3. Magnet Coil Diagnostics

1. Why 1 Tesla HSX Operation?

- Neoclassical and anomalous transport
  - The anomalous electron thermal conductivity in W7-AS has been observed to scale as 1/B, so doubling the field should significantly reduce the anomalous contribution relative to neoclassical (superbanana transport is independent of the field). Scaling in anomalous-dominated stellarators sees increased energy confinement with both density and B.

  - Power scaling
  
    Modeling suggests that anomalous transport may overwhelm 0.5 Tesla differences in neoclassical transport (although some differences have been seen [Canik – this session]). Operating at higher density and higher power should decrease the anomalous transport and increase the neoclassical contribution, especially in the broken-symmetry configurations.

  - Superthermal tail reduction
  
    Operation at B=1.0 T will permit fundamental O-points. An increase of the neoclassical contribution, especially in the broken-symmetry configurations.

2. 1.0 Tesla HSX Operation

1.0 Tesla Machine requirements

- 18 Motor Generators are needed, as compared to currently 10 being used for 0.5 Tesla operation.
- 2 Auxiliary Coil MMX Generators are required for HSX configuration flexibility at 1.0 Tesla.
- Coil currents increase from 3.5 kA at 0.5 Tesla to 11 kA at 1.0 Tesla.
- Fast turn-off of the magnet coil currents limit the ITf to equivalent 0.5 T longer-pulse operation values (~ 5 × 10^{-3} s) – lowers heat loads and permits faster machine cycling.

ANSYS modeling

- ANSYS provides forces, coil and support stresses, and displacements.
- ANSYS provides a guide to position displacement sensors on coils and supports.
- Measured displacements at different magnetic fields provide a confidence benchmark for planned 1.0 Tesla operation.
- 1.0 Tesla QHS operation appears to have stresses and coil motions well within design guidelines and material yields for all coils and supports. Coil stresses are all under 20 MPa, while support stresses are all under 250 MPa.
- Highest loads and stresses are at the coil-to-ring attachment points and the ring support points.
- Continued model refinement is underway to improve support structure representation.

3.1 HSX Coils and MG set Diagnostics

- Coil voltages are monitored for each magnet shot.
- Coil temperatures are monitored on each side of all coil feeds for each magnet shot.
- Strain gauges are currently located at 7 locations and are planned for multiple locations on each coil of one full field period, and selective coil locations around the device in other field periods (128 total).
- These provide sensitive measurements of coil-to-ring, and ring-to-support, displacements (micron sensitivity)
- Displacement signals are taken for each magnet shot.
- ANSYS comparison for various displacements and field/currents can be compared.
- Main and auxiliary coil currents and voltages are remotely monitored.
- Currents, armature-winding voltages and field-winding voltages are monitored for each Motor Generator
- Each Motor Generator flywheel (2-ton) speed is redundantly monitored with optical and mechanical tachometers – all motors have been spun up to full speed for 1.0 Tesla operation, and vibration tested.

3.2 ANSYS Comparison to 0.5T HSX Operation

- Measured Coil 4-5 motion during 0.5T QHS operation

4. No Coil 3 Mode of Operation

No Coil 3 would allow for high ripple magnetics while maintaining a centered magnetic configuration – compatible with current diagnostic implementations

Coil 5 ANSYS analysis - Displacement

- Magnetic field spectrum for No Coil 3.
- Normalized Energy confinement versus effective ripple.
- Forces and stresses at 1.0 Tesla on the coil supports (NOT the coils above material yields for full Coil 3 removal from the HSX coil set. Additional structural evaluation is underway.

5. Plasma Diagnostics and Heating

ECH Heating upgrades

- Phase 1: Line 1 Upgrade
  
  - Remove 50 kW over-moded waveguide
  - Install Line 1, 200 kW quasioptical waveguide

- Phase 2: Line 2 Installation
  
  - Install 28 GHz, 200 kW Varian gyrotron
  - Install Line 2, 200 kW quasioptical waveguide

ECE Radiometry for Te and power deposition determination.

- Modulation of gyrotron #2 ECRH power induces a localized temperature perturbation.

- Heat pulse analysis will use an expanded multi-channel ECE radiometer.