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AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

INIS-XA-N--082

PROGRESS REPORT OF PHYSICS DIVISION

including

APPLIED MATHEMATICS AND COMPUTING SECTION

1st APRIL 1971 - 30th SEPTEMBER 1971

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

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PROGRESS REPORT OF PHYSICS DIVISION

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ACTING DIVISION CHIEF - MR. W. GEMMELL

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CONTENTS (cont'd)

. INTRODUCTION

All the mechanical and electronic components for the zero power split table machine (the critical facility) arrived in excellent condition from France. Installation began and good progress was made on the mechanical side where the base and tables were successfully assembled and are being adjusted to meet the exacting specification.

Power transients arising from the insertion of short reactivity steps were studied for the reactors, HIFAR, MOATA and the critical facility. Some effort was also devoted to the study of blowdown accidents in light water reactors and calculations of some Italian experiments were made successfully.

The measurements of fast fission factor and initial conversion ratios for a range of natural uranium heavy water reactors were completed, and good progress is being made with neutron streaming in aluminium-water lattices. Many other investigators of this problem appear to have neglected or given insufficient attention to the case where the neutron beam is parallel to the plates. It is difficult to fit a cosine curve uniquely as coarse and fine features can not be separated.

Previous analysis of the moisture content of soils and concrete by neutron scattering was successfully applied to obtain information on the variation of the moisture in large coal stacks as a function of time. This work was done in conjunction with Electricity Commission of N.S.W.

Although a small Pu/Be source was found adequate for the above work, development continued on producing neutron pulses by means of a coaxial plasma focus device. Neutron pulses were produced regularly, but the output was variable; the fault was traced to breakdowns at the breech end of the device where restriking occurs.

Although discrepancies of about 2% exist between $\bar{\nu}$ for spontaneous fission of ^{252}Cf as measured by the liquid scintillation method and by the Manganese bath method, this important quantity is being measured locally using the liquid scintillator method. Preliminary results suggest a value somewhat lower than obtained by other scintillator groups but still discrepant from the results obtained by other methods. The measurement of the kinetic energy of fission fragments is being extended because of its assistance in elucidating the energy dependence of $\bar{\nu}$.

A diffusion theory code is under development as a basic module to a kinetics code package.

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

2.1 Reactor Neutron Measurements

2.1.1 Neutron streaming (D. B. McCulloch, G. Durance)

The problems previously reported with higher mode contamination of the assembly flux distributions were successfully resolved. The principal gain resulted from 'tuning', by means of a cadmium sheet liner, a 12 inch length of the reactor thermal column to the same cross sectional dimensions as the experimental assembly.

Measurements were subsequently made in 0.25 in. water-spaced lattices of 0.25 in., 0.50 in. and 1.00 in. thick aluminium slabs. Flux scans in directions parallel to each of the three axes of each lattice were made in at least two locations for both 'parallel' and 'perpendicular' orientations of the slabs with respect to the source plane.

For the perpendicular orientation, the results show the expected discrete eigenvalue behaviour. Flux scans in both directions perpendicular to the source plane are good fits to cosine shape and show no significant differences in extrapolated width. Neither is there significant variation of extrapolated width with distance from the source plane or from the edge of the assembly. The fitted extrapolation lengths range from 2.03 cm for 0.25 in. plate assembly to 2.85 cm for the 1 in. assembly. Single discrete relaxation lengths were clearly established in all three lattices, ranging from 3.85 cm to 5.63 cm in 0.25 in. and 1 in. plates respectively.

For the parallel orientation the situation is less satisfactory. While flux scans in the direction parallel to the plates and the source plane (vertical) are good fits to a cosine shape, there is clear evidence of a variation in the resulting extrapolated width with distance from the source plane. There is no variation as the measuring line is moved laterally in the stack at a constant distance from the source.

In the direction perpendicular to the plates, it appears that the marked heterogeneity of the system leads to non-separability of the overall and fine structure fluxes, so that the measured scans cannot be fitted to cosine forms. This will lead to difficulties in interpretation.

In the direction perpendicular to the source plane, the flux scans show the expected non-single exponential behaviour, the curvature being most marked for the 0.25 in. plates, which was predicted to be furthest removed from the discrete eigenvalue region.

The effects observed in the parallel lattices are receiving further experimental investigation before proceeding to lattices with 0.5 in. water gaps. The departure of the flux from single exponential form in the parallel lattice is illustrated in Figure 1, where semi-log plots of the fluxes at right angles to the source plane for both parallel and perpendicular 0.25 in. slab lattices are compared with straight lines.

2.2 MOATA

2.2.1 Operations (J. Sawyer)

	Days	%
Operation	60	46.88
Defect loss	7	5.47
Experiment assembly	23	17.97
Modification and maintenance	12	9.38
No operation	21	16.40
Open Days	5	3.90
	128	100.00
Total integrated power	1629 kWh	

2.2.2 Reactor uprating (J. W. Connolly)

The SPERT excursion results were studied. Although the prime objective of this work was to identify the maximum reactivity step that MOATA could withstand without core meltdown, the problems encountered are of general interest to reactor excursion studies, where the aim is to obtain the energy release following a reactivity input. This energy release is determined by the shape of the power pulse during the transient; the SPERT results show that this shape is consistent with an equation coupling reactivity changes with the power history of the form

$$\alpha(t) = \alpha_o - b\left[E(t-\tau)\right]^n \qquad \ldots(1)$$

where α = inverse reactor period

b = shutdown coefficient

$E(t-\tau)$ = energy release at time $(t-\tau)$

and n is a fitting parameter determined by the variation of reactor power in a time interval containing the peak power.

From Equation (1) it can be shown that for excursions in the prompt critical range

$$\frac{\Delta k}{\Delta E} P_{Max} = \alpha_o^2 \, n\ell \, \exp(\alpha_o\tau - 1/n) \qquad \ldots(2)$$

The RHS of Equation (2) has been calculated from the experimental values of P_{Max} for the SPERT 'B' cores and values of $\Delta k/\Delta E$ calculated from temperature coefficients of reactivity and heat capacities of these cores, and is shown plotted against α_o in Figure 2. The line through these points has been drawn with a square law dependence on α_o; the experimenta data match this line quite well, even for $\alpha_o > 20$ where fuel plate temperatures exceed the saturation temperature before peak power is reached. The intercept of $\alpha_o = 1$ is 78×10^{-6}; the lifetime of the B12/64 and B16/40 cores are close to this value which suggests that $n \exp(\alpha_o\tau - 1/n)$ is close to unity. This is contrary to the conclusions reached in the SPERT literature where long delay times and values of n of the order of two were used to match the power burst shapes. A tentative conclusion reached here is that void formation is of more importance to the post peak shutdown mechanism, and that the temperature coefficient of reactivity contains all the shutdown mechanisms of importance up to the time of peak power. The shorter lifetime (50 μs) of the B24/32 core should lead to lower values of $\Delta k/\Delta E \, P_{Max}$ than for the B12/64 and B16/40 cores for a given α_o. This difference is not apparent and the discrepancy is receiving further attention

The shape of the power pulse for several periods below peak power has been reported as

$$P = P_{Max}\left[r\,e^{\alpha t} - (r-1)\exp\left(\frac{r}{r-1}\,\alpha r\right)\right] \qquad \ldots(3)$$

where the fitting parameter $r = \exp(1/n)$. For n = 1, this gives

$$E\alpha_o = 1.6\,P_{Max} \qquad \ldots(4)$$

This correlation is good for the SPERT results where peak power is reached before the onset of nucleate boiling. For faster initial periods the spread of the data becomes more pronounced, although the same trend is apparent, as shown in Figure 3.

From Equations (2) and (4) the energy release up to peak power is given by

$$E_{tMax} = \frac{1.6\ \alpha\ n\beta\ (\exp\ \alpha\ \ -1/n)}{k/\Delta\ E} \qquad \ldots(5)$$

Figure 3 shows the energy release as a function of α_0 for SPERT core D12/25 calculated from Equation (5). For $\alpha > 20$ the energy release increases more slowly with α than suggested by Equation (5). This is attributed to an increase in the value of n as boiling becomes an increasingly important shutdown mechanism.

The above study of the SPERT transients indicates that fuel plate melting would commence at the centre of the MOATA core following a step addition of 1.90% δk. Such a reactivity step would produce an initial reactor period of 10 ms. The present maximum excess reactivity possible for the reactor is 0.9% δk. This is capable of producing a peak power of 75 MW and a total energy release of 7.5 MW seconds. The energy density in a central fuel plate would then be 70 cal gm^{-1}; 253 cal gm^{-1} is required to initiate melting.

This work is being incorporated into the safety assessment of the uprated reactor.

2.3 Heavy Water Reactor Physics

2.3.1 Fast fission ratios (A. Rose)

A revision of the experimental error analysis became necessary, which led to small revisions of the overall results. A final draft report incorporating BARC's comments on an earlier version is ready for processing. A summary of the results is given in Table 1.

Completion of the comparison of these experiments with environment-corrected MONTE calculations awaits only minor revision in the light of the final experimental results.

2.3.2 Initial conversion ratios (P. Duerden, G. K. Gubbi*)

The NaI crystal data were found to be inconsistent. Insufficient standard count data, etc. were available to enable a reliable correction to be made, and work on these data was terminated.

Analysis of the Ge(Li) detector data was completed, and the results are given in Tables 2 and 3. At this stage, the error analysis is preliminary only. No allowance has been included for systematic bias due to cross section uncertainties, etc. in the thermal column calibration experiment.

Lattice calculations of a cell corresponding to a cross section through each experimental test section were performed using the WIMS code. The system was made critical by adjusting the radial buckling. The environment correction was calculated using a radial model in which the central cell was represented discretely. The eight surrounding experimental cells were smeared into a ring of the correct volume and this was surrounded by a region of smeared ZERLINA core whose outer radius was adjusted to obtain criticality.

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*On attachment from B.A.R.C., Trombay, India.

The average calculated ratio of capture in ^{238}U to fission in ^{235}U for the 7 rod clusters appears to be the same as the experimental ratios; the calculated 19 rod cluster ratios are about 1½% lower than the experiment and the calculated 37 rod cluster ratios are about 4% lower than the experiment.

The variations of the calculated and experimental capture/fission ratios across the clusters were different. The calculations overestimate the ratios in the outer rings and underestimate the ratios in the central fuel product. In the 37 rod cluster cores, the calculation is down by 3% in the centre and up by 2% in the outer ring. Both experiment and calculation are normalised to their average rates for the cluster.

These results are also shown in Tables 2 and 3.

2.4 HIFAR (D. Wilson, T. Wall, D. Culley)

Preparatory work was done for the proposed experimental measurements to be made at low power after installation of the X-170 rig in HIFAR.

Calculations were made of the reactivity effect to be expected from small displacements of an outer fuel element towards the reactor centre by shock-waves or missiles generated in the event of failure of the X-170 pressure vessel. A small negative reactivity change was found.

2.5 Critical Facility (W. Gemmell, D. B. McCulloch)

Civil construction work on cell and ancillary building was completed. Problems were encountered with 'bleeding' of the tar-epoxy coating through the finishing paint on the cell ceiling, but this was remedied by stripping and repainting.

Electrical installation (with the exception of cabling associated with the machine to be supplied by Alcatel) was completed, and is operational. The hydraulic equipment is installed but remains to be commissioned.

The ventilation/air conditioning system was installed. Air flows have still to be balanced and the whole system commissioned. Testing has not been possible as yet owing to other demands on use of the cell. A full-scale overpressure leak-test subsequent to final coating of the cell gave a leak rate equivalent to 1.6% of cell volume per 24 hours for an overpressure of 0.1 kg cm^{-2} compared with the specification requirement of less than 2%.

The machine, its allied mechanical components, together with mechanical and control equipment, etc., arrived safely from France in early September. Installation is proceeding in the hands of the French technical team of five.

2.5.1 Reactivity transients (D. Culley)

The work previously reported using the AIREK III code (AMTD 131) continued, with the addition of a subroutine to represent more accurately the response function of the period meter. It is not clear that the data supplied on period meter response are being correctly interpreted in the application to ramp reactivity insertions, and further studies on the hybrid computer are planned, using a period meter unit as soon as one can be made available. The effects of temperature reactivity feedback on systems where melting of the fuel is shown to be possible are being considered.

2.5.2 Critical facility safety (T. Wail, A. Dalton, J. Harries)

In support of this work major excursion analyses and design-brief accident studies proceeded in parallel.

(a) Major excursion analysis

General operation of the machine was considered to determine the ultimate shutdown mechanism in various accidents. The incredible situation of a complete breakdown in all safety systems, administrative procedure and operator control, coupled with gross negligence was assumed to give the maximum possible excursion. The excursion was stopped by re-arrangement of the assembly, either by the flow of molten fuel or by vapour pressure disassembly. Even if the core had a negative temperature coefficient of reactivity, the lack of cooling ultimately caused melting of the fuel. Vapour pressure disassembly only occurred if the neutron period was sufficiently short so that vaporisation began before there was significant flow of the molten fuel.

(b) Design-brief accident

The design-brief accident was studied with regard to the dispersion of plutonium oxide aerosols. The in-cell transient pressure and the measured leak rate were used to estimat the PuO_2 aerosol leakage to atmosphere. Various settling models were used based on information from the literature. Leakage to atmosphere occurs at a low release height and preliminary calculation showed that action level tolerances might be reached about 40 metres from the cell site after a release of about 3 g of PuO_2. However, calculations have still to be made to account for local turbulence effects and the prolonged rather than instantaneous nature of the aerosol release. The results of the study on aerosol in-cell settling indicate that even if the leakage paths from the cell to atmosphere have a combined filtration efficiency of only about 50%, action level tolerances outside will not be exceeded for the complete in-cell vaporization of 50 kg Pu.

2.6 Moisture Determination in Massive Coal Stacks (A. Rose)

Assistance has been provided to the Electricity Commission of N.S.W. in determining the relative moisture content of massive coal stacks at conventional power stations. A neutron scattering technique was used. Laboratory experiments were made to determine the sensitivity of the method to moisture and density variations.

