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BERKELEY NUCLEAR LABORATORIES REACTOR PHYSICS Mk.III EXPERIMENTAL PROGRAMME

Description of Facility and Programme for 1971

by

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INTRODUCTION

Reactor physics experiments have been carried out at Berkeley Nuclear Laboratories during the past few years in support of the Civil Advanced Gas-Cooled Reactors (Mk.II) the Generating Board is building. These experiments are part of an overall programme whose objective is to assess the accuracy of the calculational methods used in the design and operation of these reactors. The facility used was a critical, zero-energy reactor built within a large concrete enclosure (11x11x12 metres). Control and safety instrumentation, fuel and graphite storage and handling facilities, counting laboratories and other facilities are provided as part of an integrated complex (Clarke and Staniland, 1968). No provision is made for heating or air-pressurisation and flux levels are essentially limited by the simple post-irradiation fuel handling methods used.

The possibility of the C.E.G.B. ordering an H.T.R. type reactor has resulted in the start of an equivalent back-up experimental/theoretical programme designed to support its position as an operator. It covers the strategy and tactics of fuel management, the choice of initial fuel loading and the interpretation of reactor data obtained from operational and post-irradiation examination studies. Towards this end, a large (approximately 60 block-columns, 3 metres high) critical zero-energy reactor will be built at B.N.L. by early 1972. The reactor will be large and flexible enough to allow a range of operational problems to be studied, e.g. fuel cycle equilibrium, block-to-block power variations, achieved by a suitable mixture of nuclear fuels (U, PU, enrichment) and integral poisons. The moderator and fuel geometries used will be influenced by the commercial designs submitted.

It is proposed to 'lead-into' this programme with measurements on limited quantities of compact fuel. These plans are well advanced and measurements on a critical stack should start by the middle of 1971. These 'lead-in' measurements will allow the experimental and analytical groups to establish and develop techniques, provide some additional data to assess the uncertainties associated with the design methods used in the first tender, and allow the various commercial designs to finalise before committing large resources to fuel and graphite manufacture. This note outlines these 'lead-in' measurements.

2. DESIGN BASIS OF INITIAL REACTOR

The design of these early measurements has largely been governed by the dual requirements of flexibility and fuel availability. The information sought is that relevant to the determination of core size and shut-down rod investment. It is not the intention to carry out a range of idealised measurements in order to allow confident extrapolation of predicted uncertainties to more realistic power reactor situations. Instead we have attempted to identify those areas of core design where physics information might be critical, and to create deliberately similar situations in the B.N.L. reactor to examine how well available theories can predict the resultant rating and damage rate distributions. This 1971 programme is therefore not designed specifically to examine the circumstances under which predictions diverge from measurement, but simply to establish the likely extent of this divergence in an operating H.T.R. In addition, in selecting the fuel compact designs it was sensible to extend the range of the lattice studied by the A.E.A. but not at the cost of departing radically from current commercial proposals or removing the possibility of interchanging fuel with the A.E.A. in the future.

3. DESCRIPTION OF THE FIRST B.N.L. MK.III REACTOR

The first B.N.L. Mk.III stack is a two fuel region stack. The central region is hexagonal and fuelled with 174 fuel channels of teledial fuel to a height of 2 metres. It is surrounded by 368 channels of annular compact fuel of the same axial height. The whole arrangement makes up the equivalent of a 31 block-column reactor (18 fuel channels per block) surrounded axially and radially with a solid graphite reflector (typical thickness 60 cms) - see Figure 1.

Both inner and outer zones are built from identical hexagonal moderator bricks, 399.5 mm across flats, each containing 19 holes of diameter 74.8 mm. The central hole contains no fuel, and the 18 fuelled channels are centred on 3 pitch circles, details of which are given in Table 1.

Inner Zone Fuel (Teledial)

The teledial compacts for the inner zone are being manufactured by the DRAGON project from 260 kg of the type 'B' fuel particles, which were used in the A.E.A.'s early low enrichment H.T.R. lattice studies at Winfrith (Johnstone and Della Loggia, 1970).

