Reactor Physics Activities in Italy

Compiled by R. Martinelli

1.0 INTRODUCTION

After more than three years of moratorium, some signs of political rethinking on the abandonment of nuclear power were recently given by members of the Government. Whether this positive (but not unanimous) attitude preludes to some form of revival of Italy's nuclear programme, is difficult to tell. In any case, no early changes are in sight, as virtually all the research and industrial efforts in the area are still concentrated on the analysis and development of (innovative or evolutionary) concepts for the new generation of reactors with increased passive safety features.
In this context, it is worth mentioning the technical cooperation agreements signed by ENEA and Ansaldo with General Electric and Westinghouse on the certification programs of SBWR and AP-600 designs; it is fair to say, though, that the italian contributions -which include extensive thermohydraulics and structural testing of safety-related components at ENEA facilities- do not involve much reactor physics work.
On the other hand, ENEA's technical/scientific agreements for cooperation in other programs contemplate more substantial reactor physics activities. This is the case for :

- core design optimization and analysis of reactivity control devices for PIUS (with ABB-Ansaldo);
- studies of fuel management and actinide burning options in the core of the advanced modular LMR PRISM (with GE);
- three-dimensional core dynamics code development and benchmarking for transient analysis in RBMK cores (with RDIPE, URSS);
- data validation and code testing, in the framework of a new research and development agreement with CEA on the "reactors of the future".

Most reactor physics activities are carried out at ENEA by the Innovative Reactors Department, in the Energy Research Centers of Bologna and Casaccia. Nuclear data evaluation and processing for fission and fusion applications are mainly performed by the Advanced Technology Department, Bologna. Finally, blanket design neutronics studies are under the responsibility of the Fusion Department, Frascati.

2.0 REACTOR CALCULATIONAL METHODS

Two important subjects addressed in core calculations were : the detailed space-time representation of transients in complex configurations and the feasibility/optimization of minor actinide transmutation processes.

2.1 3-D LWR Core Dynamics. All the modules of the new NADYP-LWR code have been assembled and the service programs for interactive graphic input-output management have been implemented. The performance of the improved metastatic method /1/ has been tested in artificially created extreme cases, so that the limits beyond which the method becomes unreliable, are well documented and understood. In the framework of the research programme on RBMK core dynamics, the code was extensively used to analyze the "positive scram" effect for various burnup and control rod configurations. The code was also instrumental in generating and pre-testing the specifications for the BWR problems of the NEACRP-sponsored 3-D LWR core transient benchmark /2/.

2.2 Actinide Transmutation. The effectiveness of minor actinide burning in a PRISM-like reactor with oxide fuel was evaluated. The impact of actinide concentration changes on core parameters such as control rod worths, feedback coefficients and burnup reactivity losses, was calculated as well.Two basic strategies were investigated in detail : a homogeneous option (actinides dispersed in the fuel or in the radial blanket) and a heterogeneous option (actinides concentrated in some special hosting assemblies placed in different core locations). The results of this work are presented in /3/.
A different, more general scoping study on actinide transmutation was performed, aiming at assessing the relative importance of the variables that more significantly affect the feasibility or the acceptability of the process. This parametric study considers the effects of : neutron spectrum, flux and fluence; initial actinide concentration, with and without Np-237; characteristics of the dispersing matrix. On the basis of the results of the study, the authors draw preliminary conclusions on the expected performances of some new machines proposed as potentially efficient burners of minor actinides and of long-lived fission products /4/.

3.0 DEVELOPMENT AND APPLICATION OF MATHEMATICAL METHODS

The development of mathematical methodologies like Monte Carlo or generalized perturbation theory is still pursued in the reactor physics community, even though most of the new applications are of interest in different areas.

3.1 Monte Carlo Methods. Effort has continued in the field of variance reduction schemes for Monte Carlo through optimization of space-energy cell importances using the DSA cell model. With the implementation and testing of a complete calculational procedure during the first half of 1991 /5/, an important stage in this activity has been completed. Besides, a contribution was given for outlining a NEACRP benchmark activity on variance reduction schemes employed in neutron and photon transport codes /6/. Work is underway on developing a new version of the MCNP code to perform

electron and positron transport calculations, too. This code version has been tested for the implementation of a new multiple scattering model developed at INFN, Milan
Significant efforts have been spent in the field of the development of Monte Carlo codes applicable to the reliability and availability analysis of complex systems. The potential of optimization methods based on MC-calculated sensitivities has been demonstrated for simplified /7/ as well as for realistic /8/ applications.

3.2 Generalized Perturbation Techniques. The applicability of the heuristically based generalized perturbation theory techniques (HGPT) has been demonstrated, in relation to the calculation of the sensitivity coefficients required for the analysis of multichannel thermohydraulic systems. Satisfactory results obtained in terms of accuracy and of reduction in computing time are shown in /9/ for steady-state thermal-hydraulics calculations performed using the COBRA-IV code. Applications of the technique have been limited to PWRs so far, but will be extended to BWRs in the near future.

4.0 DATA EVALUATION AND VALIDATION

Most activities in these areas are performed in the framework of international projects such as NEA's JEF and File Evaluation Intercomparison (fission) ; EFF, GEFF and IAEA's FENDL (fusion).