Because the method essentially determines the local hydrogen atom density and because in the expected moisture range (~2 to ~10 $^{w}/_{o}$ H_2O) the water hydrogen is only a fraction of the bound hydrogen in the coal, density and ash content variations lead to much greater changes in scattered neutrons detected than do the changes in moisture content. It was clear that absolute measurements of the moisture content would not be feasible by this technique.

Since, however, a rapid monitoring technique which could show changes from previously chemically assayed moisture contents was of considerable interest to E.C. of N.S.W., a Pu/Be source and BF_3 detector were used to log a pattern of boreholes in coal stacks at the Vales Point Power Station in July. The measurements were repeated in August, and the two sets of data compared.

Count rate variations along and between boreholes were well reproduced by the two measurements (Figures 4 and 5). As expected, the ash and density variations of the coal prevented clear correlation being established between count rate variations and moisture content variations as determined by chemical analyses of the core samples. An overall decrease in count rate between the two sets of measurements, however, indicated a general drying out of the stack in the intervening period which was confirmed by the chemical assays. There seems little doubt that this comparative method can provide a useful means of quickly checking whether or not stack moisture content has changed since laying down, provided the stack is not tampered with during the intervening period.

2.7 Uranium Analysis (A. Rose, G. K. Brown, R. Knott)

Construction of the fast pneumatic sample transfer system for MOATA is well advanced. The associated neutron detection system has been designed, and is being made. The complete system should be ready for test in December.

Preliminary calculations suggest that the use of a pulsed (D,T) neutron source could be feasible for borehole logging of uranium by a delayed neutron counting technique. Multigroup transport calculations are now being carried out for sand/water/uranium mixtures to provide a sounder basis for the assessment of this approach.

2.8 Reactor Dynamics (W. J. Turner)

An unconditionally stable finite difference scheme was established for transient two phase compressible flow with slip between the phases. This was implemented in the code OWEN 1. The code was used to simulate the CISE loss of inlet flow experiments (A. Premoli 1969, Energia Nucleare 16, 626). The calculated time-variations of mass of coolant in the heated channel were in good agreement with the experimental observations.

2.9 Pulsed Neutron Studies (I. Ritchie)

2.9.1 Pulsed measurements in thorium (M. Rainbow, S. Moo)

It was reported previously that an examination of room wall scattered neutrons and shielding effects had indicated that useful measurements could be made with broad range energy detectors, such as ^{239}Pu, ^{235}U fission detectors in an unshielded assembly during the first 400 ns or so after the pulse. However, because it has not yet been possible to vary the location of the assembly in any significant way with respect to the floor of the building, the possibility that floor scattered neutrons affect the decay of the neutron population during this period still exists.

The decay measured by threshold detectors (^{237}Np, ^{238}U) should not be affected in any significant way by floor scattered neutrons since

(i) in the short time ($\lesssim$100 ns) after the pulse in which measurements are made scattered neutrons will not have had time to return to the stack;

(ii) scattered neutrons are most likely to have energies below the threshold energy of the detectors.

For these reasons, work with broad range detectors was temporarily halted and effort concentrated on measurements with threshold detectors.

Initial measurements with a ^{237}Np detector in which standard cross-over timing techniques were used indicated that there was significant timing jitter. This can be seen in the rather flat topped response of the detector in the thorium assembly into which a pulse ~10 ns wide was injected (Figure 6), and in the response of the detector to a ~5 ns wide pulse of ~1 MeV neutrons with little or no scattering material in the vicinity of the detector (Figure 7). Much of the jitter was traced to variations in the rise times of pulses from the detector, which was greatly reduced by application of constant fraction timing techniques (Figure 6 and 7). The improved timing accuracy is adequate to allow useful measurements to be made with ^{237}Np detectors. However, the much faster decay of the ^{238}U reaction rate (~5 ns compared to ~15 ns for ^{237}Np) necessitates further investigation of sources of timing jitter.

Figure 8 shows the space dependent response of a ^{237}Np detector at three different times after the injection of the fast neutron pulse. These preliminary measurements were made in a direction parallel to the incident accelerator beam and indicate that three or four Fourier modes should adequately describe the spatial distribution in this direction.

2.9.2 Neutron wave measurements in BeO (S. Whittlestone)

The experimental investigation of neutron waves in BeO at high frequencies was completed. Measurements of phase and amplitude were carried out at 515.7, 736.6, 982.3, 1473.3 and 1717.0 Hz in a stack 54.15 cm long and of transverse buckling 0.0513 cm^{-2}, where all parameters have been corrected to the reference density of 2.96 g cm^{-3}.

Figures 9 and 10 show the measured phase and amplitude curves. Attenuation and phase shift 'constants' obtained for successive 10 cm intervals by fitting appropriate functions to the data are plotted in Figures 11 and 12. In all cases, the errors associated with the points are as indicated or are smaller than the points shown; the lines on these curves are for guidance only and have no other significance. The results show that at ~500 Hz the neutron wave parameters are sensibly constant for distances from the source greater than 9 cm, and the wave can possibly be described by a propagation constant [$P(\chi)^2$<0.05%], whereas in all other cases such a description is impossible. The result at ~500 Hz is not in accord with current theory.

Measurements at 982.3 Hz were carried out with the normal 2 in. of polythene moderator (runs A and C in Figures 10 and 11) and with 3 in. of polythene (run C) to check the effect of the source conditions. It can be seen that there is no marked effect.

2.9.3 Theory of neutron wave propagation (K. Maher)

The multigroup one dimensional diffusion program described previously proved incapable of handling calculations with a large number of groups. This program used exponentiated complex matrices in the role of transfer operators to derive the real and imaginary fluxes inside heterogeneous assemblies, given the source face flux. However, as the matrices increased in size with increasing number of energy groups, they developed numerical properties which made them unsuitable for machine calculation.

As an alternative, a more conventional finite difference multigroup code was written with the same aim of calculating the wave properties in both the source material (polythene in the present case) and in the region in which measurements are normally carried out by the experimenter. This code has not encountered numerical difficulties other than the usual (and solvable) problems of slow convergence.

2.10 Neutron Source Project (G. Hogg, J. Tendys)

Experiments continued with the negative centre electrode coaxial gun (Mark I) with a low resistance (0.5 ohm) termination at the breech. This solved the voltage oscillation problem, but insulator breakdown behind the current front persisted and true focii were obtained for less than one per cent of gun firings. The positive centre electrode gun (Mark II) was installed and successful focii were obtained immediately. The earthing system of the energy storage bank was modified to permit the use of the Mark II gun with a negative centre electrode and the results obtained were similar to those with the Mark I gun. This indicated that electrode polarity is an important factor in gun operation, contrary to other reported work.*

The positive centre electrode gun was operated with both hydrogen and deuterium gas fillings in the pressure range 1.5-10.0 torr and with bank voltage in the range 15-21 kV. The X-ray emitting regions of the focus were delineated by means of an X-ray pinhole camera. The time distribution of both the X-ray and neutron pulses were measured with a scintillator-photomultiplier arrangement and the neutron flux by a silver activation detector. The X-ray and neutron pulse shapes varied considerably from shot to shot and it was possible to obtain 2 to 3 separate pulses per shot. The neutron pulse width varied from 50 to 200 nsec. The shot to shot variation of the neutron flux was several orders of magnitude with an estimated peak flux of 5×10^9 neutrons per shot.

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

3.1 Fission Physics (J. Boldeman, R. Walsh)

3.1.1 Nubar measurements

The absolute value of $\bar{\nu}_p$ in the spontaneous fission of ^{252}Cf is being measured. The neutron detection efficiency of the large liquid scintillator is being determined at a number of neutron energies using (n,p) scattering. For this purpose a proton recoil chamber utilizing a surface barrier detector was constructed. A preliminary value of $\bar{\nu}_p(^{252}\text{Cf}) = 3.762 \pm 0.042$ was obtained from the analysis of data already taken.

3.1.2 Total fragment kinetic energy measurements

Measurements were completed of the variation of the average total fragment kinetic energy with incident neutron energy $\bar{E}_K(E_n)$ in the neutron fission of ^{233}U. Data were taken at a large number of points between 26 keV and 1 MeV. The striking feature of the data is the strong rise in the value of $\bar{E}_K$ between 100 and 150 keV. Above 150 keV, $\bar{E}_K(E_n)$ remains constant to at least 1 MeV. The data have the same functional form as the relative probability of p wave to s wave fission and constitute strong evidence of channel effects in the fission of ^{233}U. The data contrast with previous $\bar{E}_K(E_n)$ data obtained for ^{235}U which was found to be constant over the range 0-1 MeV.

*Mather, J. W. (1966) - Proc. of IAEA 2nd Conference on Plasma Physics and Controlled Nuclear Fusion Research, 2, 389.

The ^{233}U $\bar{E}_K(E_n)$ data are in very good complementary agreement with previous measurements of $\bar{\nu}_p(\bar{E}_n)$ for ^{233}U.

3.1.3 Neutron emission from specific fission fragments

The experimental system is being modified so that a high resolution X-ray detector (390 eV for the 26.36 keV X-ray from ^{241}Am decay) can be installed.

3.1.4 Fission fragment angular distribution

The angular distribution of fragments in the fast neutron fission of ^{235}U was measured at eight energies between thermal and 1 MeV. For each incident neutron energy, data are taken at six angles between 0 and 90 degrees with respect to the neutron beam. The data are in agreement with previous measurements and show an increase in the anisotropy between 400 and 600 keV.

3.2 Neutron Capture

3.2.1 Resonance keV capture in 2s-1d shell nuclei (M. J. Kenny, P. W. Martin, J. A. Biggerstaff, J. R. Bird)

Resolved resonance spectra were measured for keV capture by samples of F, Al, Si and S. Sample sizes were 1-2 kg and the Ge(Li) detector used was 7.8% efficient. Data collection facilities were improved to allow γ-ray energies to be measured in the range from 0.8 MeV up to the binding energy, so that both primary and secondary γ-rays were observed. Decay schemes for the various resonances were derived to provide new and more accurate energy level data and information on the roles of s-, p- and d-wave capture in the mass region below A=40.

3.2.2 Resonance keV capture in nickel (M. J. Kenny)

Previous data for nickel was of limited value because of copper contamination in the target. New data were obtained using a pure nickel target and high resolution pulse height and time analysis. The results show that keV capture by the isotopes ^{58}Ni, ^{60}Ni, ^{62}Ni produce spectra similar to thermal capture. In each case the strongest transition is to the ground state. Other transitions are mostly to low lying states, both high and low spin.

3.2.3 Capture cross section (D. B. Stroud and D. M. H. Chan)

The Moxon-Rae detectors described previously (PR34-P) were used to measure 30 keV averaged cross sections for small samples of ^{110}Cd, ^{136}Ba and natural calcium.

3.2.4 Thermal capture (D. M. H. Chan)

The energy spectrum of γ-rays following thermal capture in a ^{110}Cd sample was obtained.

3.2.5 Single particle states (F. Hille, J. R. Bird)

A survey of strong transitions following neutron capture in even-even nuclei was extended to include masses up to 130 and compared with results from (d,p) experiments. Systematic features are observed which can be related to known shell structure, but further measurements are needed to complete the region from mass 70 to 90.

3.3 Experimental Facilities

3.3.1 3 MeV accelerator (A. van Heugten, H. G. Broe, J. Copland, L. H. Russell)

Of the total time in the period 996 hours or 23% were taken up by maintenance and developments. Of the remaining time the accelerator was operated for 3279 hours and used in experiments for 3094 hours. The distribution of this time is shown in Table 4. Maintenance and modifications in this period included:-

(a) further trouble with leaks in joints sealed by O rings in the terminal,

(b) pressure dependent faults in the terminal microsecond pulsing circuits required extensive testing, including remote measurements made with the tank pressurised and the accelerator operating at zero volts. The faults disappeared after complete check and overhaul of all contacts and components,

(c) improvements to the quadrupole and switch magnet power supplies,

(d) the installation of a full flow filter in the accelerator cooling water circuit,

(e) a preliminary trial of an independent Einzel lens control.

A second beam line in the low background area was completed for three different target chambers in series. This line is being used for charged particle reactions and studies of gamma ray angular distribution.

3.3.2 Liquid scintillator tank (J. W. Boldeman, L. H. Russell)

The scintillator liquid had deteriorated during six years of use. The liquid was changed and original performance restored.

3.3.3 Data acquisition facilities (J. A. Biggerstaff, R. Cawley, M. Scott)

A light pen was interfaced to the PDP15 display and some earlier aberrations in the picture were removed by modifications to the oscilloscope and the interface circuitry.

A new program was written for data acquisition with the PDP15, incorporating the command structure familiar to users of the PDP7 system. Provision was made for use of the light pen to manipulate the display and draw in background approximations.

The PDP15-PDP7 link was installed, but noise problems and interference with other devices necessitated extensive modifications (by I. and C. Division). Testing continues during periods when the computers are not required for experiments.

4. THEORETICAL PHYSICS SECTION

4.1 Nuclear Data Group

4.1.1 Fissionproduct data (J. Cook, E. Clayton, E. Rose)

The basic fission product cross section file was updated to agree with the latest compilation of thermal cross sections and resonance integrals. A deficiency in the theoretical technique of estimating unmeasured point cross sections was discovered and steps are being taken to improve the theory in this respect. It is proposed that the file be updated and checked every two years since all servicing programs are now available.

4.1.2 Multilevel analysis (W. K. Bertram, J. Cook)

It was discovered that the simplified version of the equiphase theory used to remove the complexity of inverting the channel matrix possesses defects that had been discussed by previous authors. However, the general theory developed by Moldauer was found to be free of these defects, but being rather more complicated did not offer any particular advantage over existing theories. Since all these theories were shown to be reducible to the Adler-Adler cross section parameterization, we propose to use this formalism wherever multilevel effects are significant.

A new method for inverting the channel matrix was found. Whereas existing methods rely on the level matrix expansion, which requires the evaluation of the inverse of the large level matrix, the new method achieves the inversion of the channel matrix by means of simple recurrence relations. It appears that the new method offers computational advantages over existing methods although the programming aspects have not yet been fully investigated.

