Diagnostic Set Requirements and Technology for Magnetic Confinement Fusion Pilot Plants (FPP)

T. Akiyama, L. Bardoczi*, R.L. Boivin, W. Choi, B. Grierson, A. Hennessy, S.H. Hong, S. Houshmandyar, D. Humphreys, M. Jaris, A.W. Leonard, D. Lin, D. Liu, A. Lvovskiy, O. Meneghini, A. Moser, C. Muscatello, N. Eidietis, P. Schroeder, T. Strait, M.A. Van Zeeland, D. Weisberg, and Z.A. Xing

General Atomics, CA 92121, USA

Corresponding Author Email: akiyamat@fusion.gat.com

In an FPP, the role of diagnostics is targeted toward control of the burning plasma and machine protection - this contrasts with the diagnostic sets in ITER and current machines that include many diagnostic systems dedicated to plasma physics research. The FPP environment is characterized by harsher radiation, higher temperature, longer pulses, and reduced access relative to ITER and existing machines. Therefore, significant advances in diagnostic technology are required beyond that currently envisioned for ITER.

Based on these unique diagnostic challenges, a general FPP diagnostic approach is defined:

i) Utilize microwave/RF and neutron/gamma diagnostics, which are robust even in an FPP environment, as much as possible
ii) Use proxy parameters rather than conventional control parameters as required
iii) Adopt simplified and more robust versions of proven technologies
iv) Compensate for the limited diagnostic data with modern data analysis techniques

The initial control parameters and related diagnostic requirements are also defined. According to these requirements and above diagnostic approach, an initial diagnostic ensemble has been determined. The ensemble includes several non-traditional/alternative diagnostics such as microwave diagnostics for plasma shape/position control and fast wave diagnostics for fueling control. The diagnostic challenges in a tokamak-based FPP are identified and impacts on each diagnostic are considered. Most laser/spectroscopy diagnostics in the visible range, semiconductor-based diagnostics, and beam-based diagnostics are likely excluded due to the lack of robustness needed in the harsh environment. A stringent requirement from reactor design is that maintenance/replacement opportunities of diagnostic components are greatly limited. Additionally, the surface area for diagnostics on the first wall must be minimized to reduce the impact on tritium breeding ratio (TBR) and neutron streaming. The Technical Readiness Level (TRL) of each diagnostic is assessed to identify any gaps between present and required diagnostic capabilities. Feasibility studies of relevant diagnostics under FPP conditions have been also conducted.

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* Present affiliation is University of California, Irvine, CA 92697