NEACRP-L-119

NUCLEAR ENERGY AGENCY COMMITTEE ON REACTOR PHYSICS

SUMMARY RECORD OF THE SEVENTEENTH MEETING

(TECHNICAL SESSIONS)

CADARACHE, FRANCE
4th - 7th June 1974

Compiled by

ERIC HELLSTRAND

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
NUCLEAR ENERGY AGENCY
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The Organisation for Economic Co-operation and Development (OECD), which was set up under a Convention signed in Paris on 14th December, 1960, provides that the OECD shall promote policies designed:

- *to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;*
- *to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development;*
- *to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.*

The Members of OECD are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

The OECD Nuclear Energy Agency (NEA) was established on 20th April 1972, replacing OECD's European Nuclear Energy Agency (ENEA) on the adhesion of Japan as a full Member. NEA now groups eighteen European Member countries of OECD, Japan and Australia, with Canada and the United States as Associated countries. The Commission of the European Communities takes part in the work of the Agency.

The objectives of NEA remain substantially those of ENEA, namely the orderly development of the uses of nuclear energy for peaceful purposes. This is achieved by:

- *assessing the future role of nuclear energy as a contributor to economic progress, and encouraging co-operation between governments towards its optimum development;*
- *encouraging harmonisation of governments' regulatory policies and practices in the nuclear field, with particular reference to health and safety, radioactive waste management and nuclear third party liability and insurance;*
- *forecasts of uranium resources, production and demand;*
- *operation of common services and encouragement of co-operation in the field of nuclear energy information;*
- *sponsorship of research and development undertakings jointly organised and operated by OECD countries.*

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.

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TECHNICAL SESSIONS

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1. GENERAL

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

The national reports prepared by the NEACRP members and corresponding members were presented and discussed. The reports are listed in Annex 2, together with the other papers distributed at the meeting.

IAEA: Kolbasov gave an account of past and future IAEA sponsored meetings of interest to NEACRP. He specifically requested the views of NEACRP on a meeting "Workshop on transport method calculations". The committee thought the workshop would be an interesting one and participation could be expected from several member countries. It recommended, however, that the scope of the meeting be narrowed by leaving out the special item on Monte Carlo. It also pointed out that the workshop should be devoted to the analytical methods in neutron transport theory, leaving the aspects of numerical methods and applications to be dealt with at a forthcoming IAEA meeting.

Farinelli took an action on himself to forward the committee's views to the IAEA.

Hellstrand informed about the planned IAEA specialists meeting on Spatial Control Problem to be held at Studsvik in October 1974. A tentative programme was distributed for comment.

The committee supported the meeting and emphasized the importance of having the reactor physics aspects adequately covered. Hellstrand agreed to forward additional information on the meeting to the committee members when it became available.

1.2 Report on the first CSNI meeting

No NEACRP member had participated in the first meeting of the newly formed Committee on Safety of Nuclear Installations (CSNI). CSNI favoured meetings with a small number of participants and no observers were expected to be invited to its meetings, at least not in the near future.

The committee expressed its interest in having a working contact with the new body in areas of mutual interest. One way of obtaining this, still keeping the average number of participants low, would be to limit the invitation of an observer to special items on the agenda.

The committee members agreed to discuss such a proposal and other means of co-operation - such as specialists' meetings - between NEACRP and CSNI with their national representative in the latter committee.

1.3 Highlights from recent meetings of interest to NEACRP

Short summaries of about ten different conferences were given by different members of the committee.

1.4 Report on the seventeenth NEANDC meeting

The meeting was attended by Hirota who distributed a written account of the meeting. Concerning data requests it was recommended that fission product yield data be included in the request list and the Euratom Working Group on In-Pile Dosimetry would be encouraged to inform NEANDC and NEACRP of its data requests for activation detector cross sections. A review of data needs for fusion reactors had been made and it had been further suggested that data centres should serve the needs of the biomedical sciences. Regarding loans of separated isotopes from the USAEC the endorsement of NEANDC would not always be necessary in the future. Finally, a draft "Discrepancy List" involving the most important cross sections had been prepared.

Ribon added that NEANDC had discussed sponsoring a panel on fission cross sections. An action had been placed on the members to discuss this matter with their local data committees and report back at the next meeting.

He further asked for advice from NEACRP concerning the accuracy on the fission cross sections for the main isotopes required by the reactor physicists.

Hemmig said that for U235 the goal was 1 % (1 sd). The same would be true for $\nu(E)$ but it might be quite difficult to reach that goal.

Certain NEACRP reports might be of interest to NEANDC members. It was recommended that the list of documents presented at the NEACRP meetings be distributed to NEANDC members by the NEANDC observer. Anyone interested in a special report could then contact the author and ask for a copy.