The weight of kernels available, and the size of fuel zone required, influenced the decision to have an 8 pin teledial, of total compact cross-sectional area 9 cm^2 and a heavy metal density of 0.7 gm/cc. The 8 pins are equally spaced on a radius of 22.15 mm within a graphite annulus of outer radius 32.50 mm and inner radius of 11.90 mm. A fuel pin is either 25 or 50 cms long and sealed at either end by thin aluminium discs. A stack of fuel pins is handled as a stringer (2 metres long) by means of an aluminium guide-tube attached to a support plate. The hole down the centre of the guide-tube (radius

10.3 mm) is available for poisons and for experimental equipment.

Details of the teledial compact and mean lattice properties are given in Table 2.

Outer Fuel Zone (Annular Compacts)

The outer zone is fuelled with elements of annular fuel compacts which are being manufactured by A.E.A. Springfields. They have an outer diameter of 55 mm and inner diameter of 40 mm, using the same dies as those used for the A.E.A.'s Zenith II series. The fuel enrichment is 3% and heavy metal density 0.65 gm/cc, and the annulus is placed within inner and outer graphite sleeves 7.75 and 5.0 mm thick respectively.

The fuel pin lengths and stringer handling arrangements are the same as those for the teledial fuel pin.

Details of the annular compact and mean lattice properties are given in Table 2.

4. EXPERIMENTAL PROGRAMME

Attention will be concentrated during this 'lead-in' experimental stage on the problems associated with reactor environments:- block-to-block and pin-to-pin distributions, graphite damage dose rates, power and damage gradients as functions of leakage, burn-up simulation, control rod and core/reflector effects.

Three or possibly four different reactor situations will be studied by a suitable deployment of poisons and/or control rods in one basic stack. This is the two-zone stack described, but with all the excess reactivity (∿5 niles) taken up by poison rods uniformly distributed throughout the teledial zone. Typical 9-energy group flux shapes are shown in Figure 4 for this reactor configuration.

This is the simplest stack to interpret and it will therefore be used to study the reactivity and power shape trim procedures that will be used in the remainder of the programme, e.g. alternate poisons, fuel to graphite and fuel to vacancy substitution etc.

The modifications to this stack which will be studied are:-

(1) The 'half-fuel' blocks on the outer edge of the core (see Fig.1) will be plugged with graphite and cross-block tilt effects next to core/reflector interfaces measured.

(2) Block-to-block differentially poisoned teledial zone (see Figures 2 and 3). Two possible configurations are:-

- (i) pronounced cross-block power and damage gradients across the centre of the stack, coupled with equivalent ones at the core/reflector interface,
- (ii) block-to-block buckling variations typical of large super-cell equilibrium conditions.

(3) Control rod studies in teledial zone. The geometrical arrangements of the control rods and moderator block have not yet been finalised. Grey rods, black rods and rod interaction effects will be looked at in addition to power distribution effects on approaching the rods.

5. TIMING

If present timescales are held the reactor will be fully commissioned by July 1971.

REFERENCES

1. A Reactor Physics Facility and First B.N.L. Reactor - R.W. Clarke and R. J. Staniland, RD/B/N1095.
2. Experimental Results from the U.K.A.E.A. Reactor Physics Programme on Low Enrichment H.T.R. Lattices at A.E.E. Winfrith - I. Johnstone and V.E. Della Loggia, D.P. Report 730.

