AAEC/PR38-P

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INDC (AUL) - 20G

XA04N0963

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

PROGRESS REPORT OF PHYSICS DIVISION

1st OCTOBER 1972 – 31st MARCH 1973

INIS-XA-N--084

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ACTING DIVISION CHIEF - MR. W. GEMMELL

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CONTENTS (cont'd)

1. INTRODUCTION

MOATA was operated at a nominal 90 kW to assess the problems which might have arisen from the modifications and the higher power levels. No problems were evident. The neutronics and modified cooling circuits proved satisfactory. Greater interest is being shown in MOATA as its higher flux levels and ease of access become better known. A detailed shielding survey indicated that radiation levels greater than 1 mrem were very localised and remedial action would be minor.

The overall shielding in the building is, however, not so satisfactory. When the recently installed elevated target platform (ELF) is in use with moderate beam current from the 3 MeV accelerator, shielding arrangements have been found inadequate overall, although levels in the offices cause no concern.

The zero power split table machine for reactor studies operated in a satisfactory, trouble-free, manner. Several modifications have been made to improve its operation and safety. The work on MOATA mockup has provided more detail on the reactivity behaviour of the reactor under isothermal and transient temperature conditions. An investigation of the neutronic cross coupling between the twin slab core tanks commenced.

Studies have developed out of the safety assessments of the Commission's reactors and some calculations have been performed to define the irradiation field at different reactor's pressure vessels.

The neutron capture mechanisms continued under study by means of γ-ray de-excitation for a wide selection of elements using NaI and Ge(Li) detectors. An attempt was made to clarify the 5.5 MeV bump on the spectra.

2. EXPERIMENTAL REACTOR PHYSICS (A/Head D. B. McCulloch)

2.1 MOATA (W. Wall)

2.1.1 Operations

	Days	%
Operation	56	45
Defect loss	1	1
Experimental assembly	-	-
Modifications and maintenance	44	35
No operation	23	19
	124	100
Total integrated power	2285 kWh	

Experimental uses of the reactor have included:

- Capture gamma ray spectroscopy
- Neutron radiography
- Fast neutron damage in transistors
- Reactor kinetics studies
- Molecular decompositions by nuclear reactions
- Uranium ore assay
- Low activity isotope production

Two new MOATA operators were appointed after successfully completing their period of training.

The outstanding plant modifications to upgrade MOATA to operate on a routine basis at 100 kW were completed. The major items - primary coolant flow control, source movement control, rod movement times, and bypass and period trip functions, are all operating satisfactorily. Only a few localised weaknesses in the biological shield now remain to be remedied.

Further data on the flux profile and spectrum characteristics of the IR1 neutron beam were obtained. The fission averaged fast flux was also measured at the IR1 source position using an aluminium detector and the ^{232}Th fission rate at this position determined using a fission track detector technique.

Some rod drop flux profiles were also obtained for the shim and safety rods using a 512 channel multiscaler.

2.1.2 Reactor kinetics (J. R. Harries, R. B. Knott)

Neutron population fluctuations were measured in MOATA at very low power levels, to determine $\frac{\beta}{\ell}$ for the reactor and reactivity coupling between the core tanks.

Power spectral densities and auto and cross-correlation functions for the data were derived using equipment from the ERD Noise Analysis Laboratory. These results were least-squares fitted to their corresponding theoretical functions to give values of β_{eff}/ℓ. The spread in the β_{eff}/ℓ values is being investigated to isolate and eliminate unwanted effects of the measuring equipment, techniques and the analysis methods.

Some difficulties were encountered in operating at sufficiently low power for the very high efficiency detectors used, and it was not possible to locate the detectors so that each was influenced almost exclusively by neutrons from only one tank.

Further measurements are to be made in the MOATA mock-up experiment in the Critical Facility, where it is expected that many of the problems associated with lack of ideal detector placing in MOATA itself, etc., can be overcome.

2.2 Neutron Streaming (D. B. McCulloch, D. J. Wilson)

Analysis of the raw experimental data was continued and is nearing completion. Effort was severely restricted owing to demands of other projects.

2.3 HIFAR

2.3.1 HIFAR safety assessment (D. J. Wilson, W. J. Turner)

Work continued in support of this project, mainly through re-assessment of the results of the PACE analogue computer studies of the effects of reactivity transients, and an investigation of the best application of available operational fuel element temperature sensing facilities. Digital studies are also being made to check certain aspects of the analogue results.

2.4 Critical Facility (J. W. Connolly, D. B. McCulloch)

The detailed design and assessment of the MOATA mockup experiment was completed. A hazards analyses for this experiment alone was completed and submitted to the Reactor Safety Committee for consideration in conjunction with Part 1 of the general Facility Safety Assessment - Plant Description.

Favourable advice was received from the Reactor Safety Committee, and following implementation of a number of modifications to the plant and control circuits, which post-commissioning tests and experience had indicated would lead to improved safety and/or operational convenience, fuel loading commenced on 9th March, 1973.

Measurements of system parameters to confirm the core were made (section 2.4.3) and the assembly will now be used to measure a number of reactivity worth coefficients relevant to MOATA, and to investigate reactor noise analysis measurements for deriving reactor kinetics parameters.

2.4.1 Safety assessment (A. W. Dalton)

Part II of the general Safety Assessment Document - Operational Procedures and Hazards Analysis - was assembled in first draft form and supplied to the Reactor Safety Committee for information. This proved sufficient to enable their consideration of the special assessment submitted for the MOATA mockup experiment.

Much work is still needed and is in progress on many facets of this document. For example, the measured table and rod scram time delays now available, together with better information on instrumentation response, necessitate recalculation of reactivity transient accidents; further work is needed on self-limiting excursions, particularly for thermal and near-thermal cores: and the limited operating experience accumulated to date has shown areas where control circuits and/or administrative rules should be modified for more effective results. In addition, a major editing effort will still be necessary before a self-consistent finalised version can be considered complete.

A fuel movements recording and accounting system, based on punched cards and the use of the IBM 360 computer, has been developed and is nearing completion of its full testing schedule.

2.4.2 Modifications (J. R. Harries, D. B. McCulloch, J. P. Sawyer)

Further modifications to improve system safety margins and operational convenience have been formulated, assessed independently by Instrumentation and Control Division and subsequently implemented. Some of these proposals arose from direct operational experience with the machine.

For example, the automatic source retraction facility on SCRAM has been deleted since it was found that the resulting flux levels at full table separation were below the ϕ_{min} threshold. Prior to this, the guard lines could not be made and the rods latched to enable the sources to be run into the assembly unless a bypass was applied to the ϕ_{min} function.

In the safety testing area, a device has been made which in the daily routine start-up checks will detect any interconnection between the two guard lines. It is important to detect the first such interconnection, as the existence of two of them at any time could lead to an unsafe failure in the event of an accident condition. Similarly, indicator lamps have been provided to display the condition of the triplicated 1500 mm position micro-switches, which are operated in a two-out-of-three configuration to protect the plant routinely, but in the event of failure of two of these, could lead to failure of the tables to retract on demand from the SCRAM circuits.

The noise and long term drift measurements on the current-operated neutronics channels show that some 1/2 decade of reliable operation is available before the nominal minimum current threshold of 10^{-11} amp for 0 volts output is reached. This enables the trip levels of the high flux safety channels to be set as low as 10^{-11} amps during early stages of approach to critical measurements if required.

Further modification proposals have now been prepared to cover:

(i) the scramming of individual rods without consequent separation of the tables. This will enable rod reactivity worths to be measured by the 'rod-drop' technique;

(ii) withdrawal of designated safety rods to their 900 mm positions by a single key operated switch following rod-latching. The present individual switches cannot be operated simultaneously by an unaided operator. The time wastage to operate them singly or even in pairs is unwarranted, and the operator's attention is distracted when the aid of several assistants is required for simultaneous operation, and

(iii) to change the present key switch for table movement interlock and which serves a very limited function, to one for the safety circuits. This will enable full two-key administrative procedures to be applied for start-up.

2.4.3 Experiments (J. W. Connolly, D. B. McCulloch, P. Duerden)

The MOATA mockup experiment was loaded to critical on 20th March. The core loading is now 2.87 kg ^{235}U and the available excess reactivity 350×10^{-5} $\delta k/k$. This compares with a calculated critical loading of 2.94 kg ^{235}U.

Four absorber rods designated safety and two designated control, are used in the assembly. Their reactivity worths and that of the gap between the tables have been measured by subcritical countrates and diverging doubling time techniques. A comparison of some measured and calculated parameters is as follows:

	Measured	Calculated
Critical mass	2.85 kg ^{235}U	2.94 kg ^{235}U
Control rod worth	420×10^{-5} $\delta k/k$	450×10^{-5} $\delta k/k$
Gap worth	80×10^{-5} $\delta k/k$ min^{-1}	100×10^{-5} $\delta k/k$ min^{-1}
Outer fuel worth	11×10^{-5} $\delta k/k$ g^{-1} U5	5.5×10^{-5} $\delta k/k$ g^{-1}U5
Total safety tank worth	2240×10^{-5} $\delta k/k$	1800×10^{-5} $\delta k/k$
Centre flux at 1 watt	1.5×10^{9} n cm^{-2} s^{-1}	-

The apparent discrepancy between calculated and observed fuel reactivity coefficients arises because the solid polythene ('water') wrapped, fuel replaces the void represented by the fuel slots in the polythene thus enhancing the reactivity change compared with water.

The reliability of machine operation has been satisfactory and the reproducibility of critical settings, etc., has been very good. Gold foil irradiations have been made to calibrate the neutron flux levels and have established that the trip levels presently set (8×10^{-10} amp on both N1D2S and N2D2S) correspond to a central flux of approximately 8×10^{7} n cm^{-2} sec^{-1}, and an assembly fission power of about 5 watts.

2.5 Uranium Analysis (A. Rose, G. K. Brown)

The delayed neutron assay rig has been modified to ensure that residual activity from samples counted earlier is not adding to the recorded counts from the sample under test. The general background countrate has also been substantially reduced.

The rig is now permanently installed on the south face of MOATA with the transfer tube taking the samples approximately to the reactor centre. The PTFE transfer tube was damaged as a result of radiation induced embrittlement. It appears that a tube made from material with better radiation resistance will be necessary, assuming reasonably regular 10 kW operation.

A batch of 60 uranium ore samples of uranium contents between 0.002 and 60 lb/ton was assayed using the rig as a 'production test run'. The time taken was about 1 hour. The repeatability of results is about ±3 per cent at the 0.2 lb/ton level. The absolute uranium assessment accuracy will be known when chemical assay results for a selection of the same samples are available.

2.6 Neutron Radiography (T. Wall)

Investigation of film response characteristics showed that thermal neutron radiography work is feasible using the MOATA IR1 beam facility and some good film exposure densities have been achieved. The project on measurement of zirconium hydriding has been delayed because of limited reactor availability during the 100 kW uprating modification work. However, some experimental work has been done recently to determine the optimum thermal and resonance neutron filter thicknesses to use in conjunction with the detector screen to provide satisfactory exposed film densities.

