INDC 303
IAEA/NPR/5

International Atomic Energy Agency

International Working Group on Fast Reactors

Meeting of Specialists on the Value of Plutonium Alpha

Winfrith, UK, 30 June - 1 July 1969

Summary Report

1. Introduction

The meeting of specialists on the value of plutonium alpha was held at Winfrith in accordance to the recommendation of the International Working Group on Fast Reactors, and in agreement with the UK authorities. Participants from six countries and two international organizations took part in the meeting, chaired by Dr. R.D. Smith of the United Kingdom Atomic Energy Authority. The list of participants is found in Attachment 1.

Dr. Fry, Director of the Winfrith Establishment, opened the meeting and wished it all success.

The Agenda - Attachment 2 - was adopted without any changes.

2. Differential Measurements

A short review on available data for plutonium alpha received by the IAEA Nuclear Data Unit was presented by Dr. Konshin. He referred to three experiments recently known where the measurements of the alpha-value have been made in the energy range of interest. These are the experiments by Schomberg, Sowerby and others,(1) by Ryabov and others,(2) and by Patrick, Sowerby and Schomberg.(3)

(1) M.G. Schomberg, M.G. Sowerby, F.W. Evans, EANDC(UK)100AL.

(2) J.V. Ryabov et al, AE, 24, 351 (April 1968).

(3) B.H. Patrick, M.G. Schomberg, M.G. Sowerby, EANDC(UK)96AL.

The data of Ryabov for the fission cross section are consistently lower than other measurements in the energy range below 600 eV and higher than other data above this energy, showing an almost constant value of alpha of 0.4 above 2 KeV. When alpha is close to 1, a given relative error in fission cross-section produces a double error in α.

In Ryabov's experiment, the efficiency of detection was low (20% for fission events and 30% for capture), and there was also probably a risk of confusion in identifying the nature of the events detected. Moreover, the background was very high (15 - 50% depending on the energy, in the case of fission, and 30 - 70% in the case of capture).

Patrick, Sowerby and Schomberg measured the fission and the total cross-sections of Pu^{239} by time-of-flight spectrometer, using the same samples and resolution conditions because of simplicity for multiple scattering correction. Normalisation of the data was done through eta. The values of α were derived from those results and from the scattering cross section. The scattering cross sections were calculated by them with an accuracy as large as 30% in the lower energy region and about 20% in the kilovolt region.

The fission cross section observed by Patrick et al in the energy region 1 - 7 KeV is relatively lower than the other existing data. In the region from 7 KeV to 25 KeV the Patrick's data agree well with the average values of the fission cross sections.

During this year two more experiments were carried out, where alpha was directly measured. These were the experiment of Gwin and others, and the experiment of Czirr. A further analysis of the alpha values by Schomberg and others has also been made.

Dr. R. Gwin and others have measured the fission and capture cross sections of Pu^{239} with the electron linear accelerator used as the neutron source. Measurements were carried out with a fission chamber and a scintillator as a capture detector. Preliminary data of α were obtained in the energy region from 100 eV to about 30 KeV. A fission chamber was used up to the energy of 2 KeV to determine

alpha, and then thick metallic Pu^{239} foils were used to extend the alpha measurements over 10 KeV. A combination of high bias (to detect mostly fission) and low bias (to detect capture and fission) were used for recording the capture detector data.

The primary normalisation of the fission chamber experiment was at thermal energy and 0.3 eV using values for α of 0.357 and 0.66 respectively. They found the fission chamber efficiency. With this normalisation they obtained the resonance parameters which were then used to normalise the metal foil experiments, to give α in the energy region about 3 KeV.

There is a reasonable agreement between the values of alpha obtained by using two different methods, including the points at 0.35 KeV, 0.65 KeV, and 0.95 KeV, where the alpha values coincide within the errors. The combined uncertainties are about 10 - 15%.

The direct measurement of alpha for Pu^{239}, using time-of-flight spectrometer, was made by Schomberg, Sowerby and Evans. The experimental arrangement consists of a fission neutron detector and a gamma-ray detector. The efficiencies of the two detectors for fission and capture events were assumed to be independent of incident neutron energy. There is some difficulty in evaluating the efficiencies of the detector for capture of γ-rays and for fission events.

The experiment was normalised by assuming the values of on the peaks of seventeen well-resolved resonances in the energy region below 100 eV. The values of α were obtained from the measurements of η obtained with the same energy resolution.

