SUMMARY REPORT
OF THE FIFTEENTH MEETING

ZURICH, JULY 3-7, 1972

Compiled by
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In these tasks NEA works in close collaboration with the International Atomic Energy Agency, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.
EUROPEAN AMERICAN COMMITTEE ON REACTOR PHYSICS

SUMMARY REPORT OF THE FIFTEENTH MEETING

ZURICH, SWITZERLAND, July 3-7, 1972

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1. GENERAL

1.1 Review of recent activities, national programs, discrepancies, evaluation work

The reports prepared by EACRP members and corresponding members were presented and discussed. The reports are listed in Annex 3.

A list of future reactor physics meetings is given in Annex 4.

In his account of the activities of IAEA of interest to EACRP Dr. Inyutin went through a list of past and future meetings sponsored by IAEA (Annex 5). He furthermore mentioned that the research coordinated programs - Burnup, Reactor Control and the Summer School activity - were under revision. He mentioned that the International Working Group for Fast Reactors (IWGFR) had been transferred from the Engineering section to the Reactor Physics section of the agency's Reactor Division. Despite this, most of the specialist meetings sponsored by IWGFR dealt with engineering problems. NEA had observers at these meetings and reports of the meetings could be obtained either from these observers or from the members of IWGFR. A study group on gas cooled fast reactors was convened in Minsk for July 1972.

1.2 Report on the Seventh CREST Meeting

As the EACRP observer at the last CREST meeting, Laponche, was not present Royen gave a short account of the meeting. Of direct interest to EACRP was the decision taken by CREST to sponsor, if possible jointly with EACRP, a meeting on Space-Time Dynamics some time during 1972 (perhaps in Germany). In view of new developments, this meeting was likely to be delayed to 1973.

1.3 Highlights from recent meetings of interest to EACRP

Deutsches Atomforum

Küsters reported that the main theme for the meeting had been safety problems but only 11 papers dealing with that topic
were delivered. The rest of the papers covered the classical areas including reactor physics. Reports were given of noise measurements of high quality in power reactors and Küsters recommended that efforts should be made to develop the theory so that one could make maximum use of the experimental information. Reports on two- and three-dimensional burnup codes were also given and Küsters had found the Siemens 3D code Medium of special interest.

ANS

Hemmig reported on the Miami meeting. He particularly drew attention to a specialist session on benchmark experiments which he had found useful and efficient. Considerable time had been devoted to the identification and definition of benchmark experiments. Although no clear conclusion had been reached the discussion should be useful for the continued activity in this area.

Panel meeting on Pu Recycling in Thermal Power Reactors, Vienna, June 21-25, 1971

Duret and Dr. Inyutin gave some highlights from the panel. One session had been devoted to the physics of Pu recycle and it was concluded that a considerable effort had been devoted to this subject, both on the theoretical and experimental side, and much more confidence could now be placed in the calculations on plutonium fuelled systems. However, it was also concluded that information on the burnup physics of Pu systems was limited and more data on the isotopic composition of recycled plutonium, on the effect of transplutonium isotopes etc. would be welcome.

Panel meeting on Reactor Burnup Physics, Vienna, July 12-16, 1971

In his report from the panel Tyror said that the panel tried to define targets and objectives for the efforts in the burnup area. This turned out to be difficult and the requirements on the accuracy in predicting burnup could only be defined in rather broad terms.
In the fuel management area it was recognized that improved mathematical and physical models were needed. The improvements were required not only for a better prediction of the neutronics parameters but, in particular, to allow prediction of fuel performance.

A subpanel discussed the use of 3D codes for fuel management purposes. It was agreed that improvements could be obtained by a more efficient use of the successive 3D calculations which were not unrelated. It was also proposed to compare different 3D methods in a set of benchmark calculations. Dr. B. Micheelsen from Denmark had volunteered to define a suitable problem for a first comparison.

Since the meeting benchmark calculations had been performed by a large number of participants and compiled by Micheelsen. The committee was interested in the outcome of the comparison and Hellstrand agreed to ask the next Scandinavian representative on the committee to present the results at the next meeting.

International Meeting on Non-destructive Measurement and Identification Techniques in Nuclear Safeguards, Ispra, September 20-22, 1971

Hellstrand reported that the meeting was attended by about 40 specialists. The contributions were collected together in three groups according to the following applications: "Small samples", "Large samples" and "Scrap and waste". Methods utilizing passive and active techniques were described and for many applications adequate accuracies had been obtained. The larger the samples (e.g. fuel clusters) or the more ill-defined the geometry (e.g. waste in large drums) the more difficult it was to obtain accurate and unambiguous results. It was furthermore strongly emphasized by the representatives from IAEA that simple, reliable and preferably portable instruments were needed for the field applications. The situation was not satisfactory in this respect although some achievements had lately been made, especially concerning instruments for passive gamma measurements and for spontaneous fission determination (Pu240).
Enlarged Halden Programme Group Meeting on Computer Control

Berg said that more than 100 specialists from countries participating in the Halden Project took part in the meeting. It covered a broad range of subjects related to control theory and process computer hardware-software systems. A number of the papers were concerned with development work going on within the Halden project (core power distribution control, load follow control, decentralized process computer systems and computers for operator-process communication). Participants from the nuclear industry presented papers on actual applications of process computers for control and supervision of nuclear plants. These presentations were viewed and discussed in the light of research and development work going on in Halden and elsewhere.

1.4 Report from the Fifteenth EANDC Meeting

Küsters gave the following account.

Following INDC approval of merging RENDA with the non-OECD request list, the EANDC approved the schedule for the first World Request List for Nuclear Data (WRENDA). A draft produced by CCDN and TARA would be reviewed by individual committee members and be published before the end of the year. Requests for Safeguards and Fusion data would be in separate documents.

The need for an international list of evaluation requests was discussed but a decision was deferred until next year.

It was learnt that isotope production in the USA had been drastically reduced. An Isotope Subcommittee was reconstituted and asked to report next year on priorities for isotope requests.