2.7 Reactor Dynamics (W. J. Turner)

The analysis of the CISE experiments (A. Premoli 1969, Energia Nucleare 16, 626) was completed and has been submitted for publication. Typical results were shown in earlier progress reports and reasonable agreement between the experimental results and the simulations using the OWEN 1 code has now been obtained for the complete set of blowdown and channel blockage measurements.

As the computing time required for the simulations was small, no effort was made in the studies to minimise it. However, to provide a comparison with other methods, for one of the simulations only (A. Premoli, Figure 8) the minimum possible computing time was established by finding the smallest number of space nodes and time steps which would still give agreement with the detailed reference calculation. Coolant hydraulics, heat storage in the pipe walls and all modes of heat transfer were included. The calculation of the critical steady state condition plus the 12 seconds blowdown transient took only 47 sec on the AAEC 360/50 computer, with the time step varying from 0.01 to 5.12 sec in different parts of the calculation.

2.8 Pulsed Neutron Studies and Spectra (I. Ritchie)

2.8.1 Pulsed measurements in thorium: theoretical calculations (M. Rainbow, S. Moo)

Time dependent reaction rates in a pulsed thorium assembly have been calculated by a one mode, asymptotic diffusion theory code (TENDS). The calculations took into account the experimental pulse shape (~10 nsec pulse from a Be(d,n) source), the timing resolution of the detectors and the input neutron spectrum used in the measurements. The code employed a time-independent, group-independent buckling to validate a direct comparison of the one mode calculation with the lowest Fourier component derived from the experimental time-space distributions. The time dependent reaction rates from the calculations were processed in exactly the same way as the experimental results to provide the 'instantaneous decay constant' of the fundamental mode time distribution.

Figures 1, 2 and 3 show comparisons for the ^{237}Np, ^{235}U and ^{239}Pu reaction rates between the experimental results and theoretical results using 50 group data sets derived from the ENDF/B III and the Winfrith files and also the ABBN 26 group data set. Conclusions to date are as follows:

(i) Discrepancies exist for the ^{237}Np detector data between the ENDF/B II and Winfrith files, but detector data for ^{239}Pu and ^{235}U are in good agreement.

(ii) There is poor agreement between theory and experiment throughout the entire time range of the ^{237}Np reaction rate measurements.

(iii) There is poor agreement at early times (energies ~1 MeV) for the ^{235}U and ^{239}Pu measurements, but much better agreement at later times (energies ~200 keV). The influence of group size, different group averaging procedures, limitations of diffusion theory, etc., on the results are being investigated.

The sensitivity of the experimental parameters $\lambda_{111}(t)$ to changes in the nuclear data for ^{232}Th has been investigated. The results for ^{237}Np and ^{235}U reaction rates using the experimental configuration of the experiment presently under investigation, are shown in Figure 4. The changes to the nuclear data were based on the premise that the absorption, fission, (n,2n), elastic and total cross sections can be measured independently, whereas the inelastic cross section is derived from these independent measurements. It was also assumed that the total cross section is known with high precision so that any change in the partial cross sections must be accompanied by a change in σ_{inel} such that σ_{total} remains constant.

2.8.2 Pulsed measurements in thorium: experiment
(M. Rainbow, S. Moo)

Further improvements have been made in the timing resolution with which events in the fission detectors can be measured. The latest results (Figures 5b and 5c) indicate that the detector timing resolution has a standard deviation of ~1 nsec. These are compared with earlier results (Figure 5a) which were obtained using a different electronic configuration. Figure 5b, which presents results obtained with the basic detector timing system (see inset of Figure 5b), exhibits a second hump which is caused by pulses with long rise times. This hump can be removed by the addition of a simple pulse shape discrimination arrangement to the basic detector timing system (see Figure 5c and inset).

A further series of measurements of the space-time distribution in the thorium assembly has been completed. In these, the pulse length has been increased to ~200 nsec and the source has been derived from:

(i) a thick lithium target using the Li(p,n) reaction at 2.3 MeV;

(ii) a thick lithium target using the Li(p,n) reaction at 2.9 MeV;

(iii) a thick beryllium target using the Be(d,n) reaction at 2.8 MeV.

All the measurements have been done using the recently commissioned Elevated Facility (ELF) which allows the assembly to be mounted some 5 m from the floor and 3 m from the nearest massive concrete shielding. This greatly reduced the probability of backscatter of neutrons into the assembly from the surroundings during the measurement times of interest (~500 nsec after the pulse).

2.8.3 Proton recoil detectors (A. Rose)

Response functions have been measured for various pressures of CH_2 and H_2 gas fillings using monoenergetic neutrons from the Li(p,n) reaction. Comparison of measured pulse height spectra with calculations indicated that neutrons scattered from the surroundings were being detected. Two methods have been used in an attempt to eliminate this effect.

(i) A collimator made up of sandwiches of lithium carbonate and lead has been interposed between the detector and target, and further shielding has been placed round the detector. Results from this are encouraging.

(ii) The target and detector with no collimator or shield were mounted on the ELF and the proton beam pulsed at 20 μsec intervals with a 1 per cent duty cycle. The detector pulses were gated so that only those pulses originating in the first 800 nsec after the start of the beam pulse were accepted. Results here are also encouraging.

A pulse shape discriminator system has been set up which operates on the difference in the rise time between gamma and neutron events. Some success has been achieved, but further work has to be done to find the best operating parameters under different operating conditions. Improvements have also been made to the gas filling system which allows rapid changeover in gas fillings from CH_2 to H_2 with various admixtures of N_2. The best resolutions to date have been 8 per cent and 5 per cent for CH_2 and H_2 fillings respectively.

2.9 Neutron Source Project (G. R. Hogg, J. Tendys, J. A. Daniel)

The dense plasma focus has been operated at a capacitor bank energy of 13 kJ with 50:50 deuterium-tritium gas fillings. An average neutron yield of 1.1×10^{11} neutrons per pulse was obtained, an increase of ~100 over that obtained with pure deuterium gas fillings. The pulse width was 80 $\pm$ 5 nsec (FWHM) and the average neutron energy of the pulse, determined by neutron time of flight, was 15.1 MeV in the forward direction with a range of 13.5-16 MeV. The average energy for D-D and D-T neutrons are respectively 0.4 and

1 MeV greater than those resolved from nuclear reaction data for an assumed ion temperature of ~1 keV. These energy shifts indicate that neutron production is associated with a particle acceleration mechanism rather than being altogether of thermonuclear origin.

An attempt at the estimation of the electron temperature of the plasma was made using foil absorption techniques. With the assumption of a thermal electron distribution, the measurement of the ratio of the X-ray transmission through two different absorber foils permits the calculation of the electron temperature. The result obtained is too high to be consistent with the operation of the dense plasma focus. However, the technique used was relatively simple. A multi channel device has been constructed which will permit the determination of the X-ray spectrum more completely and hence the electron temperature.

3. NEUTRON PHYSICS SECTION (Head: J. R. Bird)

3.1 Neutron Data Measurements

3.1.1 Nubar absolute for ^{252}Cf (J. W. Boldeman)

Following the 2nd IAEA Panel Meeting on Neutron Standard Reference Data, two further sources of error in liquid scintillator $\bar{\nu}$ measurements have been investigated. These were:

(a) Variations in the scintillator detector efficiency for neutron capture gamma rays as a function of position within the scintillator.

(b) Representation of the fission neutron spectrum in a Watt form instead of Maxwellian.

Both possible sources of error have been shown to contribute less than 0.05 per cent error to the absolute $\bar{\nu}$ measurement for ^{252}Cf. The measured value remains at 3.735 $\pm$ 0.014.

3.1.2 Nubar values for spontaneous fission (J. W. Boldeman)

A study of the systematics of neutron emission for transplutonium elements has begun with measurements of $\bar{\nu}$ and the P_ν distribution for the spontaneous fission of ^{244}Cm and ^{248}Cm. Final data for ^{248}Cm are given in Table 1.

3.1.3 Energy dependence of $\bar{\nu}$ for ^{235}U (J. W. Boldeman, J. Caruana, R. L. Walsh)

Some measurements of the variation of $\bar{\nu}$ with neutron energy in the fission of ^{235}U have been repeated with improved accuracy to confirm earlier findings of no fine structure. At this stage, two measurements have been made at 375 ± 70 keV and 550 ± 70 keV. Both measurements confirm the previous data.

3.1.4 Fast neutron capture cross sections (B.J. Allen, J. W. Boldeman, D. M. H. Chan, M. J. Kenny, A. R. Musgrove, Hla Pe, R. L. Walsh)

Analysis of high resolution capture cross section data obtained at the Oak Ridge Electron Linear Accelerator has continued. Results have been obtained for ^{Nat}Si (Table 2) and preliminary average parameters for the isotopes of Ca and Ba are given in Table 3.

3.1.5 Neutron capture cross sections of ^{238}U (B. J. Allen, J. W. Boldeman, M. J. Kenny)

Some progress has been made with this project. A proton recoil telescope to monitor the neutron flux is under construction in the workshops and some calculations have been initiated to design the shielding for the total energy gamma ray detector.

3.2 Neutron Reactions

3.2.1 Neutron capture mechanisms (B. J. Allen, M. J. Kenny, R. Barrett, K. H. Bray, L. C. Carlson)

In order to clarify the situation regarding the 5.5 MeV 'anomalous bump' in the de-excitation gamma ray spectra following neutron capture, measurements were made for a large number of nuclei for energies up to 1 MeV. The experiments fall into two categories:

(i) Those using a NaI detector to observe gross features of the spectrum.

(ii) Those using a Ge(Li) detector to observe fine structure in the spectrum.

With the NaI detector the following samples were used: C, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zr, Ge, As, Se, Sr, Zr, Mo, Cd, Sn, Sb, Te, I, Ba, La, Tl, ^{238}U (depleted). Evidence for a 'bump' which was independent of neutron energy was seen for Fe, Sn, Te, I, Ba and Tl.

At first sight, the behaviour of iron appeared to be contrary to previous experience and expectations and it was decided to investigate the phenomenon much more closely using a Ge(Li) detector. Measurements were made for neutron energies up to 460 keV. It was found that whereas in thermal capture and keV capture for $E_n < 80$ keV the ground and first excited state doublet accounted for a high percentage of all observed gamma-rays, transitions occur with increasing strength to the next three excited states as the neutron energy increases. Hence the average gamma-ray energy does not increase and the 'bump' appears to be independent of energy.

Measurements at ORELA on ^{205}Tl for neutron energies up to 10 keV had observed the 'bump' while being able to resolve individual resonances. This work was carried further by using the Ge(Li) detector to observe averaged resonance capture in ^{Nat}Tl (oxide sample) for energies up to 70 keV. Numerous transitions were observed in both ^{204}Tl and ^{206}Tl indicating the need for a separated sample of ^{205}Tl for a precise experiment.