The normalisation of the Schomberg experiment was derived from a series of data which are in good agreement; it produces α-values which agree within its errors (say $\pm$ 0.05) with the data derived from the Derrien et al α-values.

The latest data of Schomberg and Sowerby are about 20 - 50% lower than their previous values, particularly in the energy range

from 2 to 20 KeV. These values on an average are about 15 - 30% lower than Gwin's and Czirr's data at the energy range from 100 eV to 4 KeV and about 15 - 20% higher than those at the energy from 5 KeV to 15 KeV, and as much as about 50% higher than those at 17 to 28 KeV.

The third set of α-values in the energy range of interest has been obtained by Dr. Czirr of Livermore.

The capture and fission cross sections and their ratio alpha have been measured for neutrons in the 100 eV to 10 KeV range. The data were obtained using the same detector for both capture and fission events. This detector consisted of a deuterated liquid scintillator. Fission cross-sections are obtained from the detection of knock-on deuterons and separated from gamma events by pulse shape discrimination. Capture events are obtained from the detection of the de-excitation gamma-rays in the same scintillator. Since the gamma data consisted of both capture and fission events, it was necessary to subtract a quantity proportional to the fission cross-section in order to obtain σ capture. The fraction to be subtracted was determined by normalising the neutron fission data at an energy corresponding to a very low capture-to-fission cross-section ratio (about 16 eV for Pu^{239}), to the Farrell's data obtained from multi-level analysis of the Pu^{239} fission cross section. Following the subtraction, the measured capture-to-fission ratio, α, was normalised to the value of 0.469 at 0.07 - 0.09 eV.

The effect of variations in the de-excitation gamma spectrum upon the observed capture cross section was estimated by the author. The true σ_c is expected to differ by less than 10% from the measured values due to effects arising from changes in the spectrum.

The Czirr results are on average 10% lower than the Gwin results up to the energy 5 KeV (except for two points at 0.75 and 0.85 KeV, which are 30% lower) but they coincide with those in the limits of the errors.

Mr. Barré observed that the fission cross section of Pu^{239} was measured by the time-of-flight method with the Saclay LINAC in the energy range 16 eV to 35 KeV.

A new gas scintillator containing 1 gramme of fissile material at liquid nitrogen temperature was used.

Experimental fission cross sections can be obtained from the CCDN centre.

Detailed results (resonance parameters) will be published later.

Reference: J. Blons et al "Measure à haute resolution de la section efficace de fission du Pu 239 par des neutrons de resonance", Compte Rendu, Acad. Sc., Paris, T-267, p. 901 - 904 (21 October 1968).

Dr. Schmidt reported on the Karlsruhe Van de Graaff measurements of $\sigma_f (Pu^{239})/\sigma_f (U^{235})$ by Pfletschinger and Käppeler in the energy range 5 KeV to 1 MeV, including the final mass determination of the fission foils by BCMN/Geel. The measurements use very thin foils (100 $\mu g/cm^2$) and a coincidence detection of both fission fragments. By this method 92 - 95% of the fissions are detected, the pulses from the α background are well separated from the fission fragment pulses, α pile-up is kept small and wrong coincidences are almost completely suppressed. The results will be published shortly. Below 150 KeV they are on average slightly higher than the values recommended by W. Davey; above 150 KeV there are still some corrections to be applied to the data.

Dr. Troianov said new differential experiments for measurements of α for Pu^{239} have been carried out in the USSR. The data obtained are considered as preliminary. The experiment was carried out at the pulse reactor IBR in the Dubna centre with the time-of-flight method using a flight path of 250 metres. Two sets of measurements used a reactor regime and a microtron regime. In the latter case the microtron was used as a source of neutrons to drive the reactor. The resolution was 15 nanosec/m and 220 nanosec/m respectively.

A counting rate in a fission chamber with "thin" layers of Pu^{239} and that of a large liquid scintillator for detection of from fission and capture in plutonium sample were compared. The fission chamber contained 120 mg of plutonium 239 and the sample thickness was 0.7×10^{21} nuclei/cm^2. The liquid scintillator was a 500 litre tank divided into two parts which fed into a coincidence system.

The background was monitored by resonance filters (Ag, Na, Co, Mn). Normalisation was carried out with well-resolved resonances in the energy range from 8 to 60 eV.