A subcommittee, reporting on ways of improving measurements on $^6\text{Li}(n,\alpha)$, recommended that "direct" measurements be supplemented by shell-transmission and $\sigma_{\text{tot}} - \sigma_{\text{scatt}}$ measurements. Discrepancies (20%) between Li-glass scintillator results from Harwell and Cadarache remained, but theoretical fits were now thought to be valid to about 1% below the resonance and perhaps 5% above it.
A review of the fission cross sections of U\textsubscript{235} and Pu\textsubscript{239} and their measured ratio had been written by Byer and Konshin. Up to 150 keV, results were now consistent to about 5% but agreement was less good at higher energies. New experiments had been reported at Knoxville and others were in progress. U\textsubscript{235} remained the major problem. Recent evaluations of the capture cross section of U\textsubscript{238} had been made by Byer and Konshin and by Pitterle. At all energies above 10 keV these appeared to agree within about 5%. Nevertheless, there were serious discrepancies between both old and recent results that were not understood. A critical review of measurements of $\alpha$ for Pu\textsubscript{239}, by Sowerby and Konshin, would be published early in 1972. A total uncertainty of 10-15% was expected over the energy range 0.1 keV to 1 MeV.

Several recent experiments on the "French effect" showed that it could account for only part of the differences between Cf\textsubscript{252} $\gamma$ values obtained with liquid scintillators and the Mn bath method. The differences were now smaller than before after a new Mn bath experiment by Axton and a 0.6% revision of Condé's scintillator value. An updated IAEA review would be published.

At an IAEA consultants meeting on the spectrum of prompt fission neutrons, proponents of integral and microscopic measurements failed to resolve their differences, although the nature and extent of the differences were better appreciated. Previous experiments were criticized and new measurements planned. A review of microscopic measurements, as well as a new measurement by A.B. Smith, supported old Los Alamos data. It was accepted that a Maxwellian shape was inadequate, particularly at and below the peak of the spectrum.

1.5 Report on the Joint Sub Committee Meeting

Casini reported on the meeting in Vienna in August 1971. The main subjects discussed were topics for future specialists meetings and ways and means for improving the coordination of the European efforts in the field of evaluation. A decision was made to organize two meetings, one to discuss the status of evaluated data for U\textsubscript{235}, U\textsubscript{238} and Pu\textsubscript{239} (Harwell, Jan. 1972) and one for a presentation of formats for the main nuclear data files (Bologna, July 1972).
Regarding the Harwell meeting Campbell said that a report would be published soon. It had been agreed at the meeting that the \((n,\gamma)\) and \((n,f)\) cross sections for U238 were still problem areas. This was also true over large energy regions for the cross section data of U235 and Pu239. It had been concluded that new evaluations would not improve the situation to any appreciable degree and that new accurate measurements were needed.

The meeting was the first of its kind and the lesson learned was that for future meetings it was important to choose a narrowly restricted topic attracting only a small group of specialists. It was also considered important to announce the meeting well in advance and, if possible, have someone collect and organize beforehand the contributions to be dealt with.

Casini reported on the Bologna meeting. The items on the agenda were

1) Description of and comparison between the main formats.
2) Description of the main codes for conversion of one format to another.
3) Codes for handling nuclear libraries and data files.

Concerning item 1) it had been found impossible at this stage to normalize the different formats so that only one would be needed. Rather, it was proposed to encourage a broad implementation of the different files with a consequent increased development and use of codes for passing from one format to another.

Under item 2) it was found that codes now existed that allowed conversion between the ENDF/B, KEDAK and UKNDL files. Work was also going on to transform the USSR format to UKNDL.

Descriptions of various codes were given under item 3).

The minutes of the meeting would be published during Autumn 1972.

The mechanism for deciding items for and convening specialists meetings was discussed. Dr. Hürlimann, reporting on the last EANDC meeting, said that EANDC had been under the impression that EACRP wanted to abolish the Joint Sub Committee (JSC) in preference to small specialists meetings. EANDC had accepted this and
had taken the responsibility for the two first specialists meetings and expected EACRP to take care of the following two. **Campbell** first of all said that the EACRP's views on JSC (as expressed for instance in EACRP-A-177) had been misinterpreted. EACRP had not argued for an abolishment of the JSC but rather expressed itself as being against making it a standing committee. He further suggested that EACRP, as proposed, would take the responsibility for the next two meetings. **Kiisters** explained that according to his understanding of the EACRP discussion at Stockholm the main activity of the JSC would be taken care of by ad hoc specialists meetings with different participants from meeting to meeting. **Farinelli** proposed to leave things as they were and to proceed with ad hoc specialists meetings. The committee agreed to this. Among possible topics for future meetings the following were mentioned: Cross sections for structural materials, Fission neutron spectra, Delayed neutron data and Cross section data for shielding purposes. The first one was considered timely and **Kiisters** believed that such a meeting could be arranged in Germany in late spring 1973 but no final decision was taken. No second topic was decided upon and **Campbell** offered to accept proposals for new topics during the time interval till the next EACRP meeting and take the necessary initiatives together with Dr. Story (Action 11).

1.6 **Compilations**

**Fast critical assemblies** (Hemmig)

Experimental data from US fast critical assemblies had been collected in two volumes edited by P. Palmedo. Atomics International had taken over the compilation activity and was working on a third volume containing also non-US data. No publishing date was available.

**LWR** (Farinelli)

The issuing of the compilation had been delayed because of difficulties in introducing some PWR data. The material had been published but it had proved difficult to collect the relevant material. The first part of the compilation should be issued at the end of 1972.
Clean experiments (Casini)

A number of countries had responded to the request for experimental data for the Ispra compilation. Most of the contributions referred to homogeneous- or single rod-systems and only a very limited amount of data was related to cluster geometries. The latter information would be left out for the time being. Casini's attention had further been drawn to a similar activity at Lawrence Livermore Laboratory and he intended, with the aid of Hemmig, to contact Livermore and suggest an exchange of information.

A short list of types of systems and countries of origin was included in the status report distributed by Casini. It was agreed that sufficient information existed for uranium and probably also for plutonium systems. Information was lacking on isotopic composition of irradiated fuel, as were data from benchmark experiments for checking scattering law kernels. The committee recommended that the information available should be collected on standard forms and circulated to participants.

2. INFORMATION ON MEETINGS RECOMMENDED BY EACRP

2.1 Thermalization

It was decided not to pursue any further the question carried over from previous meetings, of convening a specialists meeting on thermalization. A US report (DP-1276) was distributed providing tests of thermalization models but Hemmig at the same time pointed out the difficulties in obtaining experimental data that were really sensitive to the scattering models. Tyror stressed the importance of the models for the prediction of temperature coefficients in HTGR systems and believed that the situation would be similar in LWR's. The change in the scattering properties in graphite as a function of radiation damage was mentioned but it was recognized that experimental verification of the effect of such changes would be very difficult.
In order not to leave the field altogether, the committee agreed to a suggestion by Farinelli to discuss, as a new topic on the agenda for the next meeting, questions related to discrepancies between experimental and calculated temperature coefficients, including the sensitivity of such discrepancies to the scattering models. A review paper would be desirable on that occasion but no one at the meeting could promise to undertake to write such a report.