3.2.2 Averaged neutron capture in cadmium (Hla Pe, B. J. Allen, J. R. Bird, M. J. Kenny)

The large volume Ge(Li) detector was used to measure the gamma-ray spectra averaged over many resonances for neutron energies up to 70 keV. Strong transitions to positive parity final states indicated the significance of p-wave capture in ^{Nat}Cd. The aim of the experiment is to derive information on p-wave strength functions as a function of neutron energy.

3.2.3 Neutron capture gamma rays in Ti (J. B. Garg, B. J. Allen, M. J. Kenny)

The large neutron widths of s-wave resonances in ^{48}Ti in the range 10 to 60 keV are indications of the presence of a doorway state. In order to investigate this possibility the capture gamma ray spectra have been examined with a Ge(Li) detector at 30 keV (with and without an Fe filter) and at neutron energies up to 200 keV.

3.2.4 Neutron emission from individual fission fragments of ^{252}Cf (R. L. Walsh)

Analysis of the initial series of measurements is almost complete. The high resolution of the system (450 eV at 26 keV) enabled positive identification of fission fragments of different charge Z. A K X-ray energy spectrum for one series of runs is shown in Figure 6. In this spectrum the contribution of Compton scattered prompt fission gamma rays has been eliminated from the raw data. The relative neutron emission $\nu(Z)$ is shown in Figure 7 as a function of Z. The apparent small variation of $\nu(Z)$ for the heavy element group has not been reported before. However, it produces a substantial slope in the ν_{total} versus Z curve (also shown in Figure 7) which is in good agreement with the recent study on total neutron emission by Nifenecker et al. (Nifenecker (1972) - private communcation).

The statistical errors associated with the present $\nu(Z)$ data are relatively large. It is intended to repeat the measurements with higher count rates and with 1024 channels available for X-ray pulse height analysis to obtain better peak separation. On-line data analysis will be possible now that an 8K PDP-11/10 computer has been interfaced to the magnetic tape deck.

3.3 Facilities and Techniques

3.3.1 3 MeV accelerator (H. Broe, J. Copland, A. van Heugten, S. Kannard, P. Lloyd)

The accelerator was used in experiments for 2811 hours distributed as shown in Table 4. Maintenance required 856 hours and a considerable proportion of this was spent on finding and fixing unusual vacuum troubles associated with new components in the elevated target facility. A new type Penning gauge was provided with a simple 'slide-in' O-ring seal which was found to be unsatisfactory. The gauge body has been modified and is now ready for testing. Trouble was also experienced with stainless steel blanking plates provided with the new magnets for the elevated facility. Extensive testing revealed that the material itself was porous.

The elevated target facility was put into use after some delays caused by the vacuum troubles mentioned above. The system is working to expectation apart from an occasional slight instability which could well be caused by the particular ion source in use.

The double electrode in one of the terminal deflection chambers was fitted with ceramic insulating sleeves and has been in use for several ion-source periods. The ceramic sleeves have proved to be far superior to the old sleeves and the second deflection chamber will be modified as soon as further sleeves are available.

A new cooling system was designed and replaced the defective coil in the switching magnet. All parts were reassembled and the magnet is back to normal operation.

An external source-gas supply was installed and tested with the tank off. It worked quite satisfactorily. The ion source was operated for about twenty minutes with tank gas at normal pressure, when the system broke down. It was found that the nylon tube from the base to the terminal was punctured in several places, most likely caused by a tank spark.

A considerable amount of time and effort has been spent in updating and completing all circuit diagrams for the accelerator.

As common power supplies are used for either the analysing and switching magnets or for the magnets of the elevated facility, an easy changeover system has been designed. Manufacture is complete except for the wiring. A new de-gauss system will be incorporated in the changeover system and the operating instructions modified accordingly.

3.3.2 Data acquisition facilities (M. D. Scott, R. J. Cawley)

An interface has been built for the PDP-15 to accommodate the Hewlett Packard 7004B X-Y plotter belonging to AINSE. Pending the delivery of digital to analogue converter cards, this interface has been wired temporarily to share the display digital to analogue converters. The Hewlett Packard 7004B can be used either in a point plot mode or conventional pen up/down mode.

Software for histogram-type plots was added to the PDP-15 program CLOD, but reliable operation of the hardware has not yet been established.

Instrumentation and Control Division has installed the PDP-15 Dataway controller and interface. Programs have been loaded successfully into the PDP-15 from the disk at the IBM 360 by means of local software. It has also enabled jobs to be submitted to the IBM 360 jobstream from the PDP-15 console. Work is continuing on Dataway transfer of PHA data and interactive use of IBM 360 data analysis programs.

3.3.3 (p,γ) analysis (L. H. Russell in collaboration with G. J. Murch, Flinders University)

The following prompt gamma rays were found to be useful for the simultaneous analysis of three oxygen isotopes by irradiation with 1.932 MeV protons:

$$^{16}O(p,\gamma)^{17}F \quad : \quad E_\gamma = 0.495 \text{ MeV}$$
$$^{17}O(p,p'\gamma)^{17}O \quad : \quad E_\gamma = 0.873 \text{ MeV}$$
$$^{18}O(p,\gamma)^{19}F \quad : \quad E_\gamma = 0.198 \text{ MeV}$$

Zirconium samples oxidised at high temperature with water vapour having various known isotopic concentrations have been used to check the linearity of this technique (Figure 8).

Measurements of oxygen diffusion coefficients in oxide samples have also been carried out by a series of measurements across the surface of samples which had been ground at a shallow angle.

3.3.4 Neutron capture analysis (L. H. Russell)

Improved detector shielding has been used in measurements of chlorine content of 100 g wheat samples.

4. THEORETICAL PHYSICS SECTION (Head: B. Clancy)

4.1 Nuclear Data Group

4.1.1 Adler-Adler resonance parameters (W. K. Bertram, J. L. Cook, E. K. Rose)

Investigations into the Adler-Adler resonance theory continued and the statistics of the Adler-Adler resonance parameters were derived. The nuclei ^{233}U and ^{235}U were then investigated and agreement was found to be satisfactory between theory and experiment for the Adler-Adler parameters obtained from fitting the total, fission and radiative capture cross sections.

4.1.2 Nuclear data file (A. R. Musgrove, J. L. Cook)

An up to date compilation of neutron strength functions was made and recommended values were included in a nuclear data file of average resonance parameters. A similar compilation of average radiative widths is under way and one for average nuclear level spacings is to be commenced shortly.

A compilation of nuclear decay schemes for those parent nuclides which are stable is being made for use in activation analysis programs to be written. The original concept of the parameter file has been modified to a more restricted collection of parameters required to compute cross sections than was originally planned. Some 1,000 fission products will still be considered, but only about 250 of these will be investigated in detail.

4.1.3 ENDF/B library and associated programs (H. D. Ferguson)

The ENDF/B processing program SUPERTOG-III has been adapted to local requirements and several minor bugs have been corrected. Apart from its slowness, it appears that most (if not all) the bugs in SUPERTOG-II have been fixed and the routine production of data has now begun.

Adaptation of the ENDF/B subroutine package to local requirements has begun.

Programs have been written to (a) streamline the translation of ENDF/B tapes to 9-track EBCD1C and (b) plot angular distribution data from ENDF/B files.

Improvements are being made to the production (from the ENDF/B file) of statistical resonance parameters for the AUS/GYMEA libraries. The previous method, which produced one multi-resonance per compound nucleus state has proved inadequate, principally since the parameters chosen had to be compromise values and the narrow resonances, which produce the strongest temperature dependent shielding effects, are not represented. An improved method, taking samples from the entire statistical distribution for each partial width, is in preparation.

4.2 Reactor Physics Group

4.2.1 Transport approximations (B. Clancy)

The anisotropy associated with neutron scattering cannot be modelled correctly in standard multigroup diffusion codes and this is treated by replacing the group total cross section by a transport cross section. Such transport approximations are often used in multigroup transport codes because of the computational time penalty associated with a more accurate modelling of the scattering anisotropy. A variety of prescriptions for applying a transport correction is available in the literature.

A new scheme is being developed for a transport correction which aims to calculate leakage correctly in simple systems with the idea that it should produce better estimates of leakage when applied to more complex systems.

4.2.2 Fast reactor calculations (G. Robinson)

The series of calculations of simple systems constructed on the ZPR3 critical facility has been completed. Central fission ratio calculations were carried out for all the cores previously analysed and central material worths were calculated for the Pu fuelled assemblies. The results obtained pointed up some serious data deficiencies in all three sets of data used (Hansen and Roach, ABBN and GYMEA). A variety of calculations were carried out for assembly 48 using ABBN data as this data has the most suitable form. The calculations included ^{238}U Doppler coefficient, sodium voiding, plate bunching and reaction distributions within the cell. Deficiencies were apparent in sodium voiding and effects within the unit cell.

Some calculations have also been made of ^{235}U Doppler coefficients in the series of assemblies ZPR9-12 to ZPR9-17. Much better data is required before any reliable results can be obtained.

4.2.3 Diffusion theory code based on Lie series (I. Donnelly)

The method of Lie series has been used to write the computer code MGLIE, a semi-analytic one-dimensional, multigroup diffusion theory code. A one group version of the code has been tested and used to evaluate the convergence criteria, while the multigroup version is being tested at present. This code can be used to evaluate boundary conditions, needed as input for the heterogeneous reactor code SOS-1, in their most general form. It will also be useful for investigations of the effect of assumed cell boundary conditions in reactor cell calculations.

4.2.4 Radiation shielding in PWRs (D. Culley and I. Donnelly)

Calculations have been performed to obtain the neutron and gamma ray flux levels in the pressure vessels of the KWU and Westinghouse PWRs tendered for Jervis Bay. Knowledge of these fluxes is required for evaluation of the amount of radiation damage and gamma ray heating in the pressure vessels. Considerable effort has been expended in assessing the shielding codes used and the importance of various aspects of the shielding calculations so that future calculation of the flux levels can be carried out quickly and accurately.

Agreement with the few values supplied by the tenderer was adequate. For example, the maximum neutron flux ($E > 1.0$ MeV) in the pressure vessel of the Westinghouse PWR was calculated to be 20 per cent higher than the value claimed by the tenderer; however as the maximum error in the results is ± 30 per cent, agreement is obtained within that range.

4.3 Reactor Code Group

4.3.1 The AUS modular scheme (G. Doherty, B. Harrington, J. Pollard, G. Robinson)

The AUS modular scheme consists of a collection of 'modules' (codes) communicating with each other via disk 'data pools' (cross section libraries, etc.) in order greatly to facilitate complex neutronics calculations. Presently the scheme is restricted to up to 2D diffusion and 1D transport calculations. A site manual is available and a summary of the scheme is given as an appendix to the POW report.

