SPECIALISTS' MEETING ON IN-CORE INSTRUMENTATION AND THE ASSESSMENT OF REACTOR NUCLEAR AND THERMAL/HYDRAULIC PERFORMANCE (Frederikstad, Norway, 10th - 13th October, 1983)

A Summary Report to the NEACRP

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The SM was organized by the NEACRP and hosted by the OECD Halden Project, whose staff contributed a most valuable effort to run a smooth and productive meeting, which attracted 24 papers (See Annex). The format - a "rapporteur" summarizing the points of general interest raised by the papers and a chairman conducting and stimulating the discussion in each of the four sessions - was very much appreciated by the 50 participants (only 20% of which, rather disappointingly, represented utilities).

The purpose of the SM was in fact to provide designers, manufacturers and utilities an opportunity to discuss instrumentation and techniques to obtain the data required to determine core performance, and methods to interpret in-core measurements and to predict future core behavior.

Emphasis was placed on in-core instruments for use in water reactor systems to monitor normal operating conditions and to detect anomalies - i.e., out-of-core measurements, accident
conditions and LMFBRs were more or less explicitly excluded from the discussions.

No really new instrumentation was presented at the meeting, but interesting developments were reported of various types of sensors and techniques (wide-range neutron monitoring by counting & campbelling; gamma and noise thermometry; water level measurements in BWRs) together with reliability data for thermocouples and fission chambers.

Problems relating to self-powered detectors (SPND and SPGD) were discussed in great detail - covering: selection of materials and geometries; cost and lifetime evaluations; sensitivity and perturbation effects; dynamic response and testing for degradation; calibration and leak cable current compensation methods - thus testifying the continuing effort spent to optimize the use of these sensors in various reactor types.

The main feature of the session was the discussion on gamma-sensitive instrumentation being implemented to work in conjunction with - or in replacement of - fission chamber local power monitors in LWRs. The sensors - TIPS for BWRs and RADCALS (fixed integral multisensor gamma thermometers) for PWRs - were described as well developed and successfully in-plant tested. With respect to neutron detectors, the main advantages were identified in lower flux gradients in water gaps (leading to more accurate estimates of the hot channel factors in BWRs), lower costs
and potentially longer lifetime; the main disadvantages seemed to be: smaller signals needing compensation; more complicated geometry to model (in TIPS, due to significant contributions by a larger number of pins); delayed response (in RADCALS, as in any other gamma thermometer, time constants cannot be quite speeded-up for use in safety systems).

In the general discussion, it was pointed out that in-core instrumentation must not be considered in isolation, but in connection with reactor physics modelling, i.e. with the understanding of what is being measured and correlated to power. From this point of view, gamma measurements are expected to be much more difficult to interpret (n-fields being much better known) and gamma codes much more difficult to validate. These considerations take nothing out of the interest with which more extensive in-reactor tests of gamma sensors will be looked at in the future.

A few papers illustrated - in the pertinent session and in others - two aspects of noise techniques applications: in-situ testing of (safety related) instrumentation channels, and monitoring of (thermal/hydraulic) parameters related to reactor performance.

It was recognized that noise techniques as simple as the analysis of autocorrelation (or auto power spectral density) functions have demonstrated their effectiveness as a good indirect method to check integrity and dynamic response of all types of nuclear and process sensor and transducers, with the possible exception
of pressure measuring instrumentation, for which the implementation is still at an early stage.

Noise techniques appeared - at present - less acceptable by the utilities for on-line monitoring and surveillance purposes. The main objections related to the complexity of mathematics and software involved, which would require continuous expert assistance on the plant; less arguably, it was objected that such techniques are not really on-line, and that the interpretation of measurements is often unclear, particularly in the case of coolant flow velocity profiles. Noise analysis is an area in continuous and rapid progress, though, and its prospects look very good for a wide variety of reactor applications.

In the session devoted to methods of reactor performance evaluation, the papers presented the characteristics of codes with various degrees of predictive, adaptive and monitoring capabilities, developed for use in PWR (+VVER), BWR, PHWR and SGHWR plants. The quoted rms accuracies in predicting power distributions almost invariably fell within the range of in-core measurement inaccuracies.

The presentations and the discussion confirmed the continuing interest in developing and improving system-tailored "compressed" models, but the differences among the structures of the codes (choice of methods of model parameters tuning; data correction and rejection criteria; use of precalculated functions for flux shape; emphasis on reactor theory or on-line surveillance
performances) were such, that any attempts of intercomparison for a global analysis made virtually no sense.