2.2 Shielding

Royen informed the meeting that the Program Committee for the Paris Shielding conference had been concerned about the few papers that had been received for the nuclear data session. This was said to be a manifestation on the part of the shielding community of its disappointment at the lack of response among evaluators to the specific needs of data for shielding purposes. It had been decided to arrange a panel on "Shielding data needs". It had also been proposed that the TARA (preferably in conjunction with other interested organizations) should arrange in 1974 a conference on the sensitivity of radiation penetration to nuclear data accuracy. Dr. Inyutin said that it would be useful for the agency to have EACRP's views on the proposed conference.

Campbell said that it was difficult at this time to express an opinion. Clearly it was necessary to engage in sensitivity studies to define what the requirements were and in a year's time or so it would be easier to make a comment.

Hemmig added that sensitivity studies were necessary to back up requests for specific measurements and evaluations. He thought the time was appropriate for the proposed meeting and results of sensitivity studies in the US would be available then.

It was decided to take up the question of sensitivity studies as a special topic on the agenda for the next meeting.

2.3 Specialist meeting on benchmark experiments and calculations

Dealt with under A.2.3 b) in these minutes.
2.4 CREST/EACRP specialist meeting on space-time dynamics

No such meeting had taken place since the last EACRP meeting.

3. TOPICS FROM PREVIOUS MEETINGS

3.1 Central perturbation discrepancies

US

Till presented a paper (EACRP-A-180) containing a collection of data from about 80 different critical assemblies. The data concerned were calculated (C) and experimental (E) values of central worths of U235, U238, Pu239 and B10 as well as a number of reaction rate ratios. The data were characterized in terms of type of data, the calculational methods used, the measuring techniques applied, etc. The assemblies were similarly characterized in terms of geometry, fissile material, bare or reflected, etc. With a specially written code the C/E values were sorted against various combinations of the input parameters. 136 sorting runs had been made and among the results obtained the following could be mentioned. The mean value of C/E was 1.18 and the discrepancies in Pu fuelled assemblies were less than in U-fuelled ones. All C/E ratios relative to C/E for a chosen standard (U235 for instance) were close to unity, irrespective of whether central worths or reaction rate ratios were involved. No strong correlation with cross section set was found, transport theory gave somewhat improved values of C/E, C/E values for spherical assemblies came out somewhat closer to unity, etc. A clear correlation was found against core size and U238 content. The use of the new $\beta$-values for U238 would improve the C/E values by about 8%. At present new analyses were being made on a few assemblies with the aim of treating them in as much detail as possible.

UK

Campbell summarized the paper (EACRP-A-181) on central worths for fissile isotopes. The effect of sample size, sample environment and delayed neutron data had been studied. The inter-
action between the sample and the environment had been found important. This problem was particularly difficult to deal with in the case of a sample placed in a cavity. This technique was therefore no longer used; instead, a plate in the unit cell was used as a sample and the effect of removing it from the cell was determined. Great attention had been paid to the delayed neutron data and one important conclusion had been that it would be more correct to treat the delayed neutron yields as independent of energy as the delayed neutron fractions. By taking this into account and by including the recent Los Alamos data, an increase had been observed in the total effective delayed neutron fraction of about 8% for Pu cores and about 5% for U cores. By using the new $\beta$-values and by restricting the comparisons between calculations and experiments to the removal of a plate from a central cell, the discrepancy between C and E had been reduced to ± 7%. A separate investigation showed that first order perturbation calculations gave results in agreement within about 1% with more accurate calculations.

Germany

Küsters reminded members of the report (EACRP-A-165) distributed at the last meeting and added that some new investigations had been made in SNEAK 7A and 7B. Furthermore, a code had been developed for a proper treatment of the sample-environment interaction. C/E values had been determined using different cross section sets. The new data set KFKINR gave C/E values about 8% above unity using Keepin's data for delayed neutron fractions. An increase in the $\beta$-values would reduce the discrepancy.

Discussion

The discussion centered around what delayed neutron data to use and whether or not to perform the experiments in a central cavity. It was agreed that an increase in the delayed neutron fractions for U238 was supported both by the new measurements at Los Alamos and, indirectly, by the $\beta_{eff}$ measurements in Germany, Sweden and the US. The situation was not altogether unambiguous, however, and a firm statement should not be made until the new measurements at
Aldermaston and Argonne were completed. Furthermore, no one disagreed with the suggestion brought forward in the UK paper of using constant delayed neutron yields rather than constant fractions to determine $\beta$ for a given spectrum.

As for how to perform the experiments, Hirota said that a cavity was utilized at FCA, the advantage being that samples of various sizes could be used allowing extrapolation to zero sample thickness. The agreement theory-experiment had generally been good. Till said that in performing experiments with sodium the interaction with the surrounding region was large and such measurements were preferably made in a central cell. For the fissile samples about the same C/E values had been obtained irrespective of whether a cavity or a central cell had been used. Campbell said that he preferred the central cell type of experiments and this technique would be used for future work at Winfrith.

It was concluded that by using justified changes in the delayed neutron data the old discrepancy between calculated and experimental central worths could be reduced from about 20% to below 10%. Further work remained to be carried out before any conclusion could be drawn whether the calculational methods were adequate or not. It was also decided that further information on central worth discrepancies should be included in future progress reports and that "$\beta$-values. Reactivity scales" should be retained as a separate topic for the next meeting.

3.2 Standard fast neutron spectrum facility

Dealt with under item A.2.3 c).

3.3 CPL questionnaire: form for report on reactor physics codes

Royen said that the ad hoc group set up to make suggestions concerning the future activities of CPL, had noted the efforts of EACRP to encourage CPL to help in promoting a feedback between users and originators of codes. EACRP had recommended that this could be achieved through the use of a special questionnaire. The ad hoc group now recommended that a test be performed to investigate
the usefulness of such an activity. It suggested that CPL should set up a "Service of Experience on Code Utilization". Such a service should engage in three types of activities

a) Selection of areas of special interest.

b) Collection, correlation and analysis of users' experience (by a consultant).

c) User-author confrontation.

As a first effort a workshop on shielding codes would be arranged involving a presentation of modern shielding codes.

