectors. The aperture pieces, made of a tungsten alloy, are separated by 1 cm.

The 21 plates of the rear collimator are stacked, doweled, and bolted together. An outline of one type of plate is shown in Fig. 2, along with an indication of the method of stacking.

A scanning apparatus for manually adjusting (panning) the collimator has been included in the base of the collimator, along with an dial indicator.

Up to 7.5 cm of lead are included in the gamma filter assembly in the form of six plates each of 1.25 cm thickness. Any number of plates may be positioned manually.

The aluminum detector plate supports each detector at the proper angle of beam emergence. This detector plate is mounted within the neutron detector enclosure.

A remotely controlled motorized drive has been designed for positioning the calibration source in front of each detector. The source may be positioned in 0.025 mm increments with positioning reproducibility of ±0.0125 mm vertically or horizontally. The locator is interfaced to a microprocessor which operates under paper tape or operator control.

Fabrication

Fixturing and machining of the rear collimator lamination assembly represented the largest task in fabrication of the collimator. Nineteen carbon steel plates (1.90 x 137.79 x 182.24 cm) were first rough cut to profile and heat treated. Then another rough cut was made, this time to taper on a horizontal mill. Next, the plates were finished on a surface grinder using a vacuum chuck mounted on a sine table. The plates were ground to one of two sizes.

Each plate was then slotted on the horizontal mill by mounting the vacuum chuck and sine table vertically; an indexing fixture was used to rotate the plate together with the chuck and table, in order to provide the angles required for each of the slots. The outside surface of each side plate was stepped using the horizontal mill; these steps correspond to positions for collimator shielding blocks which reduce leakage radiation.

The plates were then stacked and aligned on a fixture, starting with the unslotted side plate followed by the 19 tapered plates, alternating the two types of plates. The slotted side plate finished the stack, which was then clamped and dimensionally inspected. The inspection was used to verify the dimensions required to machine the instrument hole locations in the detector plate so as to assure alignment of the detectors with the stack slots.

After inspection, the lamination stack was transferred to the vertical position and drilled and reamed for bolts and dowel holes, as shown in Fig. 3. Next, the stack was disassembled for cleanup and deburring of holes in each plate. The plates were coated with a thin layer of silicon grease and restacked. The assembly was bolted together with side brackets in place.

Quality Control Provisions

Project practices were in accordance with Argonne Quality Assurance Division (QAD) policies and procedures. A plan was prepared which established specific QA requirements for design, procurement, and fabrication. These measures were particularly important with respect to the rear collimator and its relationship to the detectors.

Inspections of the slotted plates by QAD were made at the completion of each of the fabrication steps indicated in the previous section. The tapered plate surfaces were checked for flatness while held in the vacuum chuck mounted on the bed of the surface grinder. The plates were then released and inspected for thickness and taper.

The indexing fixture used to establish the angle of the slots on each plate was inspected for angular conformance while mounted on the horizontal milling machine. After each slot was cut it was checked for depth, width, and surface finish. The lamination stack was inspected after assembly to establish final dimensional requirements for the detector plate.

Lead sheets for the gamma filter were radiographed and inspected for voids.

Discussion

Because the new collimator design represents an extension of the previous multi-channel collimator, no significant problems in design or fabrication were encountered. The use of cross-focussing accommodates some limitations caused by the requirement that reactor modifications be minimized. In this case, no cutting of concrete from the biological shield area was needed, and only a cable trench was extended on the reactor floor. Had the design not been limited in this fashion, the cross-focussing feature could have been applied to reducing the width of the slot through the reactor which was retained at a nominal width of 10 cm. It was necessary to compromise on the amount of material in the minimal neutron cross-over path between detectors, but close to 100 cm of steel is probably conservative in terms of preventing neutron cross-talk.

By filling all gaps between the front collimator, rear collimator, and biological shield with stepped concrete blocks, a significant reduction in ambient background is expected. This reduction is primarily needed during steady-state experiments when personnel are allowed on the reactor floor. Because calibration of the hodoscope detectors will be based on a 30 Ci Pu-Be source, it may be necessary to add portable shielding to minimize inadvertent exposure.

Present status of the project is as follows: All major components have been fabricated and assembled. Slotted fuel elements have already been used in the reactor. Modifications of the TREAT facility necessary to accommodate the new collimator have been completed. The front collimator has been installed and aligned with minimal difficulty during an allocated reactor shutdown in October. The next major phase of installation is scheduled to start in December for the primary purpose of installing the rear collimator and alignment of the two collimator sections with the core centerline. Then the detector system will be reconnected to the electronics, and testing of the entire system will take place.

