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Neutral Beam Shine-Through Power And Its Dependence On The Line Density Of The DIII–D Plasma*

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ABSTRACT

Neutral beams are the primary source of auxiliary plasma heating in the DIII–D Tokamak. Part of the beam power passes through the plasma and is deposited on the wall of the tokamak (shine-through power) and does not contribute to plasma heating. It is therefore crucial to know the shine-through power in order to give an accurate account of the total power deposited in the plasma. We have recently remeasured the shine-through power using data taken from thermocouples embedded in the beam target tiles of the tokamak vessel. The tile temperature rise was correlated to the injected beam power. A dependance of the tile temperature rise on the initial tile temperature has been empirically measured and accounted for in order to obtain a more accurate determination of the shine-through beam power. Measurements of the shine-through beam power as a function of plasma density and beam energy confirm that shine-through power decreases exponentially with plasma density, and increases linearly with beam energy.

INTRODUCTION

When neutral beams are injected into DIII–D plasmas, a fraction of the beam power passes through the plasma and is deposited on the beam-target armor tiles on the interior walls of the tokamak (shine-through power). Knowing the correct value for the shine-through power is important for an accurate accounting of beam power deposited in the plasma. The shine-through beam power is calculated based on the armor tile temperature rise measured by the thermocouples embedded in the tiles. Calibrations are required in order to obtain the shine-through power as a function of the thermocouple readings. These calibrations were performed by measuring the tile temperature rises when neutral beams with known power were injected onto the armor tiles without plasma discharge inside the tokamak. With these calibrations, the shine-through neutral beam power injected into the plasma can be obtained from the armor tile temperature rise independent of beam energy and plasma density. To study the dependence of shine-through beam power on the plasma density we have measured shine-through power as a function of the plasma density when beam energy was held at a constant value of 75 keV. The result shows that shine-through power is an exponential function of the plasma density. We have also determined that shine-through beam power increases linearly with beam energy between 55 and 75 keV when plasma density is held at a constant.

CALIBRATIONS OF ARMOR TILE THERMOCOUPLES

The armor tile temperature rise as measured by a thermocouple imbedded in the tile is a function of the beam power deposited on the tile and the beam pulse length. A parameter called *shine-through power constant Ks is defined and is* equal to beam embedded in the tiles the beam pulse length divided by the armor tile temperature rise ($Ks = Pd \times t / \Delta T$). With no plasma present, we have observed that Ks varied with the initial (or baseline) temperature of the armor tile when beam power and pulse length were kept constant. This is due to slight changes in the armor tile thermal characteristics at different tile temperatures. We also observed that Ks is independent of beam power (Fig.1) and/or beam pulse length as long as the tile is at the same initial temperature prior to beam heating of the armor tile. Thus, we obtain a constant which can be used to calculate the beam power deposited on the armor tile and is only function of the initial tile temperature. Shine-through power constants Ks for two thermocouples are shown in Fig. 2, indicating that Ks increases linearly with armor tile baseline temperature.

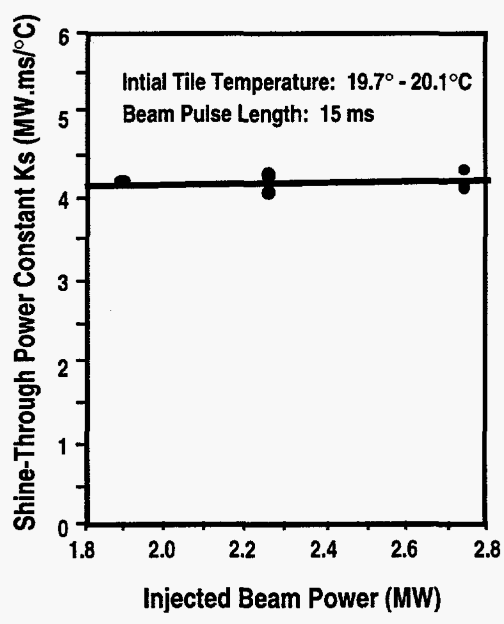

Fig 1. Shine-through power constant Ks is independent of beam power.