The committee discussed the proposal and broadly supported it. However, in view of the large number of codes available for shielding calculations ranging from 1D removal diffusion theory to full 3D and Monte Carlo codes it recommended that the pilot study on shielding code evaluation should be restricted to a limited range of shielding codes. The Chairman undertook to put forward the committee's views in a letter to the NEA secretariat. The letter is reproduced as Annex 9.

3.4 Modular codes

Royen indicated that the USAEC "Report of the Sub-Committee on Standard Interface Files" (EACRP-U-42) had been received at CPL.

Campbell and Tyror said that in their opinion it was still too early to make recommendations on standardization as there were practical difficulties in achieving the objectives of standardization at this time. On the other hand, the development in different countries followed different routes and it might be difficult ever to achieve a general type of standardization.

Hemmig said that the US interface testing was being concentrated at Los Alamos and that he believed that by standardizing now, an improved coordination of the activity in this area would be achieved.
4. NEW TOPICS

4.1 Use made of the results of differential neutron spectrum measurements

**Japan**

Hirota presented the paper EACRP-A-183. He said that measured spectra in fast assemblies would be used for adjusting cross sections by means of the least square method. The differential data of the neutron spectrum would be grouped into fifteen energy groups and each group spectrum would be treated as a fictitious reaction rate. High accuracy would then be required for the relative ratio of groups but the need for high resolution would be low.

Certain unexplained discrepancies between spectra measured with different detectors had been observed. Spectra calculated with different methods also showed some systematic differences. Preliminary studies indicated that there were rather large differences between calculated and measured spectra in certain energy regions. The conclusion had been reached that measured spectra had to be accurate to within about 5 % in order to be of use in adjustment schemes.

**Germany**

In presenting EACRP-A-184, Küsters said that the accuracy of measured spectra above 10 keV at Karlsruhe was below about 10 %. This had been concluded from comparisons between spectra measured with different methods (time-of-flight vs proton recoil, proton recoil vs He3). Thus, the discrepancy between calculated and measured spectra must be larger than 10 % if the measured values are to be useful in adjustment procedures. The experience from recent work at Karlsruhe was that the discrepancies referred to were generally of the order of 10 % in multiplying systems and the comparisons were therefore not very conclusive.

For specific tests of methods and data, two routes were being used. The first one was to study assemblies which predominantly differed only in one component. The method had been tried on two assemblies in STARK with large differences in oxygen
content. The main purpose was to check the influence of theoretical procedures on the calculated spectrum near the 0.442 MeV oxygen resonance. The investigations made had given the following results: The use of smooth collision density spectrum in preparing a 26 group set for systems containing oxygen had lead to large errors in the spectrum above 300 keV, with large errors in threshold fission rates as a consequence.

The second route was to investigate systems in which the spectrum was strongly influenced by one component. Measurements had been made on blocks of depleted and natural uranium in which the spectrum, in particular at high energies, was strongly influenced by the inelastic cross section in U238. The preliminary results indicated that with the new KFKINR set, the agreement calculation-experiment was reasonably good except for the energy region 400 to 800 keV.

UK

Campbell presented the report EACRP-A-185 and began by briefly reviewing the status of the experimental techniques used in the UK. An energy region from about 200 eV to almost 10 MeV could now be covered by a combination of various techniques and with such overlapping that at any energy, results obtained by at least two techniques were available, the only exception being the region below a few keV. In this region only time-of-flight results existed. Besides time-of-flight, proton recoil detectors in core and in beam, lithium-6 semiconductors and double scintillator detectors (in beam) were being used. The accuracy of the measured spectra was about 10% at 500 keV, about 5% between 100 keV and 10 keV and rose again to about 10% at 500 eV and to 30% at 200 eV. Efforts would be made to improve the accuracy of the time-of-flight technique by using a new, smaller detector the efficiency of which would be easier to calculate. This was considered important as the existing uncertainty in the spectrum would yield an undesirably large contribution to the overall uncertainty in the calculated Doppler effect.
The measured spectra were being used in two different ways. The detailed shape of the calculated spectrum was compared with the experimental one over narrow energy bands. Such comparisons had influenced the choice of data describing, for example, the sodium resonance. Calculations with a data set based on recently evaluated differential cross sections gave good agreement with experiments over narrow energy bands but not when considering the overall shape. The spectrum information was further being used in the adjustment schemes by dividing the energy region into ten groups and using the ratio of the group fluxes as parameters in the LSQ program. The results from time-of-flight and proton recoil measurements were treated separately.

C/E values for various assemblies and in different energy groups showed a particularly large deviation from unity in the energy region 3 to 25 keV, the discrepancy being largest in an assembly (core 8C) with a large volume fraction of steel in the core. By reasonable adjustments of the cross sections for various core components, C/E values much closer to unity could be obtained. Further work was needed to establish the sensitivities to spectra of the Doppler and sodium void coefficients and an improvement in the accuracy of measured spectra was still needed.

Discussion

In answer to questions by committee members Campbell said that the target accuracy was still 5% over the whole energy region but to achieve this an improved detector system was required for the time-of-flight equipment. He also said that off centre spectrum measurements were being started. Farinelli questioned the usefulness of spectrum measurements considering the time they took and the large costs involved. Tyror said that according to his experience little use had been made of differential spectra measured in thermal systems. Campbell said that accurate fast spectra were useful in a number of ways. For cross section adjustments one had to be sure that the calculated spectrum was correct, detailed spectrum measurements were useful in selecting resonance parameters, areas could be picked out where differential cross...
sections were in a particularly bad shape, etc. Above all, however, accurate spectrum predictions were needed for the calculation of the Doppler and sodium coefficients. Hemmig added that the detailed spectrum measurements at Gulf General Atomic had been very useful in selecting scattering kernels.

4.2 Effects of transplutonium isotopes on fast and thermal reactor performance

Thermal systems

Tyror presented the UK report EACRP-A-186 in which the effect of Np237 and transplutonium isotopes had been investigated in different thermal systems. For Np237 it was shown that as long as no recycling of the fuel was assumed, the parasitic absorption in Np237 was negligible. For a specific case with recycling (HTR system, burn-up 60 GWd/t) the Np237 absorption amounted to more than 1% of all absorptions at full burn-up.

The americium isotopes were more important. The effect had been studied in HTR systems with different feed fuel (U235 or plutonium enriched) and in a PWR system with plutonium fuel as feed material. An investigation had also been made of the plutonium enrichment required for a PWR system with and without consideration to the Am isotopes and for up to four recycles. The effect of americium was shown to be very significant in this case (about 0.5% difference in enrichment at the first recycle and 1.4% at the fourth).