4.1.3 Resonance parameter statistics (W. K. Bertram, J. Cook)

The statistics of resonance parameters are being investigated. It is a widely held belief that the statistical distributions of R-matrix parameters are independent of the boundary conditions used in the definition of the R-matrix. Our work shows that this belief is without foundation and that the distributions of level spacings and widths change when the boundary conditions are changed. Efforts are continuing to derive the general distributions for small changes in the boundary conditions and the implications of these findings in the statistical theory of neutron reactions are being investigated.

4.1.4 The inverse scattering problem (E. Clayton, J. Cook)

All work on the refinement of the computational methods for calculating potentials from phase shifts is now complete. Four-figure agreement between input fitted phase shifts, and those recalculated by using standard techniques with the evaluated potential was achieved. Plotting routines were written for displaying potentials as a function of energy and radius. A generalization to include Coulomb phase shifts and a non-local form for the potential are being studied.

4.1.5 Fission physics (A. Musgrove)

Detailed calculations of trajectories were made for α-particle, triton and proton accompanied fission of ^{252}Cf to give more information relating to the correlations occurring between final fragment and final particle energy. These have been compared with experiment with good agreement.

4.1.6 Nuclear physics (E. Clayton, G. Derrick)

The problem of finding the numerical real and complex eigenvalues of the Schrodinger equation is being studied. For the real eigenvalues one assumes an exponentially decaying solution outside the region of interaction and searches for a solution that is regular at the origin. A Regula-Falsi method was used which gives good agreement where analytic results are known. For the complex eigenvalues (scattering problem) the outgoing waves only were used, giving the parameters of Humblet and Rosenfeld, and a Monte Carlo method for calculating the real and imaginary parts of the eigenvalue is being developed. This will be used to determine the potential of a system given the bound states and resonance positions of that system.

4.1.7 Retrieval of ENDF/B data (H. Ferguson)

Work is in progress on the retrieval of data from the Evaluated Nuclear Data File as a result of requests from on and off site. So far, the retrieval process has been on a once-off basis, but it is hoped that this will be streamlined in the near future.

4.2 Reactor Physics Group

4.2.1 Resonance absorption studies (G. Doherty)

An equivalence relation was developed which will allow resonance absorption calculations in any geometry for which collision probability routines are available. The Russian sub-group method is used in this formulation, which is being tested on typical lattices. A Monte Carlo resonance program was written in FORTRAN for the site IBM360 computer and is being used in checking the equivalence relations.

4.2.2 Heterogeneous method (I. Donnelly)

A method for evaluating the dipole boundary conditions needed as input for the heterogeneous reactor code SOS-1 was developed, tested and found to be accurate. The N-group equations which specify the dipole flux are separated into N one-group equations which are easily solved. The required boundary conditions are then obtained.

This method was conceived for the treatment of fuel elements with small downscatter cross sections, but has also been successfully applied to strongly moderating elements.

4.2.3 Fast reactor calculations (I. Donnelly)

The critical parameters of the fast assembly GODIVA were re-evaluated using the ^{235}U cross section data recently added to GYMEA (U235, ENDFBUK, ORIG). Values found for k_{eff} (1.025) and for spectral indices are in better agreement with experiment than those obtained using the older data (U235, SCARSBNL, MOD2). The major difference in the two sets above 20 keV is in the fission cross sections, the older data having values about 5% too large.

4.3 Reactor Code Group

4.3.1 Pseudo fission product data (B. Harrington, J. Pollard)

Data for a pseudo fission product to replace 151 fission products with small reactivity effects will shortly be available when the latest corrections to the basic data have been processed.

4.3.2 The GYMEA system (B. Harrington, J. Pollard)

GYMEA finally runs under release 19.6 MVT of the operating system on the IBM360/50. One bug in the FORTRAN H compiler was detected after the code had been running for a month (Y=-ALOG(X) was wrongly interpreted as Y=ALOG(X)). Fortunately not all calculations were seriously affected.

4.3.3 2D-diffusion code, POW (B. Harrington, J. Pollard)

A 2D (XY and RZ) diffusion program was written as part of a kinetics code. The code uses an edge flux integration scheme, with an SLOR inner iteration scheme and a Chebyshev extrapolation outer iteration scheme. Convergence is hastened, particularly for problems with extensive upscatter, using a region-group rebalance scheme.

The program is being debugged.

4.3.4 The transport code, WDSN (G. Robinson)

A new version of the WDSN code was obtained from the U.K.A.E.A. and commissioned on the IBM360. The most important new feature is an e^{iBz} treatment of leakage in the transverse direction.

In common with most transport codes, the convergence of WDSN was very poor both for whole core calculations and calculations with many upscatter groups. The convergence was improved by including a Chebyshev extrapolation of the fission source and a group inbalancing scheme.

4.3.5 The PEARLS code (G. Robinson)

Work began on improving the PEARLS code by allowing more regions to be included, increasing the efficiency, and including an edit routine. This will permit more satisfactory comparisons with resonance approximations.

5. PUBLICATIONS

5.1 Papers

Ajitanand, N. N. (1971) - Delayed gamma ray emission in the spontaneous fission of ^{252}Cf - Nucl. Phys. A164, 300.

Walsh, R. L. and Boldeman, J. W. (1971) - The energy dependence of $\bar{\nu}_p$ for ^{233}U, ^{235}U and ^{239}Pu below 5.0 MeV - J. of Nucl. En. 25, 321.

Clancy, B. E. (1971) - Multigroup neutron transport theory in plane geometry - Bull. Austral. Math. Soc. 5, 2, 287.

5.2 Reports

Ritchie, A. I. M. and Whittlestone, S. (1971) - Measurement of the thermal neutron wave dispersion radiations in BeO - AAEC/TM591.

Musgrove, A. R. de L. (1971) - Trajectory calculations for light particles emitted in spontaneous ternary fission - AAEC/TM595.

Doherty, G. (1971) - Collision probability calculations including axial leakage - AAEC/E215.

6. RESEARCH CONTRACTS

6.1 Title: Study of Single Particle Wave Functions

Reference No. 70/E/1
Period: 21/4/71-30/9/71
Supervisor: Professor I. E. McCarthy
University: School of Physical Science, Flinders University
Liaison Officer: J. R. Bird

Objective: To calculate single particle wave functions using optical model computer codes and to compare the results with experimental data, including information obtained from neutron capture studies.

Status: Improvements in the best fit parameters of the non local potential have been tested in calculations of single neutron state energies in ^{40}Ca, ^{90}Zr and ^{208}Pb. The positions of s, p, d, f and g states have been calculated in a number of nuclei for A=30 to 60 and 85 to 100. A d-wave strength function peak is predicted at mass 60.

6.2 Title: Development of Nuclear Analysis Methods for Light Elements

Reference No: 70/D/32
Period: 1/4/71-30/9/71
Supervisor: Dr. J. L. Rouse
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: A counter system with graphite reflector for use in measurement of photoneutrons from deuterium has been completed and is being tested using gamma rays from a 4 MeV Linac.

TABLE 1

FAST FISSION RATIOS IN CLUSTERS

(Mean of NaI and Ge(Li) Results)

Cluster	Coolant	Rod $\frac{U8}{U5}$ Ratios									Cluster Averaged $\frac{U8}{U5}$ Ratio	Cluster Average U8 / Cluster Average U5
		R1	R2	R3	R4	R7	R8	R9	R11	R12		
Exp 7 Rod	Air	0.0304±10	0.0258± 9	0.0259± 9							0.0264± 8	0.0263±11
	H_2O	0.0304±11	0.0240±10	0.0210±10							0.0234± 8	0.0231±12
7 Rod	Air	0.0364±11	0.0306±10	0.0297±10							0.0311± 9	0.0310±12
	L.D.	0.0389±12	0.0323±10	0.0308±10							0.0326±10	0.0324±12
	H.D.	0.0399±12	0.0278±10	0.0300±10							0.0304± 9	0.0303±12
	H_2O	0.0400±13	0.0288±10	0.0294±10							0.0308± 9	0.0308±13
Exp.19 Rod	Air	0.0495±15		0.0475±14	0.0370±12						0.0409±12	0.0406±15
	L.D	0.0519±15		0.0440±13	0.0328±11						0.0373±11	0.0367±14
	H.D	0.0542±16		0.0482±15	0.0304±11						0.0372±12	0.0354±15
	H_2O	0.0512±16		0.0459±14	0.0280±10						0.0350±11	0.0329±14
19 Rod	Air	0.0611±19		0.0573±18	0.0409±13						0.0471±14	0.0466±18
	L.D	0.0682±20		0.0605±18	0.0418±13						0.0491±14	0.0478±18
	H.D	0.0709±20		0.0590±17	0.0399±12						0.0475±14	0.0459±17
	H_2O	0.0678±20		0.0600±18	0.0372±12						0.0460±14	0.0440±17
37 Rod	Air	0.0939±26		0.0888±25	0.0769±21	0.0509±15	0.0491±15				0.0661±18	0.0638±21
	L.D	0.0949±27		0.0807±24	0.0887±27	0.0465±15	0.0470±15				0.0673±19	0.0637±24
	H.D	0.1043±29		0.0943±28	0.0741±22	0.0437±14	0.0449±14				0.0637±18	0.0586±21
	H_2O	0.1007±30		0.0949±28	0.0694±20	0.0399±15	0.0360±14				0.0588±18	0.0514±23
61 Rod	Air	0.1286±35		0.1246±35	0.1112±31	0.0861±24	0.0816±23	0.0545±17	0.0529±16	0.0567±17	0.0827±22	0.0768±26
	H_2O	0.1405±39		0.1321±39	0.1010±30	0.0707±21	0.0734±22	0.0385±13	0.0426±14	0.0420±13	0.0729±20	0.0611±22

NOTE Errors are in units of 10^{-4}

TABLE 2

VARIATION OF CAPTURE/FISSION RATES ACROSS THE CLUSTER

Cluster	Calculated Capture/Fission				Experimental Capture/Fission			
	Centre	1st Ring	2nd Ring	3rd Ring	Centre	1st Ring	2nd Ring	3rd Ring
7NA	0.960	1.010			0.985 ± 0.008	1.000 ± 0.008		
7ND	0.975	1.005			0.990 ± 0.008	1.000 ± 0.008		
7NH	1.005	1.000			1.015 ± 0.008	1.000 ± 0.008		
7NP	0.975	1.005			0.990 ± 0.008	1.005 ± 0.008		
7EA	0.0940	1.010			0.980 ± 0.008	1.005 ± 0.003		
7ED	0.990	1.000			1.005 ± 0.008	1.000 ± 0.008		
7EP	1.000	1.000			1.010 ± 0.008	1.000 ± 0.008		
19ND	0.995	0.980	1.010		1.025 ± 0.008	1.005 ± 0.008	0.995 ± 0.008	
19NH	1.045	1.020	0.985		1.020 ± 0.008	1.030 ± 0.008	0.985 ± 0.008	
19EA	0.930	0.930	1.040		0.990 ± 0.008	0.995 ± 0.008	1.005 ± 0.008	
19ED	1.015	1.000	1.000		1.040 ± 0.008	1.010 ± 0.008	0.995 ± 0.008	
19EP	1.020	1.005	0.995		1.050 ± 0.008	1.030 ± 0.008	0.985 ± 0.008	
37NA	0.960	0.955	0.970	1.040	0.990 ± 0.010	0.990 ± 0.010	0.970 ± 0.010	1.025 ± 0.010
37ND	1.035	1.019	0.980	1.005	1.070 ± 0.010	1.050 ± 0.010	0.995 ± 0.010	0.980 ± 0.010
37EA	0.930	0.925	0.950	1.065	0.960 ± 0.010	0.965 ± 0.010	0.970 ± 0.010	1.035 ± 0.010

Normalised to the average capture/fission rates for the cluster

TABLE 3

CALCULATED AND EXPERIMENTAL CAPTURE/FISSION RATES RELATIVE TO THERMAL CAPTURE/FISSION RATIO

Comments	Cluster	Calculated					Experimental				Average
		Centre	1st Ring	2nd Ring	3rd Ring	Average	Centre	1st Ring	2nd Ring	3rd Ring	
	7NA	1.135	1.190			1.180	1.170±0.016	1.190±0.017			1.190±0.017
	7ND	1.160	1.195			1.190	1.185±0.017	1.195±0.017			1.195±0.017
	7NH	1.170	1.165			1.165	1.190±0.017	1.175±0.016			1.175±0.016
	7ED	1.210	1.220			1.220	1.205±0.017	1.200±0.017			1.200±0.017
	19ND	1.430	1.410	1.450		1.435	1.470±0.020	1.445±0.020	1.430±0.020		1.435±0.020
	19NH	1.425	1.390	1.345		1.365	1.430±0.020	1.440±0.020	1.380±0.020		1.400±0.020
	19ED	1.550	1.525	1.525		1.525	1.620±0.022	1.570±0.022	1.545±0.022		1.555±0.022
	37NA	1.785	1.770	1.800	1.930	1.855	1.860±0.032	1.855±0.032	1.815±0.032	1.920±0.033	1.575±0.032
	37ND	1.195	1.885	1.810	1.855	1.850	2.095±0.036	2.055±0.036	1.955±0.033	1.925±0.033	1.960±0.033
	37EA	1.940	1.930	1.980	2.225	2.090	2.135±0.036	2.140±0.036	2.155±0.036	2.295±0.039	2.220±0.038
Efficiency change between clusters and thermal measurements	7NP	1.155	1.190			1.185	1.245±0.023	1.260±0.023			1.255±0.023
	7EA	1.135	1.220			1.205	1.315±0.024	1.345±0.024			1.340±0.024
	7EP	1.185	1.185			1.185	1.300±0.024	1.285±0.024			1.285±0.024
	19EA	1.420	1.415	1.590		1.525	1.700±0.031	1.710±0.031	1.720±0.031		1.175±0.031
	19EP	1.435	1.420	1.400		1.410	1.605±0.029	1.575±0.028	1.505±0.027		1.530±0.028

(cont'd)

TABLE 3 (cont'd)

