Initial Wall Conditioning and Impurity Control Techniques in NSTX

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I. Introduction

The National Spherical Torus Experiment (NSTX) is a newly commissioned[1,2] spherical torus (R≤0.85m, a≤0.68m, R/a≥1.25, B_t ~ 0.3 T, I_p ≤ 1 MA) which began operation in Feb. 1999. Initial runs[3,4,5] have focused on exploring the operational limits of the device (e.g. in plasma current, shape, density, safety factor), as well as exploring the physics of high-harmonic fast wave radio frequency heating and non-inductive current drive via coaxial helicity injection (CHI). In this paper we summarize the wall conditioning used, and the effect of helium glow discharge cleaning (HeGDC) on discharge reproducibility. Additional details of the wall conditioning techniques are presented in ref. [6].

In November 1998, following pump down of the vacuum vessel, 39 hrs. of deuterium glow discharge cleaning (D_2GDC) and 4 hrs. of HeGDC was applied to the mostly stainless steel plasma facing surfaces. This preparation aided in the rapid achievement of 280 KA plasma discharges in February 1999. A five month vent followed for the installation of the present configuration which includes a divertor region clad 100% with graphite tiles, and copper passive stabilizer plates clad about 50% with graphite tiles. The vessel was pumped down again in August 1999, followed by 140 hrs. of D_2GDC to remove impurities and 20 hrs. of HeGDC to remove residual D_2. Wall conditioning during maintenance weeks included 3 separate bake outs of the center stack via resistive heating, the final one reaching 309 deg. C on the center stack and 220 deg. C on the passive stabilizing plates. Wall conditioning during experiments included HeGDC between discharges as requested by session leaders or as required by the physics operation staff. Physics experiments were conducted from Sept. 1999 through January 2000, and culminated in the achievement[7] of 1 MA plasma discharges by optimization of the plasma startup.

II. Helium Glow Discharge Cleaning Experiments and Observations

HeGDC proved to be a useful tool during this initial startup phase. HeGDC was typically run with the following parameters: helium pressure ~ four mTorr, electrode voltage ~ 500 V, electrode current ~ 1.5A. It was found that 30 minutes of HeGDC was essential for rapid recovery from a bake out, vent or from CHI operation[8] (the latter required cleanup due to the high gas loads introduced during CHI). Without HeGDC, a failure to burn-through and create the full plasma after break-down was observed after a bake out, vent, or CHI.

However it was also found that HeGDC between discharges did not have a systematic, reproducible effect on plasma parameters during routine operation. For example, a sequence of five reproducible discharges without inter-discharge HeGDC was followed by five discharges with preceding HeGDC of variable duration from 5-20 minutes and glow parameters (pressure from 1.75 – 4 mTorr). The D_α and Carbon-III light for the discharges with HeGDC were nearly identical; the Helium-II light was indeed higher for the discharges with preceding HeGDC due to residual Helium in the wall. Moreover, the volt second consumption and line-average electron density were nearly identical.

In certain instances, a single application of HeGDC between discharges did change the details of the successive discharge, sometimes allowing a higher plasma current or longer flat top. Fig. 1 shows two discharges with a five min. HeGDC between them. The discharge with preceding HeGDC (100860) achieved a 10% higher plasma current (fig. 1a). The main difference was related to the absence of an MHD event which terminated the current ramp in 100859 at t=.095 sec. The effect of this MHD event can be seen in fig. 1c-1e, i.e. a rapid increase of D_α,, Carbon-III and Helium-II light, suggesting an ejection of particles from the core. A similar, larger event can be seen in 100860 at ~ t=0.139 sec, which initiates the plasma current ramp down phase. These events bear resemblance to internal reconnection events (IRE) seen on START[9] and CDX-U but are more global. Visible light images of the plasma during the event from a fast framing camera are shown in fig. 2. The quiescent frame at t=0.138 sec shows the standard level of light during double-null divertor (DND) discharges in NSTX. At the time of the event, visible light increases first at the bottom divertor, followed by a movement up the center stack and to the top divertor. This time sequence appears shape independent, occurring during large MHD events in DND,

