# NSTX-U Contributions to Disruption Mitigation Studies in Support of ITER

R. Raman[1], W-S. Lay[1], T.R. Jarboe[1], S.P. Gerhardt[2], S.C. Jardin[2],
J.E. Menard[2], B.A. Nelson[1], M. Ono[2], J. Schmitt[2]
[1]*University of Washington, Seattle WA USA*
[2]*Princeton Plasma Physics Laboratory, Princeton NJ USA*

Predicting and controlling disruptions is an important and urgent issue for ITER. In support of this activity, NSTX-U will employ three Massive Gas Injection (MGI) valves that are similar to the double flyer plate design being developed for ITER [1]. NSTX-U will be the first device to operate this valve configuration in plasma discharges. NSTX-U experiments will offer new insight to the MGI database by studying gas assimilation efficiencies for MGI gas injection from different poloidal locations, with emphasis on injection into the private flux region. These results are expected during Spring 2016. The valve has also been successfully operated in external magnetic fields of 1 T.

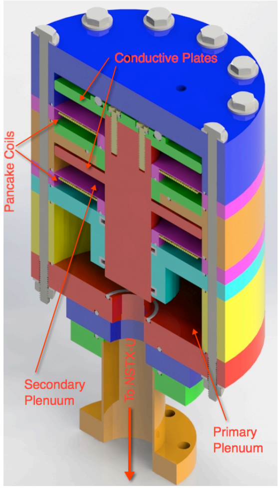

Fig. 1: Internal view of the NSTX-U double flyer plate MGI valve. Gas from the primary plenum is injected into the plasma discharge.

External magnetic fields can interact with the currents flowing in the MGI valve coil and the conducting disk to generate forces that act on these components. The most recent improvements to the valve design for ITER uses a double solenoid configuration [1]. The advantage of this configuration is that currents in both coils are driven in opposite directions, which results in the J x B force that generates a torque on the valve from cancelling. Figure 2 shows the internal components of this type of valve for NSTX-U MGI studies.

An important observation was that, compared to the single flyer plate design [2], adding a second solenoid did not substantially increase the size of the capacitor bank power supply or the operating voltage for injecting similar amounts of gas, and with similar gas pressure rise times in the test chamber. The double solenoid valve was also operated with the two coils connected in a parallel and series configuration. The series connection required a lower operating voltage, but the measured gas time response was nearly the same for both cases. This is because the longer current pulse duration for the series configuration results in the magnetic forces acting on the piston for a longer period. The valve operation is not affected by fields <0.8 T. As shown in Fig. 2, as the field increases to 1 T, there is a 10% reduction in the amount of injected gas.

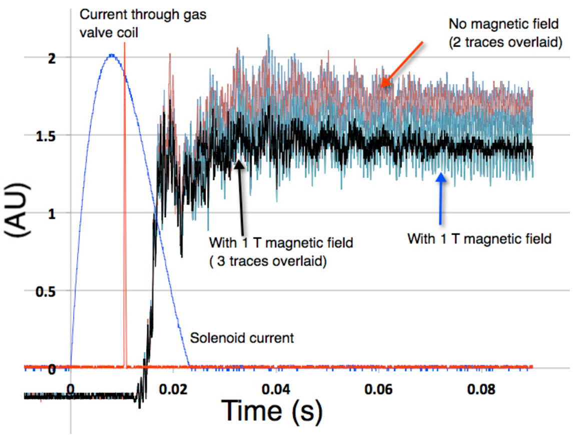

Fig. 2: Shown are the current pulse through the solenoid used for generating an external magnetic field of 1 T, the current pulse through the gas valve pancake coils, and gas pressure traces inside a 1.5 $m^3$ test chamber as measured by a fast baratron, for cases with and without an external magnetic field.

A limitation with the use of gases for pellet propulsion, whether they be solid refractory, shell, or cryogenic shatterable, is that the propellant gas limits the velocity to about 300-400 m/s [1].