Preliminary data for Pu^{239} fission cross section and α were obtained. The uncertainty in fission cross sections was as much as $\pm$ 15%. Uncertainties in α measurements were of the order of 20 - 50% for the microtron regime and 15 - 20% for the reactor regime. In certain intervals of neutron energies there was no agreement between these two sets of measurements.

Dr. Sowerby presented recent data from the measurement of α in the energy range 100 eV to 30 KeV obtained using the Harwell Linear Accelerator time-of-flight spectrometer. The experiment was originally reported by Schomberg et al[1] and the new data replaces the original results and those reported by Schomberg et al[2] and Rae.[3] The detector has recently been rebuilt to investigate the anomalously high ratio of efficiencies of the gamma ray detector for fission and capture events. No reason has been found to doubt the validity of the data obtained with the original system. The data presented tended to be lower than the data of Gwin et al below 5 KeV and higher between 5 and 30 KeV. It was felt that much of the discrepancy was due to errors in normalisation.

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(1) Schomberg, M.G., Sowerby, M.G., and Evans, F.W., "Fast Reactor Physics, 1, 289, IAEA, Vienna (1968).

(2) Schomberg, M.G., Sowerby, M.G., and Evans, F.W., EANDC(UK)100AL.

(3) Rae, E.R., presented to EANDC Meeting, January 1969.

Values of evaluated average total (σ_{nT}) and fission (σ_{nf}) cross-section data were presented in the energy range 0.1 to 30 KeV. These were used to obtain the average capture cross section ($\sigma_{n\gamma}$) and hence α from the relation:

$$\langle\sigma_{n\gamma}\rangle = \langle\sigma_{nT}\rangle - \langle\sigma_{nF}\rangle - \langle\sigma_{nn}\rangle$$

where σ_{nn} is scattering cross-section.

These results agree with the direct measurements particularly below 1 KeV where comparisons are meaningful.

Dr. Gwin reported that the ORNL-RPI data on Pu^{239} relating to alpha have been reduced to neutron cross sections. The values of obtained from these measurements have been compared with the results of other measurements such as those of M.G. Sowerby of Harwell and J.B. Czirr of Livermore. This comparison shows that the results differ by an amount which is estimated to be of the order of 5 to 10% in σ_f/σ_a. An error of 5% in σ_f/σ_a is a reasonable estimate of the uncertainty in the ORNL/RPI data neglecting primary normalisation uncertainties at 0.025 eV. The uncertainty of the Livermore results are also about 5% in σ_f/σ_a. It is not clear at the present time that a significant part of the discrepancy among the various differential results is not due to normalisation.

The fission cross section for Pu^{239} as derived from the ORNL-RPI data is in good agreement with the measurements of James of Harwell. It is noted that the average cross section from 1 KeV to 25 KeV is the same for the James and the ORNL-RPI results while the average deviations for arbitrary energy 1 KeV intervals is about 5%.

3. Integral Experiments

Mr. Bouchard presented an outline of analysis and irradiation and critical experiments which can give evidence on Pu^{239} alpha values.

(1) Statistical analysis of integral experiments (BARRACA method)

The statistical analysis of a large number of integral experiments measured in fast critical assemblies gives tendencies to

modify the cross sections of the initial Cadarache set. This work was presented to the BNES London Conference: J.Y. Barré, M. Heindler, T. Lacabelle, J. Ravier, Lessons drawn from integral experiments on a set of multigroup cross sections, BNES Conference, 1/15, London, June 1969.

(2) Analysis of measurements in EBR-I, Mark III

The increase of α above 25 KeV selected in the preceding work brings a large improvement in the comparison of measured and calculated $\bar{\alpha}$ values. (Reference: BNES Conference, 1/15, London, June 1969.)

(3) Irradiation in OSIRIS

An irradiation of uranium and plutonium samples is being performed inside a capsule of Boron in the core of the swimming pool reactor OSIRIS.

The $\bar{\alpha}$ values will be obtained without using fission product yields - a check of the spectrum has been made in ISIS which is a low power exact mock-up of OSIRIS.

The results might be available before the end of 1969: J.Y. Barré, J. Bouchard, M. Darrouret, A. Meyerheine, R. Vidal, Measurement of Pu^{239} $\bar{\alpha}$ parameter in the 1 - 25 KeV energy range by irradiation in OSIRIS. To be published.

