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Brief History and Status of Cryogenic Pellets in Fusion Energy Research

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Brief History and Status of Cryogenic Pellets in Fusion Energy Research*

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High-speed injection of solid fuel was first proposed in 1954 (Spitzer et al., USAEC Report NYO-6047) as a possible solution to the problem of transporting fresh fuel across the confining magnetic fields into the plasma of a fusion reactor. While it took a few decades, the use of cryogenic pellets (typically H2 and D2) on fusion experiments eventually became commonplace, with most tokamaks and stellarators around the world equipped with a pellet injector at some point. Hydrogen pellet injection devices operate at very low temperatures (10 to 20 K) at which solid hydrogen ice can be formed and sustained. Most injectors use conventional pneumatic (light gas gun) acceleration to routinely accelerate macroscopic sized pellets (0.3 to 6 mm diameter) to speeds of 100 to 1000 m/s. Two other key operating parameters for plasma fueling are the pellet injection rate and time duration, with a single pellet adequate for some experiments and a steady-state injection rate of up to 50 Hz or greater appropriate for other experiments. Even testing with T2 and D–T pellets were carried out in the late 80s to demonstrate reliable operations with the radioactive isotope. As a testimony to the maturity of this specialized technology, pellet injectors have been available commercially from a Russian company (PELIN) for about 20 years; several of these systems are presently operating on major fusion experiments in Europe and Asia. A significant finding from tokamak studies in the late 90s indicated that appreciable improvement in pellet penetration and fueling efficiency could be achieved by injecting pellets from the magnetic high-field side (HFS) of the device. This scheme requires the use of curved guide tubes to transport/deliver the pellets to the plasma. Extensive testing in the lab and pellet experiments on fusion devices around the world have shown that intact pellets can be reliably delivered through any curved tube track if the speed is maintained below a specific limit (typically 100 to 500 m/s) for the given system. Thus, pellet fueling from the HFS is planned for ITER. In addition to plasma fueling, cryogenic pellets have often been used for particle transport and impurity studies on fusion experiments, including Ne, Ar, CH4, and gas mixtures. During the last decade or so, a few new applications for cryogenic pellets have been demonstrated, one for edge-localized mode mitigation, one for plasma disruption mitigation (requires large pellets that are shattered before injection into plasma), and another in which pure Ar pellets are used to trigger runaway electrons in the plasma for scientific studies. In the paper, a brief history and the present status of cryogenic pellets in fusion energy research will be presented.

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