Work for the period has consisted in developing three new modules:

- AUSED for cross section library maintenance,
- CHAR for space dependent burnup calculations,
- FIVE for flux spectral plots,

as well as thoroughly testing out the system as presently available. Fuel loading calculations were undertaken for the first experiment with the critical facility (MOATA mockup). The calculations relied on GYMEA data (with the polythene data being specially prepared) and were considered satisfactory (about 1 per cent in weight of fuel load). As faster spectrum systems are tackled with the critical facility, the need for a 2000 group library will become more acute.

4.3.2 AUS module POW (B. Harrington and J. Pollard)

Most extensions to the 2D 'workhorse' module POW related to improving editing facilities such as perturbation calculations on detectors and plotting capabilities (a sample 2D plot is given as Figure 9.) A write up of the module will shortly be issued.

4.3.3 AUS module AUSED (B. Harrington)

The module AUSED is used for general editing of AUS cross section libraries including loading, copying, updating and listing. The DTAV free input routine (Appendix of the POW report) is used to simplify data presentation. A report is being prepared.

4.3.4 AUS module CHAR (G. Robinson)

A space dependent burnup module CHAR has been completed and has undergone limited testing. The module solves the isotope depletion equations by the analytic method for as many spacial regions as required. The use of the analytic method means that the size of time steps is limited only by the change in flux during the step. The necessary reaction rates are computed using the flux produced by a transport or diffusion theory module and a library of isotope cross sections. An additional data pool (the STATUS pool) has been introduced to pass information on isotopic compositions of materials, spatial-energy mixing rules and other miscellaneous information between modules. The inclusion of mixing rules allows a general cell to be unsmeared and each discrete material burnt up in the correct flux. The macroscopic materials may be remixed if desired and some of it passes through the data preparation modules thereby eliminated.

4.3.5 AUS module FIVE (B. Harrington)

FIVE is a module made available for automatic plotting of flux spectra on the CALCOMP plotter.

4.3.6 The ZHEX code (G. Doherty)

A multigroup, finite difference diffusion code ZHEX was written and tested on representative fast reactor problems. The spatial representation consists of seven mesh points per hexagonal channel (corners and centre) confined with a variable axial mesh. The group iteration consists of a plane-by-plane over-relaxation procedure, with a further block over-relaxation process employed for the within-plane solution. Extensive use of direct access input/output (which does not involve a large time penalty under MVT mode) enables the core storage requirements to be made independent of the number of axial mesh intervals and the number of groups.

The code contains automatic over-relaxation parameter estimation, region rebalance and modified Chebyshev fission source extrapolation, all based on similar features in the AUS module POW. Upscattering is not permitted as the code is oriented specifically to fast power reactors. With the present overlay structure, core storage requirements are 246K bytes for a 250 MW reactor and 342K bytes for a 1000 MW reactor. Six group calculations with 16 axial mesh intervals converging to 10^{-4} in fission source required 4 hours and 12 hours on the IBM 360/50 for the same two reactors. The coding has been optimised (including an ASSEMBLER inner loop) so that further reductions in time for the same iteration strategy are unlikely. A better flux guess and/or a less stringent convergence criterion may improve the calculation times in specific applications.

4.4 Nuclear Physics Group

4.4.1 Resonance parameters (W. K. Bertram)

An investigation into methods for transforming Adler-Adler parameters into ordinary multilevel R-matrix parameters was abandoned. It was found that, except in some special cases, it is virtually impossible to devise a numerical technique for transforming a given set of Adler and Adler parameters into a meaningful set of R-matrix parameters.

4.4.2 Fission cross sections (W. K. Bertram)

Results of the $\bar{\nu}$ experiments show that the dependence of $\bar{\nu}$ on the energy of the incident neutron is different for each nuclide. To assist with the interpretation of these experiments, the (n,f) fission cross sections of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu are being investigated. The channel theory of fission was used to calculate the (n,f) cross sections of these nuclei for neutrons between 10 keV and 500 keV, as well as the cross sections for inelastic scattering and capture. Initial results indicated that many difficulties must be overcome before the channel theory of fission can be used to describe the (n,f) cross sections for the entire range of energies considered.

4.4.3 Unfolding of resolution functions from experimental data (D. W. Lang)

A previously described technique was used to unfold the results of gedunken experiments on the IBM 360 computer. The technique depends on replacing an integral equation by a matrix equation with the source spectrum as input vector, multiplied by a resolution matrix to obtain the given measurements. An iterative search is made for the simplest input vector with positive elements that will produce a result consistent with the given 'measurements'. It is possible to recover a non negative vector with few non zero elements even using rectangular resolution matrices with approximately five times as many columns as rows, i.e. more spectrum points than measurements. The matrices used diminish the norm drastically for almost all vectors to which they can be applied and quite large components of such experimentally invisible vectors can be added to the simplest source vector to obtain a non negative set of elements in the source space without appreciably changing the fit to data in the 'measurement' space.

4.4.4 Applications of unfolding techniques (E. J. Clayton, (D. W. Lang)

(a) Fast neutron spectra obtained from proton recoil measurements.

The Aldermaston program SPEC IV to unfold channel counts, i.e. to calculate a neutron flux spectrum that could be responsible for the observations, has been put into operation on the IBM 360. A 'user manual' and extensive notes on the methods employed have been prepared. The program, currently stored in disk, has a subroutine to produce a graphical output of the flux. The original package corrects for effects of the counter walls, but assumes that a given energy deposit in the counter produces a count in the same channel on every occasion when it occurs. An optical resolution matrix has been incorporated to take account of the variable response of the electronics to the same energy deposit in the counter. Range energy data used by the program and other features are being revised. Features of several other codes dealing with the same problem are still being examined.

(b) Dosimetry and proton recoil (E. J. Clayton, P. Cripps)

An analysis of generalised dose concepts with particular application to the use of proton recoil counters for dosimetry has begun. Some initial calculations are soon to be tested experimentally.

4.4.5 Fast neutron spectra by pulsed time of flight (D. W. Lang, E. J. Clayton)

An analysis program was written to take advantage of the actual measurement of a resolution matrix as part of the time of flight experiments on site. The program was not successful. A less ambitious form in which the matrix is kept constant throughout is currently in the process of being debugged.

4.4.6 Errors of unfolded data (D. W. Lang)

It is possible at any stage of an iterative procedure for linear unfolding to find the residual error and hence the current values of statistical parameters describing goodness of fit. A program is being devised to carry out such tests after each iteration and stop when the error is acceptable. The program then finds the error induced in measurement by particular types of vectors in the source space and the variables associated with particular common types of possible errors.

5. PUBLICATIONS

5.1 Papers

Bertram, W. K. and Cook, J. L. (1972) - Compound nucleus formulation of reaction matrix theory. Aust. J. Phys. 25, 479.

Bertram, W. K. and Cook, J. L. (1973) - Solution of the inverse reaction problem for complex potentials. Aust. J. Phys. 26, 1.

Cook, J. L. (1972) - General relativity in the equal proper time formalism. Aust. J. Phys. 25, 469.

Fraser, H. J. and Ritchie, A. I. M. (1973) - A fast square pulsing and klystron bunching count down system for a 3 MeV Van de Graaff. Nucl. Instr. and Methods 109.

Musgrove, A. R. deL. (1972) - Detailed calculations of correlations occurring in light particle accompanied spontaneous fission. Aust. J. Phys. 25, 499.

PUBLICATIONS (cont'd)

Wasson, O. A. and Allen, B. J. (1973) - p-wave resonances in ^{111}Cd(n,f)^{112}Cd. Phys. Rev. C, Vol. 7, No. 2, 780.

5.2 Reports

Moo, S. P., Rainbow, M. T. and Ritchie, A. I. M. (1973) - Time dependent ^{237}Np, ^{235}U and ^{234}Pu fission sources in a thorium assembly during the time interval 0 to 200 nsec using a pulsed ^{9}Be(d,n) source. Part 1 - Experiment. AAEC/E254.

Pollard, J. P. (1973) - AUS module POW - a general purpose 0, 1 and 2D multigroup neutron diffusion code including feedback-free kinetics. AAEC/E269.

5.3 Conference Papers

Allen, B. J. and Macklin, R. L. - Fast neutron capture cross sections for Si. Int. Conf. on Photonuclear Reactions and Applications, Asilomar, March 1973.

Boldeman, J. W. (1972) - Prompt neutron yield from the spontaneous fission of ^{252}Cf. 2nd IAEA Panel on Neutron Standard Reference Data, Vienna, Nov. 1972.

Boldeman, J. W. (1972) - Revised values of nubar for the thermal neutron fission of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu. 2nd IAEA Panel on Neutron Standard Reference Data, Vienna, Nov. 1972.

6. RESEARCH CONTRACTS

6.1 Title: Neutron Strength Function Calculations
Reference No: 72/E/2
Period: 31/10/72-30/4/73
Supervisor: Professor I. E. McCarthy
University: School of Physical Sciences, Flinders University
Liaison Officer: D. W. Lang

Objective: (a) To predict the single particle eigenvalues for single neutron states labelled $2d\frac{5}{2}$, $2d\frac{3}{2}$ and $3S\frac{1}{2}$ in the nuclear mass region 60 to 100. (b) To investigate the effect of deforming a nucleus with special reference to any isotopic effects. (c) To use the calculated wave functions to investigate strength functions for low orbital angular momentum (s, p and d waves) and nuclei of mass less than 120.

RESEARCH CONTRACTS (cont'd)

Status: One computer program has been written and checked. It computes neutron strength functions for any required particle wave as a function of neutron and proton numbers N and Z. The potential is local and of the following form:

Real and imaginary Woods-Saxon form

Real and imaginary Woods-Saxon derivative form

Spin-orbit coupling

These terms can be added in pre-determined ratios. The strengths depend on an isotopic part $V_I(N-Z)/A$ as well as a part that is constant with N and Z.

It is intended to investigate the parameters of the model to see how well it fits data and what details of the data are capable of being described.

A second program is completed and almost checked. This extends the imaginary potential into the negative-energy region with a non local potential. Ultimately it will be modified for strength-function calculations with a non local potential, but numerical analysis difficulties may require work for very small energies.

6.2	Title:	Development of Nuclear Analysis Methods for Light Elements
	Reference No:	70/D.32
	Period:	31/9/72-
	Supervisor:	Professor B. M. Spicer
	University:	School of Physics, University of Melbourne
	Liaison Officer:	J. R. Bird

Objective: To develop new methods using nuclear reactions for the quantitative estimation of deuterium and other isotopes of light elements (particularly carbon, nitrogen and oxygen).

Status: Deuterium analysis - work is now primarily concerned with the use of 4 MeV linacs, since there is some evidence that neutrons from ^{17}O may be affecting the results. Instabilities in the dosimetry systems associated with these machines are still appreciable, however the problem is only intermittent. Reasonable results are being obtained, but the accuracy is still in doubt due to the lack of independent analyses of the deuterium content of the samples.