(4) Measurements in ERMINE

Measurements of Pu^{239} α from reactivity worths of small plutonium samples are being performed in the fast thermal critical assembly ERMINE with two methods. The first one already applied is the Boron calibration and the second one is a new method with use of a local chamber.

The results must be available in September 1969. J.Y. Barré, J. Bouchard, M. Darrouret, R. Vidal, Measurement of Pu^{239} $\bar{\alpha}$ by reactivity methods in ERMINE II. To be published.

Dr. Fischer reported on integral information on α from a Doppler experiment with a Pu sample in SNEAK.

The major contribution to the Doppler effect in a fast reactor is the energy region 0.1 to 10 KeV. Therefore a Doppler experiment

can give information on α, or rather on the set of resonance parameters used in the interpretation. The experiment does not give reaction rates, but rather an adjoint-weighted combination of the Doppler changes in reaction rates.

The experiments were done in SNEAK-33, which has a composition typical of a steam-cooled fast reactor. The assembly is described in more detail in Reference (1). Measurements were made in the normal core, where the fission term and the absorption term almost cancel to give a small net effect, and also in a boron-environment, where the fission term dominates.

Calculations were done: (a) with the low α data of KFK-120; (b) with the data evaluated by Pitterle[2] which agree well with Gwin; (c) with the original Schomberg data. The experimental results are between the calculations with the Pitterle data and the original Schomberg data, but closer to Pitterle. The uncertainties in the spectrum and adjoint spectrum are difficult to assess, so that the distinction between (b) and (c) is not completely conclusive on the basis of this experiment.

Mr. Meister observed preliminary results on a PCTR-type experiment carried out on the SNEAK zero power facility at Karlsruhe. The test zone contained Pu^{239} and U^{235} as main fissile isotopes and graphite as a nuclear acting material. The experimental K_∞-value is maintained with calculations using the 26-group MOXTOT set which is based on recent U^{238} capture data of Moxon and the Pu^{239} α-values of Gwin. However, large discrepancies have been observed for some of the reaction rates, especially the fission ratio Pu^{239}/U^{235}, which is about 12 percent higher than calculated. The final results will be published in a KFK report.

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(1) M. Edelmann et al, Paper 1.11 to the BNES Conference, London, 1969.

(2) T.A. Pitterle et al, Second Conference on Neutron Cross Section Technology, Washington, March 1968.

Dr. Campbell reported on recent integral evidence on Pu^{239} α-values and data from the UK Zero Power Experiments and on Dounreay irradiations.

The Zebra experiments which have contributed are described in the BNES Conference Paper by Sanders et al and the adjustments to the nuclear data to fit these experiments are described in the BNES Conference Paper by Rowlands and Macdougall. The spectrum and more particularly the reaction rate ratios measured in Zebra lead to the α-adjustments found, rather than the critical size data used in the fit.

The trends indicated are that at all energies below about 800 KeV the α-value for Pu^{239} should be increased above the value used in the FGL4 data set by about 10%. The FGL4 data follow the α-values of de Saussure et al at energies above about 20 KeV. Below this energy the α-value, increased over FGL4 by 10% is in close agreement with the average of the latest Sowerby and Gwin measurements and the value derived from total and fission cross sections.

At present no conclusions on Pu^{239} α-values can be drawn from the analyses of Pu-irradiations made in the Dounreay fast reactor. In the work done, fissions in Pu^{239} have been determined from the radiochemical assay of Ce^{137} and Cs^{144} mass spectrometer measurements. Whilst the results for in-core irradiations in DFR (where the spectrum is hard) show that the calculated α-value is about 10% low, a similar conclusion is obtained for the U^{235} α-value. Further attention is being given to the calculation and the spectrum in DFR and further irradiations and analyses covering core and blanket positions are being made. These will check the fission product yield data and make use of mass spectrometer measurements of stable Nd isotopes as well as radiochemical measurements of Ce and Cs in determining the number of fissions.

Dr. Chernick referred to inferences from BNL Pu-α rod, heavy water lattice experiments.

At BNL, a large series of exponential experiments of 0.600 in. rods of 10 wt. percent plutonium in aluminium clad with zirconium is under way. The spectra range from thermal through intermediate energies. Completed are experiments at the following moderator to fuel volume ratios: 1 : 1, 1.5 : 1, 2 : 1, 3 : 1, 4 : 1, 7 : 1 and 14.5 : 1, both for clean and boron poisoned lattices. By squeezing out all or most of the heavy water from the lattice very hard spectra can be obtained and such experiments are in progress.