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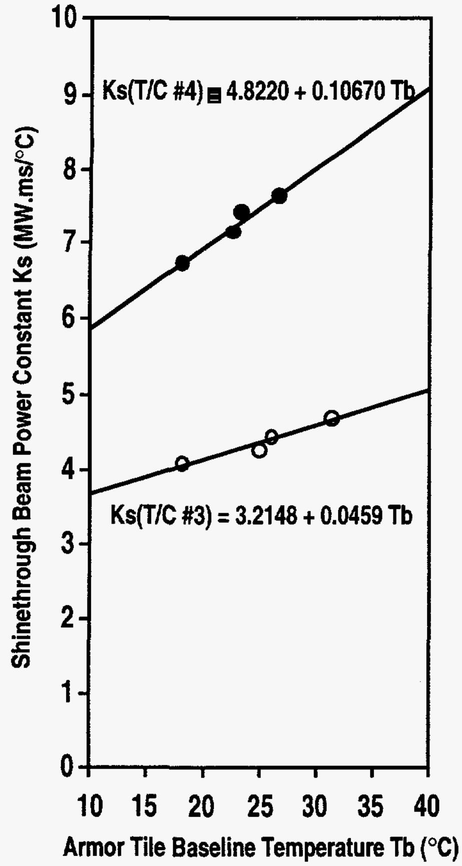

Fig 2. Shinethrough power constant Ks increases linearly with armor tile baseline temperature.

DEPENDENCE OF SHINE-THROUGH BEAM POWER ON THE PLASMA DENSITY AND THE BEAM ENERGY

Shine-through beam power was measured, using the parameter Ks, with 75 keV deuterium beams injected into the DIII–D plasmas, and the averaged plasma radial density was varied between 2.6 and 5.8×10^{13} cm^{-3}. As shown in Fig. 3, the percentage of beam shine-through decreases exponentially with plasma density. The exponential function is the best fit in that the shine-through is 100 percents with no plasma present. Fig. 3 also shows that measurements from thermocouples of two armor tiles agree very well within a few percentage.

To observe the effect of beam energy on the shine-through, we injected neutral beams with beam energy ranging from 55 to 75 kev into plasmas with a constant line density (1.0×10^{14} cm^{-3} m) and measured the shine-through power. Fig. 4 shows that fraction of shine-through beam power increases linearly with beam energy within the 20 keV energy range.

CONCLUSIONS

We have experimentally measured and calculated the shine-through beam power by calibrating the response of thermocouples, which are embedded in the beam-target armor tiles, to the neutral beam deposited on the tiles. A more accurate shine-through beam power is obtained when dependence of tile temperature rise on the initial tile temperature is accounted for in the calculations. A very small fraction of the injected neutral beam will penetrate a dense plasma and reach the armor tiles, since shine-through beam power decreases exponentially with plasma density. We have also observed that shine-through beam power increases linearly with the beam energy. The final accuracy of ±5% on the armor tile thermocouple ccalibrations (and thus shine-through power) is achieved.

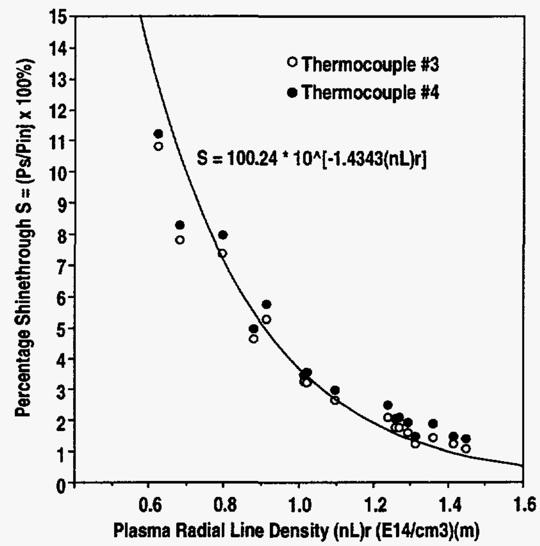

Fig 3. Neutral beam shine-through decreased exponentially with plasma density.

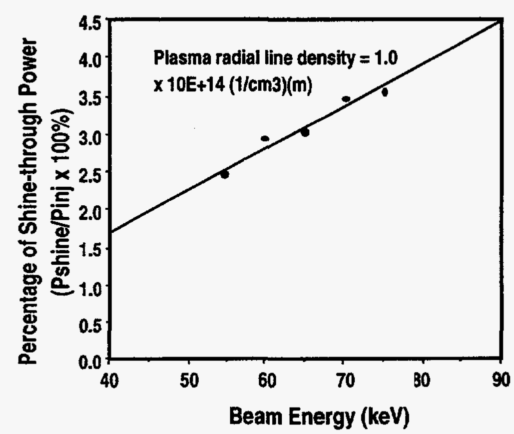

Fig 4. Beam shine-through increases linearly with beam energy.

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