Fusion Development Path – A Roll-Back Approach Based on Conceptual Fusion Power Plant Studies

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The US national power plant studies program aims as performing detailed and integrated studies of the long-term fusion energy embodiments to identify key R&D directions and provide visions for the program. The scientific basis for fusion energy involves subtle combinations of plasma physics, fusion engineering sciences, and technology. Conceptual design studies of fusion power plants invoke physics and engineering constraints which are not in present-day experiments (e.g., simultaneous high power and high particle flux to divertor). They identify and quantify interaction and trade-off among plasma parameters (MHD β limit, heating & current-drive, divertor, transport). They highlight constraints imposed by the interfaces between fusion plasma and other components (e.g., restriction on plasma elongation by location of stabilizer, and triangularity by inboard divertor slot). Furthermore, examination of long-term fusion energy embodiments is an essential tool in setting program directions as the commercial fusion energy is the most demanding of the program goals, and it provides the toughest standard to judge the usefulness of program elements.

During the past years, the ARIES Team, a national US team involving universities, national laboratories, and industry, has studied a variety of magnetic fusion power plants (tokamaks, stellarators, spherical torus, and RFP) with different degrees of extrapolation in plasma physics and technology from present database. The results of ARIES studies provide a large body of data that highlight the contribution, tradeoffs, and relative leverage of advanced plasma physics and fusion technology directions.

In this paper, I will discuss physics and engineering trade-offs in a commercial fusion power plant, will compare physics, engineering, and technology needs with present-day achievements and summarize R&D areas with highest leverage in achieving attractive fusion power plants. I will further discuss what is needed to convince power industry to invest in fusion and regulatory agencies to license a fusion power plant. I will synthesize these results into a “roll-back” frame-work for fusion development path which will take fusion research from ITER to an attractive fusion power plant and a fusion-based energy economy.

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