FINE SLIT, NEUTRON COLLIMATORS USING STRETCHED FILM

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SUMMARY

Fine slit collimators have been used extensively in neutron physics experiments to obtain neutron beams with a given angular deviation (collimation). Various methods of construction have been used, usually involving costly machining and expensive material. This report describes a simple method of construction using thin films with neutron absorbant coatings.

The first dozen or so collimators made by this method have proved to be very satisfactory both for simplicity of assembly and in efficiency of collimation and transmission.

Section A of this report describes construction and Section B gives results of performance tests in neutron beams using a typical medium size collimator (10' divergence) made in this way.

SECTION A

THE CONSTRUCTION OF FINE SLIT COLLIMATORS USING STRETCHED PLASTIC FILM

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SECTION B

INVESTIGATION OF THE PERFORMANCE OF THE COLLIMATORS WITH NEUTRONS

C Carlile

A3.0 DEFINITIONS AND FURTHER DETAILS

A3.1 Film

Polyethylene terephythalate film (ICI "Melinex") 0.025 mm inch thick has been used throughout. The film is aluminised on one side to a thickness of about 400 Å, as obtained from the supplier. This was chosen in preference to clear film because the conducting surface prevents build-up of electro-static charges on the films and dust-free conditions are easier to maintain at all stages of construction.

A3.2 Frame

This is a simple "picture-frame" shape (as shown in Fig. A1b) cut from stainless steel or aluminium alloy sheet.

Dimension 'h' determines the height of the finished collimator aperture; 'd' must be of such dimensions as to balance the forces due to the applied stretched film without bending or distortion of the frame; 'ℓ' must be longer than the effective collimator length by about 100 mm.

Numerous holes for bolts and dowels, not shown in Fig A1b, may be clearly seen in photograph Fig A3.

The frame thickness determines the final gap between adjacent films which make up the collimator assembly. All sharp corners and edges must be carefully removed and the frames must not be bent or buckled.

A3.3 Blade

This is a frame on which stretched film has been glued, painted and trimmed to length. Examples of frames and blades are shown at various stages in Fig A3.

Simple jigs and templates are used during trimming in order to ensure uniformity of foil length and shape on all blades.

A3.4 Side Plate

The two side plates in each collimator assembly must be strong enough to avoid twisting or distortion of the assembled blades. The side plates are also slightly longer than the blades in order to provide protection to the trimmed edges of foil.

A3.5 Adhesive

Eastman 910 (Eastman Chemical International or CIBA) adhesive has been used extensively throughout construction. This is a cyanoacrylate type adhesive which cures at room temperature. Precautions which are outlined in the manufacturer's brochure must be observed.

The adhesive has a pungent, unpleasant odour and has a mild lachrymatory effect on the mucous membranes of the nose and eyes. It is essential to provide a good ventilation when using this material in significant quantities. Toxicity tests have indicated that cyanoacrylate adhesives are relatively non-toxic substances and they do not appear to be a skin sensitizer. Under no circumstances should the adhesive be allowed to come into contact with the eyes. If the material contacts the skin, immediately flush the area with copious quantities of water.

A3.6 Neutron Absorbing Paint

This is an acrylic based paint containing Gadolinium oxide. Constituents:-

Solvents	XYLENE	90 gms
	AROMASOL (ICI Ltd)	10 gms
Gadolinium Oxide		80 gms
Bedacryle (ICI)		100 gms

Aromasol is a mixture of solvents but contains a large proportion of isomeric trimethyl benzenes. These should be regarded as dangerous materials showing narcotic effects and some disturbance of the blood.

Gadolinium oxide is a powder suspended in the paint and may be regarded as moderately toxic if ingested in sufficient quantities.

It is essential to carry out all painting and curing inside a fume cupboard. The paint as prepared above is dense white in colour and when applying with a simple paint pad uniformity is easy to judge from the opacity of the deposit. It is estimated that up to 0.01 mm of oxide are deposited for each 0.025 mm of paint and that one uniform coat is sufficient.

A3.7 Foil Stretching Bed

The design and use of this bed is described in Ref (1) and illustrated in Fig A4.

A4 MAKING A "BLADE"

A4.1 During the whole of this operation and during assembly, cleanliness of working and a dust-free atmosphere are very important. Cleaning of components and film may be carried out with clean lint-free cloths wetted with absolute alcohol.

The film must be taken straight from the roll and laid carefully on to the stretching bed. Inflation of the air tube to a predetermined pressure is controlled with valve and pressure gauge as described in Ref (1). Adhesive is applied to the frame before it is laid on a flat lifting table placed beneath the bed (Fig A4). The table is raised until the film is pressed firmly onto the frame, exerting steady force on the glue bead. After a period of about half an hour for curing, the film is cut around the frame and removed from the bed.

A4.2 Painting

A uniform, single coat of the special paint (para. A3.6) is applied to both sides of the film on each frame using a simple paint pad. The outer surfaces of the frame must be kept free from paint so that the final glueing is unimpaired.

The blades are laid horizontally during drying in a dust-free atomosphere and never stacked together, as this would result in poor surface texture of paint and difficulties when trimming.

Two coats of the paint are applied in a similar fashion to the inner surfaces of each side plate.

A4.3 Trimming

Each painted blade (when dry) is set into the specially designed cutting jig and surplus film is removed with a very sharp scalpel. This trimming is made easier if the drying time is limited to 2 to 3 hours, because after this length of time flaking may occur. On no account trim before painting, as this will result in an ill-defined edge.