RESEARCH CONTRACTS (cont'd)

6.3 Title: Possible Techniques for Identifying Energy Levels of Short Lived Fission Fragments

Reference No: 71/D.32

Period: 1/9/71-31/8/72

Supervisor: Dr. G. J. F. Legge

University: School of Physics, University of Melbourne

Liaison Officer: M. J. Kenny

Status: The contract has been satisfactorily completed and the final report has been submitted. The research student involved has had his thesis accepted by the university. No further work is anticipated at this stage.

TABLE 1

NEUTRON EMISSION DATA FOR ^{248}Cm RELATIVE TO

$\bar{\nu}_p(^{252}Cf) = 3.724$

$\bar{\nu}_p$	3.092 ± 0.007
P_0	0.0071 ± 0.001
P_1	0.0671 ± 0.0021
P_2	0.2343 ± 0.0031
P_3	0.3449 ± 0.0035
P_4	0.2372 ± 0.0034
P_5	0.0868 ± 0.0040
P_6	0.0195 ± 0.0020
P_7	0.0031 ± 0.0014
$<\nu^2>_{av}$	10.928 ± 0.041
$\Sigma P_\nu(\nu-\bar{\nu})^2$	1.368 ± 0.005

TABLE 2

RESONANCE ENERGIES AND PARAMETERS FROM NEUTRON CAPTURE IN SILICON IN THE ENERGY RANGE 2.5-1404 keV

E_n (keV)	Γ_n (keV) ±20%	A_γ (b.eV) ±20%	$g\Gamma_n\Gamma_\gamma/\Gamma$ (eV)	J^π	g	Γ_γ
4.980		5.5	0.006			
15.14		1.2	0.004			
15.29		14.8	0.052			
31.74 (^{29}Si)		6.5	0.047			
38.82	0.085	26.3	0.23			
55.6 ± 0.2	0.99	36±20*	0.45	$1/2^+$	1	0.45
67.73		106.2	1.64	$1/2^-, 3/2^-$	1,2	
70.84		1.9	0.03			
86.98		15.0	0.30			
180.6 ± 4	28	335*	13.8	$1/2^+$	1	13.8
298.7		17.7	1.20			
354.6		12.9	1.04			
399.6		9.7	0.89	$3/2^-$	2	0.45
(426.1)		(1.7)	(0.16)			
532.7		20.7	2.5	$5/2^+$	3	0.8
561 ± 3	14	63*	8.1	$3/2^-$	2	4.0
586.8		24.6	3.3	$1/2^-$	1	3.3
601.7		30.2	4.1			
711.0		8.6	1.39			
772.2	≤ 3.2	22.6*	4.0*			
784						
804.5		48.6	8.9			
812 ± 2	38.7	226*	41.5*	$3/2^-$	2	20.8
846.4	≤ 3.6	36	7			
872.3	≤ 3.8	85.3	17			
(910.9)		12.5	2.6			
974.6	≤ 4.7	44	9.7	$3/2^-$	2	4.8
1148	≤ 6.3					
1163	≤ 6.3					
1202	≤ 11.6					
1227	≤ 5.7					
1263	≤ 10.8					
1404	≤ 6.6					

*Corrected for detector neutron sensitivity

TABLE 3

PRELIMINARY AVERAGE RESONANCE PARAMETERS

Isotope	ΔE keV	$\langle\sigma\rangle_{30}$ mb	N_0	N_1	$\langle D\rangle$ eV	S_0 10^{-4}	S_1 10^{-4}	$\langle\Gamma_\gamma\rangle_s$	$\langle\Gamma_\gamma\rangle_p$
^{40}Ca	2.5-355	10.5	7	54	67K	2.2	0.03	2.5	0.8
^{42}Ca	2.5-364	14	10	81	32.6K	1.4	0.06	1.4	0.3
^{43}Ca	2.5-100	46	29	106	3.4K	2.0	0.2	0.8	0.4
^{44}Ca	1.5-187	6.7	6	26	27K	0.8	0.04	1.0	0.3
^{134}Ba	3-10.6		24	31	300	0.5	0.2	0.12	
^{135}Ba	3-10.5		143	28	48	1.5	0.16	0.13	
^{136}Ba	3-15	47	10	21	950	1.2	0.3	0.18	
^{137}Ba	3-11		9	46	450	0.5	0.2	0.14	
^{138}Ba	3-80	3	8	14	10K	0.5	0.01	0.19	

TABLE 4
ACCELERATOR TIME ALLOCATION

Topic	Expt. No.	Title	Personnel	Origin	Running time (hours)
Neutron Data	11	Nubar absolute	Boldeman	Physics	152
Fission	12	Nubar vs E_N	Boldeman, Walsh	Physics	121
	13	Kinetic Energy	Boldeman, Walsh	Physics	12
Capture	21	Ge(Li) Capture Spectra	Kenny, Bird, Pe, Allen	Physics, UNSW	438
	22	Angular Distributions	Kenny	Physics	39
	23	Capture Mechanisms	Allen, Kenny, Barrett, Bray, Carlson	Physics, Melbourne, ANU	182
Neutron Transport	31	Pulsed Integral - thorium	Rainbow,	Physics	534
	33	Spectra Fast Assemblies	Rose	Physics	94
Nuclear Analysis	41	Oxygen Analysis	Russell, Murch	Physics, Flinders	149
Calibrations	43	Dosimetry	Cripps, Davy	Health Physics	131
Atomic Physics	51	Channelling	Price	UNSW	462
Isotope Production	53	^{13}N	Nicholas	Adelaide	13
Radiation Damage	55	Crystal Damage	Anderson, Pollard	UNSW	102
Charged Particle	60	(p,γ) Spectroscopy	Boydell, Smith, Sargood	Melbourne	256
	62	(d,n) Reactions	Armitage, McKenzie	Melbourne	42

Tests: 56 hours
Total operating time: 2811 hours
Maintenance: 856 hours

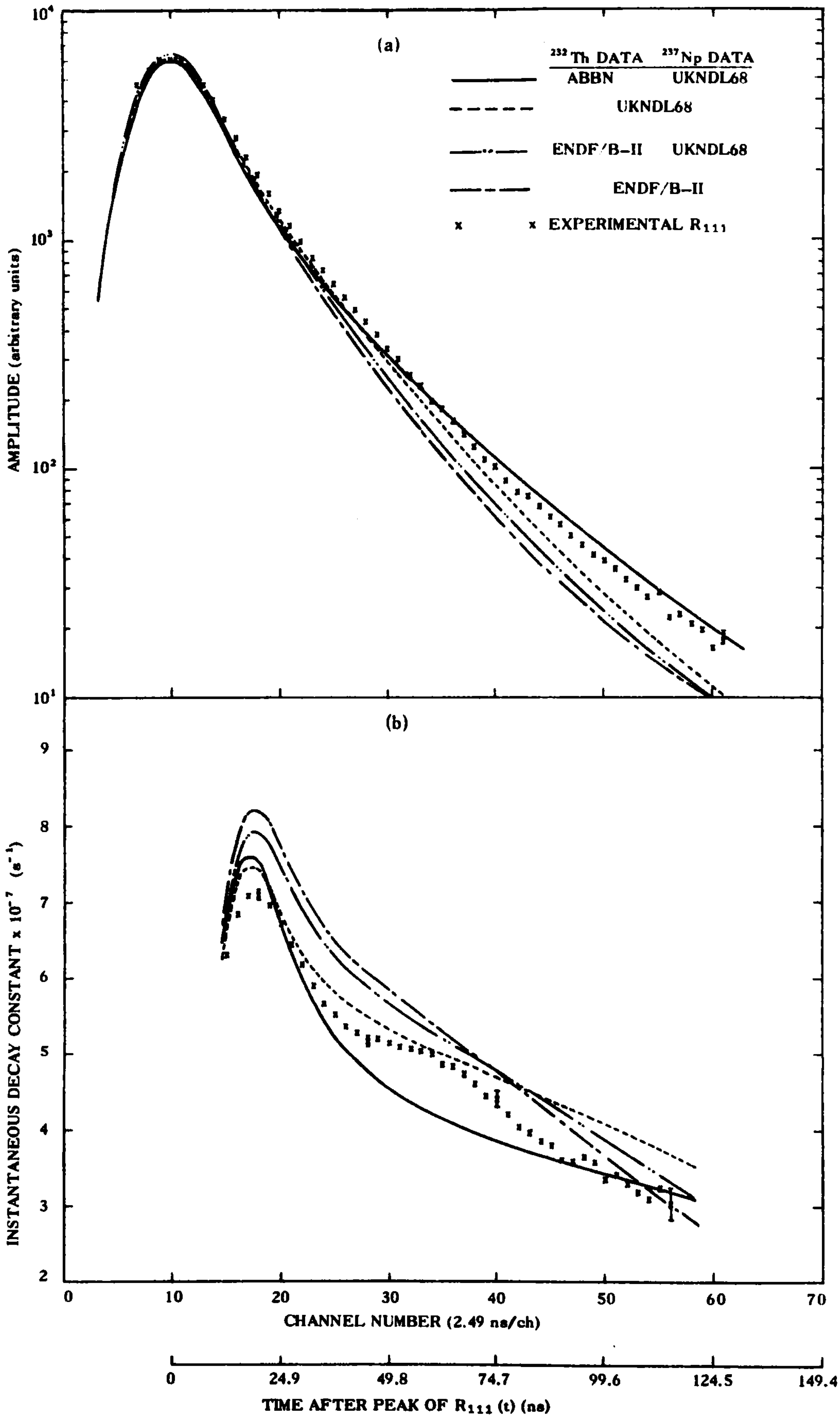

FIGURE 1 *THEORETICAL AND EXPERIMENTAL VALUES OF THE FUNDAMENTAL MODE FISSION RATES FOR ^{237}Np AS A FUNCTION OF TIME. (a) THE FUNDAMENTAL MODE TIME DISTRIBUTION. (b) THE INSTANTANEOUS DECAY CONSTANT $\lambda(t)$*

