Experimental and Numerical studies for Hydrogen Management in Nuclear Reactor Containment

During a severe accident in water-cooled power reactors, large quantities of hydrogen can be released in steam condensing atmosphere of nuclear reactor containment. The main source of hydrogen generation is clad oxidation in presence of steam. The generated hydrogen got distributed in the containment and due to low density it has the potential to form high concentration hydrogen-air mixture in the containment. The integrity of the containment could be threatened due to hydrogen combustion. If composition of the hydrogen–steam–air mixture lay within a certain limits, the combustion would occur. The steam condensation phenomenon is important from hydrogen distribution point of view to locate the flammable region in the containment. The prediction of hydrogen behaviour at severe accident conditions may help in devising adequate accident management procedures.

To estimate the quantity and location of suitable mitigating system, it is necessary to have a reliable knowledge of hydrogen distribution in the containment. The lumped parameter (LP) and the computational fluid dynamics (CFD) approach are being used for this purpose. The LP codes are very useful and practical since they predict the distribution in large size geometry very fast and model the relevant phenomenon. CFD codes give detailed distribution, concentration profile and derived quantities, but are highly time consuming and modelling various processes like spray, direct contact condensation is difficult. However efforts are being made to model various phenomenons relevant to nuclear reactor containment in CFD codes and to use them for detailed safety calculations. The steam condensation model is incorporated in commercial CFD code. 3D CAD model of three different reactor containments have been made and used for detailed CFD computations for full transient of hydrogen release during a severe accident in actual reactor containment. Full scale geometry of Kaiga 220 Mwe, TAPS 540 MWe, KAPP 700 MWe have been built and used for analysis.

Three catalyst designs developed at BARC were evaluated for their performance in terms of removal rates, peak catalyst temperatures, etc. under dry and steam-laden conditions at HRTF Tarapur. Tests were performed upto 3 % (v/v) H2 concentration under dry conditions and upto 8 % (v/v) H2 concentration under steam-inerted conditions. The catalysts from BARC have been developed by Material Processing Division (MPD), Chemistry Division (ChD) & Technical Physics Division (TPD), BARC using three different techniques.

On the basis of the experimental data generated from the various tests conducted in HRTF, a technical evaluation of the performance has been performed both at BARC and NPCIL. Analysis has been performed for two concentrations- 3.6 % (v/v) and 7.5 % (v/v) H2 concentration.

Besides the evaluation of the removal rates, T1/2 , T1/3 and T1/4 values have also been evaluated. The T1/2 value denoted the time required for the hydrogen concentration to drop to half of the peak concentration. Similarly T1/4 value denotes the time required for the hydrogen concentration to drop to one-fourth of the peak concentration. These values helped to evaluate the catalyst performance under depleting hydrogen concentrations and were good parameter to judge the catalyst performance at lower concentrations.