Comments	Cluster	Calculated					Experimental				Average
		Centre	1st Ring	2nd Ring	3rd Ring	Average	Centre	1st Ring	2nd Ring	3rd Ring	
Corrected for change in efficiency	7NP	1.155	1.190			1.185	1.150±0.022	1.165±0.024			1.160±0.024
	7EA	1.135	1.220			1.205	1.215±0.044	1.240±0.025			1.240±0.025
	7EP	1.185	1.185			1.185	1.200±0.024	1.185±0.024			1.185±0.024
	19EA	1.420	1.415	1.590		1.525	1.570±0.032	1.580±0.032	1.590±0.032		1.585±0.032
	19EP	1.435	1.420	1.400		1.410	1.485±0.030	1.455±0.029	1.390±0.028		1.415±0.028

TABLE 4

ACCELERATOR TIME ALLOCATION

Topic	Expt. No.	Title	Personnel	Origin	Running Time (hours)
Fission	31	^{233}U kinetic energy	Boldeman, Walsh	Physics	624
	51	Angular distribution of fission fragments	Caruana, Boldeman	Wollongong/Physics	108
Capture	37	Cross sections	Stroud	Melbourne	163
	47	keV Fast Timing	Kenny	Physics	31
	57	keV Spectra	Bird, Kenny, Biggerstaff	Physics	519
	67	keV Spectra	Chan	Melbourne	51
Transport	55	Thorium assemblies	Rainbow, Ritchie, Moo	Physics Tasmania	583
Radiation Damage	16	Crystals	French	U.N.S.W.	41
	26	Cells	Davy	Health Physics	128
Nuclear Analysis	38	^{18}O Concentrations	Campbell	Isotopes	22
Charged Particle Reactions	49	(p,γ) Reactions	Din	A.N.U.	56
	59	(p,γ) Reactions	Lasich	Queensland	8
	69	(p,γ) Reactions	Boydell	Melbourne	107
	79	(p,γ) Reactions	Sargood	Melbourne	58
Atomic Physics	44	Proton Channelling	Price	U.N.S.W.	265
Isotope Production	22	^{13}N Tracing	Nicholas	Adelaide	41
		^{11}C Tracing	Moorby	Macquarie	14
Other experiments	30	(n,γ) reactions	Martin	Physics (attached)	40

Tests: 67 hours

Total Operating Time: 3279 hours

Maintenance: 990 hours

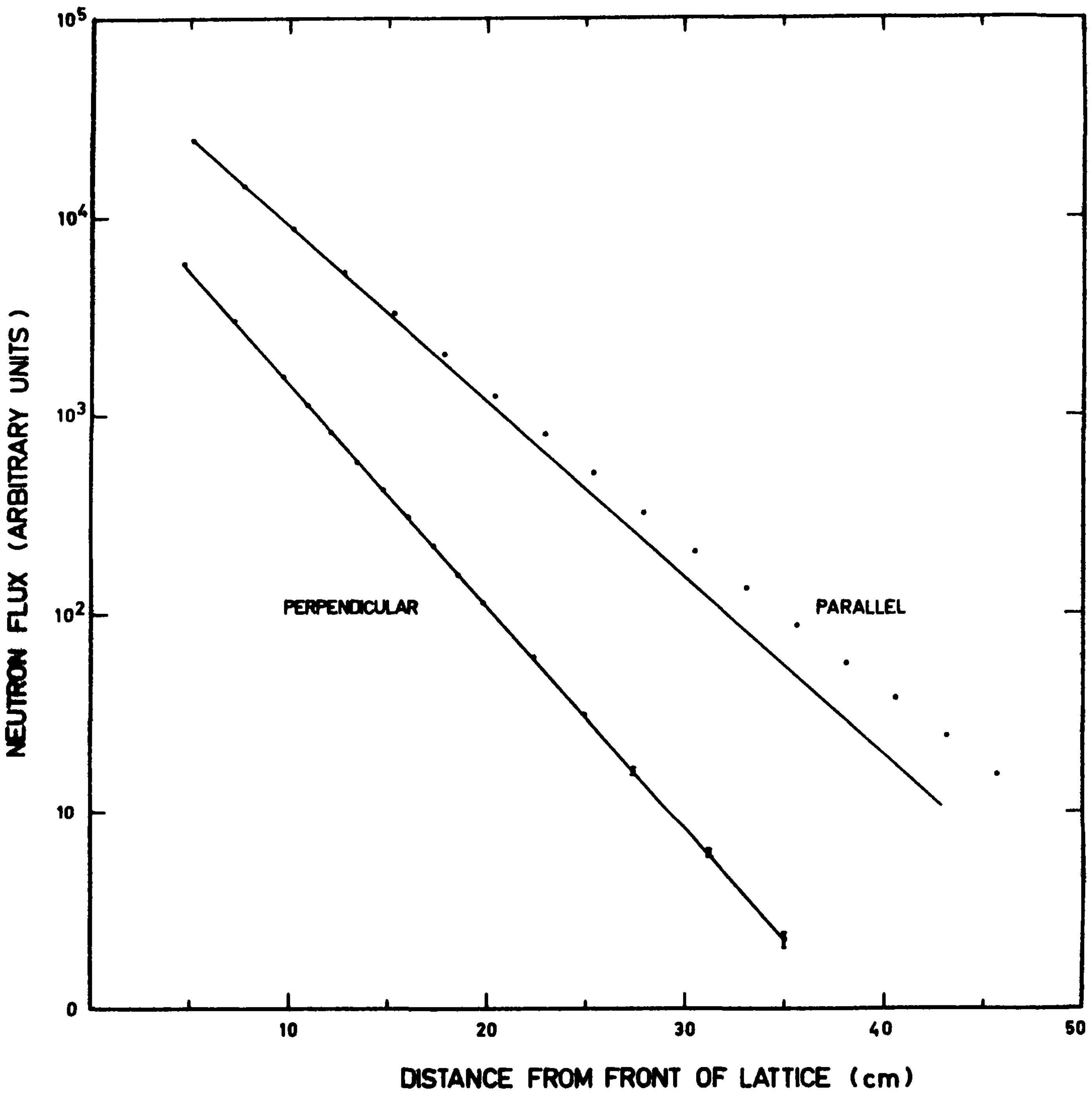

FIGURE 1. NEUTRON FLUXES IN DIRECTION PERPENDICULAR TO SOURCE PLANE FOR PARALLEL AND PERPENDICULAR 0.25 INCH Al/0.25 INCH H_2O LATTICES