Related activities still to be performed include fixtures and enclosures for the fission and gamma detectors and the reinstallation of the 51-cm collimator. A flat fission plate to simulate a uniform plane source of neutrons at the center of the reactor is currently being designed. This will be used to provide a more precise calibration of the detection systems.

A RAS project was formed for the fabrication and installation of the collimator. Scheduling, cost control, and adherence to standards were managed by project personnel linking engineering, machine shop, vendor, operator, and user requirements. Use was made of the network processor program PMS-IV and of EZPERT project graphics.

The design, fabrication, installation, and project experience gained from this larger collimator will provide another steppingstone for scaling hodoscope techniques to other safety test facilities.

Acknowledgements

We are indebted to N. Kramer for supervising installation at TREAT, G. Lobell for fabrication planning and supervision, J. Kotura for procurement assistance, and C. Miller and E. Hill for scheduling assistance.

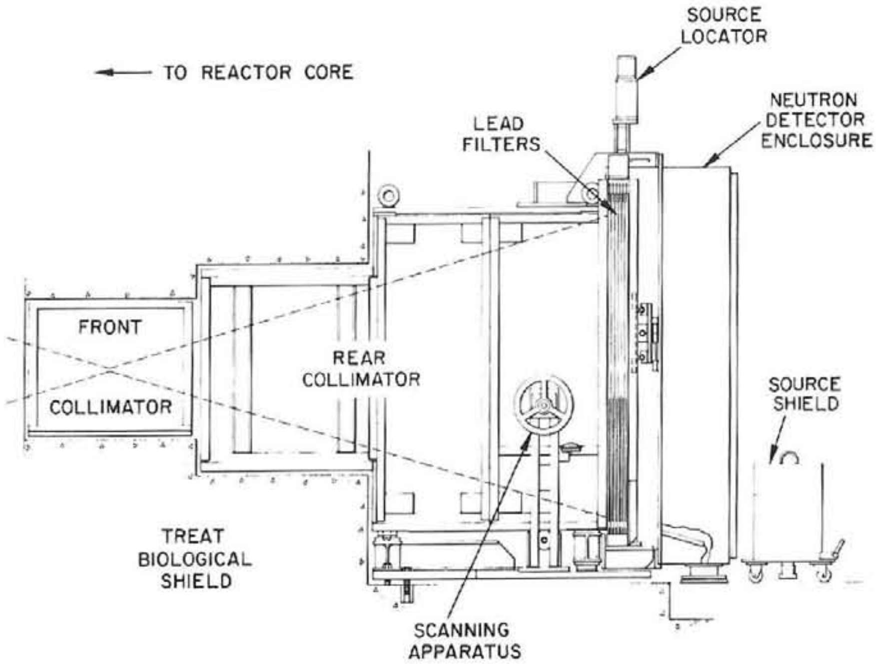

Figure 1. Schematic Assembly Drawing of New Collimator Positioned at Reactor Face