The conclusion drawn was that in many reactor systems no considerations of Np237 and transplutonium isotopes were required. For high irradiations, especially with plutonium fuel, the isotopes Am241, Am242 and Am243 became of some importance. The curium isotopes, on the other hand, were of no importance for on power operation but they might cause problems by spontaneous fission neutron emission in connection with transportation, etc.

Hemmig mentioned that measurements of the capture and fission cross sections of Am241 were under way at ORNL.
**Fast systems**

No paper had been prepared but Campbell and Küsters gave short accounts of certain investigations made in the UK and Germany. The reactivity effect from neutron absorption in the americium isotopes was negligible but the build-up of curium, especially of Cm242, was important because of the spontaneous fission neutron source it represented. It affected the reactivity determination at low power, it caused difficulties in connection with the transportation of burnt fuel and it introduced particular problems in connection with non-destructive fissile isotope determinations for nuclear safeguard purposes. Accurate estimates of the actual Cm content in a given system were hampered by the uncertainties in the Am cross sections. Furthermore, the storage time for the separated plutonium fuel before insertion in the fast reactor was an additional parameter, which strongly influenced the Cm production in the reactor. It was agreed to take up this topic again at a future meeting, for instance at the third one from the present one.

4.3 Prediction of void coefficients in fast and thermal reactors

**Thermal systems**

**Sweden**

Hellstrand summarized the report EACRP-A-187. A new method to determine the void coefficient in light water moderated systems was being tried in the high temperature critical facility KRITZ at Studsvik. Voiding in the reactor was accomplished by opening a valve to the storage tank in which the water was kept at a lower temperature than in the reactor. This was done while the system was just critical and the change in reactivity caused by the voiding was measured with a reactivity meter. Preliminary experiments had been rather successful but a complicated analysis was required to obtain a void coefficient. The uncertainty of the void coefficient deduced from the experiments had been estimated to be about \( \pm 10 \% \).
Casini described a series of experiments under way at Ispra. The investigations had been performed in a central zone of the ECO reactor, using 28 rod clusters. The clusters contained aluminium tubes placed between the fuel rods in rings and the void in the tubes could be controlled by a nitrogen pressure system. Each ring could be voided independent of the other allowing the radial dependence of the void effect to be studied. Besides this arrangement a more homogeneous voiding could be arranged by introducing air through hypodermic needles at the bottom of the clusters.

The analytical treatment of the first type of experiments had made it clear that the heterogeneity of bubble formation had to be taken into account. 2D multigroup calculations were used for the analysis, but a more sophisticated treatment would be needed in particular for the heterogeneous cases. Experiments on plutonium systems were under way.

Küsters referred to the document EACRP-A-188 in which transients caused by pump coast-down had been studied. The dependence of the axial power profile on the void coefficient had been mapped and the conclusion was that an accuracy of better than 10% was required for the void coefficient. During the discussion Tyror mentioned that a number of investigations had been made to establish the void coefficient of SGRWR systems. The benchmark tests of the WIMS system had included the effect of density variations. As a result of these investigations small changes had been introduced in WIMS. Regarding the uncertainty in void coefficient calculations Tyror thought it might be difficult and perhaps not necessary to come within ±10%.

In discussing the fast reactor part of the report EACRP-A-188 Küsters first reminded the committee of the experimental studies on hydrogen-containing systems in SNEAK. The investigations were
made as part of the work on steam cooled systems. Recently, the experimental results had been compared with calculations and very good agreement had been obtained.

The sodium void effect had been measured in an all uranium fuelled assembly in SNEAK as well as in the plutonium part of systems containing a 90° or 150° plutonium fuelled sector. Central worths and axial and radial traverses of sodium worths had been measured. The corresponding calculations had been made using the MOXTOT set. The central worths were well reproduced by the calculations granted heterogeneity effects were properly taken into account. At the core boundary, on the other hand, the calculations underestimated the sodium void effect by 10 to 15 %. Similarly, larger discrepancies (20 to 30 %) were found between calculated and experimental values for voided channels, indicating that streaming effects were inadequately dealt with in the calculations. More sophisticated analyses of the channel experiments were under way.

**Japan**

Hirota summarized the report EACRP-A-189. Void coefficient measurements had been performed as part of the JOYO physics mock up experiments in FCA. The measurements included radial and axial traverses of sodium worths as well as the effect of voiding a number of channels. Special experiments had been made to study streaming effects.

The analysis of the experiments had been made by two different groups. In the first analysis, performed by NAIG, the sodium void effect had been calculated both by six group 2D diffusion theory and by 25 group perturbation theory. Additional calculations using transport theory were made to study the effect of heterogeneity. The result of the calculation was that the effect of removing sodium from a large part of the core was well predicted by theory, while the calculated central worth was strongly under-predicted.

A second set of calculations had been made by the JAERI group. Six group cross sections had been produced for the voided and non-voided cases from 70 group 1D calculations. Streaming
could be calculated separately by introducing anisotropic diffusion coefficients based on Benoist's theory. If streaming effects were taken into account the C/E values for the cases with voided channels were about 0.9. The calculated central void effects were on the other hand grossly in error. The discrepancy decreased with increasing length of the voided region, however, indicating that the error in the calculations might be due to inadequate treatment of the spectrum component; in particular, the elastic removal cross section was thought to be incorrect.

US

Till gave a comprehensive summary of the report EACRP-A-190 dealing with analysis of sodium void effect measurements in benchmark critical systems and in FTR mock ups. The analysis had included results from single zone experiments in ZPR-VI and two zone experiments in ZPPR. A first step had been to go through the measurements in the benchmark systems of ZPPR and ZPR-VI. Results for various sample geometries in the two assemblies had been compiled and compared. Using the ratio of sodium worth to plutonium worth (Na/Pu) as the quantity to be compared, the investigation had shown that the results for comparable cases agreed well, irrespective of whether different measuring techniques and somewhat different sample geometries had been used. Furthermore, results for pin and plate geometries showed a difference in Na/Pu of about 15%. This difference could be fairly well reproduced by calculations. For off-centre results the difference between plate and pin geometries became smaller the further out from the centre the measurements had been made.

The importance of the medium surrounding a small sodium sample had been investigated by determining the reactivity effect of a sample in a completely sodium voided surrounding and in a normal surrounding. The Na/Pu value for the two cases differed by about 50%.

