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Materials concepts in steel containment for PWR Nuclear Power Plants

L.M.G. Magalhães[(1)], R.T. Nicolescu[(1)] and A. Costa e Silva[(2)*]

(1) IBQN, Rio de Janeiro, Brazil
(2) IBQN, Rio de Janeiro and EEIMVR-UFF, Volta Redonda, Brazil, andrecs@ibqn.com.br
* Corresponding author.

Abstract – The steel containment is an important safety barrier in several PWR plants. Materials and manufacturing specifications for these vessels have evolved in the last decades, aiming at avoiding failure by guaranteeing toughness and strength. Evolutions in chemical composition as well as thermomechanical processing of these HSLA steels are discussed, and their impact on weldability and assurance of toughness in the final product highlighted. In this work this evolution is discussed, considering the American and German regulations, highlighting the metallurgical reasons that support the various decisions incorporated in the codes and standards.

Several PWR nuclear power plant designs rely on a steel containment as an important safety barrier to avoid undesirable releases to the environment. These steel containments are designed as large pressure vessels required to withstand moderate temperatures and pressures in the case of accidents but also to maintain significant toughness when operating at room temperature. This is defined mostly by the plant location. In view of their relevance for safety and their size and relative complexity, stringent requirements are established not only for the base material properties but also for the manufacturing and testing, in special related to welds and accessories. During the last decades, the requirements applicable to containment materials have evolved towards improved toughness and higher quality assurance requirements in several countries. In this context, the effects of chemical composition, in special microalloying additions, thermomechanical treatment cycles during steel production as well as during vessel fabrication and their impact on the properties of the finished vessel and its welds have been the subject of continuous evaluation and development. This work describes and compares this evolution, focusing mainly on the development of the German and American regulations and standards for high strength low alloy (HSLA) steel containment materials and their manufacturing and testing, highlighting the changes in the applicable requirements, their metallurgical justifications and the impacts in the supervision of material and component manufacture as well as testing and inspection, from the point of view of an independent inspection agency. The needs for repairs and changes, in special associated with plant modifications, and how these affect materials and weld properties are also considered. The interactions with design, when relevant to the material, are also discussed.

The importance of the use of an adequate code- a harmonic set of requirements for design, materials, inspection, testing and operation- to guarantee the safety of steel containment vessels is highlighted. In this context it is also shown that individual material requirements expressed in a given code should not be compared out of the code context.