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Plasma Facing Components[1]

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Energy escapes from a magnetically confined plasma by convection and diffusion from closed flux regions to open field lines where it is transported to solid surfaces on the device walls. Particle and energy transport along the field lines is much more rapid than transport perpendicular to the field. This means the flux of power and particles on surfaces is quite narrow. Extremely high heat flux can be mitigated by tilting the plasma facing surface, spreading the magnetic field, and adding radiating impurities. Even so the peak heat flux can be in the range of 10-30 MW/m^2. While this heat flux can be removed by structures having adequate thermal conductivity and aggressive cooling, the existence of severe intermittent heat flux 10 to 100 times higher limits the choice of materials and heat sink design. Future fusion devices will have to operate successfully with particle fluence hundreds of times greater than existing devices, and fusion reactor grade plasmas will add energetic neutron damage to the picture. Advances in either materials or design of plasma facing components (PFCs) have had a profound effect on core plasma performance. Early advances relied on selection of carbon based materials that had good thermal conductivity and no melting rather than refractory metals. Carbon fiber reinforced carbon composites provided further performance improvement. Divertor plasmas allowed exploration of plasma sweeping and more effective particle control, but concentrated the heat flux onto a smaller region. Hydrogen retention in carbon is one of the challenges facing the next generation of fusion devices. Impurity shielding in divertor plasmas allows all metal PFCs to be considered. Engineering of high Z refractory metal PFCs with active cooling has matured for use on long pulse devices. Exploratory studies have shown that liquid PFCs may be able to remove high heat flux with no erosion or nuclear damage issues. The major issue for liquid surfaces is control of the magneto-hydrodynamic interaction between the liquid and the spatially and temporally varying fields in a fusion device. This paper will review the advances that have enabled fusion devices and examine the paths that are likely to meet the needs of future devices.

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