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# CEA studies about innovative water-cooled reactor concepts

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In the beginning of the 90's, CEA achieved a detailed evaluation of innovative reactors proposed by this time (AP600, SIR, PIUS, …). This evaluation has conducted CEA to launch a significant reactor innovative programme. As far as the water cooled concepts are concerned, the three main research subjects have been : the PWR with integrated design for small and medium reactor outputs, the decrease of the PWR operating point (pressure, temperature) and the supercritical-pressure concepts.

The integrated design means that the steam generators are installed within the reactor vessel (the pressuriser and the primary pumps could be also put in the vessel). Using the COPERNIC computer tool devoted to preliminary design analyses, small size reactors operating in full natural circulation have been studied. It has been showed that such a design option would be less interesting from the economic competitiveness point of view. The feasibility of one-batch long life cores has been investigated using the APOLLO2 computer code. With MOX fuel, the use of tight lattice is better but this leads to void reactivity coefficient problems. Rough estimations have been achieved to determine the maximal core size having a negative void coefficient. The use of the CATHARE thermal-hydraulic computer code has confirmed the preliminary calculations of the nominal operating point made by COPERNIC and the good resistance of the integrated design to LOCAs.

The interest of decreasing the PWR operating point comes from the very low decrease of the thermal efficiency with the primary pressure. From 155 bar to 85 bar, the expected variation of the net efficiency would be 33 % to 30 %. On the other hand, the size of all major components could be reduced by a factor two. Considering a « standard » three loops 900 MWe French PWR, a systematic analysis of the operating point decreasing has been carried out. From the neutronic point of view, the slight increase of the moderation ratio, 10 % (due to the water density increase), does not affect significantly the core neutronic design. The core thermal-hydraulic design is favoured by the increase of the critical heat flux at 85 bar. Larger margins are then found out for the DNB ratio in steady states and in loss of flow transients. The primary pressure decrease has a significant effect on the fuel element design and the water chemistry optimisation. For the fuel rod, quite clearly, the lower primary temperature reduces the cladding corrosion, one of the issues limiting the fuel burn-up. Using the PACTOLE computer code, a suitable chemistry has been searched to limit the release and the deposition of corrosion products. In this preliminary study, the solution obtained is not as good as the standard PWR case. This shows the high degree of optimisation of the latter. Another potential advantage of decreasing the primary pressure is the simplification of the safety injection systems. A limited analysis of LOCAs using CATHARE shows that it would be possible to remove the high pressure injection system and the accumulators.

The supercritical-pressure light water cooled reactor studies are conducted in the frame of an European programme called HPLWR "High Performance Light Water Reactor". In a first step, the concepts proposed by the university of Tokyo are evaluated from the core neutronic and thermal-hydraulic designs. These concepts based on once-through direct steam cycle are quite attractive from the thermal efficiency point of view (40 to 44%) and the reactor vessel compactness (compared to BWR of similar outputs). These first analyses highlight potential weaknesses of the proposed core design.