1.5 Compilations

Farinelli reported on a delay in finalising the light water reactor compilation. It was now hoped that a draft could be sent out for comments to a few members within about six months.

Nicks distributed a draft document "Thermal Benchmark Compilation" prepared by G Casini at Ispra. The comments by the committee members were invited.

2. INFORMATION ON MEETINGS RECOMMENDED BY NEACRP

2.1 Specialists' meetings on

- Resonance parameters for U238 and Pu239

Ribon reported on the meeting and informed that a document with the papers presented and the conclusions drawn would soon be out. The usefulness of arranging a meeting on the following topics

The probability table method
The effect of interference
Treatment of resonances in reactor physics calculations

had been discussed. The views of NEACRP on such a meeting would be welcome.

The committee concluded that the reactor physics aspects were of no great concern any longer and that only a few people were working on problems related to the other items. The suggested meeting would therefore not get any large support from the committee

The question of arranging a meeting on delayed neutrons was also brought up. The committee thought that too little new information was available to justify a specialists' meeting.

- Processing of Nuclear Data Libraries

Farinelli informed that the final record and proceedings were under distribution. It had been recommended at the meeting that another meeting should be organized about 18 months after the first one. The topic for the second meeting would concentrate on the effect of the physical model on the processed cross sections.

- Reactor noise

Farinelli mentioned that the original programme had been revised giving more room for papers dealing with reactor noise problems in power reactors. About 50 people were expected to attend and the progress report from the meeting would be distributed as an L-document.

- Monte Carlo

Till informed that the meeting would take place the first week in July and had attracted contributions from five or six countries.

- Dynamic benchmark comparisons

Küsters mentioned that the subject for this meeting had been expanded and the topic would be New Developments in Three-Dimensional Neutron Kinetics and Review of Kinetics Benchmark Calculations. The meeting would take place at München, January 22 to 24, 1975.

2.2 NEA/IAEA meeting on

- Methodology of sensitivity studies with regard to radiation transport and energy deposition.

The meeting was to take place in Paris in the Autumn of 1975.

3. TOPICS CARRIED OVER FROM PREVIOUS MEETINGS

3.1 Detector cross-sections

Italy

Farinelli reviewed the conclusions reached by a consultants' meeting at IAEA and by the Euratom Working Group on Reactor Dosimetry. Two categories of reactions had been identified. For "Category 1" the cross-sections used should be based on data evaluated from differential measurements only. For "Category 2" the cross-sections were obtained through adjustment procedures using differential data and well documented benchmark experiments.

A number of benchmark experiments had been identified and it had now been possible to reduce the number of requests for detector cross-sections drastically. One remaining request was for the Cu(n,α) cross-section for which the sensitivity of integral experiments was not yet good enough.

One generally aimed at an accuracy of the order of $\pm$ 15 % in the integral quantity to be measured; and the target accuracies for the cross-sections should be set accordingly.

US

Hemmig gave a summary of the report NEACRP-L-106. The activity in the US was focused on two different programmes. The first one concerned measurements of cross-sections and this effort was primarily concentrated on the fast neutron generator at Argonne. The second one - the Inter Laboratory LFMBR Reaction Rate (ILRR) Programme - was a testing programme involving benchmark experiments against which detector cross-section sets for dosimetry could be checked.

Parallel to this effort the dosimetry file in ENDF/B-IV was being developed. At present there were 36 elements in the file. Error files were included and the errors were generally smaller than

20 %. The file was undergoing tests by using various well defined spectra. The most important supporting experimental work was performed in Idaho at the CFRMF facility and at the BIG 10 facility at Los Alamos.

Adjustment procedures were not used, one of the reasons being that one was afraid such procedures would introduce shape distortions. During the discussion the remark was made that adjustment methods could contain constraints concerning changes in the shape of the cross-section curve. On the other hand, for certain energy regions notably 8 to 10 MeV, the shape was perhaps not better known than the cross-section itself and adjustments without shape constraints could be useful.

3.2 Intercomparison of adjusted cross-section sets

Japan

Hirota introduced the report NEACRP-A-222 . The work had been presented at the Tokyo meeting and only a short summary was given. Concerning the adjustment procedure Hirota observed that different initial cross-section sets and error assignments could lead to quite different adjusted sets. A particular problem that had been studied at JAERI was the effect of systematic errors in the measured cross-sections. Chi square tests were used to locate such cases and trial adjustments were repeated with increased assigned errors for these cases. As a result of the work an adjusted group cross-section set AGLI/version 2 now existed which was soundly based with reference to differential data and with which results from integral experiments could be satisfactorily reproduced. Uncertainties still existed, however, for the capture cross-section in iron and the total inelastic scattering cross-section in U238.

