Plasma Facing Component Test Facilities

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Areas of Critical Need: Technology development for DEMO will require a multitude of laboratory-scale test facilities dedicated to PFCs and related blanket development to investigate plasma-surface interactions, material modifications and changes to material properties due to redeposition/codeposition with T and He, irradiation, thermal cycling, heat transfer, and the development of engineering diagnostics and non-destructive evaluation (NDE) techniques. This requires high capacity, high temperature helium loops, liquid metal loops and handling systems, electron beams and plasma devices. Existing test facilities in the U.S. are antiquated and need of major repair and upgrade [1].

DEMO operation will expose PFCs to higher particle and heat flux, combined T and He effects, higher operating temperatures and higher neutron loading than current test facilities can attain or extrapolate. The study of synergistic effects, e.g. particle bombardment and heat flux and/or neutron irradiation will require the combination of existing test systems and diagnostics. This means relocation at the least, perhaps new chambers for existing sources, or completely new devices. International facilities like IFMIF may provide opportunities to host synergistic experiments on irradiated materials. These need to include electron beam facilities for thermal testing and linear plasma devices and plasma guns to study tritium permeation into coolants, ELMS and disruption damage. In addition, extensive material testing and characterization facilities need to be included with these systems such as calorimetry for specific heat, dilatometers for thermal expansion and flash diffusivity systems to measure thermal conductivity, as well as surface analysis (XPS, AES, RBS, XRD, EDX), microscopy and metallography during testing campaigns. New stand-alone facilities are required to study volumetric heating and coolant flow in large components or perform robotic NDE of operating components. NDE during PFC fabrication is a critical area for quality assurance and the development of engineering diagnostics to monitor PFC performance both off-line and at existing toroidal facilities. Eventually, we must test on a large-scale toroidal facility with plasma parameters representative of DEMO that can produce the complete PFC environment. In the meantime, a multitude of smaller facilities must be maintained to bridge the gap to DEMO.

Technology Readiness Levels between TRL3 and TRL6 require the presence of test facilities or the technology cannot advance. Unfortunately, U.S. industry and the private sector cannot meet all the needs of the fusion program. Other government facilities in DoD and NASA do not meet our requirements or have little availability due to their own missions.

Research Thrust: A huge gap exists in dedicated PFC test facilities. Over the last three decades, the gap has grown worse, while the EU, JA and RF have installed a multitude of new facilities including new coolant loops, liquid metal systems, e-beam facilities, plasma devices, and in-pile test assemblies (HeFUS3, HELOKA, MEKKA, Tsefey upgrade). In contrast, little investment occurred in the U.S. domestic program. Our program needs a new medium-scale research thrust on the $10M-$30M level to just begin the task of upgrading our existing facilities and adding the new facilities necessary for further technology development toward DEMO. The failure to provide our own facilities and the education and training of operating personnel will leave international collaborations as the only access to fusion technology for the DOE. This will contribute to the U.S. taking a much diminished role in the world-wide fusion effort.

References

[1] D.L. Youchison, J.M. McDonald and L.S. Wold, "High Heat Flux Testing Capabilities at Sandia National Laboratories - New Mexico," ASME -Heat Transfer in High Heat Flux Systems, HTD-**301** 31-37 (1994), also SAND95-2331C report.