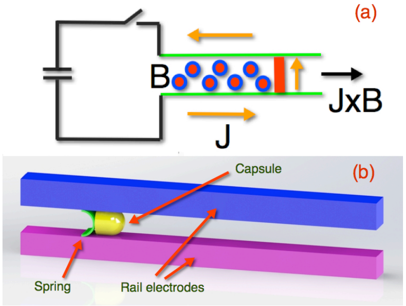

Fig. 3. (a) Cartoon showing rail gun operating principles. (b) Electrode configuration for initial NSTX-U level test.

The Electromagnetic Particle Injector (EPI) described here overcomes this limit by relying on an electromagnetic propulsion system for pellet acceleration. As shown in Fig. 3, J x B forces acting on the projectile, which is located between two linear electrodes, propel the projectile. As described in Reference [3], the sabot used for acceleration is captured before pellet injection into the plasma. The primary advantage of the EPI concept over gas-propelled injectors is its potential to meet short warning time scale events. The system could also be located very close to the reactor vessel. As shown in Fig. 4, the high levels of external magnetic fields that are present near the reactor vessel actually help to improve the efficiency of the system. The system has the potential to respond very rapidly by injecting impurities, into the plasma, within 3 ms after a command to inject is issued to the system. Fig. 4 (ITER cases) show acceleration parameters for a 15 g projectile composed of micro-spheres of boron, boron nitride or beryllium. The dramatic reduction in the injector current for a modest 2 T external magnetic field augmentation is seen in the ITER B case, compared to ITER case A that has no external magnetic field assistance. All three ITER cases have a bank capacitance of 100 mF. The NSTX case is for a near term off-line, non-tokamak test, which is underway with results expected during Spring 2016.

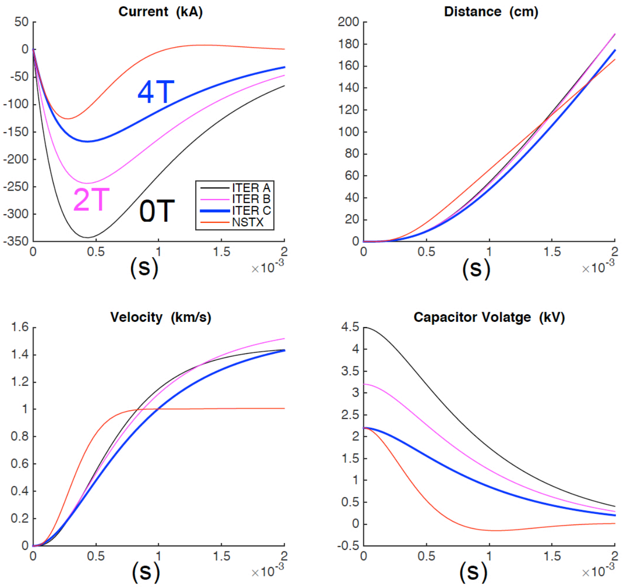

Fig. 4: Shown are traces from simulation results showing the injector current, pellet velocity, distance traveled by the pellet, and capacitor bank voltage, as a function of time. ITER cases B and C use 2 and 4 T external magnetic field augmentations, which results in the substantially reduced injector current, and reduced power supply requirements for otherwise similar acceleration parameters.

Fig. 5 shows a hypothetical installation configuration on an ITER mid-plane port plug.

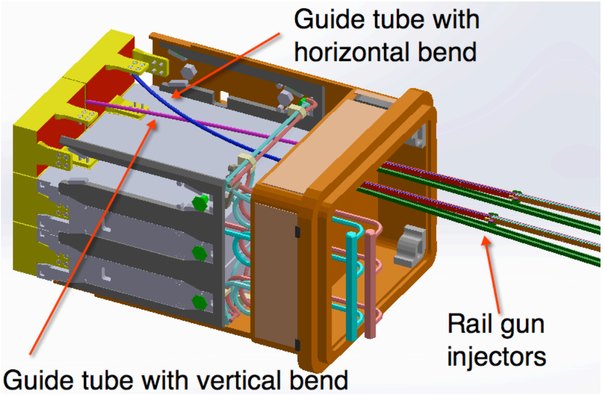

Fig. 5: Hypothetical installation configuration for two EPI injectors on the ITER mid-plane port plug.

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