Sweden

Hellstrand referred to the paper NEACRP-A-xxx but mentioned that a newly discovered input error in some computer runs made the conclusions uncertain. The paper(in a revised form) was therefore not distributed until after the meeting.

The pros and cons of using adjustment methods to obtain group cross-section sets were discussed at some length. It was pointed out that a continuous dialogue with cross-section evaluators and measurers was essential and only such adjustments that appeared reasonable to the evaluators should be accepted in the final sets. One of the main results of adjustment activities was that cross-sections and energy regions had been identified for which more measurements were needed.

The main objective of including item 3.2 on the agenda had been to get some comparison between various adjusted sets to see whether there was a common trend in the adjustments and whether different adjustment procedures gave discrepant adjustments on a common initial cross-section set. Adjusted sets suitable for such comparisons were not available, however, and as adjusted sets tended to be classified no open comparisons could be expected to be performed in the near future.

It was agreed that the cross-sections with the largest uncertainties were those for the structural materials. Differential measurements on such materials should be given high priority.

3.3 Error files and error correlation

Italy

Farinelli stressed the importance of error files for error evaluation on design parameters and in connection with the application of cross-section adjustment methods. He then presented the so called consistent method shortly described in the document NEACRP-L-117. One difficulty of ordinary adjustment techniques was that it was applied on coarse group cross-section sets. The redistribution of adjustments to fit a different group set was difficult and could introduce errors.
In the consistent method which was proposed by A Gandini and M Salvatores the adjustment procedure was applied to the parameters used for generating the group cross-sections, i.e. reso-

nance widths, level spacings etc. Error files were then required on these parameters to allow an appropriate adjustment procedure to be used. Preliminary sensitivity studies were used to limit the otherwise vast amount of data that would have to be included in the adjustment procedure.

US

Maienschein introduced the paper NEACRP-A-216 by F G Perey on data covariance files in ENDF/B-IV. The main part of the paper dealt with the problem of generating covariance matrices of group cross-sections. The approach by Perey was to arrive at a practical system with reasonable precision rather than one characterized by mathematical perfection but with high degree of complexity. A processing code had been developed and was under testing. The code would allow the generation of uncertainty files for group cross-sections from the error files in ENDF/B-IV. Reasonably complete error files were included in ENDF/B-IV for carbon, oxygen and nitrogen. It was also expected to have such filesfor iron and U238 within a short time. The plans for the next year called for inclusion of error statements including correlations for 19 cross-sections for 9 nuclides. The main emphasis was on data of direct concern for shielding and LMFBR.

4. NEW TOPICS

4.1 Benchmark test cases

Ispra

Nicks reported on the Joint NEA/Euratom Specialists' meeting held at Ispra in April 1974. One of the main aims of the meeting had been to examine current work and plans in the shielding field with the view of trying to co-ordinate the programmes and exchange results. The activities considered were primarily those in Japan and Europe.

The question of what constituted a benchmark experiment in the shielding area had been thoroughly discussed. It was agreed that deep penetration was a necessary feature. Furthermore, the

uncertainties in the theoretical treatment of the source and the geometry of the system should be small compared to the errors in the measurements.

Many of the older shielding experiments performed at various thermal reactors could no longer be accepted as benchmark experiments. The type of sources that were favoured for present and future experiments were conversion plates with spectrum modifiers and fast source reactors.

A different type of benchmark experiments had furthermore been identified. These were experiments designed to test and intercalibrate detectors and spectrometers. The iron block experiments at Winfrith and Oak Ridge,used among other things for calibrating thermoluminescent detectors, were examples of such benchmarks.

Short comments of national activities were made.

US: Maienschein mentioned that their programme on benchmark would last over the next 3 to 5 years. It would include four types of experiments, i.e. on streaming, energy deposition, neutron deep penetration and γ-ray production and transport. Reports on benchmarks on sodium, stainless steel and iron had been distributed to the committee members and the intention was to publish reports on new work as NEACRP-L documents assuming a system for mutual exchange of information existed.

UK: Campbell referred to the report NEACRP-L-100 describing the UK programme. The paper reviewed the rôle of benchmark experiments and described the work done so far at the ASPIS conversion plate facility at Winfrith. In the paper one also tried to define target accuracies for energy deposition and penetration calculations. The benchmark programme was designed with these targets in mind. The programme aimed at both method and data testing.

Japan: Hirota mentioned the shielding benchmark programme at the YAYOI fast source reactor. Sensitivity studies were furthermore underway at JAERI. The work could be reported at the next NEACRP meeting.

