NEACRP-L-161

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

Specialists' meeting on control rod measurement techniques : reactivity worth and power distribution

Cadarache, 21st-22nd April 1976

SUMMARY REPORT PREPARED FOR THE NEACRP

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Note : The proceedings will be published by the CEA in September 1976 including all the papers accepted for the meeting, summaries of the discussions and conclusions drawn at the final session (reference NEACRP-L-154)

May 1976

1 - Editorial panel

Mr. J.Y.BARRE	France	Chairman
Dr. J.SANDERS	United Kingdom	Technical Secretary
Dr. R.MARTINELLI	Italy	Technical Secretary
Mr. P.HAMMER	France	Technical Secretary

2 - Programme

Session I. Start-up and operation measurements on power reactors.
Wednesday 21 st April 9 a.m - 4 p.m

Session II. Development of experimental techniques: theoritical studies.
Wednesday 21 st April 4 - 6.30 p.m

Session III. Development of experimental techniques on critical facilities.
Thursday 22 April 9 a.m - 4.30 p.m

Final Session. Conclusions - Recommendations - Actions
Thursday 22 st April 4.30 - 7 p.m

3 - List of participants : Appendix A

List of papers : Appendix B

1. *INTRODUCTION*

The Cadarache specialists'meeting on control rod measurement techniques was one of the first meetings of this kind recommended by the NEA Committee on Reactor Physics.The main objectives were, both for fast and thermal plants :

- to review the design,safety, and operation requested accuracies for control rods worths and power distributions for various rod insertions.
- to present the current techniques available and the accuracies obtained in the present status of the art
- to define the improvements and the developments of the techniques needed to reach the power plants' requests.

A total of 18 papers was tabled at the meeting which was attended by 22 participants from 7 NEA countries. Japanese papers could not be presented but will be included in the Proceedings.

The outstanding feature of the meeting was the opportunity it afforded for a meeting between specialists from different design and operational disciplines, concerned with both thermal and fast reactors, and with interests extending from physics to electricity supply. These discussions proved extremely valuable, and the most important points arising in the formal presentations and during discussions are briefly presented below.

2. *POWER REACTOR REQUESTED ACCURACIES AND CURRENT TECHNIQUES.*

2.1. Requests

- Measurements of control rod worths on power reactors are needed for safety design and operation purposes.
- The knowledge of the overall safety margin for shut-down is requested to $\pm$ 10% in all configurations taking into account interaction problems and the hypothesis of one rod blocked.
- For the design optimisation, it is useful to know control rod reactivity worths to $\pm$ 5% due to possible strong interactions and consequences on power distributions. The eventual aim is to decrease the number of rods.
- For the normal operation of the plant, a continuous analysis of the reactivity level to detect any failure (reactivity comparator) or to follow the reactivity after shut-down (Xenon problem) needs the knowledge of control rod reactivity worth gradient with an accuracy even better than 5% during the whole reactor life (problem of absorber burn-up).
- Furthermore, monitoring of shut-down reactivity during refuelling of a power reactor is requested in several countries (accuracy $\pm$ 10%) for safety reasons (possible large errors in loading).
- As far as power distributions are concerned, very few comments on requested accuracies were made from operating or design people. For fast reactors, accuracies of $\pm$ 3% on maximum local power and of $\pm$ 2% on integrated axial power per subassembly for all control patterns were mentioned.

Criteria : The experimental techniques to be used on power reactors must also fulfil the following qualitative criteria :

- to use standard intrumentation of the plant
- to be simple
- to be quick
- to avoid supplementary calculations to get the results.

2.2. Current techniques used on power reactors.

- Measurement techniques in thermal power reactors seem largely based on point kinetics following rod movements, with reactivity balanced by interchange with boron (for PWR's) or air (for AGR). For low power measurements, the techniques seem to give satisfaction although only few comments were made on the important aspects of detailed spatial analysis and relative positions of control rods measured and detectors. Measurements of rod worths under power conditions involve problems of non linear feed back effects (fuel and coolant temperatures) and no technique taking these effects into account was presented. Further work is needed on this point.

- For fast reactors, point-kinetics are also used together with rod shuffle technique. Furthermore simple perturbation techniques have also been developed to predict the worths of control rods in 300 MWe power level fast reactors, suitable for operational use. Extension and improvements of these techniques for commercial size fast reactors with strong rod interactions are now required and better accuracies are needed.