Preliminary results show that ENDF-B cross sections yield a k_{eff} about 4% too high at the 1 : 1 volume ratio while Schomberg's (or Gwin's) data are in much better agreement with experiment. The good agreement of the exponential experiments with the latter data in the wider lattices (about 1% low in k_{eff}) indicate that the latter cross section data below 5 KeV are in good shape. The D_2O cross section data used agree with the measured age in D_2O. One also reaches the tentative conclusion that cross sections for Pu^{239} in the resolved resonance range are also in good shape.

Further theoretical work is under way to narrow the estimates of the material buckling of these lattices obtained with In, Au and Mn foils and further experimental work in much harder spectra is planned.

Dr. Till reported on integral experiments which are being carried out in Argonne National Laboratory.

(a) The Irradiation/Burnup Measurements performed, or in progress, in the U.S.

(i) EBR-2 - Argonne. 1 - 2 mg samples placed throughout core and blanket of EBR-2. Of the order of a dozen samples of U^{233}, U^{235}, U^{238}, Pu^{239}, Pu^{240} and Pu^{242}. Mass spectrometer analyses should be done in a couple of months.

(ii) EBWR - Argonne. 10 Cd-covered, 14 bare Pu^{239} samples. Analyses finished. Results for α in apparent agreement with ENDF/B, but spectrum such that quite insensitive to energies above 1 KeV.

(iii) ZPR-3 - Argonne. Specially designed assembly to emphasise kilovolt region. Pu^{239} samples, few p.p. billion 240. Status: Assembly 57 is on ZPR-3 now.

(iv) HFBR - Brookhaven. Six samples of Pu^{239} and U^{235} in boron-filtered central thimble. Irradiations completed and samples undergoing analysis.

(b) The Zero Power Measurements performed or in progress in the U.S.

(i) CFRMF - Idaho Nuclear Corp. Reactivity - reaction rate measurements in a 6 in. x 6 in. depleted U - B^{10} and U^{235} lined central section in R.M.F. Spectrum has about 1/3 of fissions below 40 KeV. Measurements completed by end of June.

(ii) BNL - D_2O lattices - Brookhaven. Exponentials using 10 $^{w}/_{o}$ Pu Pu-Al alloy. 12 lattices finished, experiments still going on. Current results indicate higher values for α than those in ENDF/B.

(iii) Argonne ZPR measurements. Assemblies 24, 24A (ZPR-9)
55, 55A (ZPR-3)

Measurements a completed set using:

(1) Two different methods on Assembly 24 - the U^{235} fuelled null composition. The reactivity-reaction rate method and the null method both gave agreement with ENDF/B and with each other for U^{235}, within the $\pm$ 10% precisions.

(2) The Pu^{239} reactivity-reaction rate measurements on Assembly 24 gave results slightly higher than the Gwin/Sowerby values, and the small null-zone 24A gave a result slightly lower than Gwin/Sowerby, and again the results of the two methods were well within the precisions.

(3) The large null-zone Pu^{239} fuelled ZPR-3 Assembly 55 which had a spectrum as similar as possible to Assemblies 24 and 24A, but which was very slightly harder in the final version, gave a result slightly higher than Gwin and about equal to Sowerby but with a precision that overlapped both.

(4) In summary, the set of measurements gave integral α results
by two methods:
on four compositions,
with reaction-rate measurements by three independent methods,
on U^{235} and Pu^{239} with the Pu having three isotopic contents,
as a function of sample size (three sizes of annulli and two plate thicknesses),
in spectra designed to put ~ 40% of Pu^{239} capture between 2 and 25 KeV and ~ 40% between 10 eV and 2 KeV.

These results will support either Gwin's or Sowerby's results. They contradict ENDF/B data, and do not agree as well with the early Schomberg results. They are not sufficiently sensitive to distinguish between Gwin's and Sowerby's values.

Panel members met together following the separate meetings of the two informal specialists groups which had discussed: (a) the differential data; and (b) the deductions from integral experiments. The conclusions reached by the two groups are summarised below.