France: Barré stressed that not only benchmark experiments but also benchmark calculations were of importance. In France parametric studies were the preferred route for obtaining the tools needed for reactor design. One example was the experiments for the radial shield for Super Phenix. The shield would consist of stainless steel and sodium. Experiments were now being performed on large geometries containing steel and sodium with the sodium content varying from 0 to 100 %. Another type of benchmark experiment was the fast core experiment SCHERZO 556 which was a co-operative effort between UK, Germany and France. It would be of great interest if the experiment also could be repeated in Japan and in the US (Till and Hirota said they would encourage such an experiment in their respective countries.)

Campbell further informed about the planned benchmark specialists' meeting. The purpose of the meeting would be to give the people involved in the collaborative benchmark programme an opportunity to review progress, discuss interpretation of experiments, agree on formats etc. The meeting was planned for April 1975. Campbell volunteered to draft an agenda for the meeting and circulate among the committee members for comment.

The importance of an efficient distribution of laboratory reports and papers from meetings in the shielding area was stressed. Nicks said that information could be disseminated through the ESIS newsletter. This could also be true for papers from meetings if NEA could not find the means for publishing the documents in question.

To illustrate the importance of the benchmark shielding activity from the cost-benefit point of view Maienschein said that for FTR the savings in cost for the shield due to the confidence in the calculational methods was of the order of $ 10^7.

4.2 Operational physics experiences from LMFBR:s

UK

Campbell presented a paper (NEACRP-U-59) describing the start up of PFR and the comparison between predicted and measured values of various reactor physics quantities. One fact emerging from the comparison was that reactivity was predicted too high. The discrepancy after all corrections on the calculated values was 1 % ± 0.7 %. It was not clear yet what the reasons were for the discrepancy, one possibility being that small systematic errors in core composition and geometry could be present. Another question of importance was whether or not the core heterogeneity was correctly treated in the calculations. Preliminary control rod calibrations had been performed. From the comparisons with calculated values some anomalies had been observed. This was true especially for one of the tantalum rods. The general conclusion was that if the calculations were to be accurate to within 5 % advanced treatment of the heterogeneity of the control rod assembly was necessary. Collision probability methods would be used for that purpose in the future. For the isothermal temperature coefficient the difference between calculated and experimental results was about 25 %, the calculation underestimating the effect. Such a discrepancy was acceptable, at least for the time being. For safety considerations it would be valuable to have data for high fuel temperatures but no experimental effort was planned to get such results.

US

Till summarized the paper NEACRP-L-109 on recent EBR II experience. The fuel element testing was continuing and about fifty test subassemblies were now in the reactor. Most fuel tests were made on oxide rods but some carbide and nitride elements were also studied. The fuel failure detecting system in the cover gas had been quite successful.

The Mark 2 fuel was being tested and had behaved well so far. There were indications that the design burn up limit could be raised from the present 4.7 % to 8 %.

There were firm plans to operate the reactor to 1985. Investigations were being made on various components to find out whether or not they could be expected to cause problems in connection with an extended operation of the reactor.

France: The description of the start up experiments in Phenix was described in detail in the tutorial session (cf NEACRP-U-54).

4.3 Sodium void effects

UK

Campbell presented the paper NEACRP-A-229 which reviewed the dependence of the sodium coefficient on various parameters and looked at different ways of reducing its size. The paper was a preliminary one with the different effects not necessarily treated in a consistent way. The application of a systematic model would follow in a later paper.

Differential effects of a change in a given parameter were studied but it was emphasized that different changes in composition and geometry interacted strongly and individual effects were not additive.

Japan

Two papers NEACRP-A-224 and NEACRP-A-223 were presented. Kobayashi introduced the first paper, which dealt with sodium void analysis. Calculations had been performed in 25 groups using cell average cross sections in plate- and pin-type cells obtained from integral transport calculations. Some of the observations made from the comparison theory-experiment were as follows. Calculations agreed well with experiments in the central region of the core but yielded more negative values when leakage

effects became dominant. Application of transport theory in the macroscopic calculations would in this case give corrections in the right direction. Results from 2D calculations were sensitive to the change assumed for the axial buckling in going from the unvoided to the voided case. Adding differential sodium reactivity worths together worked well for the central region but less well for the blanket regions. Calculations based on Benoist's first order approximation had been compared with more accurate calculations using more high order terms or S_N theory. The improvement in using more exact theory was not large. Other investigations had involved sensitivity analysis of the calculated sodium coefficient to cross-section variations and comparisons between 2D and 3D calculations.

The second paper was presented by Hirota. He mentioned the series of experiments that had been performed on the FCA assembly VI-2 and which concerned sodium void worths in different cell patterns. Central and off-centre void effects had been studied. In the analysis the fine group AGLI library had been used to generate a coarse group set (32 groups) and Benoist's theory had been used to obtain direction dependent diffusion coefficients. C/E values for the central region were about 0.9 while for cases with pronounced streaming C/E was considerably larger than unity. A more detailed analysis of the experiments with streaming was under way.

