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Modelling of Water Radiolysis Processes in Fusion Neutron Environments

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In operating a future fusion power plant with water as a coolant, an important factor for radiological impact will relate to corrosion and transport of material around the cooling circuit. This is strongly influenced by the cooling loop water chemistry. Cooling loop water chemistry is important as it dictates corrosion, and key safety and environmental issues. Under radiolysis of the steels proposed for use in ITER and DEMO, an increase in oxidation potential enhances material corrosion leading to a build-up of the gamma field from transport of activated corrosion products to the heat-exchanger/boiler units presenting a potential hazard to maintenance workers.

The activation transport and deposition code TRansport of ACTivation (TRACT) uses approximate concentrations (based on empirical data) of injected hydrogen for suppression of radiolysis in fusion power plant cooling channels The radiolysis process inside the radiation zone can only be estimated through computer simulations. The developed, new code H2ORAD, will be used to replace empirical data chemistry, and amend the injected hydrogen for suppression of radiolysis in TRACT.

This paper presents the time–dependent transport code water radiolysis (H2ORAD) with example calculations. Parameters that affect radiolysis are: primary energy (fast neutrons, electrons, gamma rays), the rate of absorption of energy (radiation intensity, linear energy transfer rate), and water chemistry (oxidising or reducing concentration, pH). The chemical radiolysis is described by a set of differential equations representing elemental reactions between radiolysis products. In previous work (PWR, BWR), in-core behaviour has been explained using a reduced set of ~14 radiolytic reactions. However, for fusion environments H2ORAD must be enhanced to include ~50 radiolytic and thermal reactions. Example calculations showed that the worst radiolysis condition arises in the mid-blanket cooling channels. With increasing distance from plasma the heat deposition rate decreases whereas the neutron/gamma ratio increases, leading to an optimum situation around the middle of the blanket. It was determined that ~10 ml/kg of dissolved H_2 are required for the suppression of radiolysis. The analysis reveals which areas require additional data to improve the modelling of fusion experimental devices and power plants.

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