Next, the results of the measurements in the FTR mock up had been extensively compared with calculated values. The comparison generally yielded good agreement for the sodium worth but the plutonium worth was overestimated, resulting in C/E values for Na/Pu around about 0.8.
The effect of various assumptions in the calculations had been investigated. It was found that for such a complicated geometry as FTR a detailed x,y-representation was necessary in the 2D calculations. Furthermore, it was found that calculations with ENDF/B versions I and II gave closely the same sodium worth value while version III gave a 40% larger value. Special investigations had shown that the changes in $\alpha$ for Pu239 and in the capture cross section of U238 in changing from version I to III gave the largest contributions to the observed difference.

The result of the study for FTR was that, by using ENDF/B-I, the sodium void effect had been predicted without statistical bias, i.e. the mean value of C/E was 1.0. The uncertainty, reactivity wise, was 0.7 inhour/kg.

Discussion

Concerning requirements for the methods of calculations Till repeated that a detailed geometric description was required, at least for FTR. The difference between first order perturbation theory (FOP) and more sophisticated methods had on the other hand been found to be rather small (10%). Küsters reported on a similar experience from Karlsruhe where Kiefhaber had compared FOP and second order perturbation methods and found only a 4% difference. However, when the two methods had been used for calculating the carbon worth, the difference had been large.

The question of target accuracy was briefly discussed. Till referred to the figure 0.7 inhour/kg mentioned in his direct report and said that this corresponded to about ± 20% in the sodium void effect. Küsters wanted to tie the required uncertainty figure to a postulated accident and mentioned that coast-down accidents had been studied at Karlsruhe. Axial voiding occurred at the centre and spread radially outwards yielding a stepwise increase in reactivity. For some cases reactivity values close to prompt critical had been obtained. Campbell agreed that target accuracies should be specified in context with an assumed accident and added that a target accuracy for the sodium void worth was
difficult to specify without specifying the uncertainty in the Doppler effect as well. He further said that new measurements of the sodium worth in plate and pin geometry were under way at Winfrith. The new information would help in establishing more accurate values for fast reactors. Meantime the effect of variations of $+5 \times 10^{-6}/^\circ \text{C}$ in sodium coefficient were considered in safety studies.

The Chairman finally concluded that the papers distributed contained new and interesting material but that a number of problems still remained that had to be looked into more thoroughly.

4.4 Blanket analyses and requirements

UK

Campbell said that in blanket analysis at Winfrith considerable attention was being paid to the power distribution across the core-blanket interface. Fission rate distributions were being measured going from a plate type core zone to a blanket zone consisting of uranium, graphite, steel and sodium. One problem encountered in the calculations was the proper description of the transition from one plate structure to another. Different 2000 group weighting spectra had been used for the core and blanket zones but the difference compared with using only one spectrum had been found small. The need for higher order $S_N$ to describe the power distribution at the core-blanket interface had been investigated. Contrary to what had been found by others, the improvement in going to higher order had so far been found to be small.

Some difficulties had been experienced in using fission chambers in narrow thimbles through the blanket region. The results differed significantly from the foil results. It had further been found that rather large differences existed between the calculated and measured U238 fission rate relaxation in the blanket zone. The capture rate in U238 was more satisfactorily predicted.

Germany

Küsters said that some blanket experiments had been performed in SNEAK and the analysis of these was under way. A con-
siderable effort was being devoted to the general problem of making blanket calculations. First normal fast reactor diffusion codes had been applied and the importance of mesh size and number of energy groups had been investigated. Then transport and Monte Carlo codes had been used and the results of the various calculations were being compared. Special attention had been given to the space dependent self shielding in U238 across the core-blanket boundary. A report on this work had earlier been distributed (EACRP-A-171). It had been shown that the variation in self shielding was limited to a very narrow region.

Much attention was being devoted to streaming effects in the blanket. Higher order Legendre polynomials had been included for the scattering but the preparation of group cross sections for the anisotropic scattering remained a problem.

US

Till reported that the ZPPK-2 core had a depleted UO$_2$ blanket with a typical sodium volume fraction. The axial blanket had the same volume fraction as the core. The same reaction rates as reported by others had been determined throughout the blanket region.

A small number of plutonium bearing pins (Pu content between 1 and 4%) will be ordered to examine the effect of plutonium build-up.

Sweden

Hellstrand presented EACRP-A-191 concerning blanket experiments at the FRO reactor. A series of experiments had been performed, special tanks containing hexagonal lattices of UO$_2$ rods separated by solid sodium being used for the blanket region. Rods with natural UO$_2$ and 1.3% and 1.8% enriched UO$_2$ had been used, the enriched material being used to mock-up the increase in fissile material caused by plutonium production in a fast reactor blanket.

Various reaction rates had been determined radially outwards from the core-blanket interface to the outer edge of the
blanket. Fission chambers (U235, Pu239 and U238), foils (U235(n,f), U238(n,γ)) and solid state track recorders (U235 and U238) had been used as detectors.

The calculations had been made using a 15 group cross section set generated by the SPENG code. Separate weighting spectra were used for the core and blanket regions. The flux and reaction rates throughout the core and blanket were calculated with the one-dimensional $S_N$ code DTF-IV. The leakage in the transverse directions was taken into account using calculated buckling values.

Preliminary curves had been obtained showing measured and calculated reaction rates as a function of the distance from the core centre. With the normalization used, i.e. calculated and measured U235 fission rates equal at about 7 cm from the core-blanket interface, the trend was that the U238 and Pu239 fission rates were underestimated by the calculations. The results for the capture in U238 were more ambiguous. The calculated values were for some arrangements higher than the measured ones and for others the opposite was true.

4.5 Thorium systems

a) An appreciation of the present state of nuclear data and methods for predicting the performance of thorium fuel systems.

Ispra

Casini described the experiments performed at Ispra on D$_2$O moderated Th$_2$O$_2$-UO$_2$ lattices using D$_2$O and H$_2$O as coolants. Buckling values had been determined for lattices using 19 and 37 rod clusters as fuel and for pitches varying between 19 and 28 cm. The experimental results had been compared with theoretical values calculated with the Pinocchio code. The discrepancy theory-experiment varied between 0.3 m$^{-2}$ and 1 m$^{-2}$ for systems with a material buckling of 8 to 10 m$^{-2}$. 
Italy

Farinelli mentioned that besides the thorium experiments already performed at Ispra with U235 as fissile material, others were being considered with fuel containing U233. The destructive analysis of the 7 rod thorium clusters irradiated in the Halden reactor would furthermore yield valuable information on burn-up effects.