US

Till summarized the paper NEACRP-L-108, which was an up-date of the report presented at the Zürich meeting in 1972. Results from ZPPR were now included and the calculations had been based on the ENDF/B-III library. For ZPPR assembly 3 which in composition and size was comparable to a demonstration plant the effect of voiding the total region in which the sodium coefficient was positive had been found to be about $ 2.5. At operating temperatures the effect would be still higher. In comparing calculations with experimental results the general trend was that C/E decreased with increasing size of the voided zone. For

assembly 3 C/E thus decreased from about 0.95 to 0.80 when the number of voided drawers was increased from 42 to 632. On the other hand, the effect of voiding control rods, empty control rod positions and regions nearby was overpredicted by the calculations. It had further been observed that group cross-sections collapsed with a neutron spectrum corresponding to a voided zone gave worse predictions than those weighted with an unperturbed spectrum. The use of ENDF/B version III compared to version I generally increased C/E. In a typical case C/E changed from 0.78 (version I) to 1.10 (version III).

France

Barré summarized the French programme. A large systematic study had been performed in cores with mixed uranium and plutonium fuel loadings, the enrichment in U235 and plutonium varying between 30 and 15 % (U235) and 25 to 12 % (Pu). Pin geometry was favoured to plate geometry.

The measurements of the reactivity effect of radially and axially displaced voided zones were complemented with studies on large voided zones. These were arrived at through repeated substitutions. From the effects of these substitutions the change in the diffusion coefficient in going from non-voided to voided regions could be determined. For the cores with large voided zones the material buckling was determined for the unvoided and voided zones by flux mapping. The main problem with the analyses concerned cases in which leakage and streaming effects were predominant.

Germany

Küsters shortly described some calculations made on a simplified model of a 300 MWe plant. Homogeneous and heterogeneous calculations had been performed on a geometry involving a voided inner core zone and adjacent axial blankets. The difference in calculated total void reactivity was 0.2 %. When the voiding of the outer zone was included the difference increased to 0.3 %. For further information he referred to the extensive review on progress in fast reactor physics, KFK-1632 and NEACRP-U-46, discussed already at the last NEACRP meeting.

Discussions

Campbell said that the sodium void effect was given increased attention in the UK. The energy release due to power excursions in connection with partial sodium voiding could lead to fuel-coolant interaction accidents. If such accidents could not be excluded the containment would have to sustain high pressures. Küsters said that boiling caused by coolant blockage started at the upper part of the core and the negative reactivity effect of neutron streaming reduced the energy release. Investigations in the US had further indicated that sodium-fuel interaction resulted in intensive boiling phenomena rather than explosive vaporization and was consequently less serious than earlier believed.

Concerning calculational methods various members recommended the use of group and region dependent bucklings in 2D calculations. In concept 3D methods should be used but the need for using many groups would make such calculations very time consuming. Calculations on pin geometry had further been found to agree better with experiment than those on plate geometry. As for delayed neutron fractions (important for the reactivity scale) Till indicated that the results of new measurements at Argonne supported the old Keepin data. These were therefore still used in the US. A review of delayed neutron data (NEACRP-L-110) had recently been completed. The UK favoured, according to Campbell, the evaluation by L Tomlinson with high delayed neutron fractions especially for U238.

4.4 Cross-section collapsing including adjoint fluxes

Italy

Farinelli presented the paper NEACRP-L-116. Comparisons had been made of various schemes for the generation of elastic removal cross-sections in energy regions where large resonances were present. The inadequacy of methods assuming constant or linearly varying slowing down density within rather broad groups had been demonstrated using the ultrafine group treatment in MC^2 as a reference. Calculations had also been made with Stacey's

continuous slowing down model, the results of those calculations being quite close to those from MC^2-2. The Stacey method was being incorporated in the code IDX. Farinelli further said that the adequacy of physical models for group cross-section collapsing had been superficially discussed at the specialists' meeting on Codes for Nuclear Data Processing at Ispra in 1973. This topic was still very important and it should be taken up on the agenda for the next NEACRP meeting.
The committee agreed to this.

US

Hemmig mentioned that 1D diffusion codes were routinely used for collapsing group cross-sections spatially. This was an efficient procedure to reduce the number of groups required for 2D and 3D calculations. Some doubts existed concerning the adequacy of this procedure, in particular for collapsing the transport cross-sections. Consistent procedures for collapsing were being worked out along three routes:

1. Zero-dimensional P_1 solution in about 2000 groups (MC^2-2)
2. One-dimensional P_1 solution
3. 5-20 group multi-dimensional P_1 solution.

These different procedures would be worked on and compared in the near future and results could be reported at the next meeting.