4. Conclusions of the Discussions on the Differential Measurements and on the Evidence from Integral Experiments Relating to Pu^{239} Alpha and Data for Higher Plutonium Isotopes

4.1 Differential measurements of Pu^{239} alpha

The agreement between the different series of differential measurements has improved during the last year and the accuracy is now about $\pm$ 5% in $\frac{\langle \sigma f \rangle}{\langle \sigma a \rangle}$. (This is equivalent to an accuracy of $\pm$ 10% in alpha, when alpha is equal to unity.) Possibly some of the main remaining discrepancies are due to differences in primary normalisation. It was agreed that in order to aid in the solution of the normalisation problem the resonance alpha values used for normalisation should be based on eta and/or alpha measurements extending into the thermal energy range. It is suggested that Czirr

should normalise his alpha measurements in the thermal range and extract the alpha values for those resonances used for normalisation in the other experiments. After having obtained the various sets of the resonance alpha values used for normalisation it is recommended that the experimentalists involved attempt to get out a standard set of resonance alpha values and renormalise their measurements to these. The renormalised average alpha values should be made available to the specialists attending the meeting and other interested people. The experts finally recommend to the IAEA to continue through its Nuclear Data Unit, in co-operation with the other centres, to help in providing the necessary information and data for the comparison of the various Pu^{239} alpha measurements.

4.2 Integral measurements

(a) Energies from ~ 10 KeV to 1 MeV

The cross section adjustment studies made by Barré (Cadarache) and Rowlands (Winfrith) show that the value of Pu^{239} alpha should be raised above the differential measurements of de Saussure et al (1966) in the energy range 10 KeV to 1 MeV.

The Winfrith study indicates an increase of 10% (with an accuracy of $\pm$ 8% for the spectrum averaged value).

The Cadarache study indicates an increase of 16% for the range 9 to 111 KeV and 40% for the range 111 to 821 KeV.

These adjustments could be dependent on the uncertainties assumed for other cross section data and the integral experiments could perhaps be fitted equally well by variations in other cross sections, for example $\bar{\nu}$ for Pu^{239}. Inaccuracies in the integral measurements and calculation methods would also influence the adjustments.

Irradiation experiments in DFR and EBR-I also indicate the need for higher values of alpha in this energy range. However, the measurements in DFR indicate a similar increase in the U^{235} alpha

value and there is some doubt whether this change could be justified. The EBR-I results do not show any need for a change in U^{235} alpha value.

The evidence for the increase in alpha in this energy range is therefore inconclusive and it is suggested that further detailed attention should be paid to the data in this energy range.

(b) Energy range 1 - 10 KeV

The Schomberg/Gwin data seems to fit the fast integral data well. This is confirmed in the lower part of the energy range by the Brookhaven measurements in D_2O lattices.

(c) Data for higher plutonium isotopes

There is little data from integral experiments relating to the Pu^{240} capture cross section. Data sets based on the recent Geel Pu^{240} capture data give agreement with the Karlsruhe integral measurements to within the experimental error.

The differential measurers agreed to circulate to the members of the specialists' meeting the results of the renormalisation studies and to send the detailed data to the nuclear data centres.

5. Intercomparison of Breeding Gain Calculations

(Dr. A.R. Baker of Winfrith attended the meeting for this item of the agenda.)

The Chairman invited the members of the meeting to consider participating in an intercomparison of breeding gain calculations. The reason for the interest in plutonium alpha was primarily for breeding gain predictions. A standard calculational model would be useful when a comparison was being made between design studies made by different organisations using different methods and cross section data. The effects of differences in data and methods could be estimated by an intercomparison of predictions made for the standard model. Dr. Schmidt said that a standard model would also be useful for assessing the significance of differences in alpha measurements and the changes resulting from a renormalisation of the measurements.

Dr. Chernick pointed out that significant differences could arise from differences in calculation methods even when these were nominally the same. For example, different results had been obtained by different groups for calculations of ZPR-III 48 made using MC^2.

Dr. Baker circulated a draft note in which a proposed standard model was detailed. This had been chosen from the models used in the 1965 Argonne Conference intercomparison study, but a fixed core size of 2.5 cubic metres had been chosen whereas in the Argonne models this had been taken to be a variable (the fuel enrichment being fixed). Dr. Baker proposed that the fuel enrichment should be chosen to give k effective of unity. A standard method of calculation was specified. The properties to be calculated were neutron balance, critical mass and breeding gain.

Members of the meeting agreed to participate in an intercomparison using their current cross section data. Dr. Baker said that he would like to check the specification given in the note, since he had produced it only that morning, and that he would circulate the specification within about a week. Dr. Smith asked participants to submit their calculations to Dr. Baker within about two weeks of receipt of the specification. Dr. Baker agreed to edit the results of the calculations.

