

Views on Neutronics and Activation Issues Facing Liquid-Protected IFE Chambers

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Over the past few years, the ARIES team has been defining the design space and operational windows for both laser and heavy ion driven inertial fusion energy (IFE) concepts from the viewpoint of a viable power plant system, rather than developing a point design [1]. For the heavy ion beam study, we were concerned with the feasibility of protecting the steel-based structure (advanced ferritic steel or 304-SS) of the chamber with a thick wall of Flibe or Flinabe liquid breeders. Specifically, the concern is the ability of the thick liquid wall to protect the structure during the entire plant life (40 FPY) while providing an adequate tritium supply for machine operation and satisfying the ARIES top-level requirement of generating only low-level waste (Class A or C). In addition, the helium production level is a concern if the design mandates cutting and rewelding the structure and flow nozzles for component replacement or maintenance during operation.

It is found that Flibe is a better breeder than Flinabe, thus a wall thickness (58% breeder and 42% void) of 85 cm is required for Flibe and 150 cm for Flinabe for a breeding ratio of 1.08. While the 200 dpa level at the structure indicates both breeders could protect the advanced ferritic steel (FS) for 40 FPY, the FS reweldability limit of 1 He appm is greatly exceeded, meaning the FS structure and flow nozzles cannot be rewelded at any time during operation.

The activation of the chamber structure is severe as all steel-based alloys generate high-level wastes. A Class C low-level waste cannot be achieved unless the impurities of the FS and 304-SS alloys are strictly controlled. The main contributors to the waste disposal rating are ^{94}Nb (from Nb), ^{99}Tc (from Mo), and, to a lesser extent, $^{192\text{n}}\text{Ir}$ (from W). Thus, consideration of advanced FS or 304-SS for ARIES-IFE rests heavily on the assumption that Nb and Mo impurities can drastically be controlled for the “off-the-shelf” materials. The high cost of impurity control must be factored in the unit costs of the modified FS and 304-SS structures. Practically and economically, complete removal of Nb and Mo impurities can never be accomplished. An alternate approach is to thicken the blanket and in the meantime adjust the breeding level by depleting the Li of the breeder. A combination of impurity control and a thicker blanket with depleted Li represents a viable solution to the high-level waste problem of the ARIES-IFE liquid-protected chamber.

Another concern for the liquid-protected chamber is related to the IFE pulsed nature. The high instantaneous damage rate can lead to significant changes in the microstructure of the material. Furthermore, the instantaneous deposition of the neutron energy can cause isochoric heating problems with significant pressure waves that could impact the fatigue life of the structure. Depending on the rep rate, the structure temperature fluctuates 4-6 times per second with internal pressure reaching 100 atm. Pulsing produces significant strain in the structure. Fatigue from repetitive shock waves could shorten structure lifetime and cause internal cracks. The validity of the structure over millions of shots is still an open question.

- 1- F. Najmabadi, “ARIES-IFE Assessment of Operational Windows for IFE Power Plants,” These proceedings.