Farinelli also reported on an experimental investigation in TAPIRO involving studies of the spatial and energy dependence of the adjoint flux. A Cf252 source and some other sources on loan from Karlsruhe had been used. Good agreement had been obtained between the experimental results for the Cf252 source and 2D transport calculations using DOT. ANISN on the other hand underestimated the flux considerably in the reflector region (normalization at core centre). Compare with NEACRP-L-115.

4.5 Target accuracies and the basis thereof for commercialized reactors

UK

Fayers summarized the report NEACRP-U-58 . The paper dealt with reactor physics uncertainties for HTR systems and the cost benefit analysis made for a research and development program. Particular attention was given to uncertainties in local criticality, temperature coefficient and power distribution. Present values and target accuracies were given. Achieving the goals would correspond to an estimated cost saving of about £ 1 per kWe, i.e. M £ 1 for a 1000 MWe reactor.

Sweden

Hellstrand gave an account of the paper NEACRP-A-228 which dealt with target accuracies for core power distributions in LWR:s. The paper discussed the problem of extracting the maximum power from a given design throughout the core life without exceeding the limits on linear heat flux, burn out margin, fuel temperature etc. imposed by material and safety considerations. Various power peaking factors were defined and engineering and uncertainty factors were introduced to allow for fabrication deficiences and inaccuracies in calculational methods. The cost benefit aspect was exemplified by stating (under the conditions given in the paper) that a one per cent improvement in the total peaking factor corresponded to about $ 0.38 per kWe.

Japan

Kobayashi presented the paper NEACRP-A-233. The improvement in predicting physics parameters due to the experimental and theoretical work from 1971 and onwards was demonstrated and present accuracies were compared with target accuracies. The latter was, however, not based on requirements for a typical commercial fast reactor but,rather,reasonable targets for future activities. The goals should be reached within five years. Tables were given in the report showing the contribution to the total error from experimental and theoretical sources of various kinds.

One important question under consideration was whether mock up experiments for a large FBR were necessary or not to attain the target accuracy. It was further recognized that experiments on burned fuel were important.

The table below illustrates present accuracies and goals.

Comparison of target accuracies and estimated accuracies in the prediction of physics parameters of fast reactor

Physics parameter	Estimated accuracy[1] 1973[2]	Target[1] accuracy
keff		
fresh core	0.7	0.5
burn up core	1.0	0.7
Power dist.		
core	4∿5	3
blanket	9	5
Control rod worth		
regulating	7	5
safety	10	7
Breeding ratio	5	3
Doppler coefficient	17	10∿15
Na-void coefficient	23	10∿15

1) 90 % confidence level (± %)

2) prototype fast reactor "Monju" not included βeff error (∿4 %)

US

Hemmig discussed the target accuracies for reactor physics efforts in the US (cf NEACRP-A-232). The general goal for the breeder reactor activity was to obtain methods and data for predicting the properties of breeder systems with an accuracy equivalent to that obtainable today for light water

reactors. The need for further critical experiments was obvious but it was important to be able to judge when new critical experiments would not be needed any longer. Sensitivity analysis and cost benefit analysis would be performed to support decisions on priorities.

The US paper contained the table given below illustrating present accuracies and target accuracies (1 sd)

Uncertainty Estimates for Major Nuclear Parameters

Parameter	Estimated Uncertainty		
	Current without EMC[a]	Goals for Demo Plant[b]	Goals for Target Plant
Breeding Ratio	±0.05	±0.04	±0.02
Doubling Time	±25 %	±20 %	±7 %
Pu Inventory in Reactor	±5 %	±2 %	±1 %
Overall Power Coefficient[c]	±25 %	±15 %	±10 %
Doppler Coefficient	±15 %	±10 %	±7 %
Total Sodium Void Reactivity	±1.5 $	±0.5 $	±0.3 $
Peak-to-Average Core Power Density	±12 %	±3 %	±2 %
Total Excess Reactivity Requirements	±30 %	±15 %	±3 %
Control-Rod Reactivity Worth	±15 %	±3 %	±2 %
Total Neutron Flux at Reactor Vessel	Factor of 5	Factor of 2	Factor of 1.2
Total Flux at Top of Head	Factor of 20	Factor of 5	Factor of 2

a) Engineering Mockup Critical

b) At time of freezing design of relevant component

c) Does not take into account mechanical and thermal-hydraulic uncertainty effects

France

Barré pointed out that the required accuracy depended on the reactor design to a certain extent. Some rough figures could be given, however, as typical for the target accuracies (2 sd). Typical values were

k_{eff}	± 1 %
Breeding gain	0.03
Axially integrated power per subassembly	± 2 %
Max local power	± 3 %
Sodium coefficient	±20 %
Doppler coefficient	±20 %
Control rod worth	5-10 %

He also emphasized the problem in going from a small demo plant to a full size commercial fast power reactor. As an example the interaction of control rods in Super Phenix was mentioned. The worth of an individual rod could vary by more than 50 % dependent on the position of other rods and changes in local power levels with rod movements could amount to 30 %. Accurate methods were required to predict such changes.

