A Special Case of Long-Pulse High Performance Operation in W7-X

G. A. Wurden[1], S. A. Bozhenkov[2], G. Fuchert[2], D. Zhang[2], S. Jablonski[3], M. Kubkowska[3], A. von Stechow[2], M. Beurskens[2], C. Brandt[2], K. J. Brunner[2], B. Buttenschoen[2], M. Hirsch[2], P. Kornejew[2], A. Krämer-Flecken[4], Y. Gao[2], M. Krychowiak[2], N. Pablant[5], E. Pasch[2], K. Rahbarnia[2], H. Thomsen[2], T. Windisch[2], V. Winters[2], and the W7-X Team

[1] *Los Alamos National Laboratory, Los Alamos, NM 87545 USA*

[2] *Max-Planck-Institut für Plasmaphysik, 17489 Greifswald Germany*

[3] *Institute of Plasma Physics and Laser Microfusion (IPPLM), 01-497 Warsaw, Poland*

[4] *Institute of Energy and Climate Research, Forschungszentrum Jülich GmbH, D-52425*

[5] *Princeton Plasma Physics Laboratory, Princeton, NJ 08543, USA*

In a W7-X discharge (3rd shot of the morning, pulse 20180808005) during the previous campaign, an accidental dropout of one of two ECRH heating gyrotrons, at 15 seconds into a 55 second planned pulse, allowed a remarkable transition to occur. Initial heating power was only 1.1 MW, but the stored plasma energy, after first dropping when the power was cut to 510 kW, actually climbed higher (to 220 kJ) over the next 2 seconds, with only half the heating power remaining. The plasma density, initially rather flat with core density of 3x10^19 cm^3, peaked to >4.5x10^19 cm^3 by itself during the same time. Turbulence was reduced, and regular island-localized mode (ILM) activity, not normally present in high-iota discharges [1] turned on, while the energy confinement time doubled, from 200 msec to 400 msec. The ion temperature climbed to 1.8 keV, approaching the electron temperature, breaking the ion temperature clamping which is often seen in W7-X plasmas [2]. Zeff increased slightly from 1.6 to 1.9, and then held constant for the remainder of the pulse. The edge soft x-rays dropped, but the core soft x-ray emission increased a factor of 5x. Bolometer signals were small, but an increase in the core radiation (due to some high Z accumulation), along with a drop in edge radiation, followed the transition. Line integrated light impurity emission (B, C, O) remained constant. Heat loads on the divertor dropped a factor of 3.7x (more than the factor of 2x one would otherwise expect). The resulting nTTau was within a factor of two of W7-X's best transient performance [3]. A key factor was that the divertor strike points for this high-iota plasma configuration were freshly boronized, and no external gas puffing was enabled. Later in the day, it could not be duplicated. The periodic ILM'ing activity has most of the features of ELM's, which along with the confinement improvement and H-alpha response, suggests the possibility that an H-mode transition occurred. We plan to look for evidence of a pedestal with more diagnostics in the upcoming campaigns, as well as explore further ways to modify the profile during the long flattop (e.g., adding NBI or pellets), hopefully without turning the normal turbulence (ITG's) back on.

[1] G. A. Wurden et al. *"Structure of island localized modes in Wendelstein 7-X*", P2.1068, 46th EPS Conference on Plasma Physics (2019)
[2] M.N.A. Beurskens et al, *2022* Nucl. Fusion ***62*** *016015*
[3] J Baldzuhn et al, *2020* Plasma Phys. Control. Fusion ***62*** *055012*