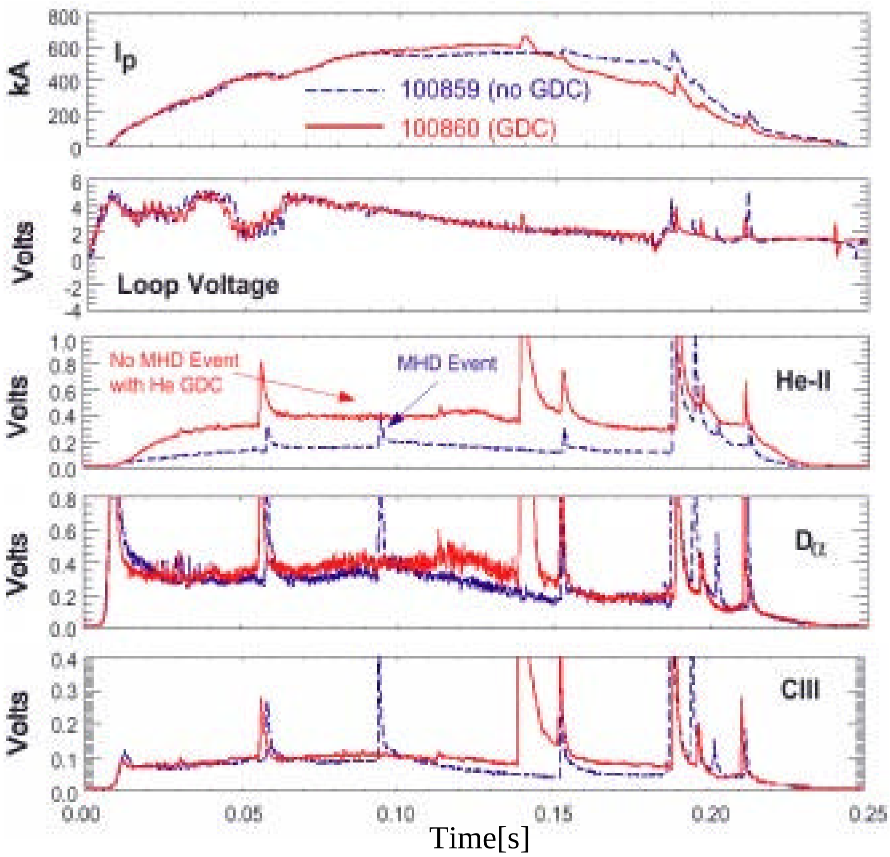

Fig. 1: Discharge preceded with a 5 min. HeGDC (100860) achieved higher I_p than without, due to delayed onset of MHD event.

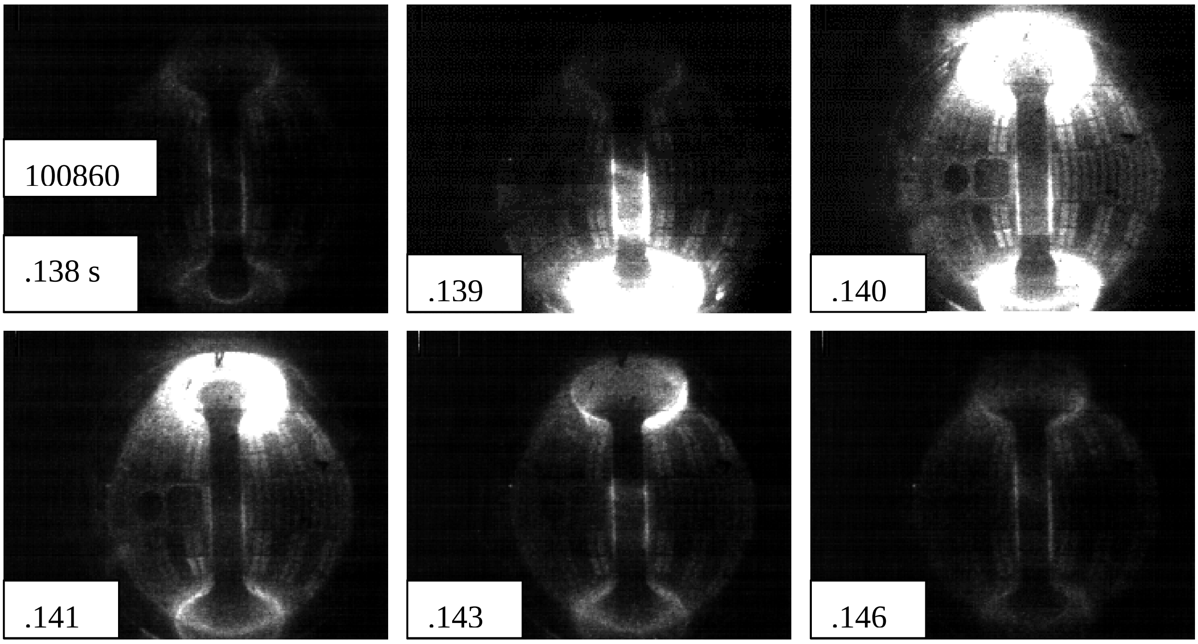

Fig. 2: Fast camera visible light pictures show plasma first moves down to lower divertor and then up to upper divertor during an MHD event.

lower-single null (LSN) and inner-wall limited (IWL) configurations. It has also been observed that application of HeGDC has resulted in an earlier onset of the MHD event.