A5. ASSEMBLY OF BLADES

It is possible to glue only 6 or 7 blades together at the same time because the adhesive tends to cure quickly. The two side plates are used as jigs in this glueing process and fitted dowels on two holes ensure correct alignment. One plain frame (ie without film) is required in the final assembly and this is placed next to one side plate to create the end gap. Finally, all packs of blades are glued together and the side plates are bolted and dowelled.

Small mirrors are used to assist inspection at the final stages, to confirm that the films remain intact, taut and clean.

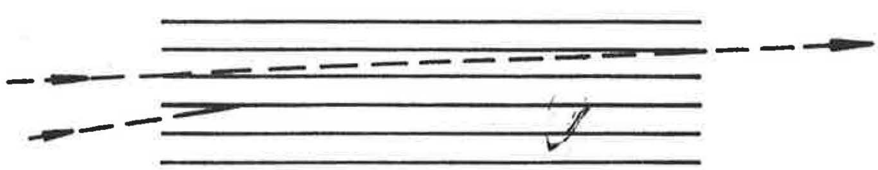
A6. REMOVAL OF FRAME ENDS

Fig A5 shows an assembled collimator before removal of the frame ends.

Adhesive tape is stretched across the faces of the side plates to seal up the entry and exit so that dust and swarf cannot enter. A fine toothed handsaw is used to cut across the line of holes in the frame ends followed by final dressing with a smooth file.

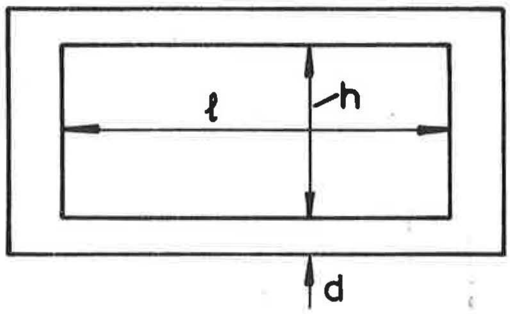
A7. REFERENCE

Hey P D, Spark chamber foil stretching techniques 1.
HEP/APP)1 (68) (RL INTERNAL REPORT).



(a)

MULTIGAP COLLIMATOR
(DIAGRAMMATIC)



(b)