UK

Tyror said that some attention was given in the UK to the thorium cycle in connection with HTR systems. In particular, an analysis had been made of the Battelle HTGR experiments at Hanford. He had found that by using the standard WIMS code the reactivity was underestimated by 2 to 2.5 %, the effect being rather independent of temperature over the measured range of 20 to 1000 °C. One potential source of error was the resonance capture in thorium grains where experimental information was lacking.

US

Till mentioned that a U233 Doppler effect measurement had been performed a year ago in a fast neutron spectrum. The effect was found to closely resemble that for U235. The calculations strongly overestimated the effect.

Discussion

During the discussion Casini drew attention to the large number of clean critical experiments that had been performed by Gulf General Atomic. He wished to include some of these experiments in the Ispra compilation and Hemmig agreed to see what US data on HTR systems is available for inclusion in Casini's compilation.

b) The rôle of thorium fuel reactors in a power program.

The Netherlands

Bustraan summarized the paper RACRP-A-193, based on contributions to a NEA study a few years ago. The amount of uranium required up till the year 2000 for different reactor system strategies had been calculated and the study clearly showed the
very much larger quantities of uranium needed for the LWR "alone" systems compared to systems including advanced converters and breeder reactors. With an early introduction of heavy water reactors the total consumption of uranium would be reduced by a factor of two, and with fast breeders another factor of two might be gained.

The advantage of the homogeneous suspension reactor (U233-Th) as far as fuel costs were concerned was pointed out; an advantage which would become still more important the higher the uranium price and the larger the cost for uranium enrichment. Plutonium could also be recycled in such systems with very low fuel fabrication costs. The capital cost of this reactor type was expected to be low. The authors of the paper had furthermore pointed out that the lack of plutonium might hamper a high installation rate of fast breeders. Thermal breeders required a lower fissile inventory and were attractive for that reason.

Germany

Küsters dealt with the paper EACRP-A-192 which gave a summary of an investigation of the use of ThO₂ in PWR-systems. The study had been done by Siemens together with Jülich and GKSS and it mainly concerned LWR-Th systems initially fuelled with plutonium. It was found that to start and maintain the Th-U233 cycle plutonium was the most economic fissile material.

Another investigation concerned the use of thorium as fertile material when plutonium was recycled in ordinary light water reactors. An advantage found was that due to the high capture cross section in thorium compared to that in U238 a higher enrichment had to be used in rods with thorium as fertile material. For a given amount of plutonium to be recycled the number of plutonium containing rods would be small. This was an economic advantage as the fabrication cost of Pu-fuel was high.

Discussion

During the discussion that followed it was concluded that the calculational techniques required for thorium systems were
much the same as those used for uranium systems. The basic experimental data from critical and exponential assemblies were available and the status of the cross section data for U233 and thorium was not much worse than for U235 and U238. Thus, if need arose for a very detailed evaluation of the thorium systems, much of that work could be based on already available data. The compilation of benchmark experiments at Ispra would be very useful in such a case.

4.6 Neutron dosimetry

This item was not on the preliminary agenda and no papers had been prepared.

Farinelli made a short statement concerning present trends to standardize sets of detectors including recommended cross section data to be used for instance for irradiation experiments, spectrum measurements and shielding experiments. In the US a list of about 30 detector materials had been selected and a special task force had been established to produce evaluated cross section data for these materials to be included in ENDF/B.

In Europe the Euratom dosimetry group was making an effort to evaluate integral cross sections for neutron dosimetry purposes. A set of recommended cross sections had been compiled and distributed to users for comments.

Tests and normalization of different detectors would be performed using standard spectra of different kinds, the goal being to reach a general agreement on choice of detectors, cross sections, etc.

5. TUTORIAL SESSION

The following lecture was delivered by courtesy of the host organization:

Dr. H. Schumacher: Production of fuel for fast reactors.
6. OTHER ACTIVITIES

The committee visited the Eidgenössisches Institut für Reaktorforschung, Würenlingen on July 7th.

A dinner was offered by the host organization in the beautiful village of Regensberg on July 4th.
## ANNEX 1

### LIST OF PARTICIPANTS

#### Members

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#### Observers

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ANNEX 2

PRELIMINARY AGENDA FOR THE SIXTEENTH MEETING
(Technical Sessions)

1. GENERAL

1.1 Review of recent activities, national programs, discrepancies, evaluation work

1.2 Report on the eighth CREST meeting

1.3 Highlights from recent meetings of interest to EACRP:


ANS National Topical Meeting on New Developments in Reactor Physics and Shielding, Kiannecha Lake, N.Y., Sept. 12-15, 1972

ANS Winter (1972) and Summer (1973) meetings

Jülich Topical Meeting: Status and Requirements for the Prediction of Physical Parameters for Thermal and Fast Reactors, Jan. 1973

International Summer School in Rumania, "Nuclear Data for Reactor Calculations", Aug. 31-Sept. 9, 1972

1.4 Report on the Sixteenth EANDC Meeting

1.5 Compilations

1.6 Miscellaneous

2. INFORMATION ON MEETINGS RECOMMENDED BY EACRP

2.1 Specialist meetings on cross section data

- Structural materials

- ?

3. TOPICS FROM PREVIOUS MEETINGS

3.1 β values. Reactivity scales
4. **NEW TOPICS**

4.1 Space time dynamics

4.2 Studies of the sensitivity of shield performance to cross section sets

4.3 Discrepancies in predicted temperature coefficients for thermal reactors

4.4 Comparison of adjusted and unadjusted group cross sections

4.5 Theoretical and experimental determination of γ and neutron energy deposition

5. **TUTORIAL SESSIONS**
ANNEX 3

LIST OF PAPERS PRESENTED DURING THE
FIFTEENTH MEETING OF THE COMMITTEE

a) PROGRESS REPORTS, July 1971 - June 1972

1. Canada  M.F. Duret
2. Belgium  F. Motte
3. Denmark  B. Micheelsen and H. Neltrup
4. Euratom-Ispra  G. Casini
5. Germany  H. Küsters
6. Italy  U. Farinelli
7. Japan  J. Hirota
8. The Netherlands  M. Bustraan
9. Norway  J.O. Berg
10. Spain  R.O. Fornaguera
11. Sweden  E. Hellstrand
12. Switzerland  R. Richmond
13. United Kingdom  C.G. Campbell, J.G. Tyror
14. United States  W. Hannum