TABLE 1

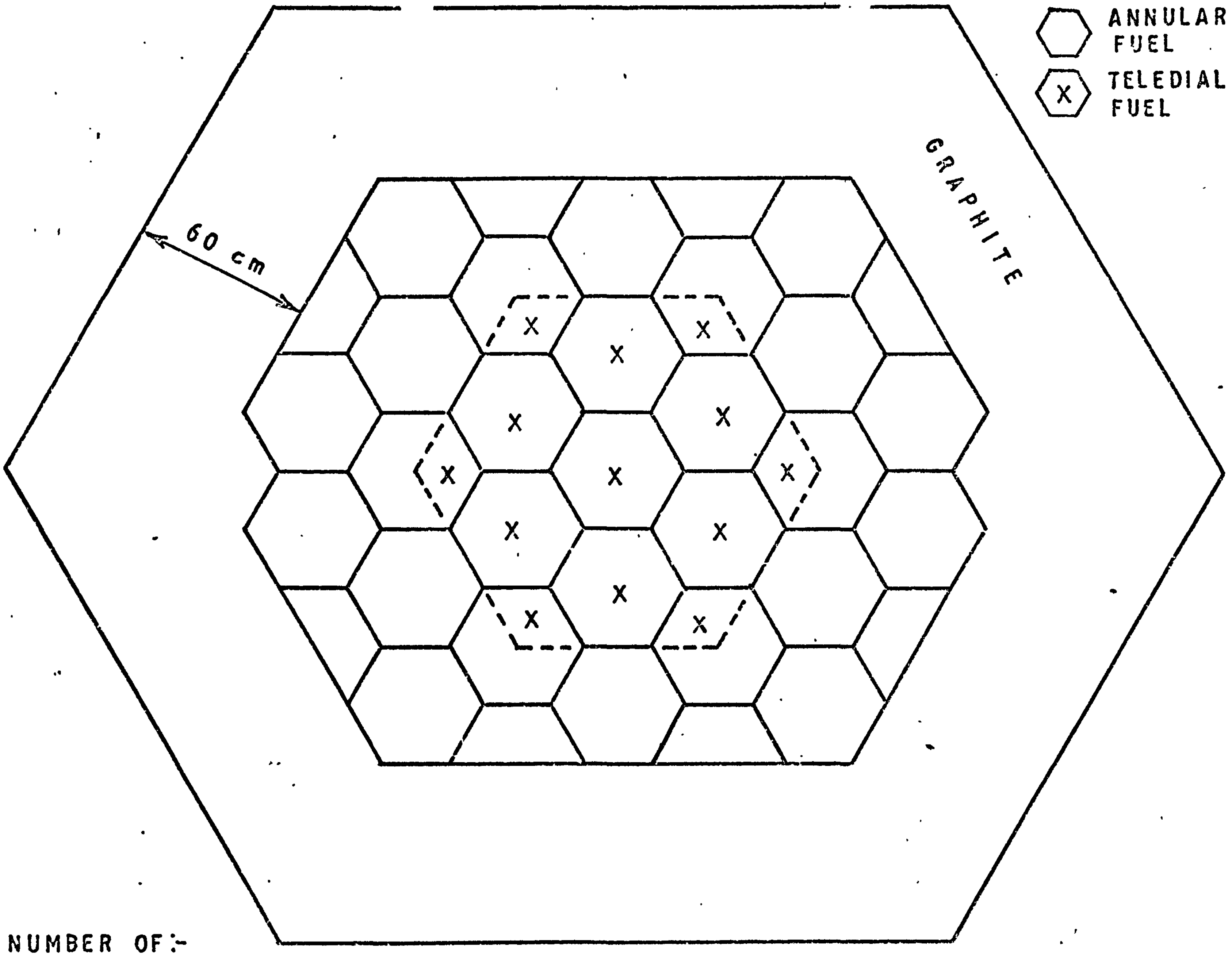
Details of Block Geometry

	B.N.L.
Shape	Hexagonal
A/F	399.5 mm
Interblock gap	4.4 mm
Number of holes	19
Channel diameter	74.8 mm
pitch circle diam P.C.D. 1 at	0 mm
6 at	173.6 mm
6 at	300.6 mm
6 at	347.2 mm

TABLE 2

		Teledial Fuel 8 pins/channel	Annular Fuel
Diameter of kernel		802 μ	800 μ
Inner carbon coat thickness		112 μ	100 μ
Silicon carbide thickness		31 μ 19·0	35 μ 190
Outer carbon coat thickness		47 μ	55 μ
Kernel density		8.77 gm/cc	10.6 gm/cc
Carbon matrix density		1.6 gm/cc	1.7 gm/cc
Dimensions		12.5mm O.D.	55mm O.D. 40mm I.D.
Heavy metal density		0.7 gm/cc	0.65 gm/cc
Enrichment		3.5%	3.0%
N_c/N_u	Compact	42.5	46.5
	Fuel pin	136.4	130.9
	Lattice	296	281
k_∞		1.289	1.240
P		0.705	0.705
ηf thermal		1.60	1.54

No inter-block streaming has been allowed for in these calculations. Approximate Bell Factor calculations have been carried out on the teledial fuel based on a simple annular smear.