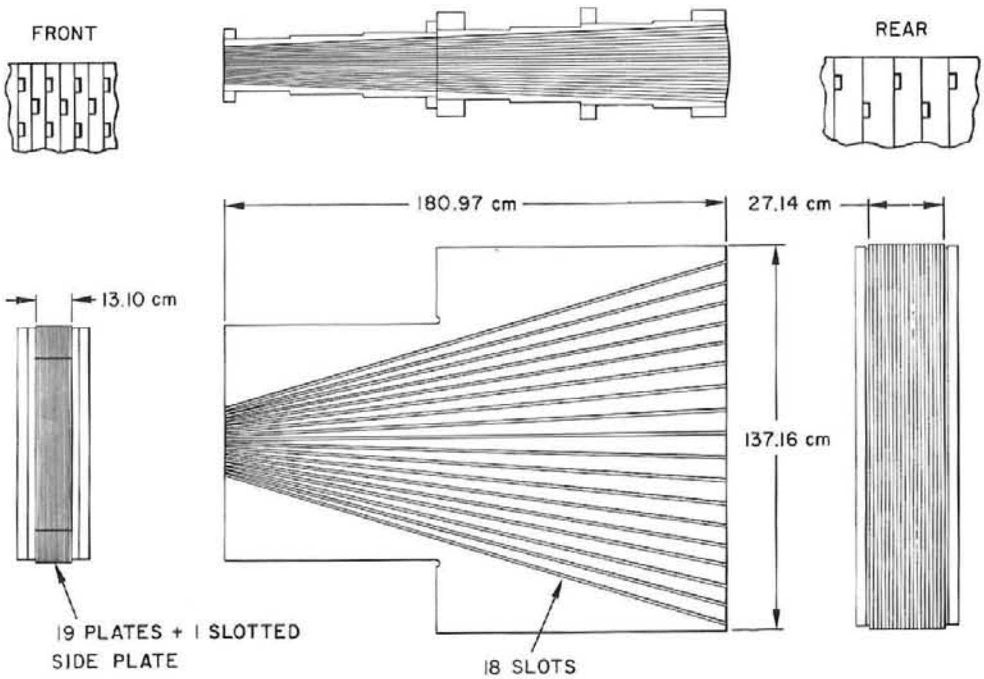

Figure 2. Design Details of New Collimator Plates

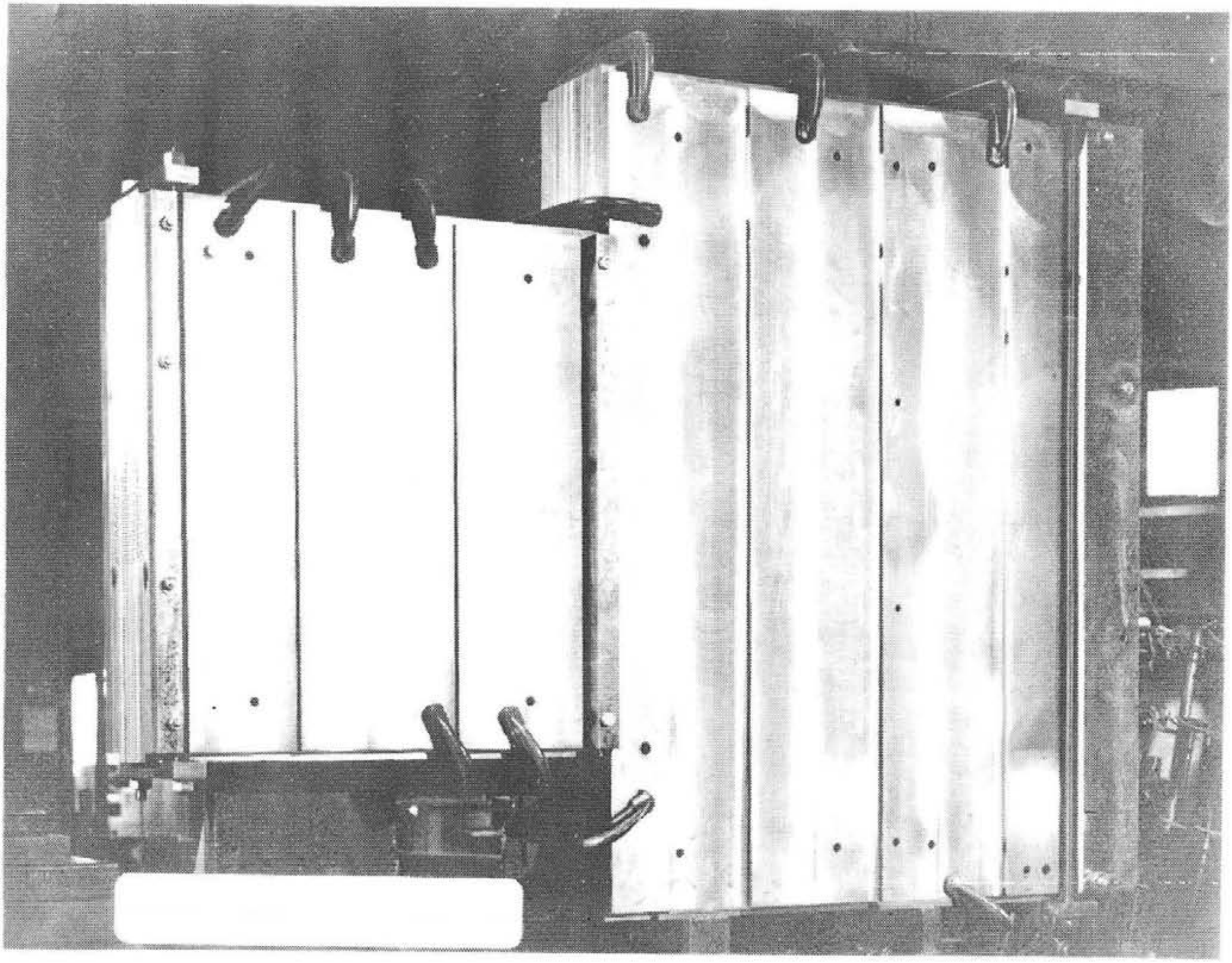

Figure 3. Collimator Plates Stacked and Clamped Temporarily Together