(These progress reports have been published in document EACKP~L-80)

b) CLASS "A" DOCUMENTS

EACRP-A-179  G. Casini: Benchmark experiments for nuclear data checking in thermal systems; Status Report (June 1972)

-180  E.M. Bohn: The Central Worth Discrepancy; 1 June 1972

-181  R.W. Smith: Some observations on the comparison of measured and calculated small sample reactivity worths of fissile isotopes in fast integral assemblies; 28 June 1972

-182  E.A. Fischer: Central Perturbation Discrepancies

-183  Y. Kaneko, H. Kuroi and J. Hirota: Use of Differential Neutron Spectrum Data in Reactor Physics; June 1972


-185  J.L. Rowlands and J.E. Sanders: Fast Reactor Spectrum Measurements and their Application to Data Adjustment Studies; June 1972


-187  R. Persson: Flashing experiments in KRITZ at Studsvik; June 1972

-189  Analyses of Sodium Void Experiment on FCA V-1: compiled by J. Hirota; June 1972


-191  T.L. Andersson and P. Stevens: Blanket experiments in FRO. Description of the experiments and preliminary analysis; June 1972

-192  G. Schlosser: Thorium Systems; June 1972

-193  J.J. Went and W.K. Wiechers: The role of thorium fuel reactors in a power programme and the impact of fuel cycle economics on the future development of nuclear power; June 1972

-194  G. Humbert and A. Khairallah: General remarks on methods of blanket calculations for fast reactors; 28 June 1972

-195  P. Caumette: Analysis of Sodium Void Effect; 29 June 1972

-196  J. Bouchard et R. Vidal: Etude des Combustibles Irradiés dans les Réacteurs à Neutrons Rapides; June 1972

-197  S. Goldstein: Problèmes liés au Coefficient de Vide dans les Réacteurs Thermiques; June 1972

c) ADDITIONAL DOCUMENTS CONSIDERED DURING THE MEETING

- Testing of ENDF/B— THERMOS Cross Sections for H₂O, D₂O, C, ZrH₂, (C₂H₄)ₓ, Be, BeO, C₆H₆, and UO₂, by J. McCrosson, D.R. Finch and E.C. Olson (DP-1276, ENDF-158)

- Measurement and Interpretation of the Coolant Void Coefficient in D₂O Lattices, by W. Hage, H. Hettinger, H. Hohmann, B. Sturm and F. Toselli.

- Measured and calculated spectra of a bare natural uranium assembly, by D. Rusch and E. Wattecamps

- Thorium in Heavy Water Reactors, a Thermal near Breeder, by C. Steinert, April 1971

- High Temperature Neutron Dosimeters, by J. Joyeux and J. van Audenhove (BCMN-Geel)
d) ADDITIONAL DOCUMENTS TABLED AT THE MEETING

- List of Members of the International Working Group on Fast Reactors

- Preliminary Program of the IAEA Study Group Meeting on Gas-Cooled Fast Reactors; Minsk, USSR, 24-28 July 1972

- Preliminary Agenda for Symposium on Physics of Fast Reactors (October 1973, Tokyo)

- Symposium on Fuel and Fuel Elements for Fast Reactors (1973); provisional list of topics

- The U.K. Chemical Nuclear Data Committee (by M.G. Sowerby)

- TARA Symposium on Applications of Nuclear Data in Science and Technology; Paris, 12-16 March 1973 (information sheet)

- Summary list of IAEA activities related to reactor physics
1. "Nuclear Data for Reactor Calculations", International Summer School, Rumania, Aug. 31-Sept. 9, 1972


ANNEX 5

SUMMARY LIST OF
IAEA ACTIVITIES RELATED TO REACTOR PHYSICS
(prepared for EACRP meeting, Zürich, July 1972)

A. REACTOR PHYSICS OR RESEARCH REACTORS

Past
2. Study Group on Research Reactor Utilization in Asia and Far East, Bandung, 2-6. August 1971

Future
2. Symposium on Physics of Fast Reactors, Tokyo, October 1973
(with scientific cooperation of the IWGFR)

B. NUCLEAR DATA

Past
1. International Nuclear Data Committee Meeting, Bombay, 12-16. July 1971

Future
1. 5th Meeting of the International Nuclear Data Committee, Vienna, 17-21. July 1972
4. Experts Meeting on Fission Products Nuclear Data, probably second half of 1973 (Place ?)
C. OTHER

Past

   1.a IWGFR Specialists Meeting on Sodium Water Reactions, Melekess, 17-21. May 1971
   1.b IWGFR SM on Fission and Corrosion Products Behaviour in Primary Systems of LMFBR's, Bensberg, 20-22 Sept. 1971
   1.c IWGFR SM on Handling and Transportation of LMFBR Spent Fuel Elements, Rome, April 1972
   1.d IWGFR SM on Sodium Combustion and its Extinguishment-Techniques and Technology, Richland, May 1972

2. 2nd Meeting of the Working Group on Nuclear Power Plant Control and Instrumentation, Rome, April 1972
   2.a NPPCI SM on Experiences in the Use of Computers in the Operation of Nuclear Power Plants, Brussels, Oct. 1971
   2.b NPPCI SM on Installation and Commissioning Problems in the Instrumentation of Nuclear Power Plants, Winfrith, Jan. 1972
   2.c NPPCI SM on Analysis to Diagnose Potential Failures in Nuclear Power Plants, Rome, April 1972


Future


5. IAEA Symposium of Fuel and Fuel Elements for Fast Reactors, Brussels, July 1973 (or later)

   6.a IWGFR SM on Sodium Impurity Measurements and Control, Cadarache, November 1972 (13-18)
   6.b IWGFR SM on Cleaning of Plant Components Contaminated by Sodium and Radioactivity, Dounreay, March 1973
6.c IWGFR SM on Development and Application of Absorber Materials, USSR?, second quarter of 1973

6.d IWGFR SM on Operating Experience and Design Criteria of Sodium Valves, USA, last quarter of 1973

7. Specialist Meetings of the International Working Group on Nuclear Power Plant Control and Instrumentation

7.a SM on application of reliability analysis of control and protection systems, UK or Norway, early 1973

7.b SM on Process Instrumentation for Nuclear Power Plants, France, June 1973


8. 3rd Meeting of the International Working Group on Reactor Radiation Measurements, Seattle, Nov. 1972

8.a SM on Damage Units in Graphite, Seattle, Nov. 1972

8.b SM on Damage Units in Ferritic and Stainless Steel, Seattle, Oct. 1972

8.c SM on International Intercomparison of Chemical Dosimetry, Athens, July 1972