NUMBER OF:-
TELEDIAL CHANNELS 174
ANNULAR CHANNELS 368

FIG.1. PLAN OF FIRST B.N.L. ZERO ENERGY REACTOR

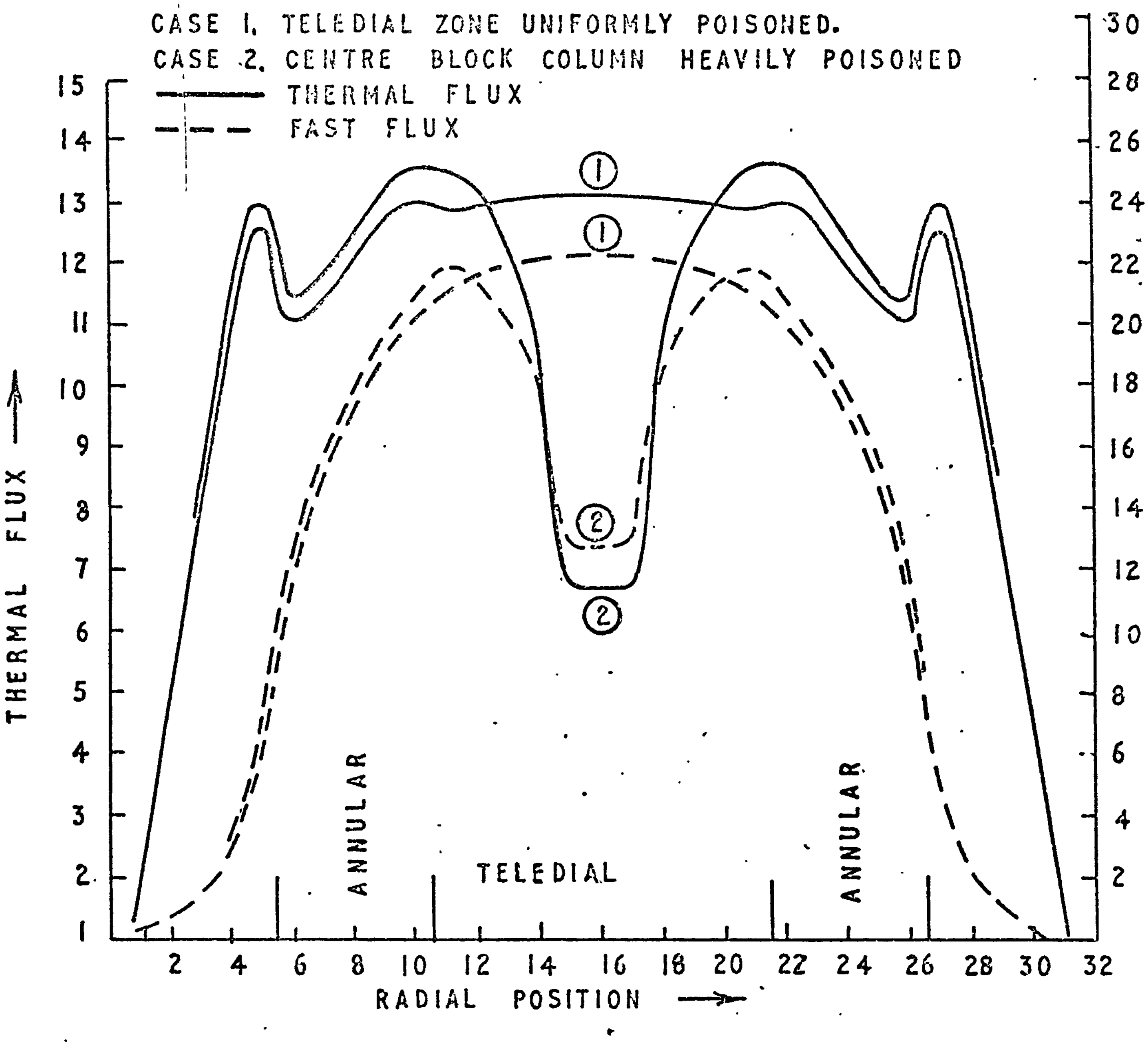


FIG. 2. CRAM (TRIANG) 2 GROUP FLUX PLOT ACROSS CORE.