6. Compilation of Integral Experimental Data

Dr. Chernick said that a compilation of integral experimental data was being assembled by Palmedo at BNL. It was intended that this compilation would include data measured outside the USA and Dr. Chernick asked for the co-operation of members of the meeting in the production of the cimpilation. He considered it particularly important that those integral experiments which gave information about plutonium alpha should be included and asked the members of the meeting to supply those.

Dr. Barré said that a proposal for a standard description of critical experiments had been made at Cadarache and this proposal had been given a wide distribution.

Some members of the meeting spoke of the difficulties of giving a concise specification of integral experiments and the need for a full description of the experiment if an accurate test of cross section data was to be obtained.

7. Self-Shielding Effects in Pu^{239}

Dr. Troianov raised the question of resonance shielding in Pu^{239}.

Dr. Chernick described the methods of treating shielding adopted in the BNL calculations. These included the use of equivalence principles, collision probability methods and Monte Carlo. The cross section data were generated from resonance parameters. A change in alpha was accounted for by changing the resonance fission widths.

Dr. Takeda described the methods of treating resonance shielding in the plutonium oxide sample used in the standard resonance spectrum pile. Shielding factors were calculated for four regions in the sample. The shielding factors at 1 KeV varied from 0.66 to 0.77 for the fission cross section and 0.56 to 0.69 for the capture cross section. By changing the sample size information would be obtained about resonance shielding.

Dr. Schmidt described a method which he had developed for obtaining average fission widths from the measured alpha curve in the unresolved resonance region.

Dr. Gwin drew attention to the Idaho Nuclear Corp. measurements of plutonium alpha made at 2 KeV using a scandium beam. Two sample thicknesses had been used and so it would be possible to obtain information about resonance shielding effects from these.

8. Concluding Remarks

The Chairman, in closing the meeting, thanked all the members of the specialists' meeting for their co-operation.

Attachment 1

List of Participants

Dr. R.D. Smith, United Kingdom (Chairman)

Dr. D.A. Yashin, IAEA (Scientific Secretary)

France

Mr. J.-Y. Barré	Commissariat à l'énergie atomique
Mr. J. Bouchard	Commissariat à l'énergie atomique

Federal Republic of Germany

Dr. E.A. Fischer	Kernforschungszentrum Karlsruhe
Dr. J.J. Schmidt	Kernforschungszentrum Karlsruhe
Mr. H. Meister	Kernforschungszentrum Karlsruhe
Dr. E. Kiefhaber	Kernforschungszentrum Karlsruhe

Japan

Mr. M. Hirata	Japan Atomic Energy Research Institute
Mr. R. Takeda	Japan Atomic Energy Research Institute

Union of Soviet Socialist Republics

Dr. M. Troianov	Institute of Nuclear Power, Obninsk

United Kingdom

Dr. R.D. Smith	United Kingdom Atomic Energy Authority
Dr. C.G. Campbell	United Kingdom Atomic Energy Authority
Dr. M.G. Sowerby	United Kingdom Atomic Energy Authority

United States of America

Dr. R. Gwin	Oak Ridge National Laboratory
Dr. C.E. Till	Argonne National Laboratory
Dr. J. Chernick	Brookhaven National Laboratory

European Nuclear Energy Agency

Dr. H. Potters	Neutron Data Compilation Centre

International Atomic Energy Agency

Dr. D.A. Yashin	Division of Nuclear Power and Reactors
Dr. V.A. Konshin	Nuclear Data Unit

Attachment 2

Agenda

1. Opening of the meeting.

2. Adoption of the agenda.

3. Recent differential measurements of Pu^{239} alpha values and related cross sections for fission, capture, nu bar, etc. (including discussion of uncertainties due to sample thickness, normalisations, delayed neutrons or gammas, and significance of structure in the KeV range).

4. Evidence on Pu^{239} alpha values from irradiation and burnup experiments (from power reactor, critical facility, or converter irradiations).

5. Evidence on Pu^{239} alpha values from critical facility zero power type integral experiments (e.g., K_{∞}, reactivity, ratio measurements, etc.).

6. Evaluations of Pu^{239} cross section data, multi-level analysis and forms required for reactor calculations.

7. Summary and review of present position.

8. Closing of the meeting.

DAYashin/aw
24 July 1969