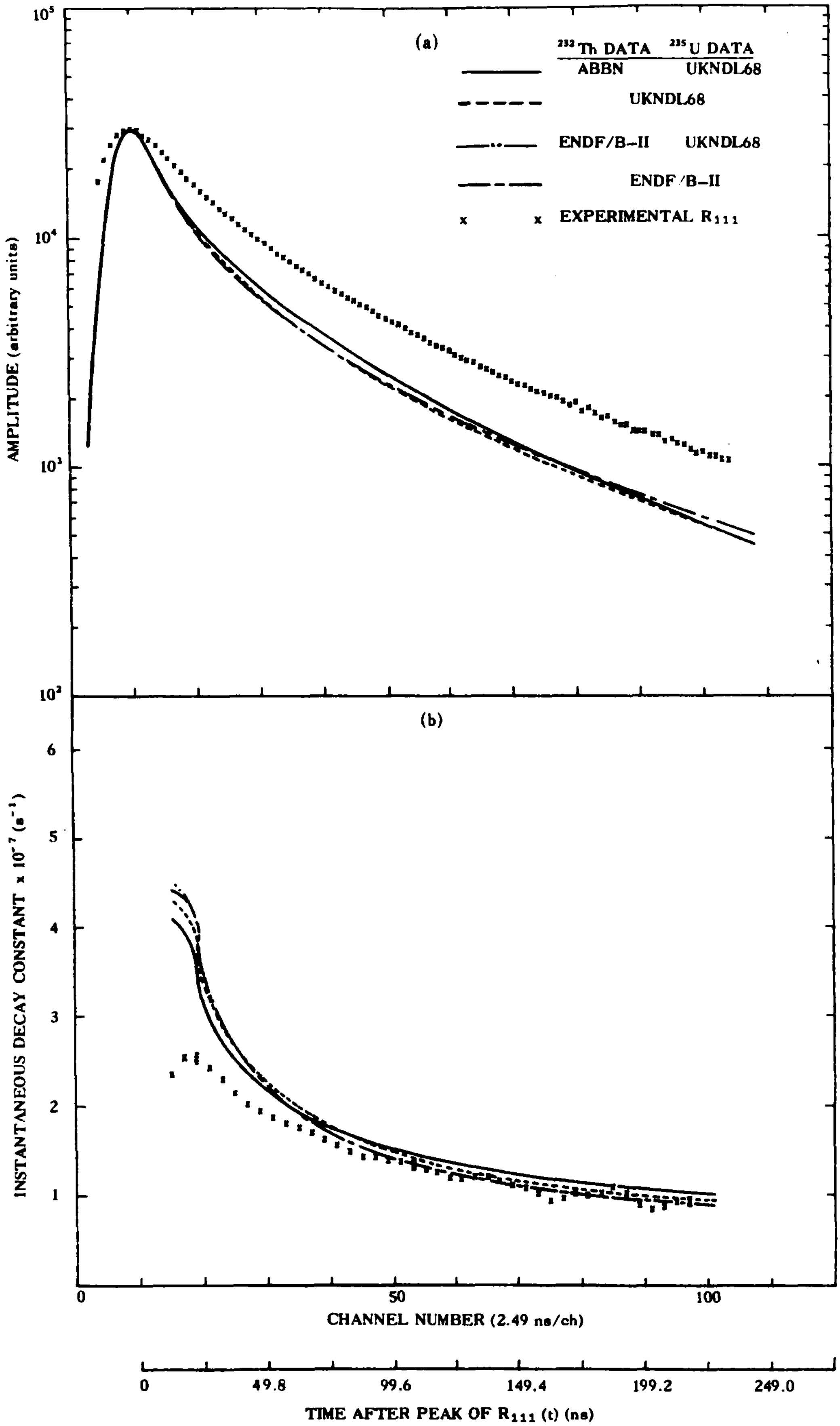

FIGURE 2 *THEORETICAL AND EXPERIMENTAL VALUES OF THE FUNDAMENTAL MODE FISSION RATES FOR ^{235}U AS A FUNCTION OF TIME. (a) THE FUNDAMENTAL MODE TIME DISTRIBUTION. (b) THE INSTANTANEOUS DECAY CONSTANT $\lambda(t)$*

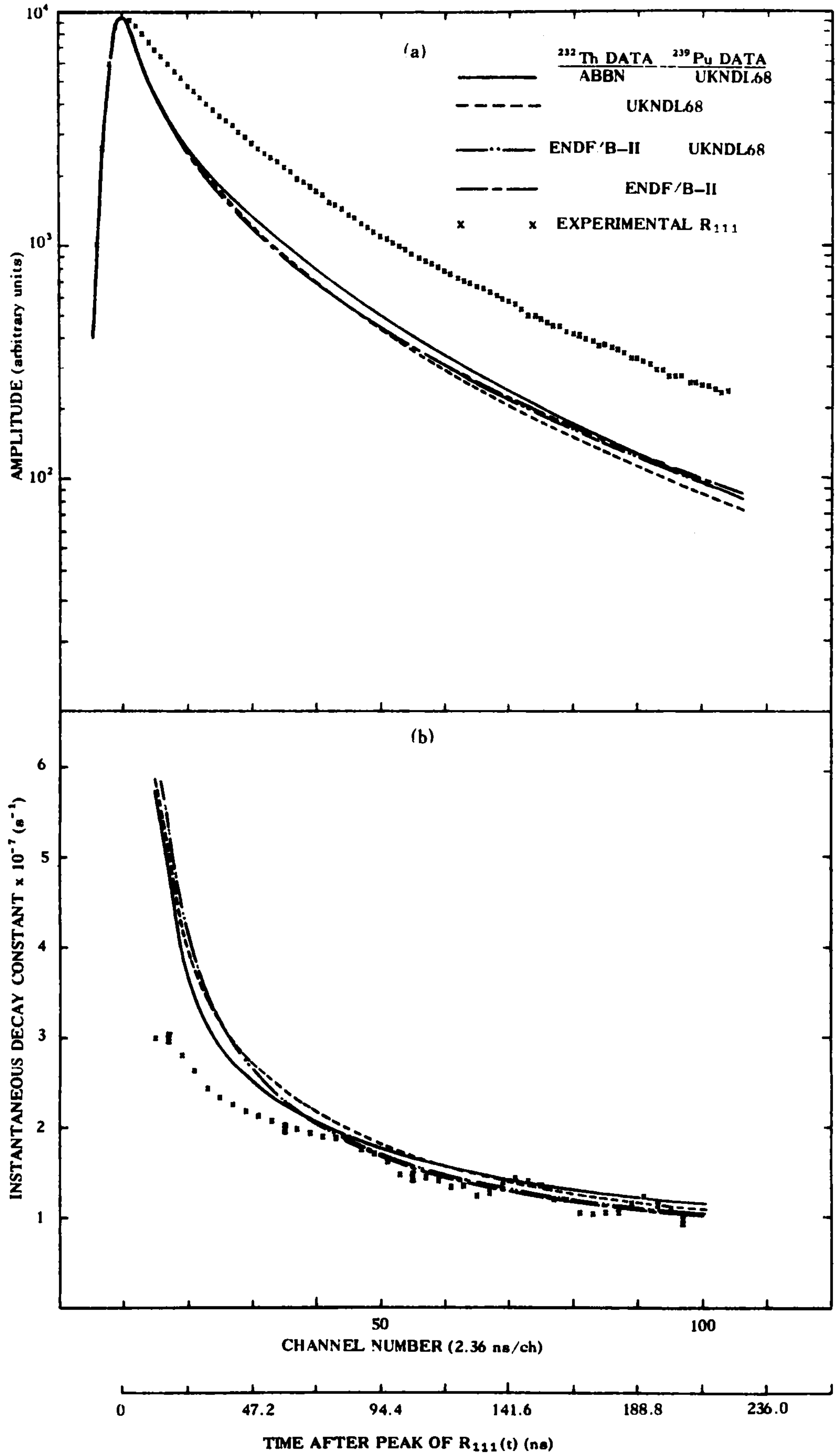

FIGURE 3 *THEORETICAL AND EXPERIMENTAL VALUES OF THE FUNDAMENTAL MODE FISSION RATES FOR ^{239}Pu AS A FUNCTION OF TIME. (a) THE FUNDAMENTAL MODE TIME DISTRIBUTION. (b) THE INSTANTANEOUS DECAY CONSTANT $\lambda(t)$*

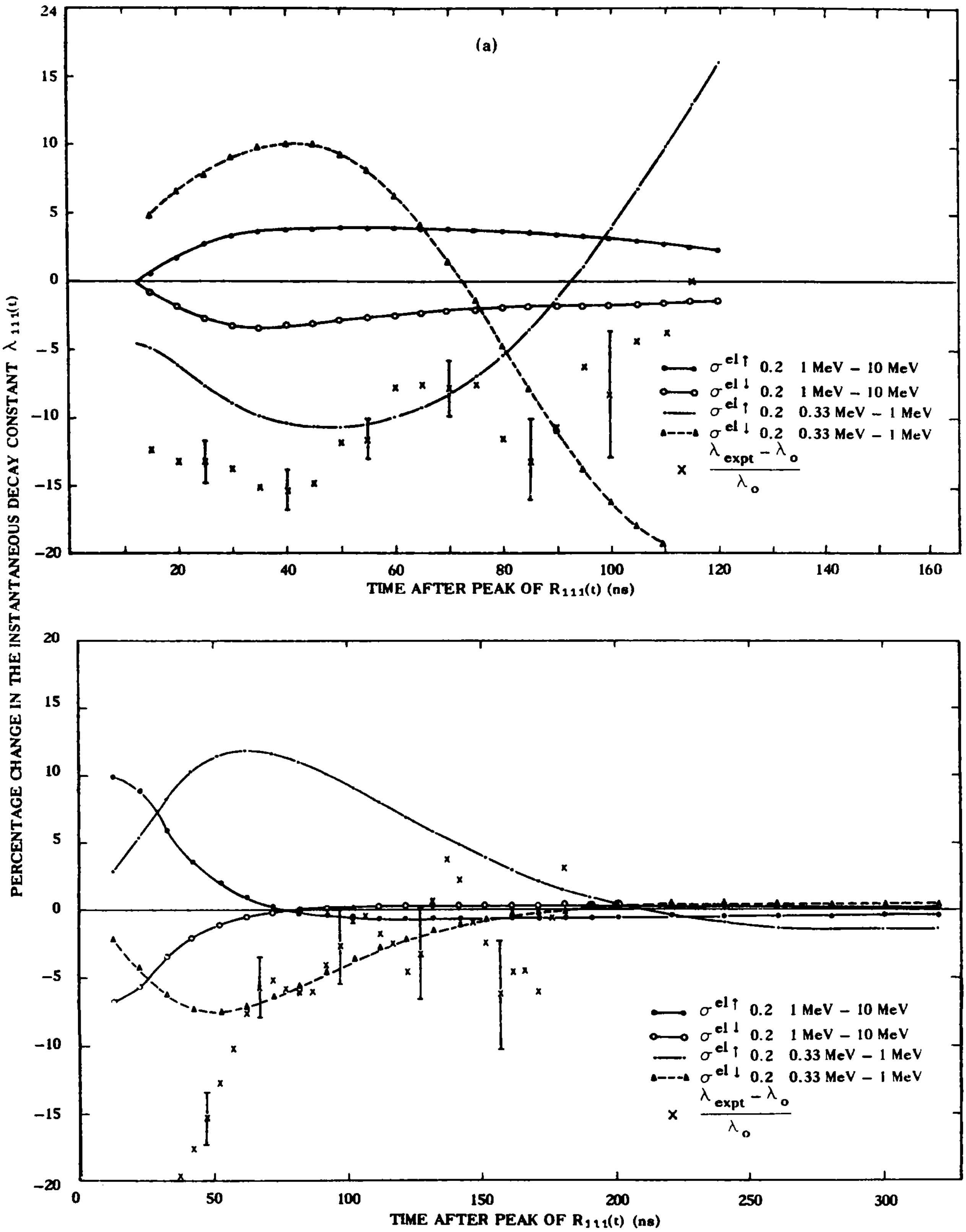

FIGURE 4 *PERCENTAGE CHANGES IN THE INSTANTANEOUS DECAY CONSTANT λ(t) OF (a) ^{237}Np AND (b) ^{235}U FISSION RATES FOR GIVEN CHANGES IN THE THORIUM GROUP-AVERAGED ELASTIC CROSS SECTION*