UK and Germany

Campbell and Küsters said that similar values as those quoted by Hemmig and Barré for the target accuracies were valid also in their countries. Besides the problems of reaching the goals for a fresh core additional uncertainties were introduced with burn up. Fission product capture cross-sections and fission and capture cross-sections for the higher plutonium isotopes, notably Pu241 were inadequately known. For further information at the German side Küsters referred to KFK-1632 and NEACRP-U-46, issued in 1973.

5. TUTORIAL SESSION

The following lecture was given

J Gourdan and B Sicard:
"Start up of Phenix".

6. OTHER ACTIVITIES

The committee visited various laboratories within the Cadarache site on June 6.

A dinner was offered by the host organisation on June 5.

ANNEX 1

LIST OF PARTICIPANTS

Members

BARRÉ, J Y	Cadarache, France
CAMPBELL, C G	AEE Winfrith, UK
DURET, M F (Chairman)	AECL, Chalk River, Canada
FARINELLI, U	CNEN, Casaccia, Italy
FAYERS, F J	AEE, Winfrith, UK
HELLSTRAND, E (Secretary)	AB Atomenergi, Studsvik, Sweden
HEMMIG, P B	USAEC, Washington, USA
HIROTA, J	JAERI, Tokai-Mura, Japan
KOBAYASHI, S	PNC, Tokyo, Japan
KÜSTERS, H	KFZ, Karlsruhe, Germany
MAIENSCHEIN, F C	ORNL, Oak Ridge, USA
NELTRUP, H	AEK, Risø, Denmark
NICKS, R	ESIS, Ispra, Italy
RICHMOND, R	EIR, Würenlingen, Switzerland
TILL, C E	ANL, Argonne, USA
VIDAL, R	Saclay, France
BUSSAC, J	Cadarache, France (part time)

Observers

KOLBASOV, B	IAEA, Vienna, Austria
RIBON, P	NEANDC, Saclay, France

Secretariat

ROSÉN, J	NEA, Paris, France
ROYEN, J	NEA, Paris, France

ANNEX 2

LIST OF DOCUMENTS DISCUSSED AT THE 17TH MEETING

Class A

NEACRP-A-221 Spano, A H: Report on the IAEA Workshop on 'Fusion Reactor Design Problems' held in Culham (UK) on 29th Jan.-15th Feb. 1974, 30th May 1974

222 Kuroi, H and Hirota J: On the Validity of Adjusted Cross Sections, May 1974

223 Shirakata, K, Kuroi, H and Hirota, J: Comments on Sodium Void Effect, May 1974

224 Zukeran, A, Iijima, S, Yamamoto, M and Kobayashi, T: Some Recent Results of Sodium Void Analysis and Related Problems.(PNC CN 241 74-2), May 1974

225 Kobayashi, S: Review of Fast Reactor Physics Activities Relevant to LMFBR Programme in PNC Japan. (PNC SN 241 74-05), June 1974

226 International Symposium on Physics of Fast Reactors (Report), held in Tokyo on 16th-19th Oct. 1973

227 Hirota, J: Report on the 17th EANDC Meeting, held in Tokyo on 25th-29th March 1974

228 Norinder, O: Discussion of Target Accuracies of Core Power Distributions in Light Water Reactors, May 1974

229 Smith, M F: A Review of the Sodium Void Coefficient and Ways of Reducing it to Produce Safer Fast Reactors, April 1974

230 Sidell, J: The Analysis of One-Dimensional Reactor Kinetic Benchmark Computations.

231 CSEWG Benchmark Specifications. 1974

232 Lewellen, J W: Target Accuracies for Commercial-Sized Reactors, 1974

233 Kobayashi, S and Kinjo, K: The Accuracy in the Prediction of Physics Parameters of Fast Breeder Reactor. (PNC SN 241 74-04), June 1974

Class L

NEACRP-L-100 Butler, J, Carter, M D, McCracken, A K and Packwood, A: The UK Programme of DATAM Experiments on Energy-Deposition and Radiation Penetration, April 1974

106 Magurno, B A: Cross Section Requirements for Threshold Detectors, May 1974

107 McFarlane, H F, Lineberry, M J, Goin, R W, Kaiser, R E and Beck, C L: Small Sample Measurements in ZPPR Assembly 3

108 Lineberry, M J, Beck, C L, Amundson, P I, Simons, G G and Olson, P N: The Present Status of Comparisons of Sodium Void Calculations and Measurements from the Critical Experiments Program, 1st June 1974