- No measurements of reactivity during refuelling were presented. Three main problems are to be solved :

  . detectors far from the core
  . strong spatial effects to correct by calculation
  . variation of the inherent spontaneous fission neutron source as the fuel is changed (problem of curium isotopes for example).

  The source multiplication technique can be considered for this problem but improvements have to be made.

- No measurements of the effects of control rods on power distributions in operating power reactor were presented, although this is a really important problem. Better measurements might allow operating margins to be reduced, leading to an overall improvement in plant efficiency, although the practical limitations due to difficulty of access for detectors was recognized.

2.3. General recommendation :

The importance of defining the accuracy requirements for measurements of control rods worths and power distributions in operating power reactors was recognized. Without such guidance, it is difficult to find the justification for expenditure of further effort in developing corresponding experimental techniques.

3. *DEVELOPMENT OF EXPERIMENTAL TECHNIQUES AND RELATED PROBLEMS IN REACTOR PHYSICS.*

3.1. Reactivity worth :

Methods of measuring control rod worth and subcriticality in zero power reactors are well established but in many cases require considerable theoretical back-up for interpretation.

- Two main approches are followed :

  1. Control rod worths measured between two critical configurations. The control rod insertion is compensated by increasing the core radius or on other control rods previously measured.
  2. Various subcritical techniques :
     Among these techniques, the basic source multiplication method with appropriate corrections for spatial dependence appears to be the most interesting and is applicable over a wide range of reactivity variation.

- A extensive and comprehensive study of these techniques, (presented by S.J. CARPENTER (ANL)) concluded to recommend the subcritical source multiplication technique for relative measurements up to ≈ 50 $. The absolute calibration of this relative technique has to be made by improved rod-drop . technique for reactivity worths up to ≈3$. Then the accuracies obtained, independently of the uncertainties in β_{eff}, are ≈ ± 2% up to 5 $ and ≈ ± 5% up to 50 $. However important calculated corrections are needed.

- These comparisons of techniques were performed and are still now being performed on various facilities.

If the accuracies previously quoted are confirmed, the core radius variation technique which is time consuming but independent of βeff value and the most accurate way of checking calculations could be partly replaced by subcritical techniques. Reactor physics requirements very clearly support further work on this question.

- Noise techniques are applicable to critical facilities when in-core detectors are used. They do not seem to be useful for power reactors.
- The usefulness of measurements on critical facilities to study and improve experimental methods for power reactor was clearly recognized.

3.2. Reactivity scale :

- Needs for improvements of βeff uncertainties appear to be variously commented. Some requests were expressed to decrease the current $\pm$ 5% uncertainty, in particular to improve knowledge of isotopic yields, decay constants and neutron energy spectra. The reasons given were transpositions of the results from critical experiments to power reactors and expression of the results in $\frac{\delta k}{k}$ units. However these arguments were not unanimously supported.
- Agreement between reactivity scales based on period calibrations and control and distributed fuel worths was demonstrated using the most recent delayed-neutron data. The long standing " central worth discrepancy " in zero power fast reactors shows signs of being resolved as a result of better data (adjusted cross sections set), improved experimental and analytical techniques.

3.3. Power distributions :

Measurements of fission distributions in zero power reactors are well established and accuracies of ± 1% in core and of a few per cent in blankets on relative distribution are obtained. Improvements are needed in the normalization of the experimental power distribution to the total core power for comparison with calculation; this is specially true for complex control rod configurations, due to the necessarily limited number of points measured, even in multi-scanning techniques.

4. *CONCLUSIONS.*

This specialist meeting appears to be really fruitful both for designers, operating people and physicists. Its interest was due, partly, to the limited number of participants, allowing free discussions, and to the attendance of the main specialists on the field.

Such meetings on experimental techniques can be recommended by NEACRP in the future. It is important to ensure that as many power reactor operating staff as possible participate.

For control rod measurement techniques, theoritical and experimental programs are now launched in various countries. The direction of these studies is likely to be affected by the trends and conclusions resulting from the Cadarache meeting. It seems worthwhile to plan a second comparison of the improvements obtained on these topics when these programs are completed, perhaps early in 1979.