FIG. A1
"PICTURE-FRAME" FORM OF COLLIMATOR FRAME

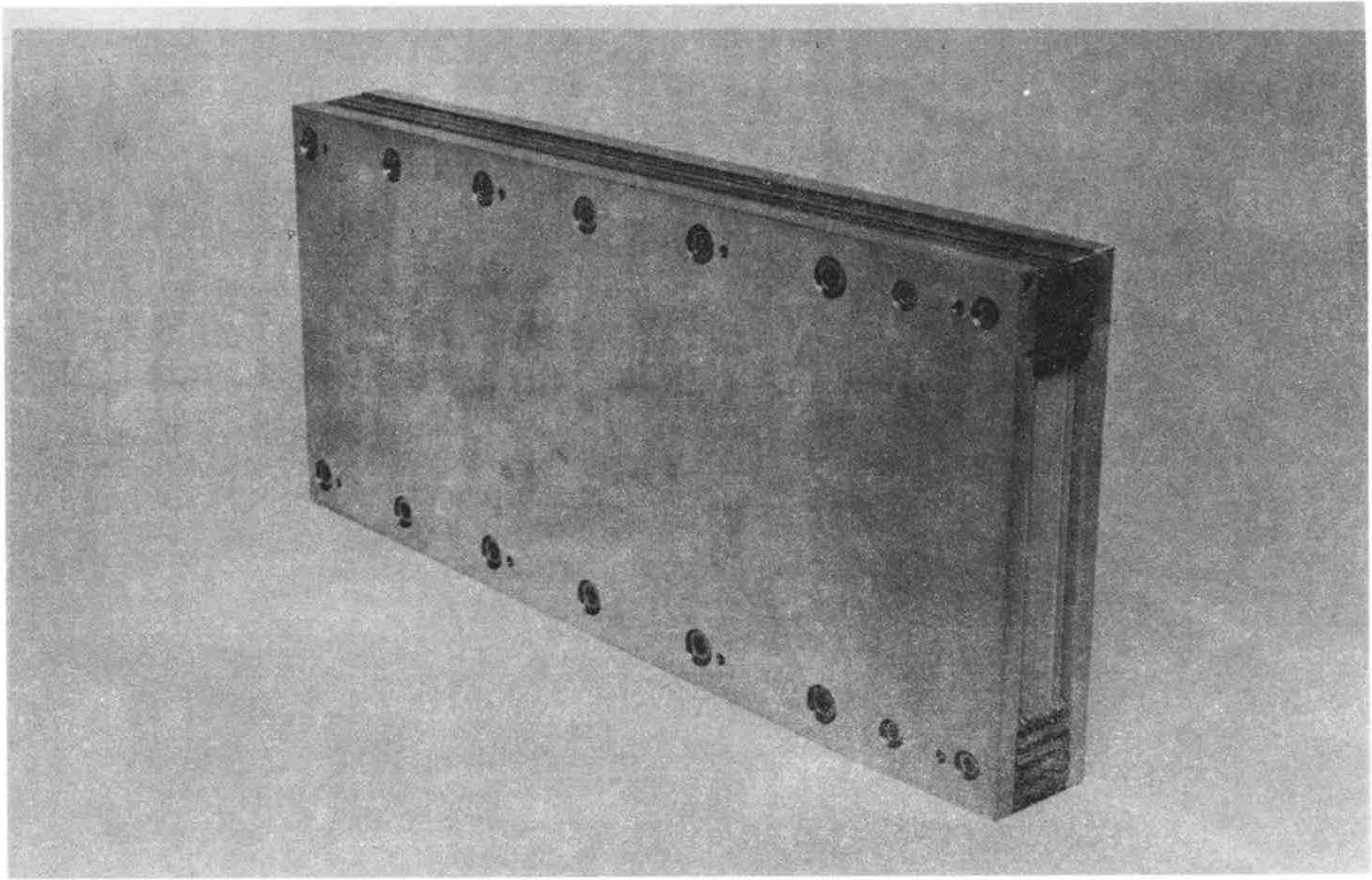


FIG A2. A COMPLETED COLLIMATOR

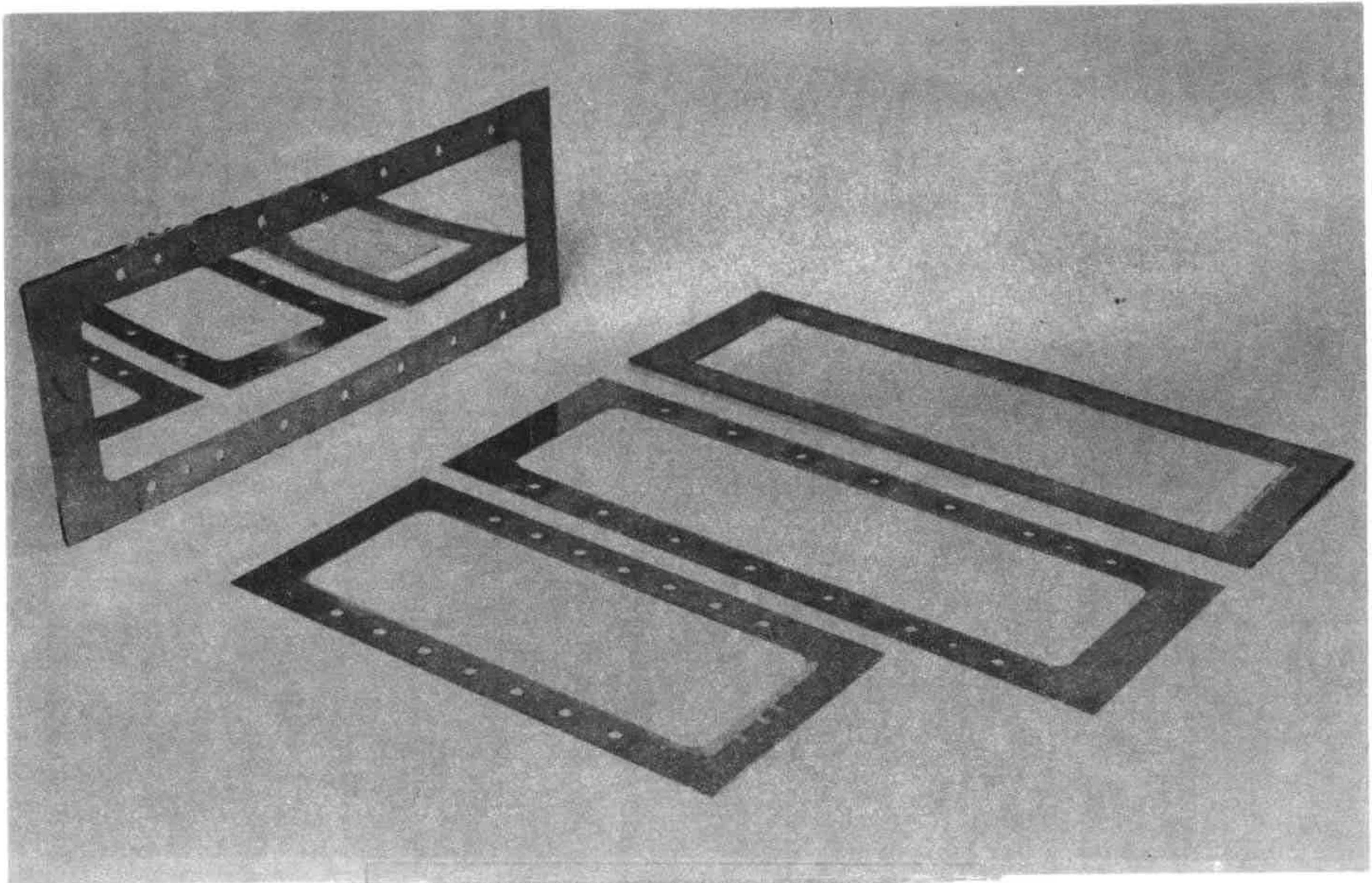


FIG. A3 FRAMES & BLADES

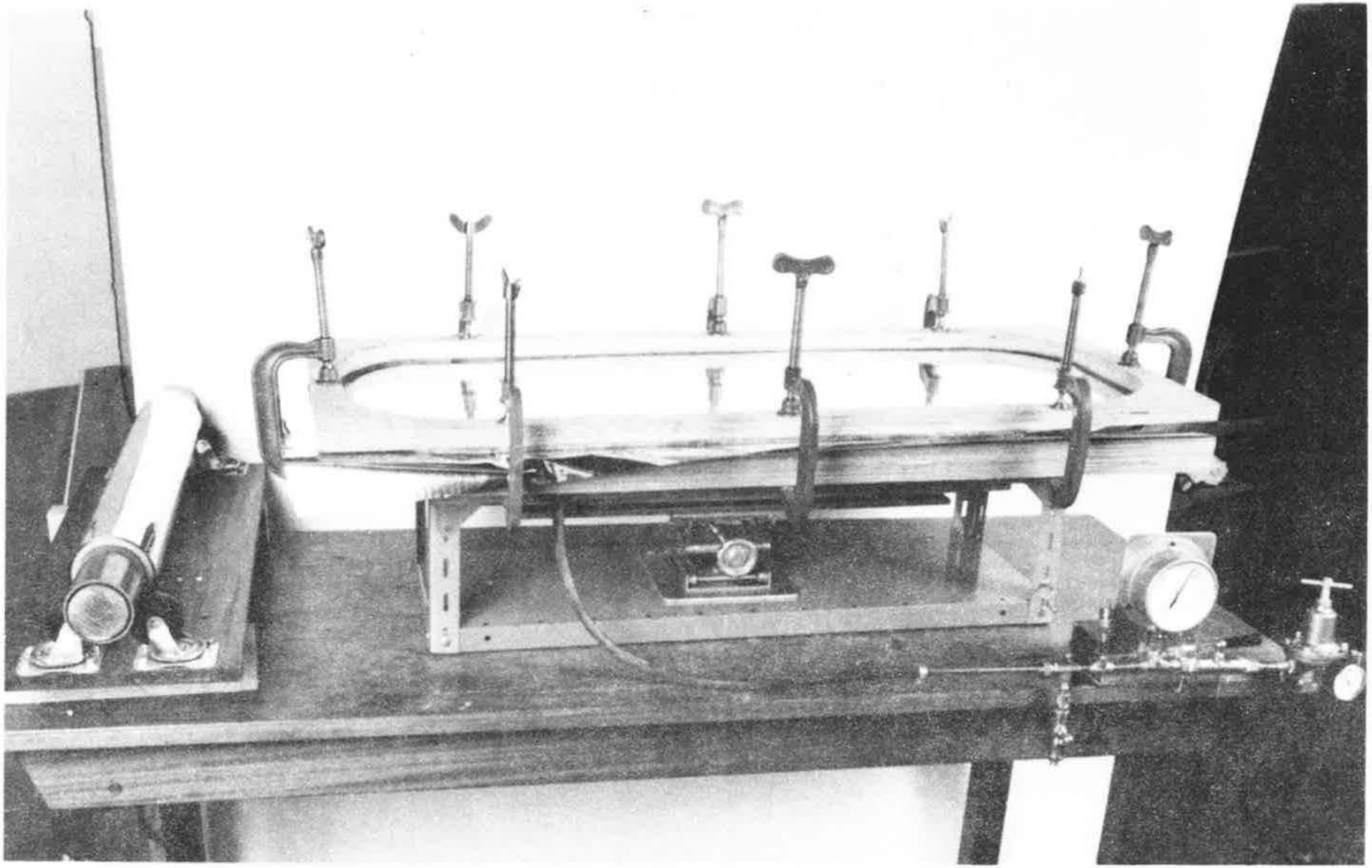


FIG. A4 FILM STRETCHING BED

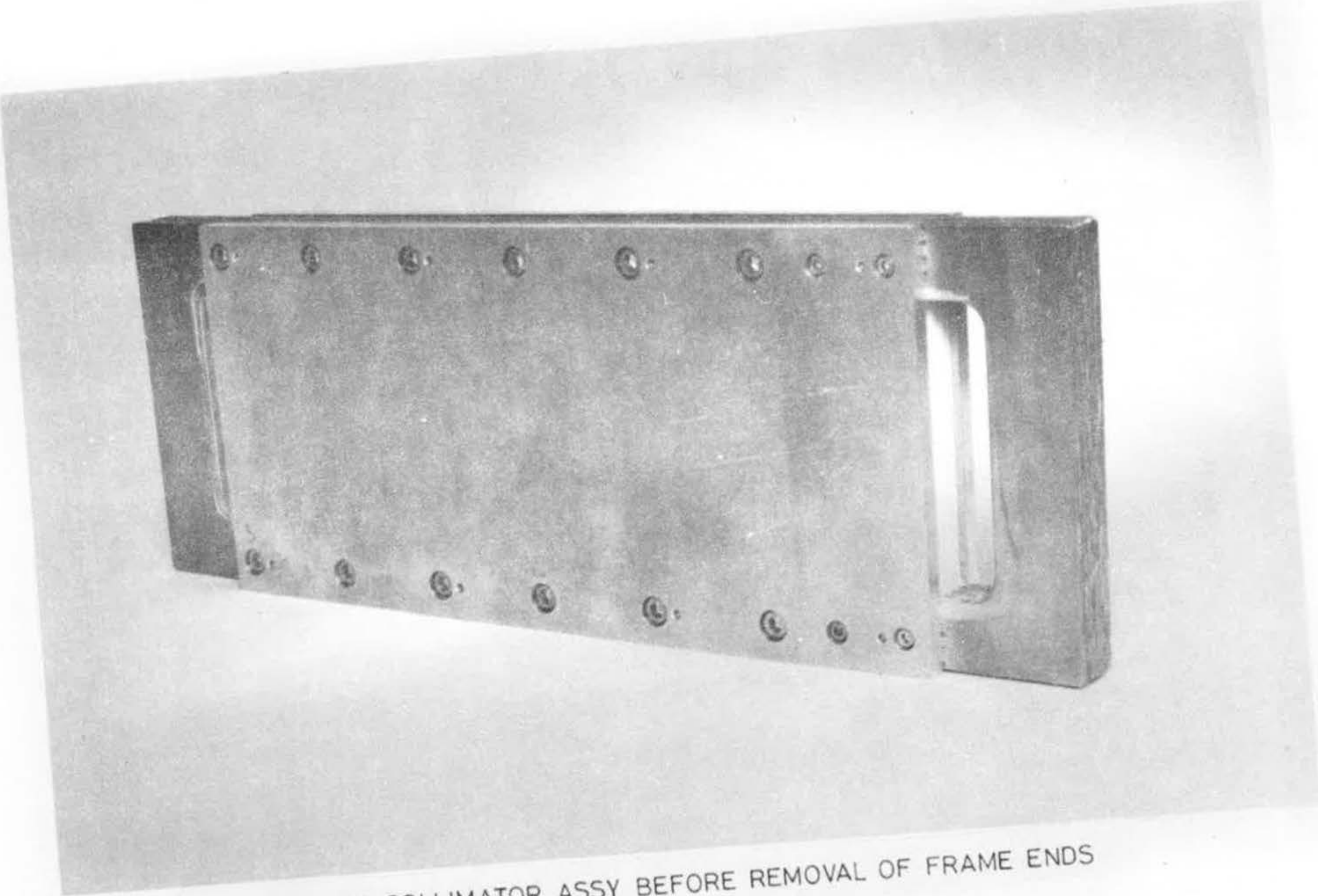


FIG. A5 COLLIMATOR ASSY BEFORE REMOVAL OF FRAME ENDS

SECTION B

B1. NEUTRON RADIOGRAPHY

Radiographs were taken of the test collimator by utilising the thermal neutron radiography facility at the Herald Reactor Aldermaston. The collimator was set up facing a neutron source of effective diameter 2.5 cms at a distance of 400 cms. By careful alignment a radiograph was obtained (Fig B1) with the extreme right-hand slot of the collimator facing along the beam centre line. The first blade is seen to be in sharp focus. As the adjacent blades become further off the centre line shadowing caused by absorption in the Gadolinium is seen until finally no neutrons are transmitted through the outermost slot. The collimator was then rotated away from the beam axis by 1^{o}. It can be seen from Fig B2 that a faint rectangular beam is still passing through the collimator but that its intensity is low even compared to the neutron transmission through the 32 cms long aluminium outer walls of the collimator.

B2. NEUTRON BEAM MEASUREMENTS

