

Second Quarterly Report Contract No. DE-FG03-99SF 21901/A00  
IRIS Program

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Administrative

Luca Oriani of POLIMI was seconded to Westinghouse for a four-month assignment starting on March 1, 2000.

In March 2000, DOE (Tom Miller) started participating to the periodic conference calls (USA-Europe) of the IRIS project.

Technical

Task 1a – Fuel System (UCB & CEA lead)

- Four benchmark problems have been defined: two for oxide fuel and two for metallic fuel. These benchmarks will be used to compare the results of burnup dependent  $k_{eff}$  as obtained by three groups: CEA, Westinghouse and UCB. CEA and W are using deterministic codes while UCB is using a Monte-Carlo burnup code.
- Axial leakage probability from tight lattice cores of different heights have been calculated by UCB. The results will be used by CEA and W to determine the minimum value of  $k_{\infty}$  in infinite lattice calculations.
- A series of calculations of both H<sub>2</sub>O and D<sub>2</sub>O cooled cores using metallic fuel have been performed, and the p/d ratio and core height that can provide burnup independent  $k_{eff}$  have been identified.
- The efficiency of the MOCUP code was significantly improved by setting it to run on parallel processors.
- The APOLLO2 transport code was used to perform a series of 1D cell calculations for oxide and MOX fuels for various isotopic compositions, moderation ratios, geometries and power densities. Preliminary indications are that a 15-year lifetime can be achieved for quite low power densities, which can be not economical.

Task 1b – Cladding (W lead)

Neutronic calculations were performed to estimate the lifetime fast neutron fluence and DPA for various p/d lattice ratios and fissile contents. The IRIS long-life core goal, fuel operating conditions exceed the experience base for known

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LWR fuel design with Zirconium alloy or stainless steel cladding. Achieving a target burnup of 150 GWd/MT-HM in 15 years in a PWR with some bulk boiling has never been attempted. The core design is proceeding using a 300 series type stainless steel cladding material; for example cold worked type 316 SS or type 348 SS. Preliminary evaluations concluded that a Zirconium alloy would probably exceed acceptable corrosion, clad growth and stress and strain limits at those conditions, but it is not excluded that an improved Zirconium alloy could be acceptable. Hence, the proposal to start the conceptual IRIS design with a stainless cladding reflects the higher confidence that such a cladding will be acceptable. Note that in the hard IRIS spectrum, the neutronic penalty of using stainless steel is acceptable. Later, after the selection of the final cladding composition and condition, these property data may need to be adjusted; however, this will not invalidate the conceptual design basis.

#### Task 1c – Novel Geometries (MIT lead)

Several geometric shapes of fuel elements for adoption in the IRIS core have been studied. The evaluation has been carried out by introducing figures of merit capable of assessing the various designs on thermohydraulic grounds. In particular, the metal to water area ratio (important to core physics), pressure drop, fuel centerline temperature and clad surface temperature magnitude and distribution were considered. Moreover, the attention in this study has been concentrated on ultra-tight cores with water-to-fuel ratios of the order of 1/3. Fuel element arrangements being investigated are triangular, square and hexagonal with cylindrical, annular and twisted geometry shapes. Also, a possibility of twisting the fuel elements axially in such a way as to provide a self-support of the fuel without the need for any other support systems is being explored.

#### Task 1c1 – Detailed Temperature Profile (TIT lead)

The CFD code CoolFD developed at TIT is going to be applied to perform 2D thermal-hydraulic analyses of:

- normal round-tube-type rod bundles of an infinite triangular array
- distorted rod bundles with one rod displaced toward adjacent rods, and
- exotic (multi-lobe type) bundles of an infinite array of triangular, square and hexagonal configurations with different P/D ratios

In parallel, development of a 3D version of the code is being prepared.

#### Task 1d – Degree of Boiling (POLIMI lead)

The trade-offs being considered are full natural circulation vs. aided (i.e., with a pump providing part of coolant flow) natural circulation, and boiling vs. single phase. The single-phase aided natural circulation solution has been identified as

the easiest and near term solution, but allowing boiling has a significant potential for increasing both core natural circulation and plant efficiency. Detailed thermal-hydraulic evaluation of a boiling core and its effect on the overall primary system configuration is underway.

#### Task 2b – Containment System (POLIMI lead)

A preliminary configuration of the containment system and layout has been proposed. This configuration adopts a pressure-suppression steel containment. The wet-well is inside the dry-well boundary and connected by several vents passing through the biological shield-support structure of the reactor pressure vessel. The maximum design pressure is 0.45 MPa under the hypothesis of a 4" LOCA and the failure of all safety systems. This configuration is being compared to a dry steel shell containment which uses the steel shell for passive heat removal.

#### Task 2c – In-Vessel Configuration (POLIMI lead)

A preliminary layout has been proposed. The layout assumes full natural circulation, medium moderation ratio (1.1), low power density and conventional fuel. The empty space in the lower downcomer has been exploited to allocate a multilayer neutronic and gamma shield, in order to reduce the neutronic fluence and activation on the reactor pressure vessel (less decommissioning constraints) and the biological shield thickness. With respect to a conventional PWR the reduction factor on the neutronic flux is about 500.

#### Task 2d – Lowering Inlet Temperature

This task has been folded into Task 2f.

#### Task 2f – Primary System Design (CEA & POLIMI lead)

An optimization procedure/sensitivity analysis has been established for examining the impact of changes to the RPV components. This analysis uses the OSCAR (Optimization Simplified Code for Analysis of integrated Reactors) and COPENIC codes. A set of key parameters has been identified and the corresponding reactor configurations have been analyzed. The procedure was applied to IRIS configurations with full natural circulation option. Further calculations will be carried out with forced convection and aided natural circulation and with different types of steam generator modules. The whole set of data for the different configurations (several hundreds) has been included in a matrix of results.

### Task 3b — Selection of Safety Systems (W lead)

We are investigating a novel approach to reactor safety, which entails that rather than coping with accidents by active or passive means, IRIS would eliminate Class IV accidents by design. Our preliminary results indicate that by the use of integral (pool) primary system arrangement, natural circulation, internal CRDMs and no refueling, we might be able to eliminate 75% of AP-600 Class IV accidents.

### Meetings

Conference calls were held between USA and European members every two to three weeks. The last call had also DOE participation. Two calls were held between Westinghouse and Japanese members.

There were no meetings, but preparations were made for a full team meeting to be held on April 2, 2000, in Baltimore during the ICONS 8 meeting.