APPENDIX A — List of participants

H. BONET	BN	BELGIUM
J.C. BRUGGINK	RCN	NETHERLANDS
S.G. CARPENTER	ANL	U S A
CHAPUS	EDF	FRANCE
M. CUZZANITI	ENEL	ITALY
F.J. FAYERS	UKAEA	U K
C. GOLINELLI	CEA	FRANCE
M. GOUFFON	FRAMATOME	FRANCE
P. GUBEL	CEN/SCK	BELGIUM
PH. HAMMER	CEA	FRANCE
F. HELM	GFK	WEST-GERMANY
T.A. LEWIS	CEGB	U K
J. MARTIN	EDF	FRANCE
R. MARTINELLI	CNEN	ITALY
S. PILATE	BN	BELGIUM
J.E. SANDERS	UKAEA	U K
M. SCHMIDT-HONOW	INTERATOM	WEST-GERMANY
J.M. STEVENSON	UKAEA	U K
P. VANDEPLAS	CEN/SCK	BELGIUM
A. VANOSSI	CNEN	ITALY
R.C. WHEELER	UKAEA	U K
J.Y. BARRÉ	CEA	FRANCE

Observers :

LEBIGOT	EDF	R.FABIANELLI	CEA
P.CLAUZON	CEA	F.LABBE	CEA
G.HUMBERT	CEA	C.PERRIGUEUR	CEA

APPENDIX B List of papers

SESSION I.

I.1. Zero power control rods worth measurements in PWR
M.GOUFFON FRAMATOME (FRANCE)

I.2. Interactions between control and shut off rods in the PFR
R.C.WHEELER UKAEA (UK)

I.3. Techniques used for control rod worths measurements in PHENIX.
J.MARTIN - J.BOYER CEA (FRANCE)

I.4. Control rod measurements during start-up of KNK I
M.SCHMIDT -HONOW INTERATOM (WEST-GERMANY)

I.5. Measurements of control rod insertion effects : experience gained by the utility and the fuel supplier during the follow-up of BR3 power station.
H.BONET - B N and P.GÜBEL CEN/SCK (BELGIUM)

SESSION II.

II.1. A comparison between the use of modal methods and conventional finite difference methods in analysing rod drop experiments.
I.BRITTAIN, F.J.FAYERS and M.J.HALSALL UKAEA (UK)

II.2. Control rod measurements by the pulsed neutron technique.
P.VANDEPLAS CEN/SCK (BELGIUM)

II.3. A comparison of diverging period and Plutonium worth reactivity scales in ZEBRA.
J.M.STEVENSON UKAEA (UK)

SESSION III.

III.1. Measurement of multiple control rods reactivity worths in semi-homogeneous critical assembly.
Y.KANEKO, F.AKINO and H.YASUDA JAERI (JAPAN)

III.2. Measurements of shut down and control rods reactivity worth for heavy water moderated pressure tube reactors.
U.BROCCOLI, G.CAMBI, F.CASALI, A.VANOSSI, G.ZAPPELLINI
CNEN and University of Bologne (ITALY)

III.3. Control rod studies for the PEC reactor in the assembly MASURCA/PECORE.
U.BROCCOLI, R.MARTINELLI, M.MARTINI CNEN (ITALY)
P.HAMMER, G.HUMBERT CEA (FRANCE)

III.4. Measurement of control rod worths using ZPPR
S.G. CARPENTER ANL (USA)

III.5. Measurements at SNEAK on control rod worths and control rod influence on power distributions in fast reactors.
H.GIESE, F.HELM, GFK (WEST-GERMANY)

III.6. Fission rate measurements in a ZEBRA mock-up of the Prototype Fast Reactor.
J.MARSHALL, J.E.SANDERS, D.W.SWEET UKAEA (UK)

III.7. Control rod measurements in light water moderated critical facilities.
R.MARTINELLI, N.PACILIO CNEN (ITALY)

III.8. Reactivity measurement on far-subcritical fast system.
N.MIZOO, N.NAKANO, T.MUKAIYAMA and M.CHO
JAERI (JAPAN)

III.9. The inverse kinetics technique for reactor shut down measurement - An experimental assessment.
T.A.LEWIS and D.Mc.DONALD CEGB (UK)

III.10. Measurements of absorber reactivity worths at EOLE.
C.GOLINELLI. CEA (FRANCE)