Status of the QPS Project

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The Quasi-Poloidal Stellarator (QPS) is being developed to test key stellarator physics issues at plasma aspect ratios 1/2-1/4 that of other stellarators. QPS has a quasi-poloidal (linked-mirror-like) rather than quasi-toroidal (tokamak-like) magnetic configuration, which allows poloidal flow and poloidal flow shear a factor of ~10 larger than in any other toroidal confinement system, and very low effective ripple to reduce neoclassical transport. It is the only toroidal device stable to drift wave turbulence over a range of temperature and density gradients, which should reduce anomalous transport even in absence of flow shearing. The magnetic field structure leads to a large fraction of trapped particles in regions of low/favorable field line curvature, which strongly reduces the drive for a class of trapped-particle instabilities. All other toroidal devices have a significant fraction of the trapped particles in regions with bad curvature. QPS also allows extending the stellarator data base to very low aspect ratio ($R/a > 2.3$), similar to the ST extending the tokamak data base to very low R/a.

The complex 3-D design requirements (large plasma radius at very low aspect ratio, a plasma cross section that varies toroidally from bean-shaped to D-shaped, and five types of toroidally-elongated non-planar coils) and the need for reduced cost and risk in fabrication drive the design. There are 2 field periods with 10 coils per period, 3 sets of poloidal field coils and 12 toroidal field coils. Independent controls on these coil currents permit varying key physics features by factor 10–30: the degree of quasi-poloidal symmetry, poloidal flow damping, neoclassical transport, stellarator/tokamak shear and trapped particle fraction.

The QPS design consists of complex, highly accurate, stainless steel modular coil winding forms that are cast and machined; conductor wound directly onto the winding forms; a vacuum-tight cover welded over each coil pack; coils vacuum pressure impregnated; and the winding forms bolted together to form a structural shell inside the vacuum vessel. The largest and most complex of the winding forms has been cast using a patternless process and is being precision machined. An internally cooled, compacted cable conductor that can be wound into complex 3-D shapes has been developed. High-temperature cyanate ester resin is used for vacuum pressure impregnation of the coils because it has several important advantages over the usual epoxy, including higher operating temperature, lower water absorption, and better handling characteristics during vacuum impregnation. Winding clamps were designed and fabricated with an open design that allows conductors to be placed and positioned in both the lateral and vertical directions automatically, without the need for additional geometric measurements or calibrated clamping pressure.