One qualitative hypothesis for this MHD event and its relation to wall conditions involves core radiation. It was observed that the radiated power preceding an MHD event in the flat-top often increased rapidly, even faster than the square of the line density, e.g. from t=0.1-0.12sec in fig. 3e-f. If this increase occurred primarily in the center, then the local radiation could exceed the ohmic input power, which is concentrated at the periphery, and change the current profile, which could drive tearing modes unstable. One signature would be a drop in the central temperature, and a decrease in the internal inductance, l_i. In fact, fig. 3g shows a drop in l_i just before the MHD event; the magnitude of the drop is outside the relative error bars associated with the EFIT reconstruction (although EFIT's ability to follow this event can be questioned). Note that this mechanism does not require a global thermal collapse; in fact, the ohmic heating power before the event was ~ 1 MW whereas the total radiation was 0.3 MW. The role of HeGDC would be to alter wall conditions and impurity influx, changing the timing of the event. A test of this hypothesis awaits radiated power and ohmic heating profile reconstruction, as well as the availability of spectroscopic diagnostics (summer 2000).

III. Summary and Conclusions

Wall conditioning including D_2GDC, HeGDC, and bake out, enabled the rapid achievement of 1 MA discharges in NSTX and allowed physics experiments to be conducted on schedule. Whereas D_2GDC was most effective for impurity removal, HeGDC cleaned up the residual D_2 in the walls. The application of HeGDC between discharges showed no

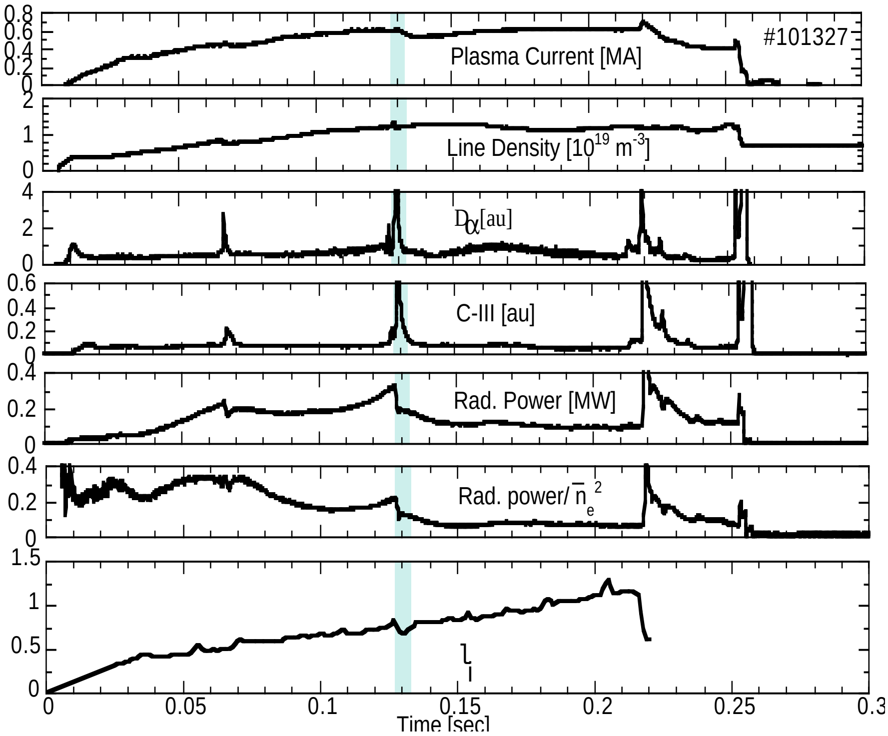

Fig. 3: Time histories for discharge with MHD event, showing increase in radiation and decrease in internal inductance preceding MHD. Fringe loss during ramp down IREs prevent line density return to zero at discharge termination.

systematic impact on reproducible discharges, but affected the time behavior of discharges in certain instances. Specifically the onset of an MHD event, which terminated the I_p ramp, could be delayed or hastened with the use of HeGDC. One qualitative hypothesis is that these flat-top MHD events were related to central radiation exceeding central power deposition. Additional heating power (five MW NBI, available 10/2000) and lower impurity levels (from complete coverage of passive stabilizing plates with graphite) may eliminate the events, allowing longer I_p flat-tops and reproducibility.

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