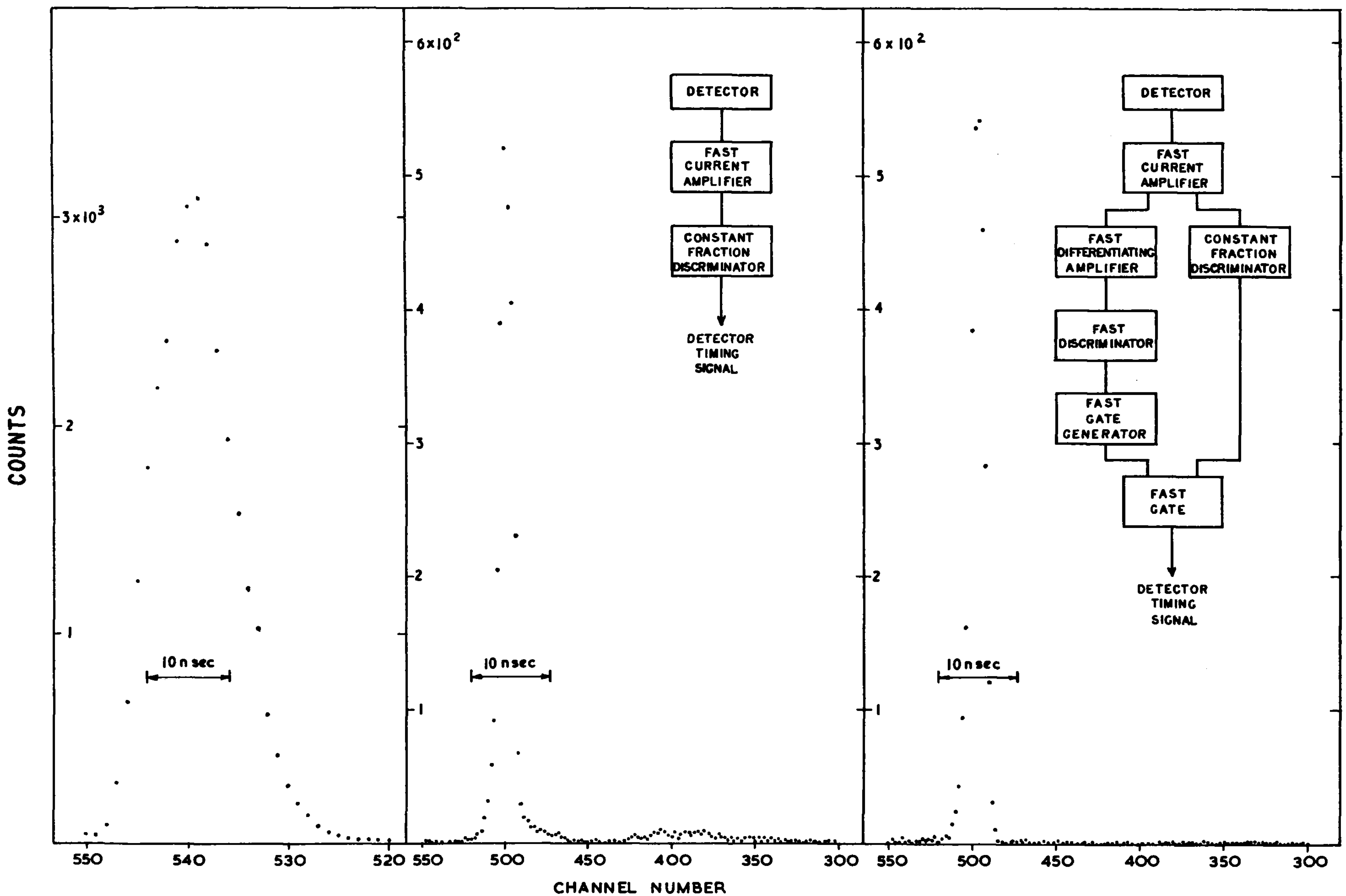

FIGURE 5 PULSE FISSION CHAMBER TIMING RESOLUTION

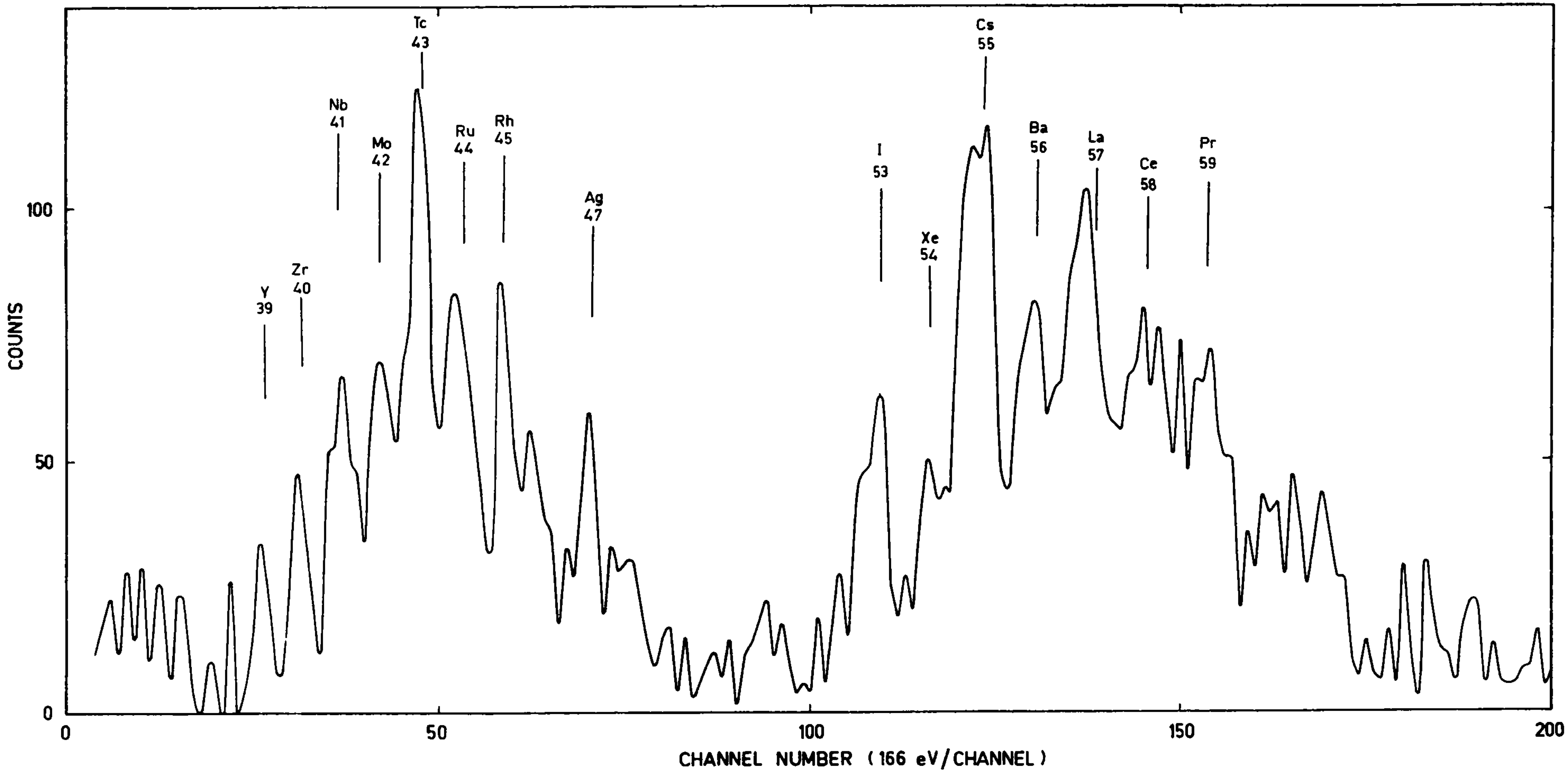

FIG 6 ENERGY SPECTRUM OF K X-RAYS FROM ^{252}Cf FISSION FRAGMENTS

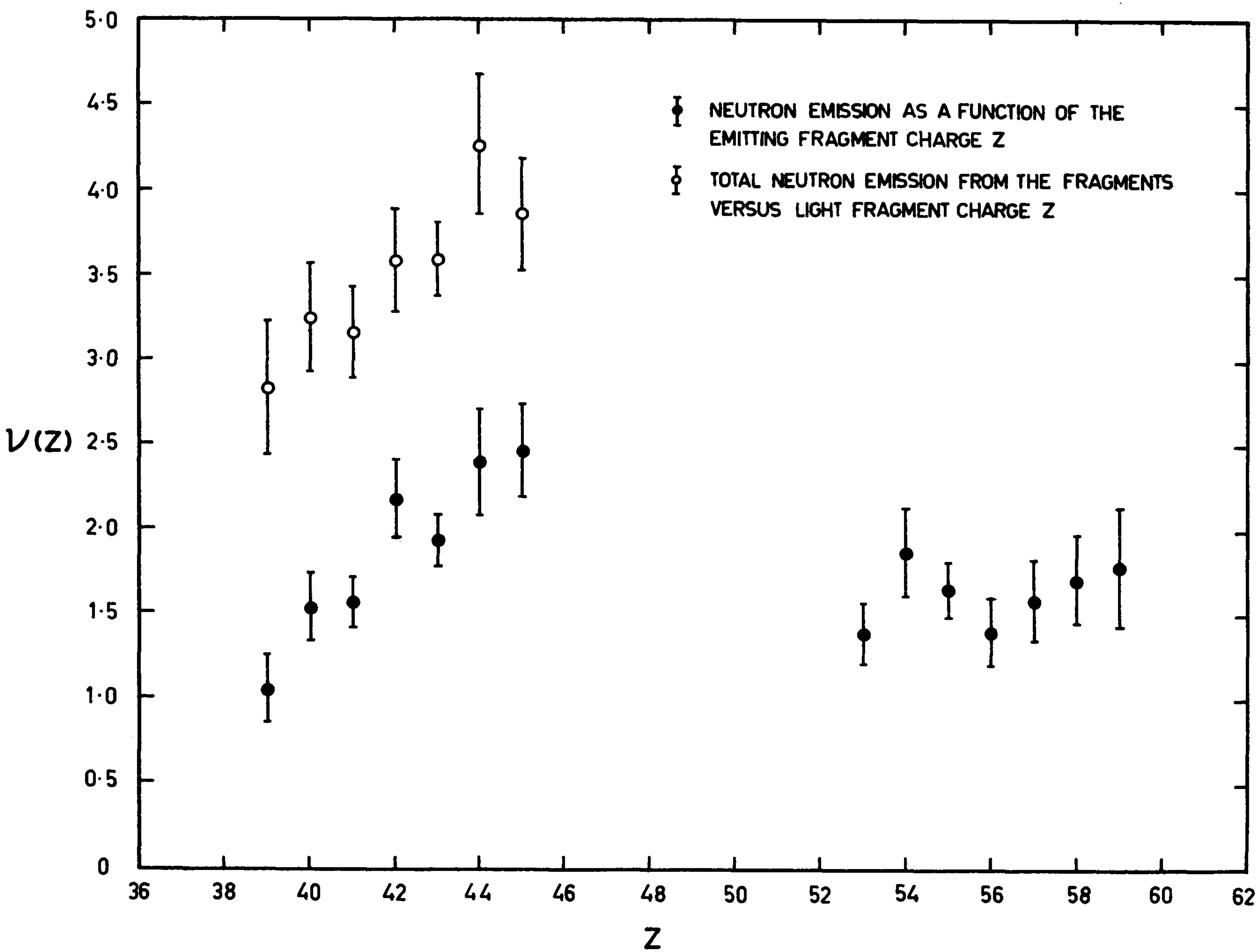

FIG 7 NEUTRON EMISSION VERSUS FRAGMENT CHARGE Z FOR ^{252}Cf

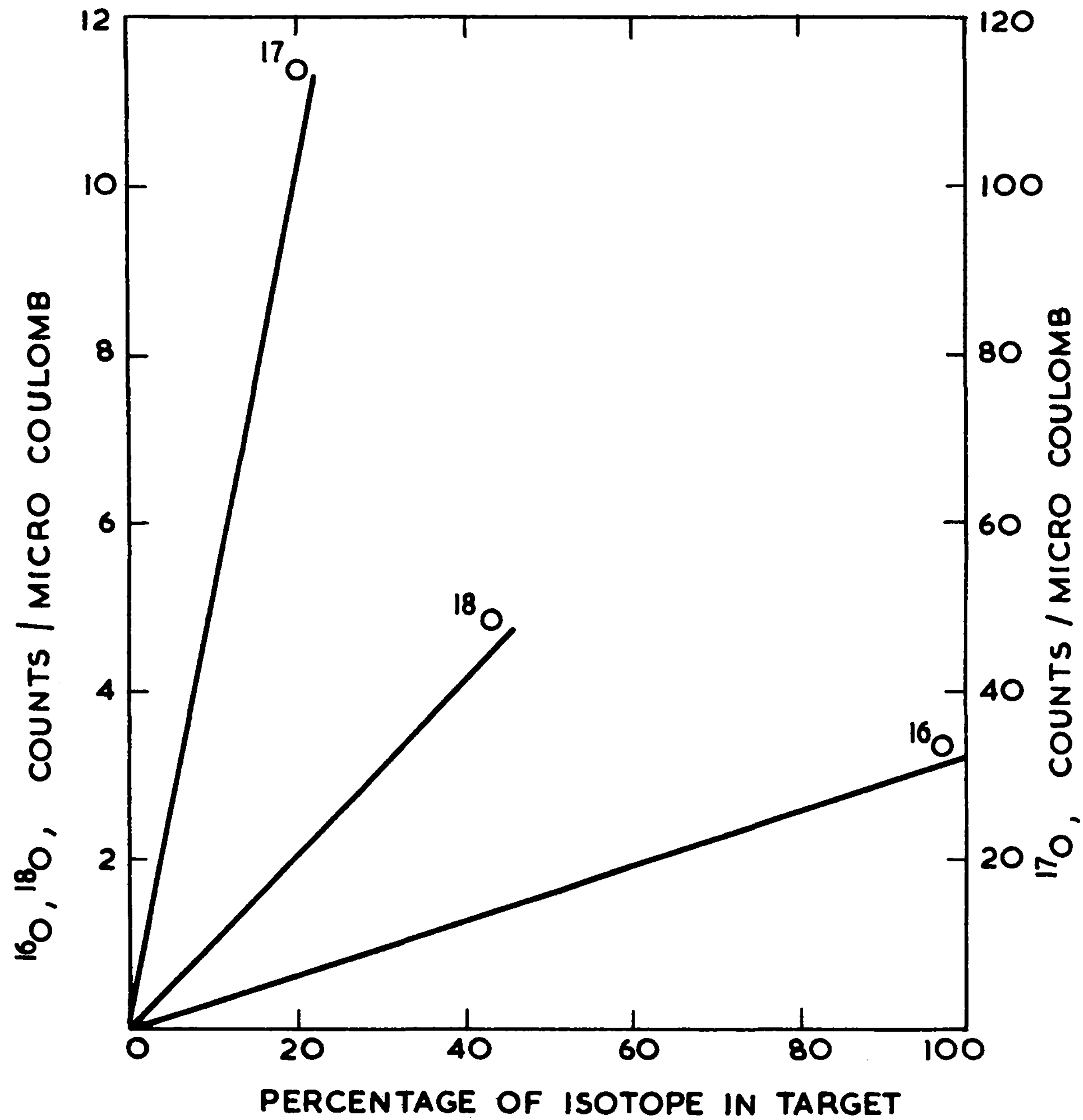

FIGURE 8 COUNT RATE VERSUS CONCENTRATION
OF OXYGEN ISOTOPES IN ZIRCONIUM OXIDE

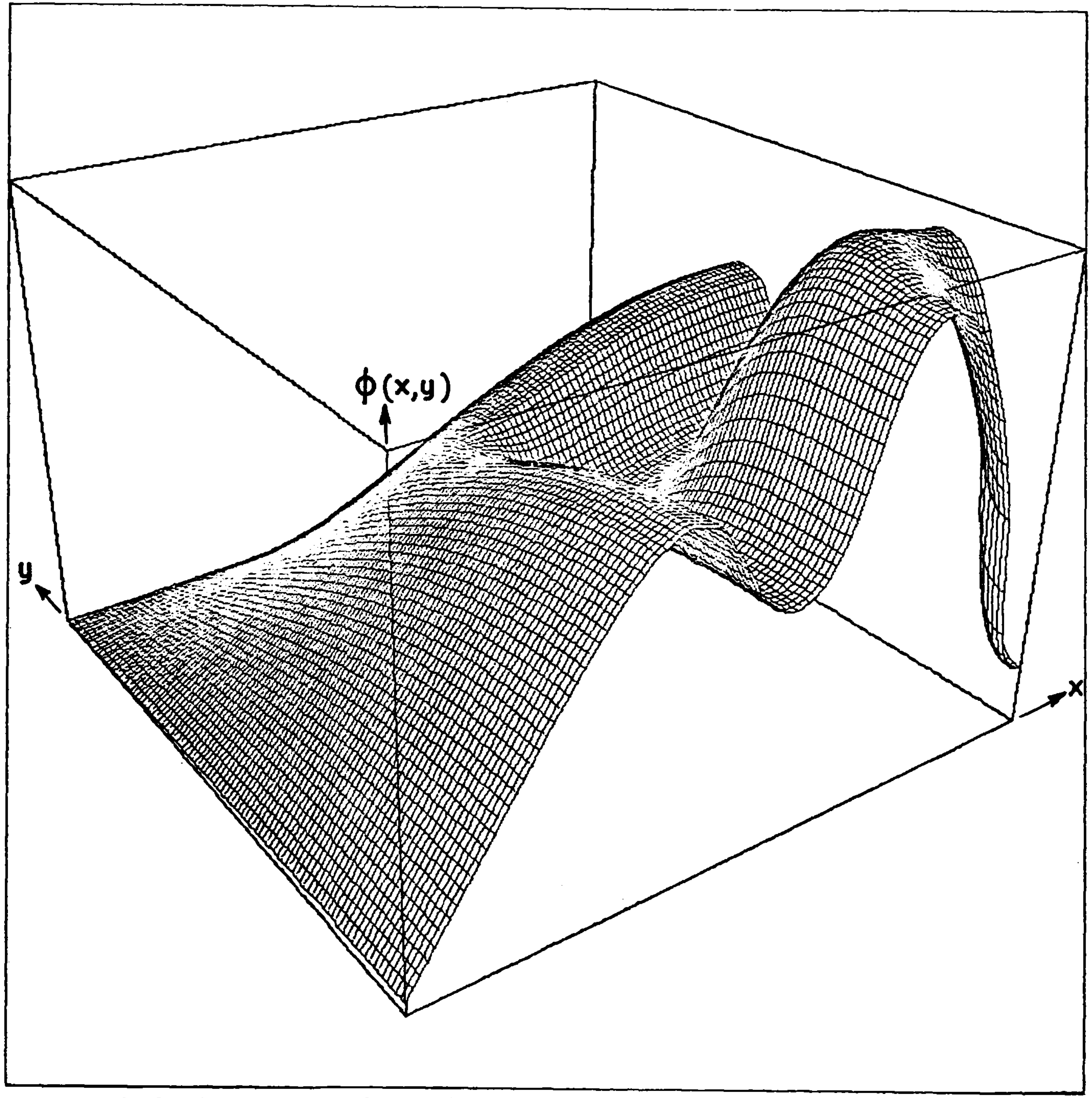

FIGURE 9 A CALCOMP PLOT OF A 2D THERMAL FLUX

APPENDIX (PHYSICS)

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EXPERIMENTAL REACTOR PHYSICS SECTION (A/Head: Mr. D. B. McCulloch)

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M. Rainbow	
EO: A. Rose	
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Reactor Experiments Group

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Nuclear Techniques Group

EO: M. Scott	TO: A. van Heugten
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APPENDIX (cont'd)

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J. Caruana	(AINSE Student, Wollongong University College)
D. Chan	(University of Melbourne)
A. Emergy	(Wollongong University College)
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F. Hille	(Wollongong University College)
S. Kannard	(AINSE)
P. Lloyd	(AINSE)
J. Mathur	(Wollongong University College)
Hla Pe	(Colombo Plan, University of New South Wales)

THEORETICAL PHYSICS SECTION (Head: Dr. B. Clancy)

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A. Musgrove
EO: E. Clayton

Nuclear Data Group

RS: J. Cook
W. Bertram
EO: H. Ferguson
E. Rose

Reactor Physics Group

RS: G. Doherty
I. Donnolly
EO: K. Maher

Reactor Codes Group

RS: J. Pollard
EO: B. McGregor (O)
G. Robinson
B. Harrington
G. Trimble

Technical Staff

TA: M. Inkster
L. Sullivan

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(O) Overseas

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