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Understanding the role of turbulence on current generation in the Madison Dynamo Experiment

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Astrophysical dynamos arise in highly turbulent flows where the eddies can contribute to the time averaged behavior of the magnetic field through a turbulent emf. The role of this turbulent emf plays in magnetic field generation in a homogeneous laboratory dynamo is studied in the Madison Dynamo Experiment. The turbulent emf observed is characterized by enhanced resistivity due to turbulent diffusion and an axisymmetric dipole field induced by correlated helical eddies. These effects are drastically reduced by the addition of an equatorial baffle. Simple scaling arguments suggest that the dominant contributions to the turbulent emf are due to the largest-scale eddies in the high Reynolds number flow. By eliminating these eddies, the power required to drive the impellers is reduced, the magnetic flux generated by differential rotation is more than doubled, and the turbulence-induced dipole field is reduced by an order of magnitude. These positive results suggest that a strategy of tailoring the large-scale turbulence by adding adjustable baffles may succeed in lowering the threshold for dynamo excitation.