B2.1 Transmission Function

The measurements reported in this section are based on the method of Meister and Weckermann (1973) (ref. 1). Measurements were made on the D13 diffractometer at the Institut Laue-Langevin the experimental arrangement being shown in Fig B3. A copper monochromator (20' mosaic spread) served to reduce the beam intensity and thus avoid dead-time effects, but more importantly it provided monoenergetic neutrons so that the effect of total external reflection from the blades of the collimator could be assessed more readily. A neutron wavelength of 1.5Å was used. Two identical collimators were set up 1 metre apart along the axis of the monochromatic beam, the blades being adjusted to the vertical. Careful manipulation was required to obtain the maximum intensity in the neutron detector. Collimator 2 was then stepped automatically through the beam axis while the intensity in the detector was recorded at each position. The rocking curve so obtained is shown in Fig B4. Ref. 1 gives a theoretical expression for this function assuming the divergence of the beam reflected from the monochromator can be represented by the first two terms of a Gaussian expansion

$$I = I_o (1 - c\alpha^2)$$

where α is the angle of the neutron from the beam centre-line and c represents the angular divergence of the beam. It is assumed in the derivation of the rocking curve formula that the collimator blades are perfectly plane and totally absorbent. In particular no account of total external reflection or transmission by the blades is taken, in which case the collimator transmission function should be triangular. The theoretical expression for the rocking curve is

$$I_{1+2}(\gamma) = I_o\left(\frac{T}{\Gamma}\right)^2 \left[\frac{4}{3}\Gamma^3 - \frac{4}{15}c\Gamma^5 + \gamma(2\Gamma^2 - \frac{2}{3}c\Gamma^4) + \gamma^2(\Gamma - c\Gamma^3) + \right.$$

$$\left. + \gamma^3(\frac{1}{6} - \frac{5}{6}c\Gamma^2) - \gamma^4\frac{1}{3}c\Gamma - \gamma^5\frac{c}{20}\right]$$

in the angular range -2Γ to $-\Gamma$

and $$I_{1+2}(\gamma) = I_o\left(\frac{T}{\Gamma}\right)^2 \left[\frac{2}{3}\Gamma^3 - \frac{1}{15}c\Gamma^5 - \gamma^2\Gamma - \gamma^3(\frac{1}{2} - \frac{1}{6}c\Gamma^2) + \right.$$

$$\left. + \gamma^4\frac{1}{3}c\Gamma + \gamma^5\frac{3c}{20}\right]$$

in the angular range $-\Gamma$ to 0.

where Γ = collimation angle of collimators 1 and 2

γ = angle of collimator 2 to the beam axis

T = integrated transmission of a collimator

This expression is plotted in Fig B4 and it can be seen that it fits the experimental points well with the values of c = .0134 mrads^{-2} and Γ = 3.12 mrads being the actual values for the beam and the collimator respectively.