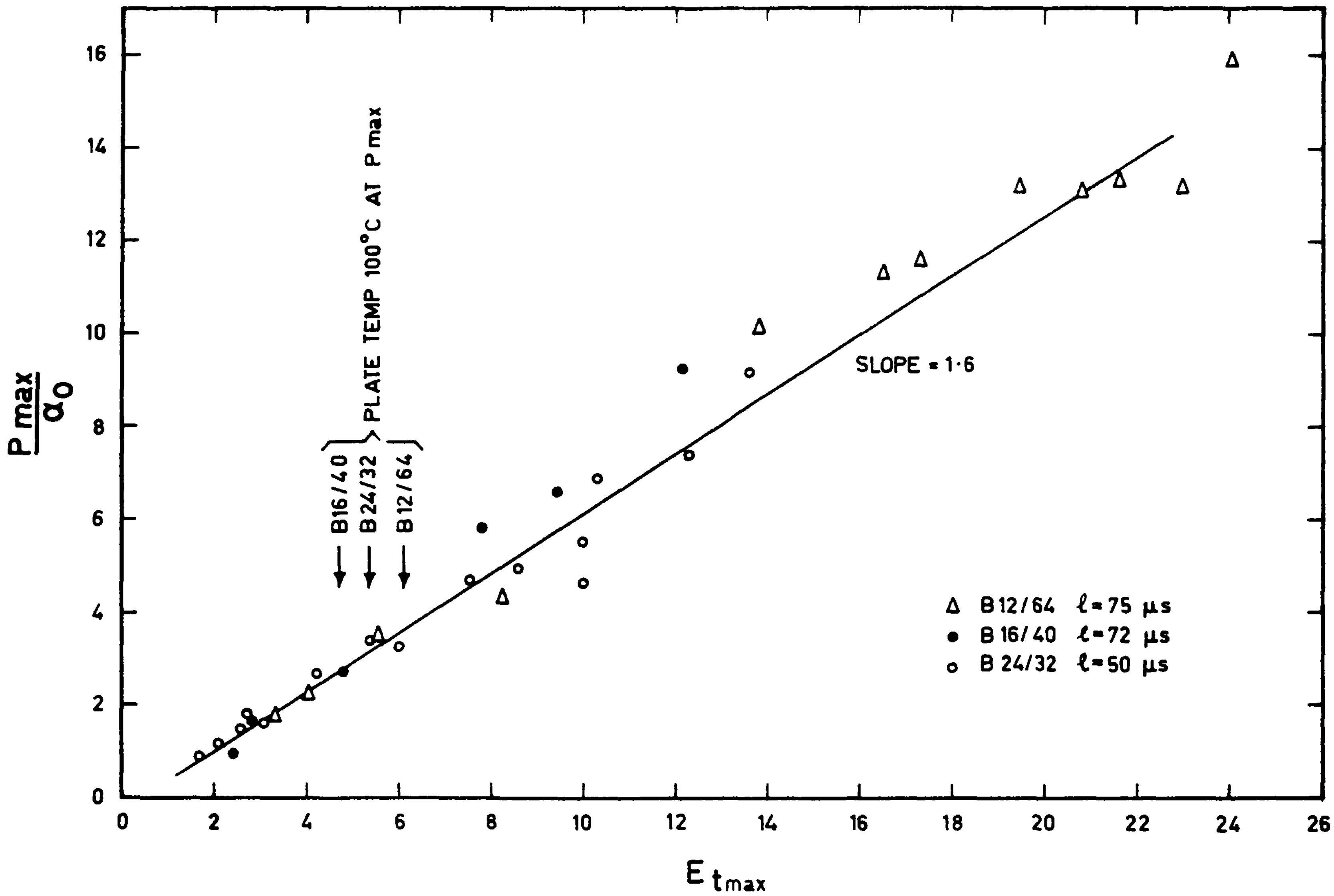

FIGURE 2. SPERT P_{max}/α_o v. $E_{t_{max}}$ FOR B SERIES

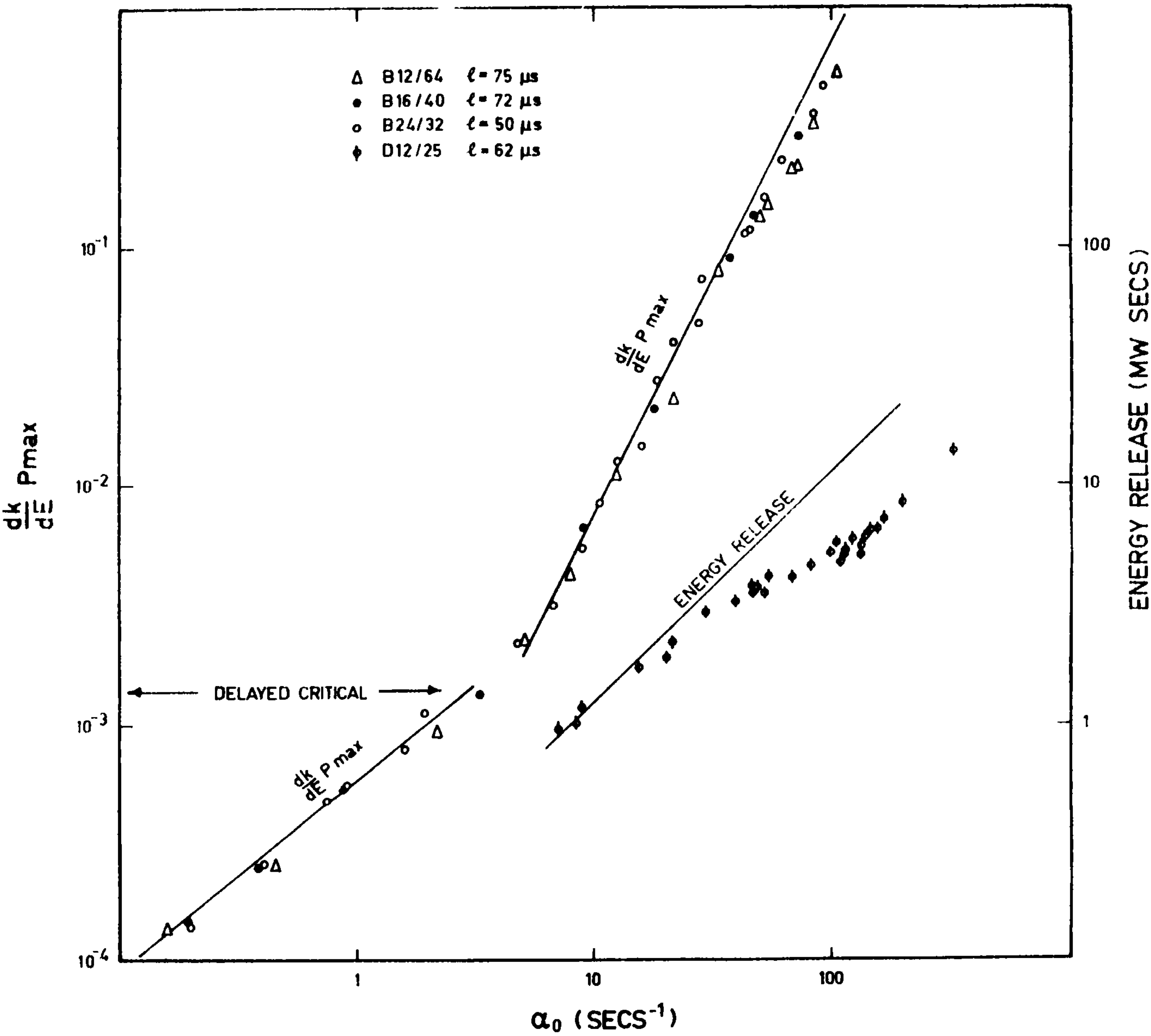

FIGURE 3. SPERT $\frac{dK}{dE}$ P_{max} v. α_0 FOR B SERIES AND ENERGY RELEASE TO TIME OF PEAK POWER FOR CORE D12/25

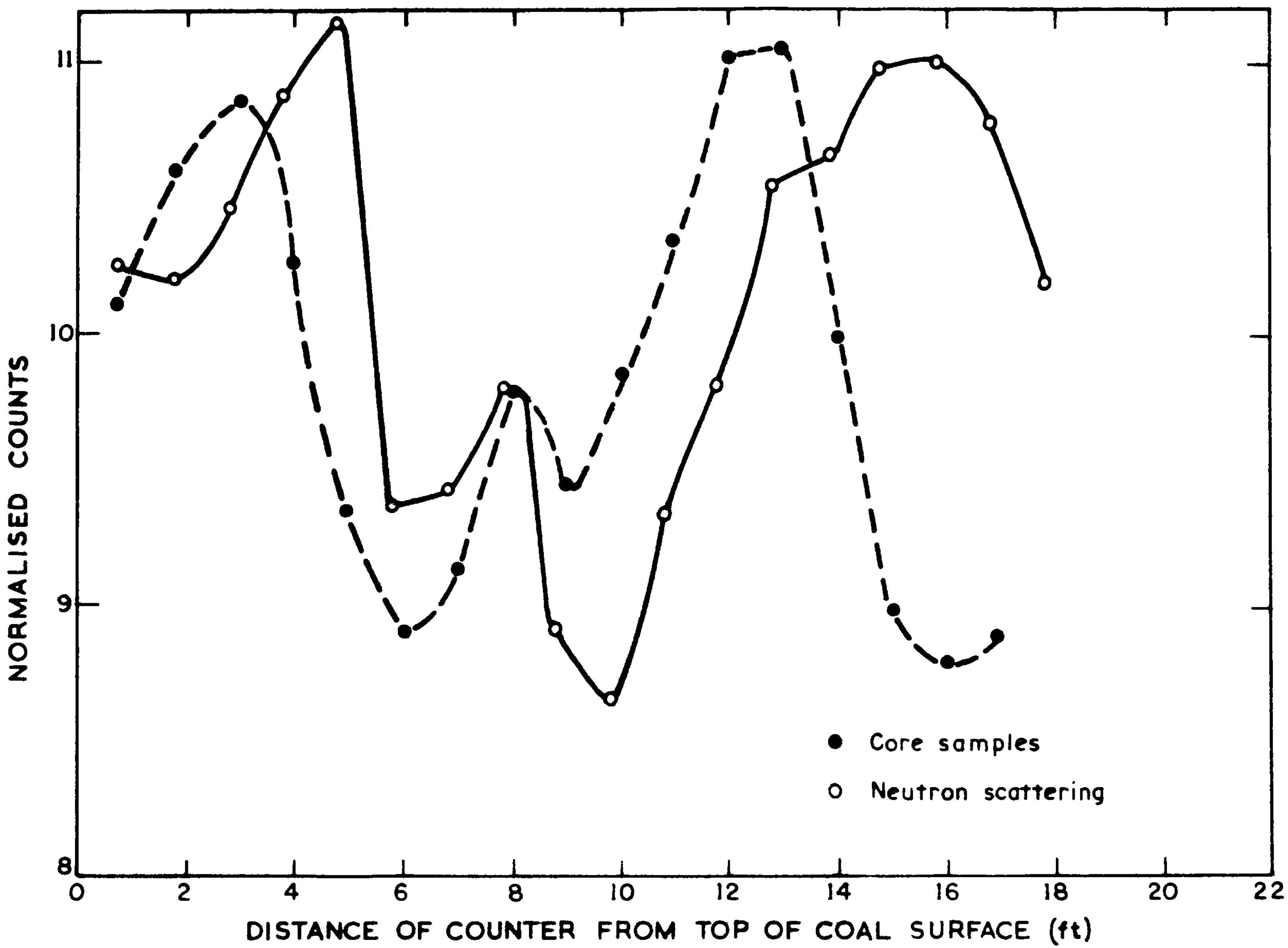

FIGURE 4. COMPARISON OF NEUTRON SCATTERING MEASUREMENTS OF CORE SAMPLES AND IN-HOLE VCS1/A5

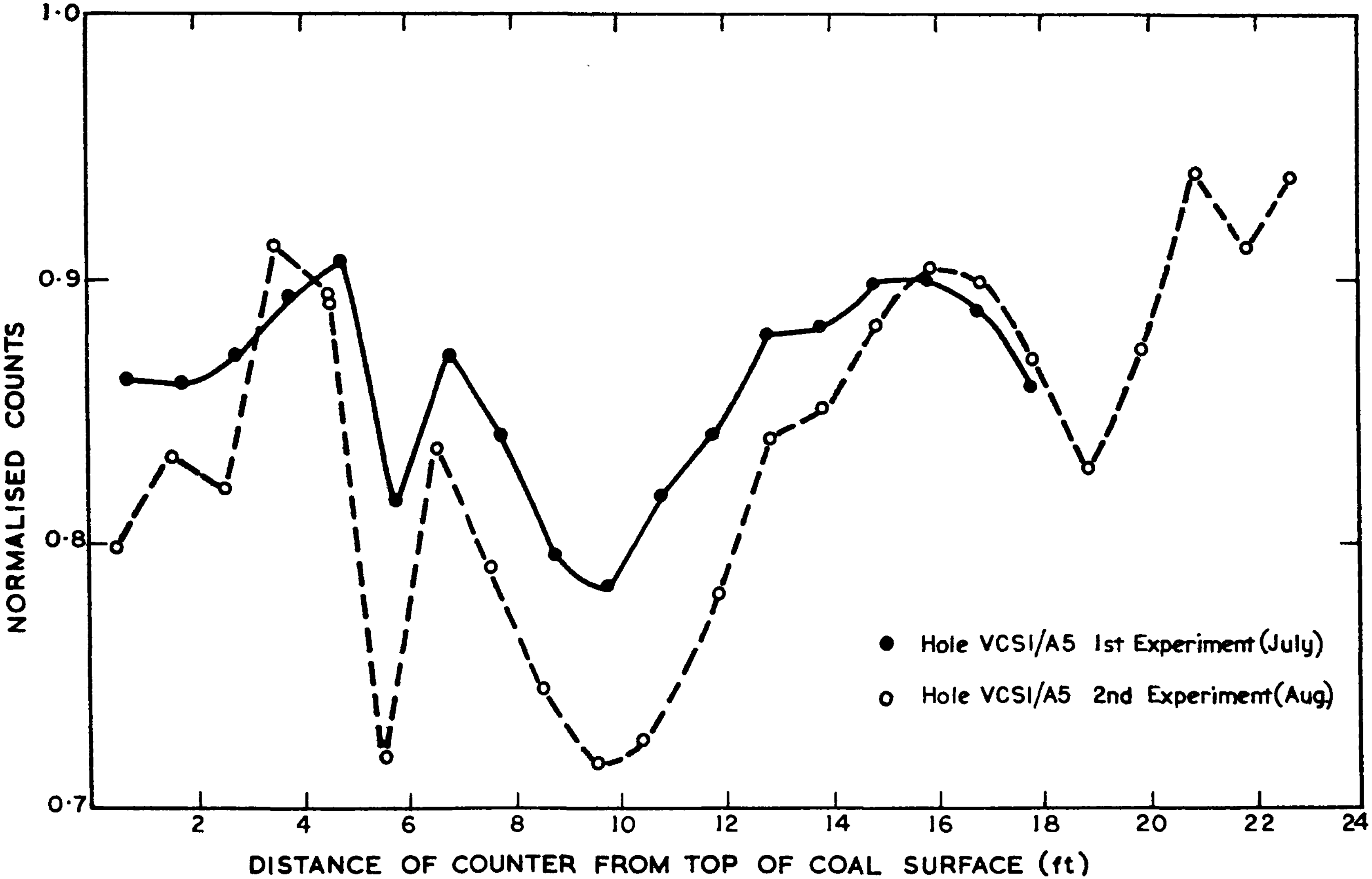

FIGURE 5. COMPARISON OF NEUTRON SCATTERING EXPERIMENTS IN COAL STACKS

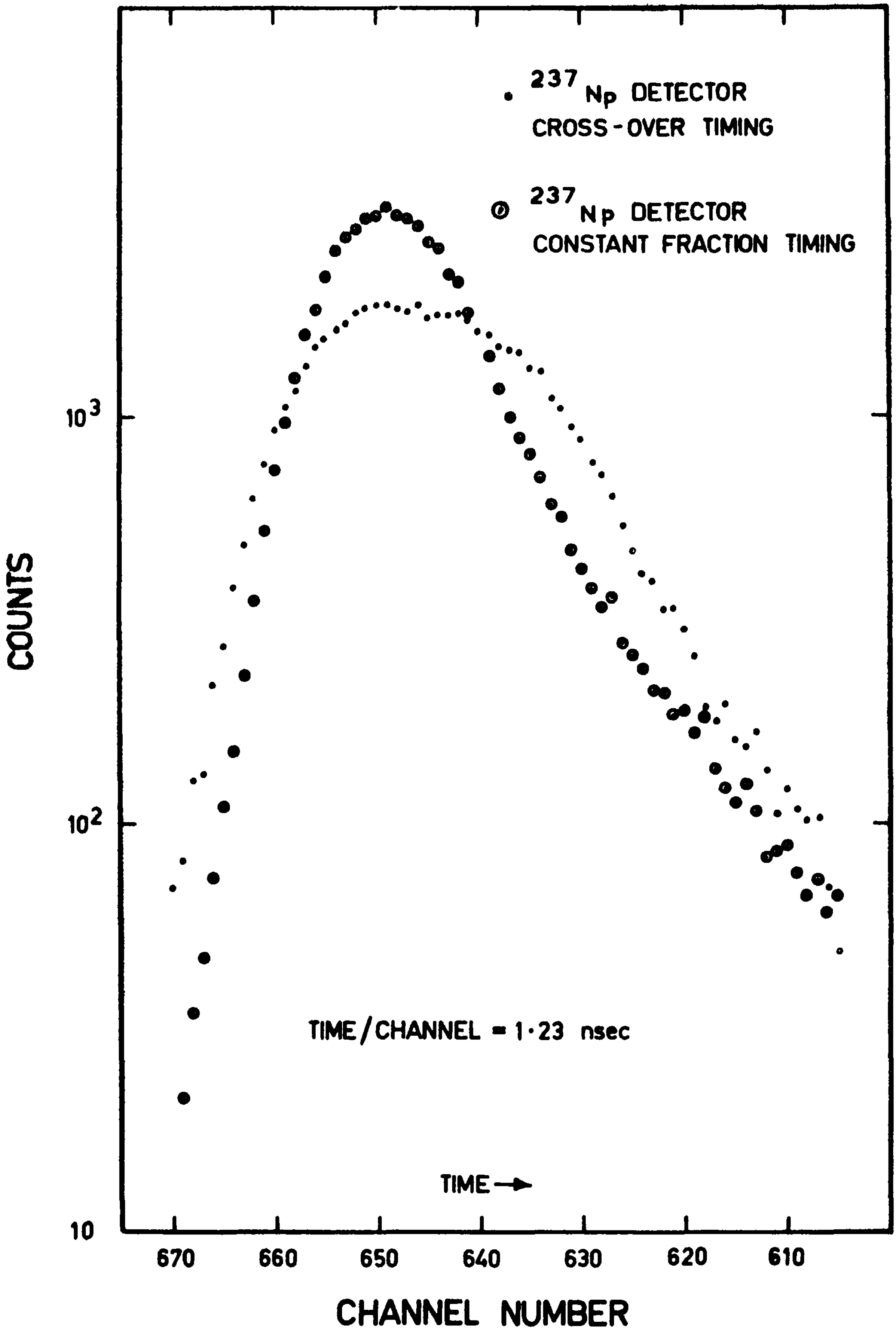

FIGURE 6. TIME-DEPENDENT RESPONSES OF A ^{237}Np PULSE FISSION CHAMBER MEASURED IN THE THORIUM ASSEMBLY

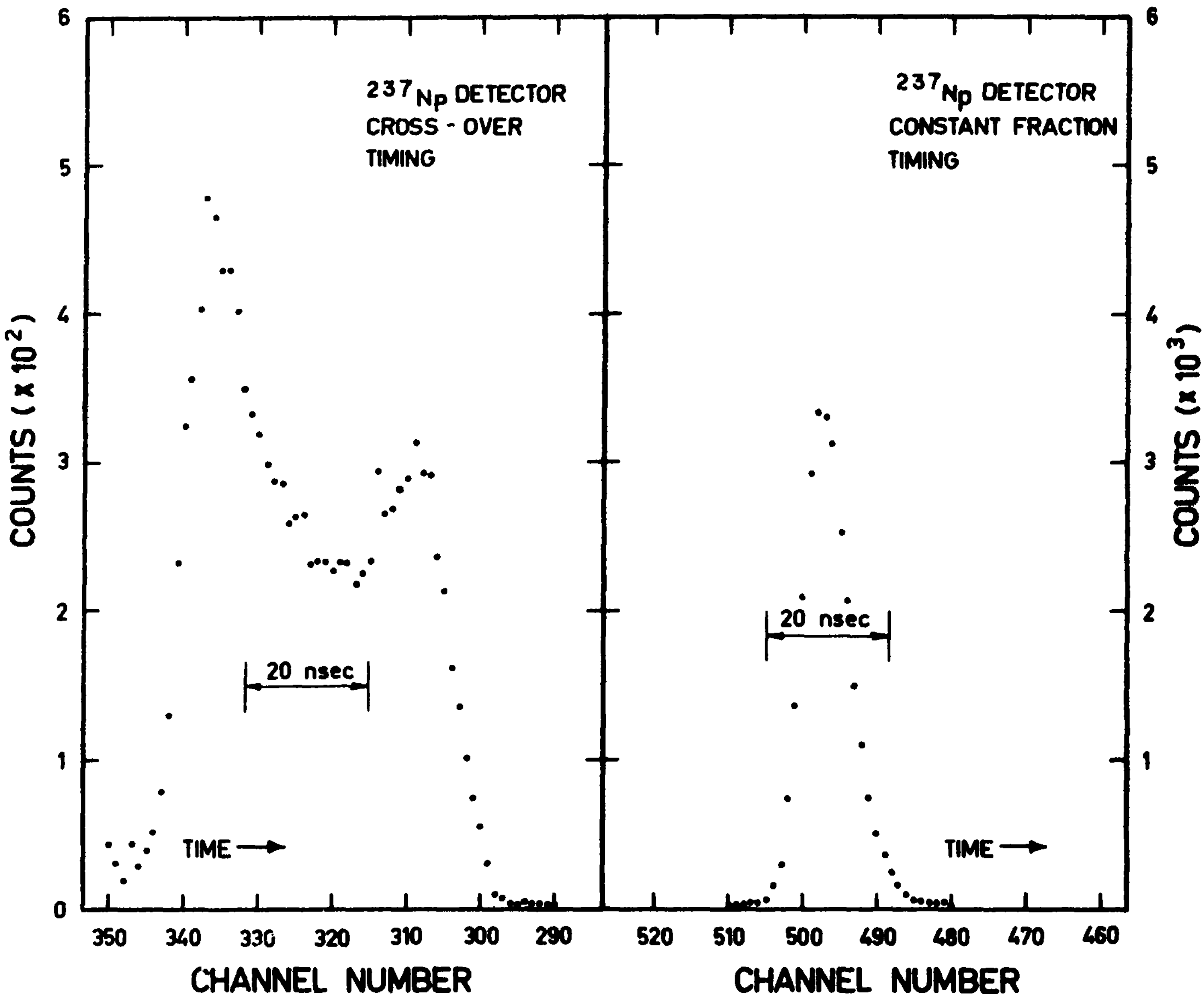

FIGURE 7. TIME DEPENDENT RESPONSES OF A ^{237}Np PULSE FISSION CHAMBER MEASURED IN THE ABSENCE OF A SCATTERING MEDIUM

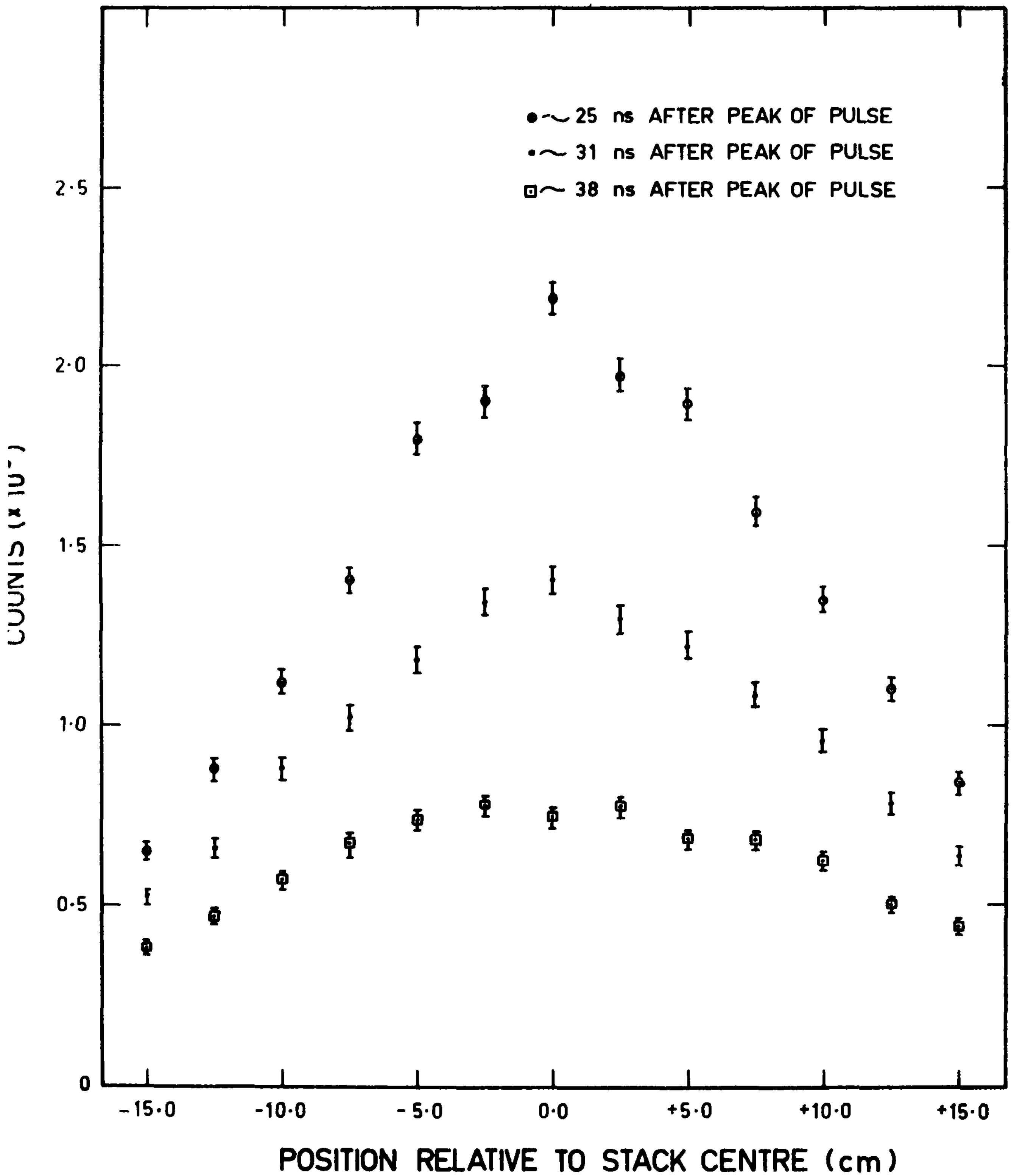

FIGURE 8. SPACE-DEPENDENT RESPONSES OF A ^{237}Np PULSE FISSION CHAMBER IN THE THORIUM ASSEMBLY

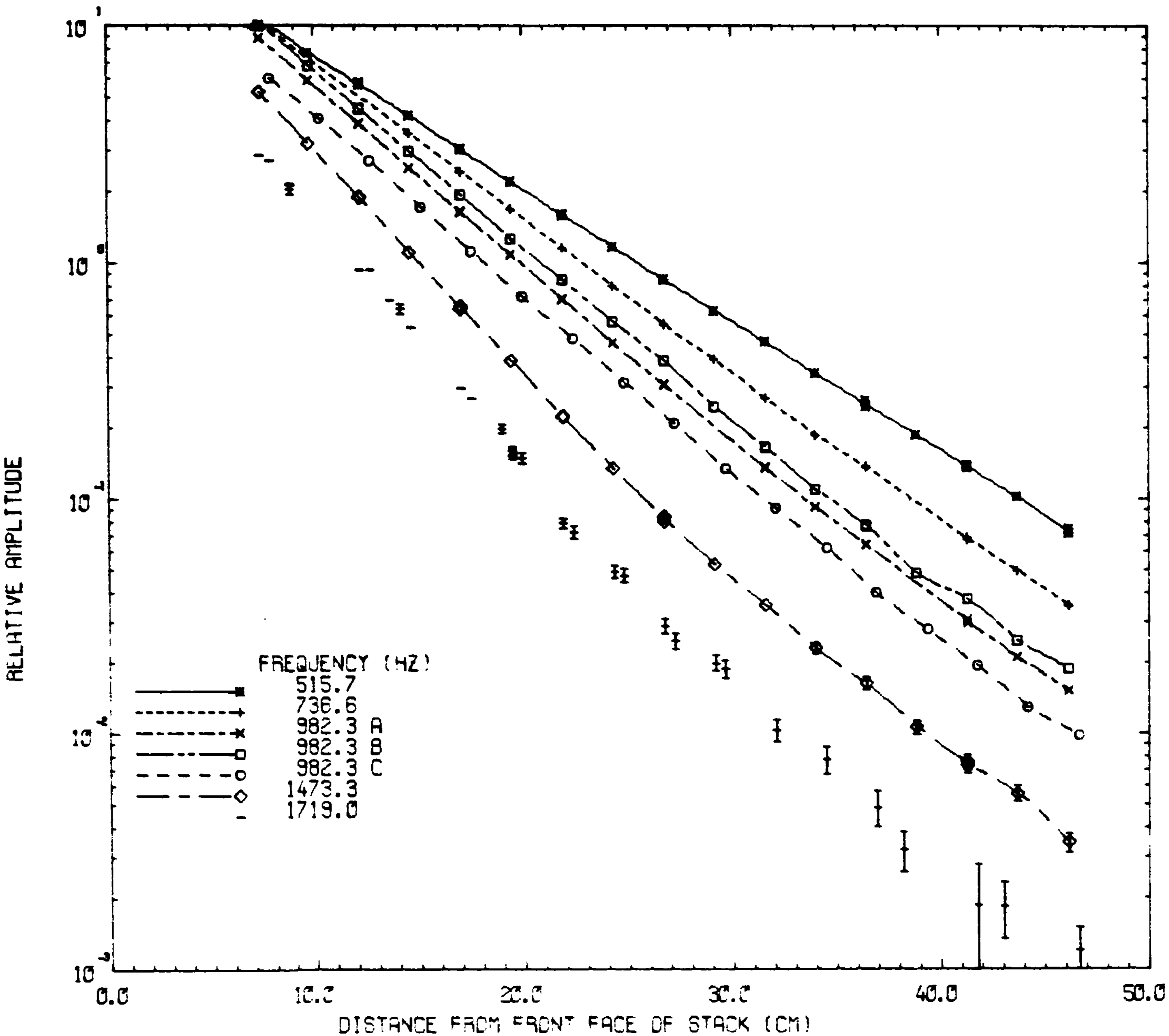

FIGURE 9. HIGH FREQUENCY NEUTRON WAVE EXPERIMENT - COMPUTER OUTPUT - AMPLITUDE CURVES

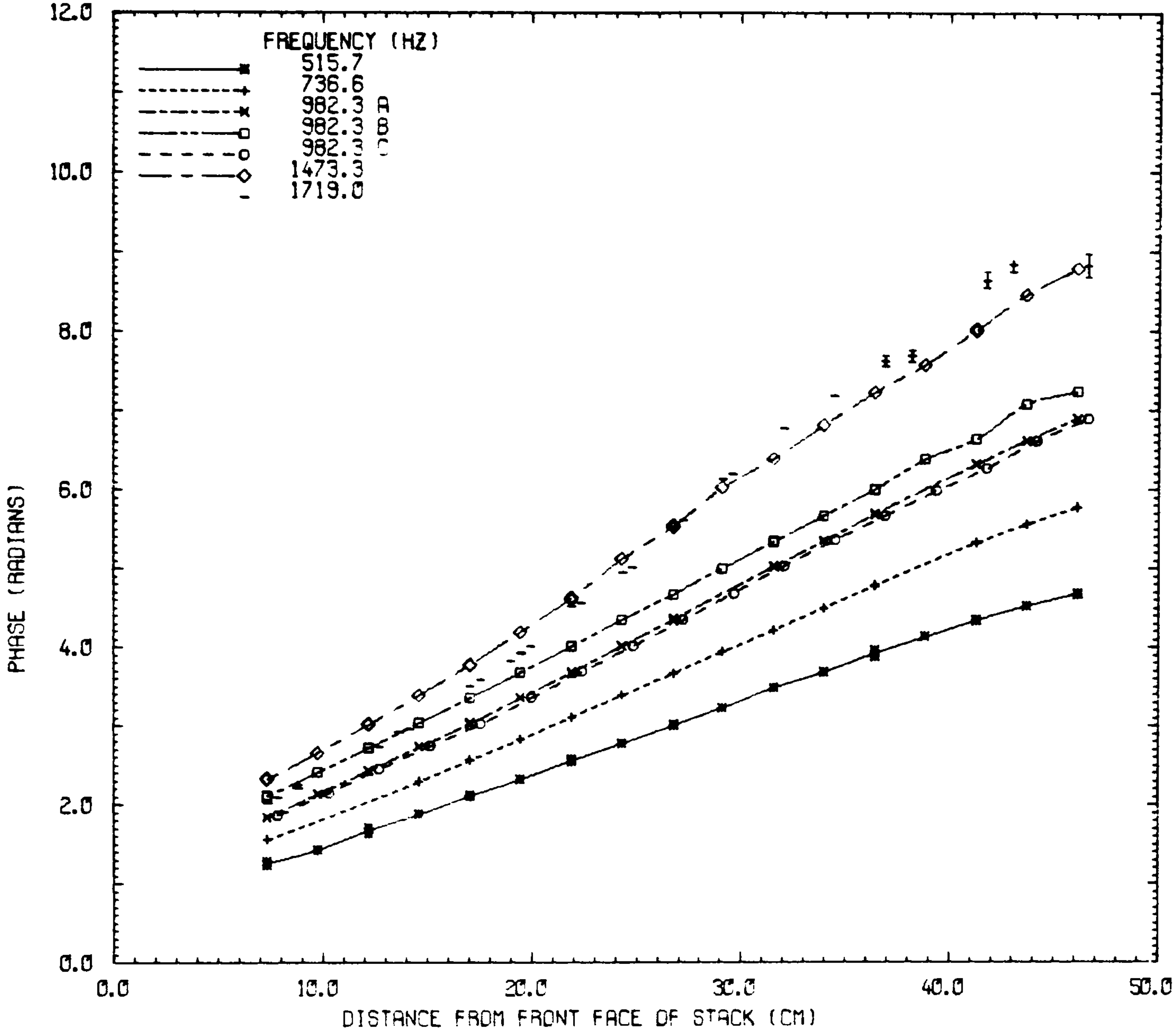

FIGURE 10. HIGH FREQUENCY NEUTRON WAVE EXPERIMENT - COMPUTER OUTPUT - PHASE CURVES

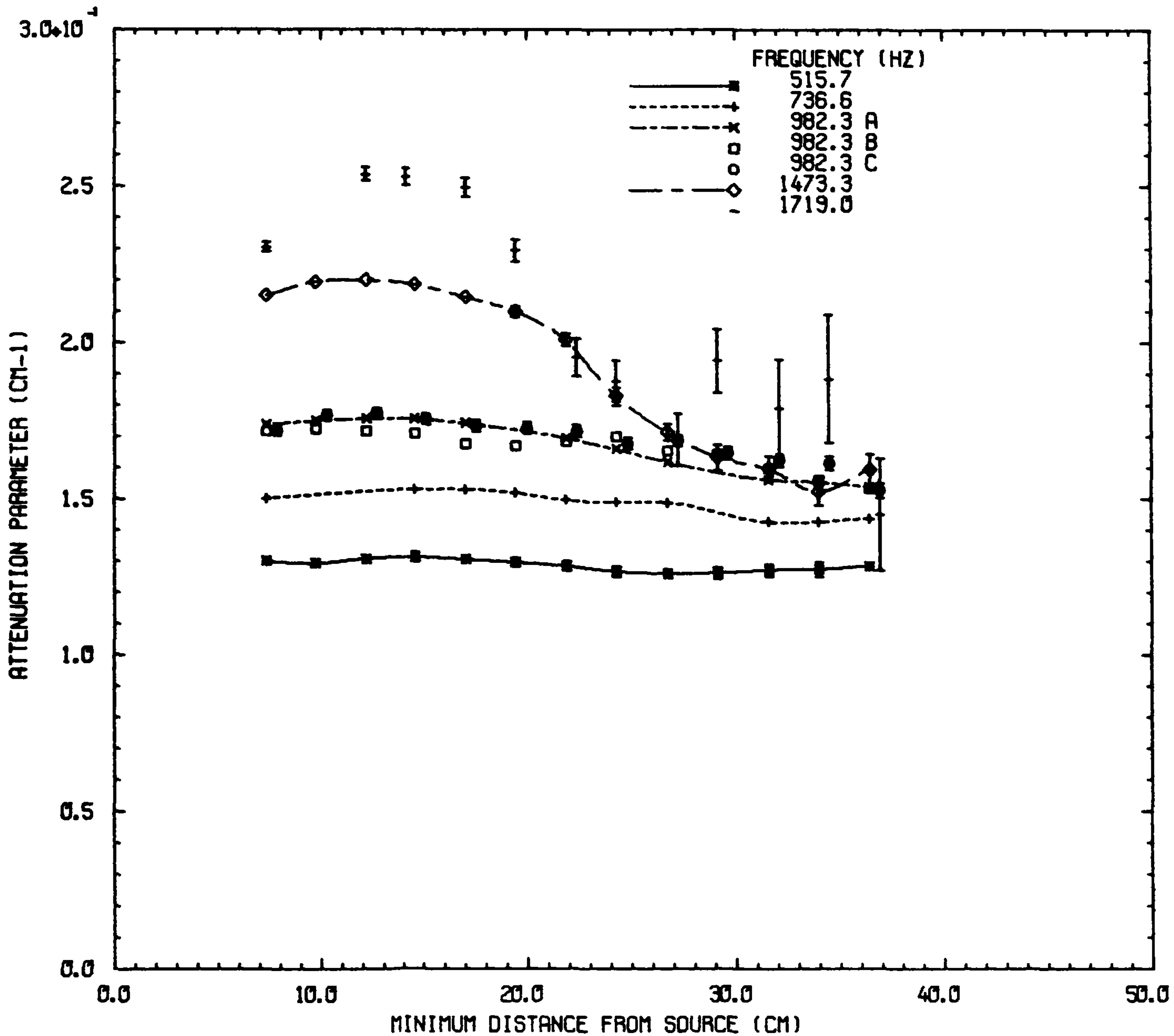

FIGURE 11. HIGH FREQUENCY NEUTRON WAVE EXPERIMENT - COMPUTER OUTPUT - ATTENUATION PARAMETERS

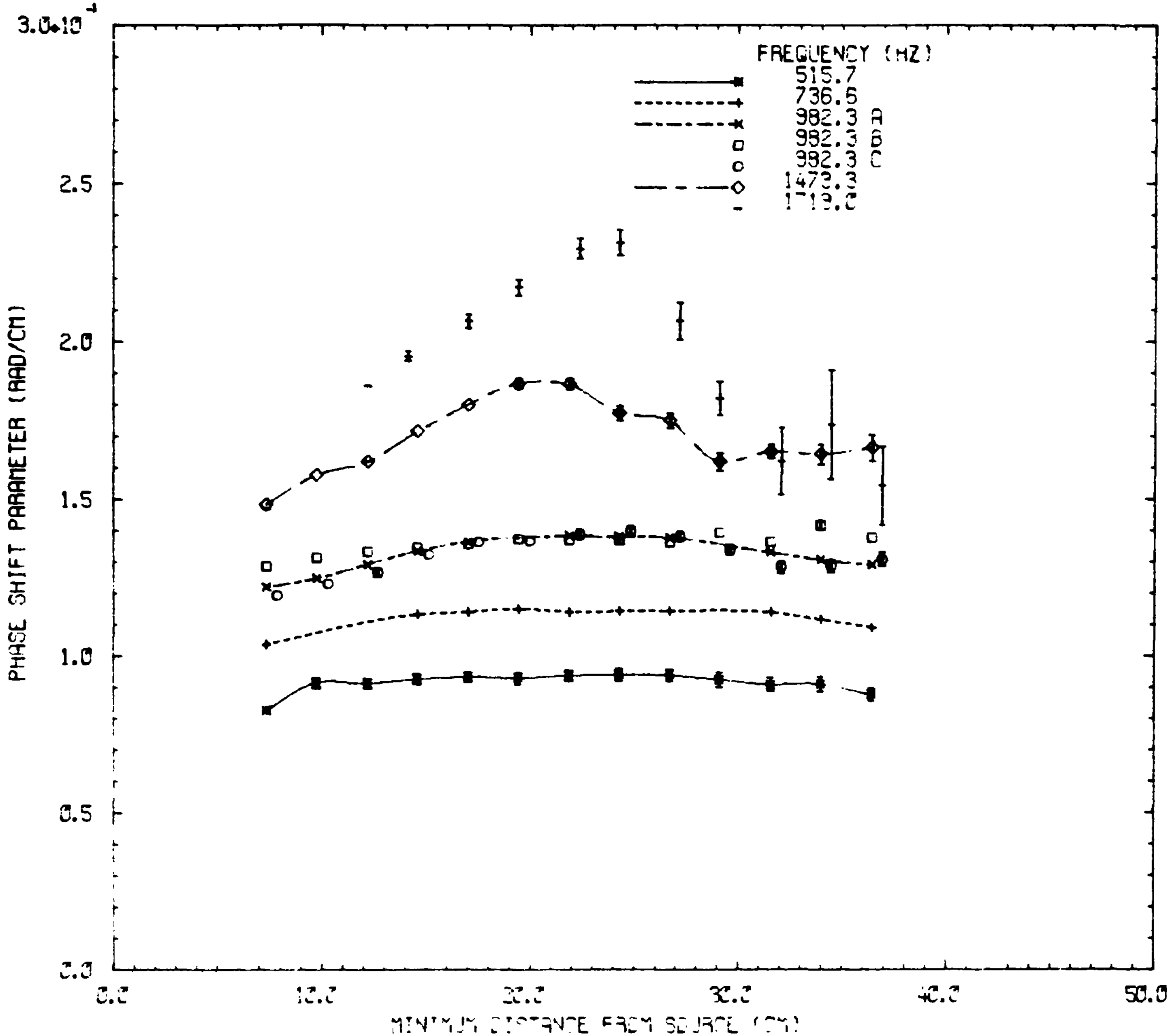

FIGURE 12. HIGH FREQUENCY NEUTRON WAVE EXPERIMENT - COMPUTER OUTPUT - PHASE SHIFT PARAMETERS

APPENDIX (PHYSICS)

STAFF

ACTING DIVISION CHIEF: MR. W. GEMMELL

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

General Reactor Physics Group

RS: J. Connolly
A. Marks (T)
A. W. Dalton
P. Duerden

EO: T. Wall
R. Knott

Technical Staff

TO: G. K. Brown

Heavy Water Group

RS: W. J. Turner
J. Harries

EO: A. Rose
G. Durance
D. Culley

TO: R. Jones
D. Stevenson

Pulsed Neutron Group

RS: A. I. M. Ritchie
M. Rainbow

EO: S. Whittlestone

TO: K. McMaster

Special Duties

EO: D. J. Wilson

TO: J. P. Sawyer
OA: R. Farmer

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

Neutron Capture Group

RS: M. J. Kenny
B. J. Allen (O)

EO: G. J. Broomhall (R)

Fission Physics Group

RS: J. Boldeman

EO: R. Walsh
P. Martin (R)

Technical Group

EO: M. Scott

Technical Staff

TO: A. van Heugten
J. Copland
H. Broe
L. Russell
TA: R. J. Cawley
OA: R. C. Hannan

ATTACHED STAFF

J. Biggerstaff	(O.R.N.L.)
S. G. Boydell	(University of Melbourne)
D. M. H. Chan	(University of Melbourne)
F. Hille	(Cook University, Townsville)
P. D. Lloyd	(A.I.N.S.E.)
J. Mathur	(University College, Wollongong)
J. Caruano	(University College, Wollongong)
D. B. Stroud	(University of Melbourne)
S. Kannard	(A.I.N.S.E.)

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

Nuclear Physics Group

RS: G. Derrick (R)
W. Bertram
D. Lang (C)

Nuclear Data Group

RS: J. Cook
A. Musgrove

EO: H. Ferguson
E. Clayton