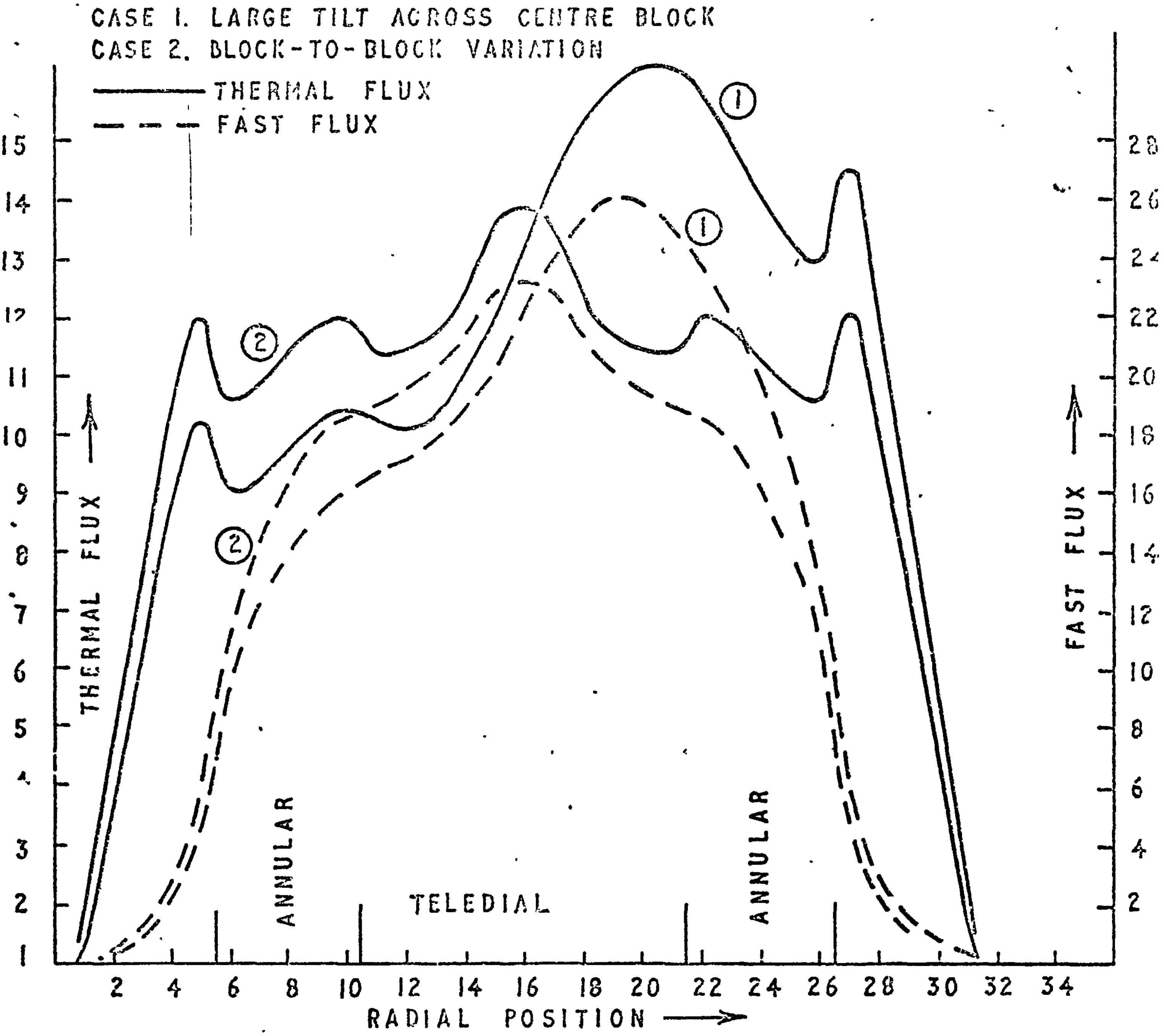
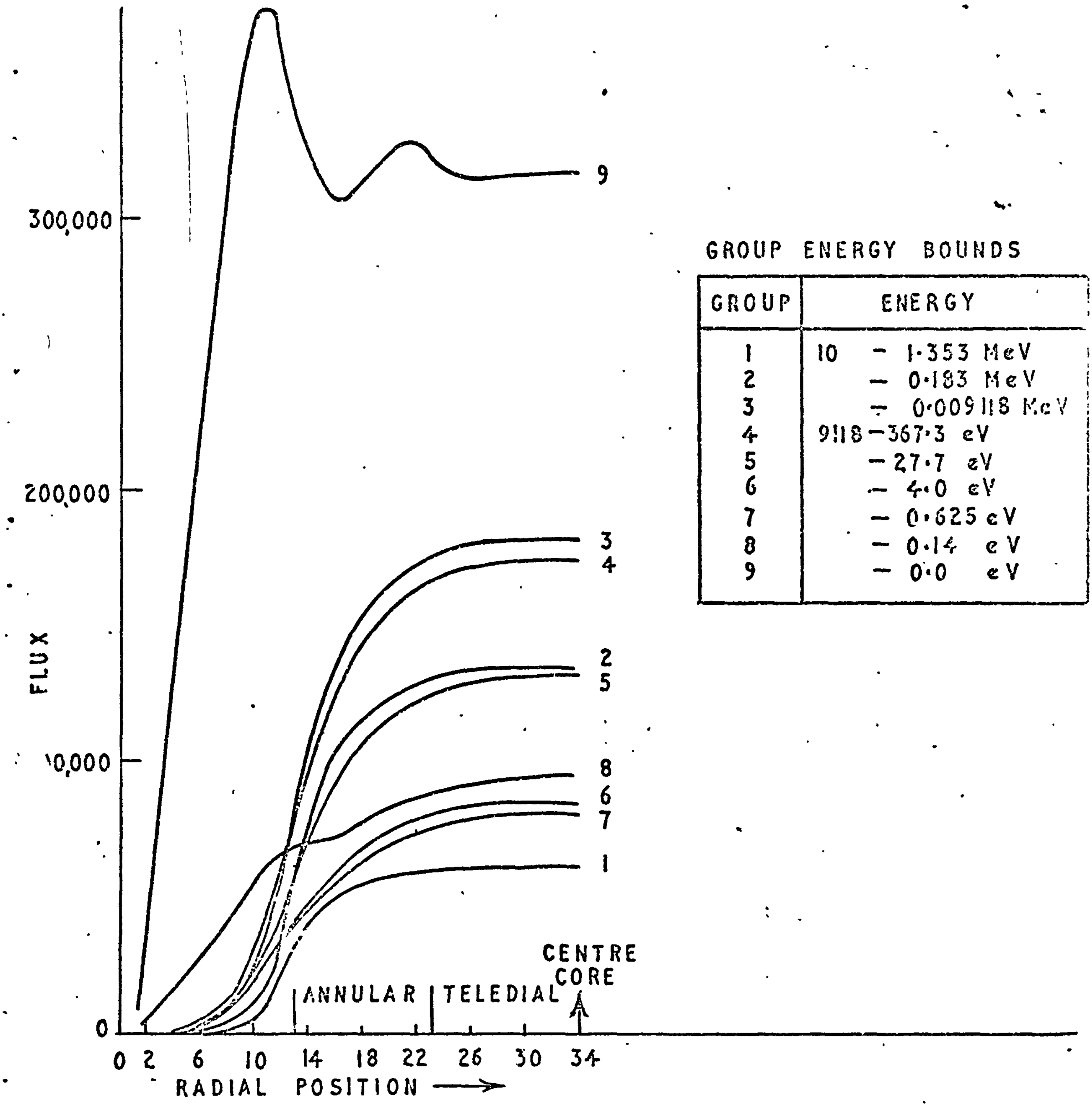


FIG.3. CRAM (TRIANG) 2 GROUP FLUX PLOT ACROSS CORE.



GROUP ENERGY BOUNDS

GROUP	ENERGY
1	10 – 1·353 MeV
2	– 0·183 MeV
3	– 0·009118 MeV
4	9118 – 367·3 eV
5	– 27·7 eV
6	– 4·0 eV
7	– 0·625 eV
8	– 0·14 eV
9	– 0·0 eV

FIG.4. 9 GROUP FLUXES FOR UNIFORM BUILD. CRAM TRIANG.