B2.2 Integrated Transmission

The Integrated Transmission T of the collimator may be obtained by the removal of collimator 2 and comparing the intensity obtained with the maximum intensity transmitted through the two collimators. T is given by the expression:-

$$T = \left[\frac{I_{1+2}(\gamma=o)}{I_1(\gamma=o)}\right] \cdot \frac{30 - 5c\Gamma^2}{20 - 2c\Gamma^2}$$

The value of I_{1+2}/I_1 is 0.650 ± 0.0015 which gives

$$T = 0.966 \pm 0.002$$

B3. CONCLUSIONS

A method of fabricating collimators for thermal neutrons has been developed which provides collimators with essentially triangular transmission functions and integrated transmission functions exceeding 95%. The method is simple and inexpensive and the collimators are robust and not subject to mechanical deformation with change in room conditions.

B4. REFERENCE

1. Meister H and Weckermann
Nucl. Instru. & Methods 108(1973)107-111.

ACKNOWLEDGEMENT

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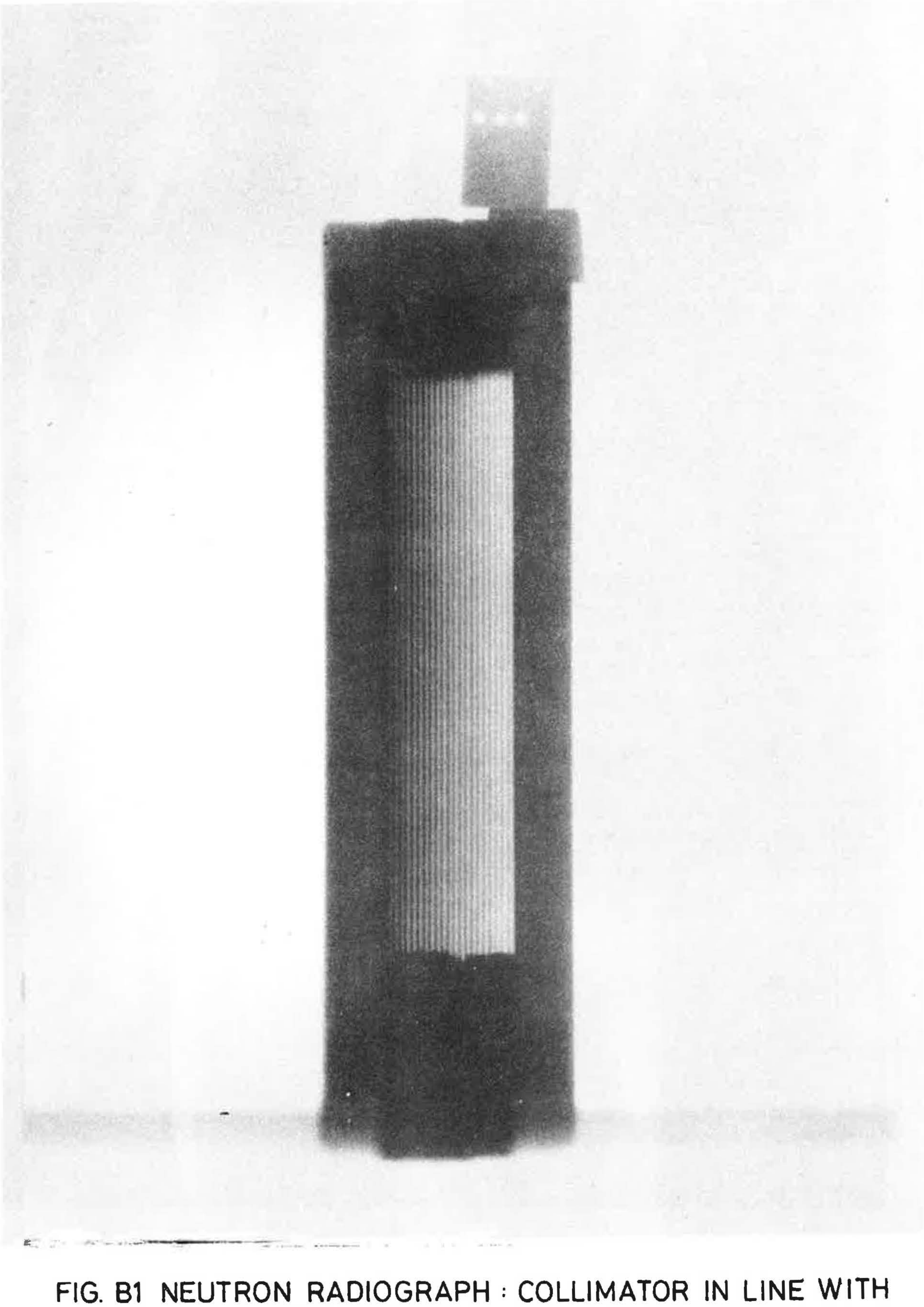

FIG. B1 NEUTRON RADIOGRAPH : COLLIMATOR IN LINE WITH NEUTRON BEAM ON RIGHT HAND SIDE.