Reactor Physics Group

RS: D. A. Newmarch
I. Donnelly

EO: G. Doherty
K. Maher
E. Rose

Reactor Codes Group

RS: J. Pollard

EO: B. McGregor (O)
G. Robinson
B. Harrington

TA: G. Trimble
J. D'Souza (R)
M. Inkster

APPENDIX (cont'd)

Neutron Source Group

RS: G. Hogg
J. Tendys

TO: J. Daniel

Technical Staff

TO: J. Fredericks

(C) Commenced

(O) Overseas

(R) Resigned

(T) Transferred

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

PROGRESS REPORT FOR APPLIED MATHEMATICS AND COMPUTING SECTION

1st APRIL 1971 – 30th SEPTEMBER 1971

HEAD OF SECTION – DR D. J. RICHARDSON

Note: Applied Mathematics and Computing Section
is responsible to Deputy Director

CONTENTS

1. INTRODUCTION

A new multi-programming computer operating system (MVT) was introduced for general use in July. This system has improved the general computer job turn-around, and has also provided the facilities necessary for the software implementation of the forthcoming computer network.

Most of the IBM 360 software for the computer network has now been written, and many applications are envisaged when the first stage of this network has been completed with the DATAWAY linking of the PDP9L and NOVA computers.

Mathematical and programming assistance to the staff of other divisions and sections is increasing, and is a major part of this Section's work. An assembler for the Honeywell 316 computer was written to run on the IBM 360 computer.

The ACL-NOVA language is now widely used on site, and a new visual display terminal is being ordered to enhance this use.

Mr. J. W. Kiel joined the section as Computer Operations Manager in August.

A facility was devised to enable the IBM 360 computer to simulate and to report on its own operations. This facility has already proved useful in diagnosing and correcting obscure system faults.

2. PROGRAMMING SYSTEMS GROUP (Leader: C. B. Mason)

2.1 IBM 360 Operating System Facilities

A major change in the computing facility of the IBM 360 was the implementation of Release 19.6 MVT (Multiprogramming with a Variable number of Tasks) on 5th July, 1971. The reasons for changing over to MVT are basically twofold:

(i) the development of the DATAWAY requires the more sophisticated operating system afforded by the multi-programming capabilities of MVT;

(ii) the PCP operating system will, in the near future, no longer be supported by IBM.

As a bonus, it is expected that MVT will increase the workload capacity of the IBM 360 and give users an improved turn-around time for their jobs.

The maximum amount of core at present available to the users under MVT is 400 K. Because this is less than that allowed by PCP the latter operating system is being retained for the time being and is run at least twice daily.

The following two sections detail activities related to the Operating System facilities provided on the IBM 360.