In the same session, two somewhat interconnected papers illustrated algorithms for radial and axial (total peak factor) power distribution monitoring on the basis of data supplied respectively by in-core thermocouples and by a newly designed ex-core multiple-detector chamber. Both the algorithm and the detector setup are proposed for implementation on large (1300 MWe) French PWRs, in connection with the SPIN programme. Only preliminary results were available - mainly based on calculations and tests in 900 MWe PWRs - but the technique looked promising; further information, particularly on the way these digital integrated systems will perform, is awaited with interest.

In the concluding session, the discussion mainly revolved around issues as adequacy of present in-core instrumentation and predictive methods, incentives and acceptance problems for new ICI, work needed and trends in the area. Not surprisingly, rather divergent opinions were expressed by the utilities and by the designers/manufacturers, on the quantity and quality of ICI needed to operate water reactor power stations at an "up to standard" level of efficiency and safety. Only the comments by the utilities are reported; the other comments can be easily inferred.

To the utilities, the problem reduces to a cost/benefit trade-off, and the reluctance to change is well justified. The gains in
effectiveness introduced by addition or backfitting of new instrumentation are difficult to assess and often turned out to be more marginal than anticipated, hardly compensating for the large costs involved in plant modifications and for the harder life due to new testing, calibration and surveillance procedures and to new requirements promptly imposed by the regulating authorities. As to improvements in operation safety, buying more insurance than actually needed (safety assessments are made carefully and sensibly) seems to make little sense.

No papers at the meeting addressed the problem of the accuracy of reference calculation methods explicitly; however, it was a safe inference - also taking into account the satisfactory situation as reviewed in the 1979 meeting - that they work pretty well.

Good instrumentation, good methods. Are ICI and RP people going to go out of business?

Actually, the consensus opinion was that much can and should be done to improve on the exploitation and the interpretation of the information supplied by in-core devices. Much work is to be done still to make full use of the ac component (noise) of the signals and much effort in the reactor physics area is also required to increase accuracy, reliability, adaptive capability and speed of the dedicated compressed models, in order to achieve a better level of development of really on-line monitoring and surveillance systems.

The trend is clearly towards the implementation of this type of systems, which will also require some changes of attitude
on the utilities' side (acceptance of the new role of the operators as supervisors of digitally displayed parameters, preparedness to provide a new type of training, and so on).

Such trends are creating new problems, too: first of all and outstanding, man-machine interaction. In considering — probably four year from now — if a new meeting would be timely and desirable, the NEACRP might find that many of the key issues fall out of its scope.

Casaccia, November 1983
"Improved noise analysis methods for on-line determination of in-core instrumentation and power reactor parameters"

E. Tükken, R. Oguma (Netherlands)

"Interpretation of noise signals of in-core neutron- and gamma-detectors in a boiling water reactor"

E.B.J. Kleiss (Netherlands)

"Dependence between transient time measurements and nuclear noise fluctuations in the BWR boiling channel"

A. Federico, R. Ragona, V. Tosi (Italy)

"Analysis of random neutron sensor fluctuations for surveillance of nuclear instrumentation channels in nuclear power plant protection systems"

D.W. Miller, A. Behbahani, J.W. Talmagi, S.A. Arndt (USA)

"Noise chemometry in a light-water reactor"


"Blank water level sensor and its applicability to measurement of in-core thermal/hydraulic performance"

K. Ato, J. Shimazaki, K. Hayashi, S. Morimoto (Japan)

"BWR core performance calculation program with adaptive capability using measured data of in-core instrumentation"

T. Fukusaki, T. Mitsuta, T. Uchida, S. Kobayashi, M. Sakurai (Japan)

"BWR radial power monitoring and diagnosis systems based on in-core thermocouples"

B. Papin, J.L. Proven, L. Boutron (France)

"A code for deriving reactor power distribution from an incomplete set of in-core measurements"

B. Hinton, A.N. Buckler (UK)

"Combining In-core measurements with reactor theory for on-line supervision of core power distribution in the Lovisa reactors"

P. Siltanen, M. Antila (Finland)

"The core surveillance system SCORPIO for core state estimation and predictive calculations"

O. Berg, S. Hvel, J. Petersen, O.S. Jørgensen (Norway)

"Calibration and compensation methods for self-powered in-core flux detectors in Candu Power Reactors"

J. Paulknot, A. James (Canada)

"Average in-core axial power distribution measurement by a multi-core detector"

G. Sengler, U.D. Mourik (France)