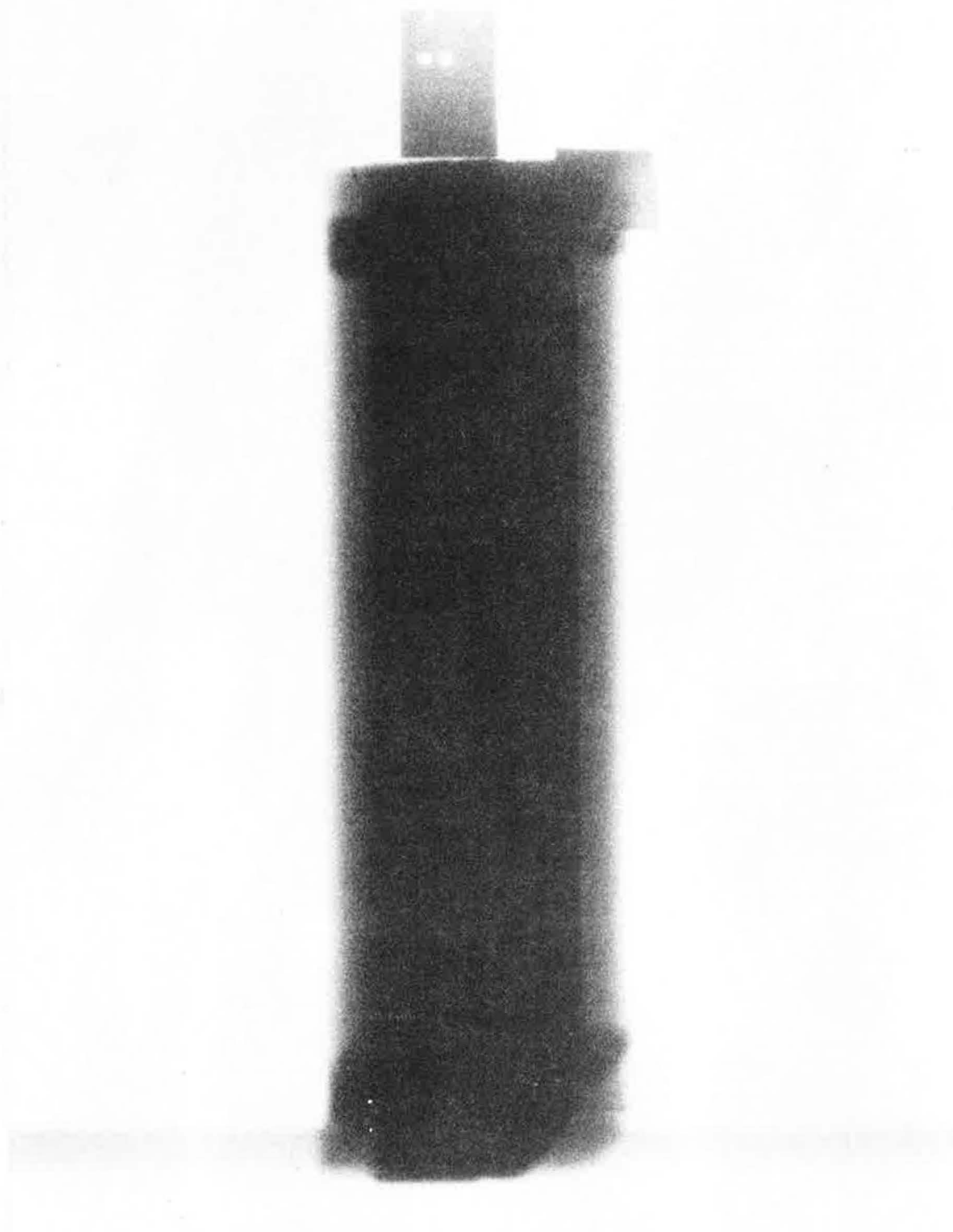

FIG. B2 NEUTRON RADIOGRAPH : COLLIMATOR AT SMALL ANGLE TO NEUTRON BEAM.