2.1.1 Modifications and additions to the operating system (W. A. Angus, C. B. Mason)

The standard MVT system was modified in several areas to cope with the

DATAWAY. SMF (System Management Facility) exit routineswere added to check on job/user validity. In connection with this, a job class structure was set up to classify the system requirements of jobs. Output was also categorised according to amount and type.

A number of other changes were made to MVT to correct faults in the operating system and to adapt its functions to the particular needs of this installation.

2.1.2 FORTRAN compilers (W. A. Angus, P. Wood (IBM))

Release 19.6 of the FORTRAN compilers saw many longstanding bugs overcome. Notable among these were the correction of the backspace file/record problem, the closing of data sets after an ABEND and the setting of register 1 to zero for FORTRAN calls without argument lists. An attempt was also made to correct some deficiencies in optimisation (level 2).

In this latter respect particularly, more bugs were introduced than corrected and users found it almost impossible to get a reliable OPT=2 compilation. The altered processing after an ABEND left much to be desired, as nearly all diagnostic information relating to the ABEND was lost.

Following requests to IBM, we were supplied with Release 20.1 versions of the FORTRAN compilers. These have been implemented, as an alternative FORTRAN system, for testing purposes and to date all problems mentioned above appear to have been corrected and no new faults have been found. It is expected that these compilers will replace the Release 19.6 versions as the standard early in November.

2.2 Program Problems due to PCP/MVT Changeover

The changeover to MVT went relatively smoothly for most computer users. This is because PCP and MVT are very nearly compatible in the area of higher-level languages. The only obvious differences occur in the Job Control Language (JCL), with the addition of a number of extra keywords and parameters in MVT, all of which are ignored in any PCP run.

This compatibility does not necessarily follow in Assembler language routines that rely on the behaviour of the Operating System itself.

The following are a number of such programs and subroutines which had to be rewritten by members of the group.

2.2.1 AELINK - a dynamic program linkage facility (C. B. Mason)

AELINK when it was originally designed three years ago made use of a system data set SYS1.SYSJOBQE as a work file. Under MVT, this data set is used continuously by the system, for the saving of information related to each job in core storage and all jobs in any of the input/output queues. It was thus no longer possible for AELINK to use this data set. New routines were written to make similar use of a new temporary data set with the result that AELINK will now operate under either MVT or PCP.