109 Recent EBR-II Experience, June 1974

110 Cox, S A: Delayed Neutron Data - Review and Evaluation, June 1974

111 Reactor Physics Activities in OECD Countries, June 1973 - May 1974

112 Butler, J and Nicks R: Shielding Benchmark Experiments - Report of a Joint NEA/EURATOM Specialists' Meeting held at Ispra on 17th-19th April 1974, May 1974

113 Available Reactor Physics Data from Power Reactors - Material Utilized by the Reactor Physics Section at Risø. (RP-2-74), compiled by T Petersen. May 1974

114 Thermal Benchmark Experiment Compilation, compiled by G Casini, May 1974

115 Bozzi, L, Martini M and Matteucci, R: Measurements of the Adjoint Flux in a Compact Fast Reactor, May 1974

116 Palmiotti, G and Salvatores, M: The Use of the Stacey Algorithm to Improve the Elastic Moderation Cross Section Generation, 1974

117 Gandini, A and Salvatores, M: Error Files and the Consistent Method, 1974

Class U

NEACRP-U-54 Clauzon, Coulon, Gourdon, Gouriou, Humbert, Martin, Mougniot and Sicard: Experimental Physics Results at the Start-Up of Phénix

55 Darrouzet, M, Chaudat, J P, Fischer, E A, Ingram, G, Sanders, J E and Scholtyssek, W: Studies of Unit k_∞ Lattices in Metallic Uranium - Assemblies Zebra 8H, Sneak 8, Ermine and Harmonie UK.

56 Oceraies, Y, Caumette, P and Devillers, C: Use of Integral Experiments to Improve Neutron Propagation and Gamma Heating Calculations

57 Kavenoky, A: A Benchmark Calculation: Two-Dimensional Transport Problem, 1974

58 Johnstone, I: The Justification for R&D Physics Work in Support of HTR. 31 May 1974

59 Smith, C G and Wheeler, R C: Reactor Physics Measurements of Some Key Parameters of the PFR

ANNEX 3

PRELIMINARY AGENDA FOR THE EIGHTEENTH MEETING

PART A COMMITTEE BUSINESS

1. GENERAL

1.1 Participants

1.2 Adoption of the final summary record of the seventeenth meeting

1.3 Adoption of the agenda

1.4 Completion of actions

1.5 Committee representation

2. OLD BUSINESS

2.1 Activities of US and NEA centres for the exchange of nuclear data information and nuclear energy computer programs of interest to NEACRP

2.2 Requests from NEANDC

2.3 Miscellaneous

3. NEW BUSINESS

3.1 Organization of the nineteenth meeting: agenda, time, place, participants

3.2 NEACRP observers at the next NEANDC meeting

3.3 Election of Officers

3.4 Future activities of the committee

PART B TECHNICAL SESSIONS

1. NEW TOPICS

1.1 Short lived fission product decay properties. Integral and differential data (UK, Sweden, US)

1.2 Breeding assessment for fast reactors including gas cooled fast reactors (France, Germany, Switzerland, UK, US,...)

1.3 Optimization of fuel management and control rod programming for thermal and fast reactors (UK, US, ...)

1.4 Streaming problems in fast and thermal reactors (France, Japan, UK, US, ...)

1.5 Transformation of actinides and fission product isotopes by neutron irradiation (Germany, UK, US, ...)

1.6 Neutronic problems in fusion reactors (Germany, Ispra, Japan, US, ...)

2. NATIONAL PROGRAMMES

2.1 Review of recent activities, national programmes, discrepancies, evaluation work (All Members)

3. BENCHMARKS

3.1 2D LWR box calculations (compare action 22)

3.2 3D LWR calculations (compare action 10)

3.3 Fast reactor benchmark calculations (compare action 24)

3.4 Review of benchmark solutions

4. INFORMATION ON MEETINGS RECOMMENDED BY NEACRP

4.1 NEA Specialists' meeting on

- Monte Carlo
- Reactor noise
- New developments in 3D neutron kinetics and review of kinetics benchmark calculations
- Shielding benchmark experiments

4.2 Future meetings

5. TOPICS CARRIED OVER FROM PREVIOUS MEETINGS

- Cross section collapsing with emphasis on physical models

6. GENERAL

6.1 Report on the 18th NEANDC meeting (UK)

6.2 Compilations

6.3 Highlights from recent meetings of interest to NEACRP

- Spatial Control Problems
- Atlanta meeting (US, ...)
- European Nuclear Society, Paris
- ANS meetings (US, ...)
- Fusion meeting in Tokyo (Japan, ...)

6.5 Miscellaneous

7. TUTORIAL SESSIONS