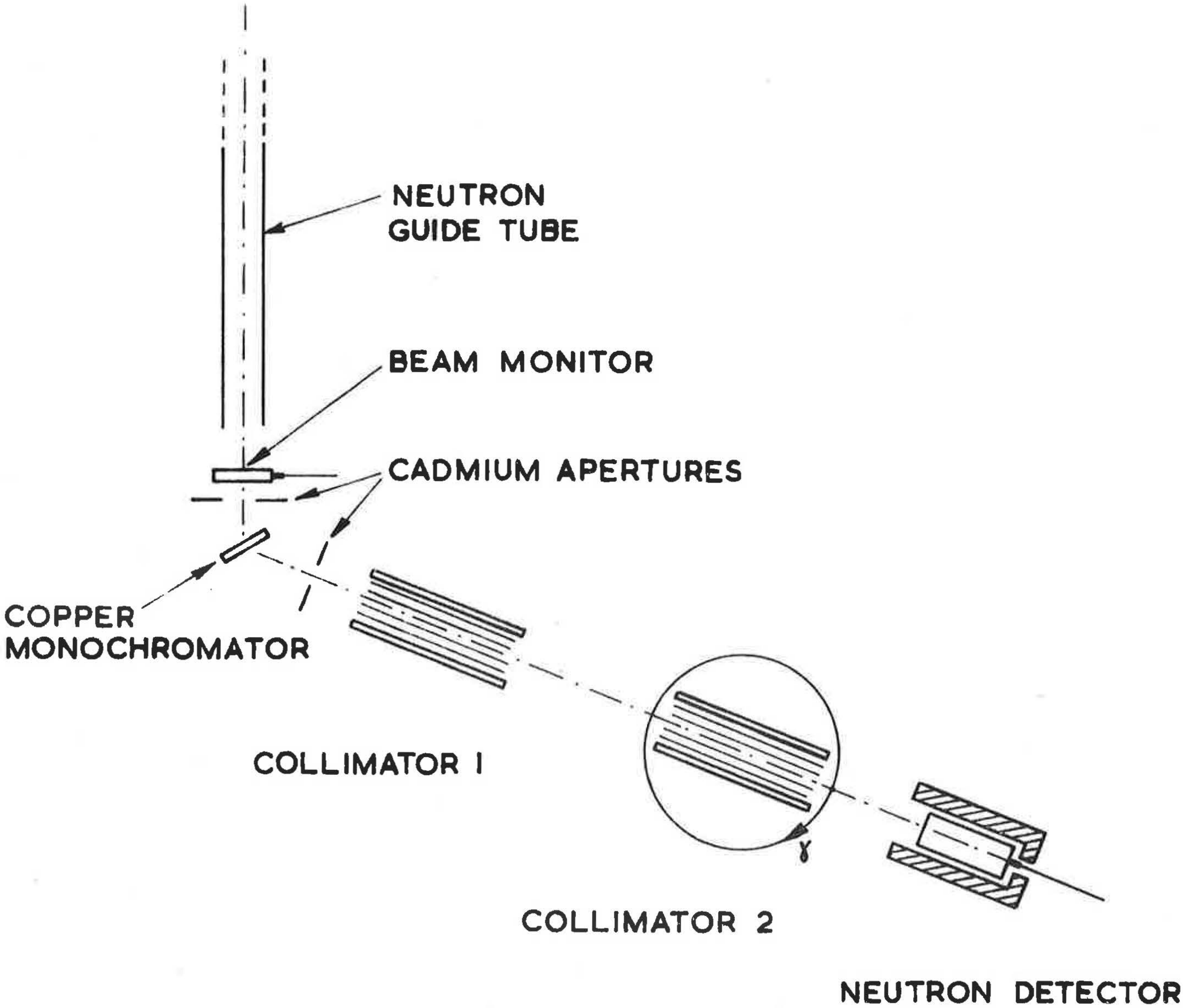

FIG. B3
ARRANGEMENT OF COMPONENTS FOR THE EXPERIMENT.

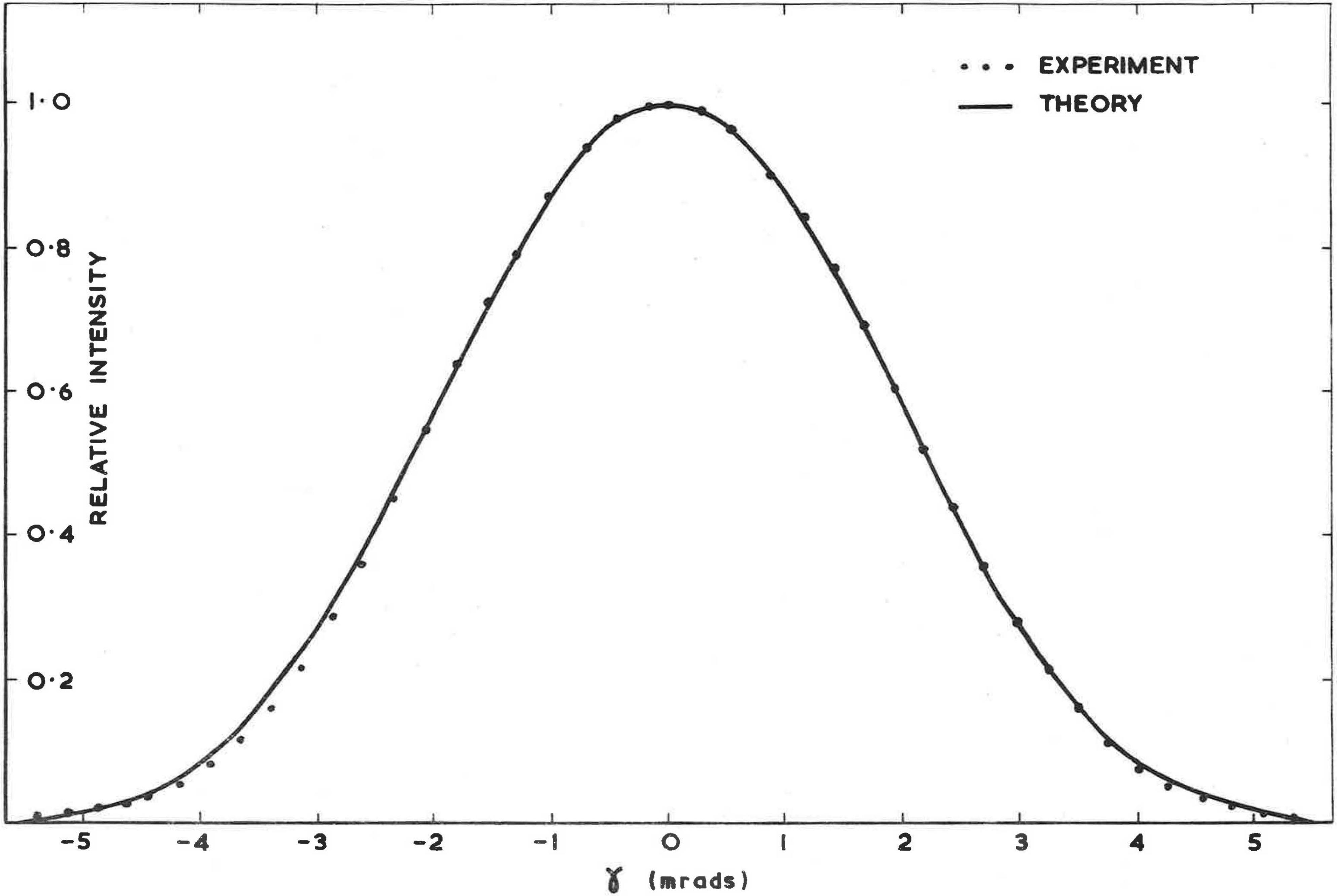

FIG. B4 ROCKING CURVE