2.2.2 AEFORT - fast FORTRAN compiler (I. J. Hayes)

As mentioned previously (AAEC/PR34-P) the ABACUS FORTRAN compiler cannot be used under MVT because of the special way it handles input/output. It was considered too difficult a task to convert ABACUS for use under MVT, so a new compiler was designed, called AEFORT, which will make better use of the operating system facilities. Work on this batch-processing compiler is continuing and the majority of FORTRAN statements can now be compiled and executed.

2.2.3 GPACCT (C. B. Mason)

GPACCT supplies a calling program with its related job accounting information, e.g. programmers name, account number, time and date. This has been used to prepare headings on graph plots and leaders on paper tapes. MVT and PCP handle accounting information in completely different ways, and so GPACCT was rewritten to cope with either Operating System.

2.2.4 SCLOCK and CLOCK (I. J. Hayes)

These two subroutines are used by FORTRAN programmers to give a measure of time passed since the start of each job. They have been rewritten so that under MVT, Central Processor (CPU) time is given and under PCP, elapsed real time.

2.2.5 PDP9OXCT and PDP9LXCT (C. B. Mason)

These routines transmit programs to the memory of the PDP9L computer over the IBM 360/PDP9L Link. This allows the rapid transfer of any monitor system or program to the PDP9L. In the past, it was necessary for the input/output routines within PDP9OXCT and PDP9LXCT to be of a non-standard, non-OS compatible nature. MVT both forced a change and provided an opportunity for the redesigning of these routines. They now use the standard Execute Channel Program (EXCP) input/output facility but do not require DD cards.

2.3 Software Development and User Support

2.3.1 APL language (I. J. Hayes)

Iversons' language APL (A Programming Language) is being implemented in conjunction with the University of N.S.W. This language is gaining world-wide popularity and we look forward to its availability on our computer. The lexical analysis stage as well as the systems and input/output routines have been completed.

2.3.2 STAGE2 (I. J. Hayes)

The STAGE2 macro processor developed by W. M. Waite of Colorado University was implemented on the IBM 360 Assembler language. A talk was given to Commission staff on its implementation and uses.

2.3.3 SYSQSP - system queue space (I. J. Hayes)

This routine is for use under MVT only, and supplies the computer operator with the amount of free space currently available in the System Queue (SQS) portion of the Operating System. An operator monitoring this figure can now prevent the SQS from over filling, as may occur if too many tasks become active at once.

2.3.4 AESWITCH (C. B. Mason)

The IBM 360 machine instruction set includes a number of 'privileged' instructions which can only be used by programs operating in the 'supervisor' state. Most IBM 360 installations, including the A.A.E.C., have written special supervisor call (SVC) routines whose purpose is to put the calling program into the 'supervisor' state. Unfortunately, the mechanics and use of such SVC routines appears to be very installation dependent.

With the possibility of programs being used at other installations, it was decided that the SVC call should be placed within a separate subroutine AESWITCH. Another installation can then write its version of AESWITCH to interface with the A.A.E.C. program without any need for modification of that program at the source level. The University of N.S.W. made use of this facility in adapting our AECOPY program to their computer.

2.3.5 GYMEA - Release 19.6 (C. B. Mason)

During the implementation of Release 19.6 of the Operating System, it was discovered that the frequently used nuclear code GYMEA would not run under this new system. The GYMEA load module consisted of routines compiled under Releases 14, 17 and 18 of OS and Release 14 FORTRAN library modules. Some of these were found to be incompatible with the Release 19.6 access methods and I/O Supervisor.

The problem was overcome by the complete recompilation of GYMEA and its controller, GYMEAX, under the Release 19.6 FORTRAN (H) compiler. Up-to date FORTRAN library modules were used and some changes were made to the GYMEA source to overcome compiler differences.

GYMEA is now independent of past releases of OS for the first time since it was originally developed by Physics Division.

2.3.6 IBM 360 to PDP9L link modification (I. J. Hayes)

A hardware fault in the PDP9L link to the IBM 360 was investigated and a suggested change to the hardware was discussed with Instrumentation and Control Division.

2.4 Education (W. A. Angus, I. J. Hayes)

A week long JCL course was given to Commission staff following the introduction of MVT to acquaint them with the new concepts introduced by MVT as well as with the standard features common between PCP and MVT.

3. COMPUTER UTILISATION AND RESEARCH GROUP (Leader: P. L. Sanger)

3.1 ACL-NOVA (P. L. Sanger)

The ACL-NOVA system has successfully completed a series of extensive field trials. The system has already proved to be very useful to many of the Commission's scientists, and the number of users will no doubt increase when terminals are available at different locations on site.

3.2 Tektronix Graphical Display Terminal (P. L. Sanger, G. W. Cox)

The Tektronix graphical display terminal attached to the NOVA computer was first delivered in May 1971. There were a number of problems associated with the NOVA interface required to control the display and this delayed acceptance until 5th October, 1971. Special software was written to test the display interface and to check that the display terminal was fully operational.

IBM 360 software compatible with the CALCOMP plotter software was written to allow graphical output from a FORTRAN program to be punched on to paper tape in a condensed format. This paper tape could later be read into the NOVA computer and the results drawn on the screen of the graphical display terminal.

Programs to use the display's interactive capabilities are currently being written. However, the full power of the graphical display terminal will not be realised until the NOVA is linked to the IBM 360 computer via the DATAWAY.

3.3 Loaders for the NOVA Computer (G. W. Cox)

A new bootstrap loader and binary loader has been written for the NOVA computer. The bootstrap loader tape format is four times as compact as that supplied by the manufacturer, while the binary loader contains comparing, displaying and monotonic loading options. Output from the binary loader can be sent to the graphical display terminal and the new loading system has overcome problems that were associated with teletype paper tape reading errors.

3.4 ACL Software (P. L. Sanger, R. P. Backstrom)

A number of demonstration programs and application packages have been written in the ACL language to be run on the ACL-NOVA system. The application packages include matrix inversion, general linear and non-linear regression and integration using Simpson's rule.

3.5 Polarised Neutron Spectrometer (G. W. Cox)

This project has been delayed by problems associated with hardware and the availability of technical staff. Calibration of the spectrometer is now in progress.

3.6 Paper Tape Input to IBM 360 (G. W. Cox)

A general program PTREC has been written for the IBM 360 computer to convert string-oriented data to record-oriented data. If used with paper tape input, this program replaces with more generality the functions of PTPGM which was specific to one paper tape code and one format. The new program optionally gives FORTRAN users a look-ahead verification of data format.

A program PTCOPY, which copies paper tape input on to magnetic tape, has been written so that users could make use of this paper tape facility under both the PCP and MVT operating systems.

4. APPLIED MATHEMATICS GROUP (Leader: J. M. Barry)

4.1 Program Development

4.1.1 AECOPY (R. P. Backstrom)

A magnetic tape utility program that was available under PCP and which bypassed the Operating System for all tape input/output, has been extensively modified to run under MVT. The command language is unchanged but all the tape I/O is performed using facilities available in both PCP and MVT.

4.1.2 PDPGENER (R. P. Backstrom)

This has now been generalised to accept either EBCDIC or column binary object deck input and to produce either type of output. PDPGENER may now be used to create libraries of DATAWAY computer programs on disc for transmission from the IBM 360 computer to any computer on the DATAWAY.

4.1.3 A console initiated program TAPETEST (R. P. Backstrom) has been written for the purpose of testing magnetic tapes on-line during periods when the tape units are free. Numbered records are written from the load point to the end of tape marker, and are read backwards. Errors are noted and the severity and distance from the loadpoint are indicated.

4.1.4 The CONCHITA program to convert IBM 7040 FORTRAN into IBM 360 FORTRAN has been rewritten to run under MVT. (R. P. Backstrom)

4.1.5 A program to transfer the PDP9L program QNPRINT from the IBM 360 to the PDP9L ahead of SYSOUT=D information from the IBM 360 has been written. (R. P. Backstrom). Programmers wishing to use the Anelex printer may now override SYSOUT=A with SYSOUT=D.

4.1.6 A program H316ASM to assemble Honeywell 316 assembler source statements on the IBM 360 was developed. (S. G. Johnson)

4.1.7 Modifications to the FORTRAN syntax analyser AESYNTAX were made (J. M. Barry) to remove errors encountered in the first months of operation.

4.1.8 Investigation into the applications of finite element techniques to elliptical boundary value problems are being carried out with a number of trial programs having been written. (J. M. Barry)

4.1.9 Work has commenced on an assembler program to perform KWIC indixing as an eventual replacement for the current PL/1 program. (J. M. Barry)

4.2 Assistance to Commission Staff

A main function of the Applied Mathematics Group continues to be the provision of programming and mathematical assistance to computer users. The nature of assistance varies from short discussions on the use of various mathematical techniques, and the correction of errors in programs through to the provision of programming packages. Areas in which assistance was provided include:

1. Documentation and assistance with the operating system maintenance. (S. G. Johnson)

2. Assistance to Ceramics Section with data analysis. (S. G. Johnson)

3. Reading of information on the SHARE library tape and the extraction of required programs. (R. P. Backstrom and J. M. Barry)

4. Assistance to Irradiation Research Section with regression analysis. (K. McGregor)

5. A system for the computerised production of graph plots from experimental data for Radiation Biology Section. (J. W. Bills)

6. Alteration to the STRESS-STRAIN-CREEP program for Head Office. (J. M. Barry)

7. Production of compound interest tables for Head Office. (G. J. Fisher)

8. Rewriting a program to assist Reactor Chemistry in nitrogen and krypton adsorbtion studies. (K. McGregor)

4.3 Education

A FORTRAN programming course and an ACL-NOVA course were provided.

5. COMPUTER OPERATIONS GROUP (Leader: J. W. Kiel)

5.1 Computer Usage

Usage figures for the IBM 360 50I computer are set out in the following table. Totals for the previous six months are shown for comparison, although such a comparison may not always be valid because of changes in the time recording method.

COMPUTER USAGE (HOURS)

Month		A.A.E.C. Usage	Universities A.I.N.S.E.	Outside Users	Total Usage		
					Processor Time	Meter	Number of Jobs
PCP Operating System		Elapsed Time in Hours for all Submitted Jobs					
	April	292	7	2	301	302	3,569
	May	402	5	-	407	407	4,312
	June	435	1	1	437	370	4,294
MVT Operating System		C.P.U. Time in Hours for Executed Job-Steps					
	July	180	11	-	191	412	4,192
	Aug.	203	9	-	212	456	3,656
	Sept.	172	5	1	178	391	3,096
TOTAL		1684	38	4	1,726	2,338	23,119
For previous six months		2,376	33	8	2,417	2,238	23,688

The above figures show a significant difference in the 'A.A.E.C. Usage' and the 'Total Usage (Processor Time)' columns on and after July 1971. This difference is caused by a new method of measuring usage time which came into operation with the introduction of MVT. Under this new system, a user job is charged for the time that each of its executed job steps had control of the Central Processing Unit (CPU). This time does not include periods when the job step is waiting for some input/output response, when a higher priority job has taken over control of the CPU, when the job is initially being read and interpreted, when the system is initiating each step or when the output in SYSOUT queues is being written on to printers, etc.

In contrast, the PCP Operating System recorded a total elapsed time for each job which included all the non-CPU periods mentioned above. In addition, the total job time was rounded up by 0.01 hours (36 seconds) to account for inter-job system overhead and other factors affecting job timing.

If comparisons are to be made between the halves of the period or with the previous six months, they should be confined to the 'Meter' and 'No. of Jobs' columns as these figures are not significantly affected by the PCP/MVT changeover. One small effect is that jobs read in under MVT and cancelled at 'reader' time because of JCL errors are not recorded in the 'No. of Jobs' column, as they have been in the past under PCP. This may explain the apparent drop in the total number of jobs.

The average monthly computer usage was 390 hours (meter time). The average job elapsed time under PCP was 5.6 minutes compared with 6.5 minutes in the previous six months. The average job CPU time under MVT was 3.2 minutes.

Significant proportions of the computer usage were:

Theoretical Physics	(24.2%)
Experimental Physics	(15.0%)
Administration	(13.6%)
Applied Mathematics and Computing	(12.8%)

5.2 Programming Assistance

The computer operations group has been reorganised to allow one of its members to assist users full-time with computing problems. This assistance will be additional to the normal access to the section's programming staff, who will continue to be available for programming assistance including the solving of more difficult problems.

5.3 Computer User's Group

A 'Computer User's Group' has been formed by the ten divisions currently using the computer. Representatives from each division will now meet as required (initially monthly) to provide communication between users and the Applied Mathematics and Computing Section representatives.

5.4 Systems Bulletins

A series of publications, known as 'Systems Bulletins' will be published as a means of communicating with computer users. The existing 'User Notes' communication will continue, but will be supplemented by the Systems Bulletins. Users who submit jobs infrequently and, as a result, receive 'User Notes' infrequently will be updated by the Systems Bulletins. The Bulletins will also cover a wider scope than the User Notes, including a reference to publications.

6. PUBLICATIONS

Richardson, D. J. (1971) - The A.A.E.C. Computer Network Design - The Australian Computer Journal, Vol. 3, No. 2, May 1971.

Sanger, P. L. (1971) - ACL-NOVA: A Multi-user Conversational Interpreter for the NOVA Computer - AAEC/E221.

APPENDIX

APPLIED MATHEMATICS AND COMPUTING SECTION STAFF

SECTION HEAD: DR. D. J. RICHARDSON

Programming Systems Group

EO: C. B. Mason (Leader)
W. A. Angus
I. J. Hayes

Computer Utilisation and Research Group

RS: P. L. Sanger (Leader)
G. W. Cox

Applied Mathematics Group

EO: J. M. Barry (Leader)
R. P. Backstrom
S. G. Johnson (Mrs)

Computer Operations Group

EO: J. W. Kiel (Leader) (C)

TO: R. S. Dunne
P. D. Williams

TA: H. B. Banister (Mrs)
D. P. Belbin
J. W. Best (Mrs) (T)
J. W. Bills
W. J. Blundy
G. J. Fisher
K. J. McGregor
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