4.1 JEF/EFF Data Evaluation and Processing. Evaluated data for structural materials (Fe,Cr,Al,Si) have been thoroughly revised, as a contribution to both JEF-2.1 and EFF-2, with regard to inelastic, gamma production and activation cross-sections and to double-differential distributions. Evaluated data for Fe above the resonance region are presented in /10/. In connection with the Subgroup on Processing Methods, work has continued on the development of ENEA's code MILER as an efficient interface between the NJOY and AMPX systems.
In the framework of the new CEA-ENEA cooperation agreement, the development of processing codes , finalized to the production of data for the ECCO cell code , has continued. A fine-group library (1968 groups with subgroup data) has been derived from JEF-2 /11/.

4.2 JEF Dosimetry Data Validation. The results of a DOT 3.5/JEF-1 analysis of the PCA-REPLICA shielding benchmark /12/ confirmed previous indications pointing to an overestimate of Fe-56 inelastic scattering cross-section in JEF-1 (the values are lower in the new JEF-2 versions). Further validation work is in progress for Fe-nat files, which are of primary interest in LWR-PV dosimetry transport calculations.

4.3 Delayed Neutron Data Benchmarking. In the framework of the activities of the pertinent NEACRP/NEANDC Subgroup, a new strategy has been defined to significantly reduce the uncertainties on the total delayed neutron yields of U-235, U-238 and Pu-239 /13/. In order to isolate the Pu-239 contribution to C/E discrepancies, a new effective beta measurement has been proposed in a Pu-fueled core of the thermal critical facility EOLE (CEA Cadarache). At the same time, an improved semi-analytical method has been defined for adjustments, using "clean" effective beta measurements to obtain isotopic breakdowns of the overall discrepancies.

5.0 FUSION BLANKET NEUTRONICS

The activities summarized here are performed in support to the design of blanket concepts to be proposed for testing in NET/ITER in view of a possible installation in a future DEMO reactor. CEA and ENEA have defined a common design of a "BIT" (Breeder-In-Tube), Helium-cooled ceramic blanket with a Lithium aluminate breeder and a Beryllium multiplier. The principal technical advantages of the common design are described in /14/ as : tritium breeding potential; moderate development risk; high reliability and safety; potential for high thermal efficiency.
In order to estimate the TBR under postulated operating conditions, two- and three-dimensional neutronics analyses of the reference configuration have been made by the two laboratories, using the same EFF-1 library with different Monte Carlo codes (TRIPOLI at CEA, MCNP at ENEA) /15/. In a parallel effort, sensitivity analyses are made for the TBR with respect to the Li-6/Li-7 isotopic ratio, in an attempt to determine alternative blanket configurations that are optimized from the neutronics standpoint and still meet the technological design requirements and constraints.

6;0 REFERENCES

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/3/ C. Artioli :"Actinide Transmutation in a Fast Inherently Safe Core", to be presented at FR '91, Kyoto, October 1991
/4/ A. Buccafurni, P.A. Landeyro :"Feasibility Analysis of Minor Actinides Burning", ANS Meeting, San Francisco, November 1991
/5/ K.W. Burn : "Complete Optimization of Space-Energy Cell Importances with the DSA Importance Model", submitted for publication in ANE (1991)
/6/ K.W. Burn : Private Communication (1991)
/7/ A. Dubi, A. Gandini et al. : "Analysis of Non-Markovian Systems by Monte Carlo Method", Int.l Meeting on Advances in Math., Comp. and Reactor Physics, Pittsburgh, April 1991
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Your Ref.	Your Letter	Our Ref.	Date
		KWU BT2/fn / 136	February 18, 1992

To : Participants in the 3–D LWR Core Transient Benchmark (3DLWRCT)

From : Herbert Finnemann, SIEMENS/KWU

Subject : PWR Benchmark

As a complement to the benchmark specification NEACRP–L–335 we would like to add the following information:

HZP is defined by an inlet temperature of 286 °C
an initial power of 2775 W
and a critical boron concentration dependent on CA configuration

The macroscopic increments of the control assemblies are valid in the core and in the reflector with the exception that the increments of the fission cross sections of the latter are put to zero. (see attached Table)

Yours sincerely,

H. Finnemann

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Addendum to PWR Benchmark Specification

Table 2.5 is split up into Tables 2.5.1 and 2.5.2

.373220E-02	-.319253E-02	.247770E-02	-.102786E-03	-.377989E-04
-.219926E-01	.255875E-01	-.282319E-02	-.115483E-02	absorber type1
.374092E-02	-.314239E-02	.242926E-02	-.122634E-03	-.459250E-04
-.167503E-01	.256478E-01	-.328086E-02	-.134262E-02	absorber type2

Table 2.5.1 – Cross sections $\Delta\Sigma_{CA}$ of control assemblies in axial layers 2 through 17 (active core)

.373220E-02	-.319253E-02	.247770E-02	.000000E+00	.000000E+00
-.219926E-01	.255875E-01	.000000E+00	.000000E+00	absorber type1
.374092E-02	-.314239E-02	.242926E-02	.000000E+00	.000000E+00
-.167503E-01	.256478E-01	.000000E+00	.000000E+00	absorber type2
.697102E-02	-.119034E-02	.879034E-04	.000000E+00	.000000E+00
-.113498E-01	.170043E-02	.000000E+00	.000000E+00	driver device

Table 2.5.2 – Cross sections $\Delta\Sigma_{CA}$ of control assemblies in axial layer 18 (upper axial reflector)