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Abstract—**The engineering design status of the Quasi-Poloidal Stellarator Experiment (QPS) is presented. The purpose, configuration, and possible manufacturing and assembly techniques of the various components of the core are described**

I. INTRODUCTION

The proposed Quasi-Poloidal Stellarator, QPS, is a low-aspect-ratio (R/a = 2.7), concept exploration experiment with a non-axisymmetric, near-poloidally-symmetric magnetic configuration. The nominal QPS design parameters are <R> = 0.9 m, <a> = 0.33 m, B = 1 T, and a 1 s pulse length. The facility includes the stellarator core, the plasma heating, diagnostics and data acquisition systems, the power supplies and cooling systems, and the test cell. The experiment will be built at the Oak Ridge National Laboratory (ORNL) and will make maximum use of existing equipment and infrastructure. Reference 1 describes the physics and engineering features in detail.

The stellarator core consists of the modular coil set that provides the primary magnetic field configuration, auxiliary coils including vertical field and toroidal field coils and an ohmic heating solenoid, machine structure, and an external vacuum vessel. A cut-away view of the stellarator is provided in Figure 1. The general design parameters are given in Table 1.

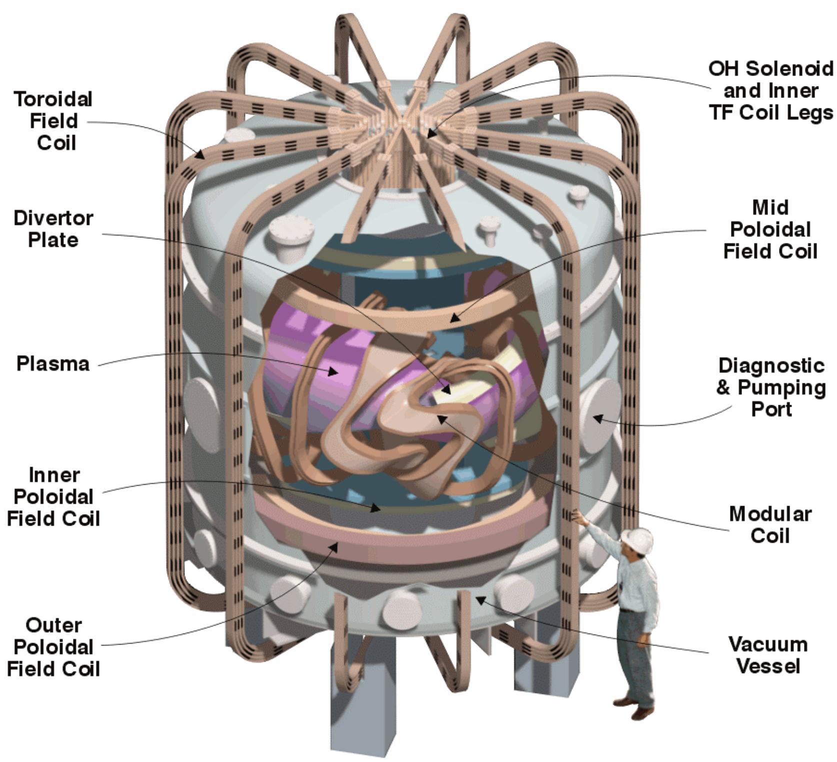

Fig. 1 Cut-away view of QPS stellarator

Table 1 QPS General Design Parameters

Parameter	Value
Major radius, R_o	0.9 m
Aspect ratio, R_o/a	2.7
Toroidal field at $R_{o,}$ B_o	
From modular coils	1 T
From TF coils	+/- 0.2 T
No. of Field Periods	2
Plasma current, I_p	< 150 kA
Flattop Pulse length at 1 T	~1.0 s
Auxiliary drive power, P_{aux}	1-3 MW

II. MODULAR COILS

The modular coils represent the most difficult part of the core design and fabrication. The coil set has two field periods with 8 modular coils per period. Due to symmetry, only four different coil types are required. The coils are connected electrically in 4 circuits so like coils are independently powered to provide maximum flexibility. The maximum toroidal field at 0.9 m produced by the modular coils with a flattop of ~1 s is 1.0 T. The toroidal field on axis can be raised above 1 T by energizing the TF coils, which can add ± 0.2 T to the field generated by the modular coils. Figure 2 shows the geometry of the coil windings. As shown in the figure, the two winding packs that form the coils in the center of the long section were allowed to follow independent winding paths to improve the magnetic configuration.

The design concept uses flexible, copper cable conductor to facilitate winding into the complex shape. The cable is compacted from round cable to a packing fraction of over 75 %. Once wound, the conductor is vacuum impregnated with epoxy so the winding pack becomes a monolithic copper-glass-epoxy composite. The coil cross section is shown in Figure 3 and the basic coil parameters are listed in Table 2. The modular coils are gas cooled and operate above room temperature because they are located inside the plasma vacuum space. Figure 4 illustrates the operating temperature vs current density for the windings based on temperature limits of the epoxy and power supply voltage limitations.

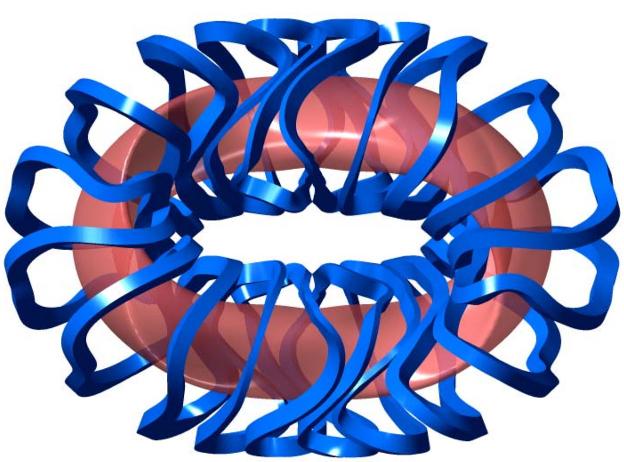

Fig. 2 Modular coil winding geometry showing split windings in the middle of the long section.

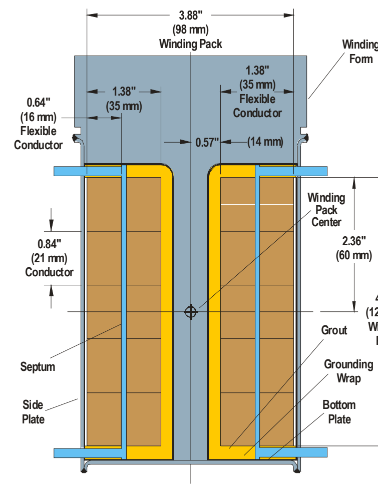

Fig. 3 Modular coil cross section

Table 2. Modular Coil Parameters

No. of coils	16 (2 x 8)
Winding length	6.6 to 7.4 m per turn
Number of turns /coil	16
Gross cross section	2 x 36 mm x 120 mm
Current per coil*	431 kA
Current density in Cu	8 kA/cm^2
Peak power, coil set	~ 40 MW

* at nominal 1.0 T operating scenario

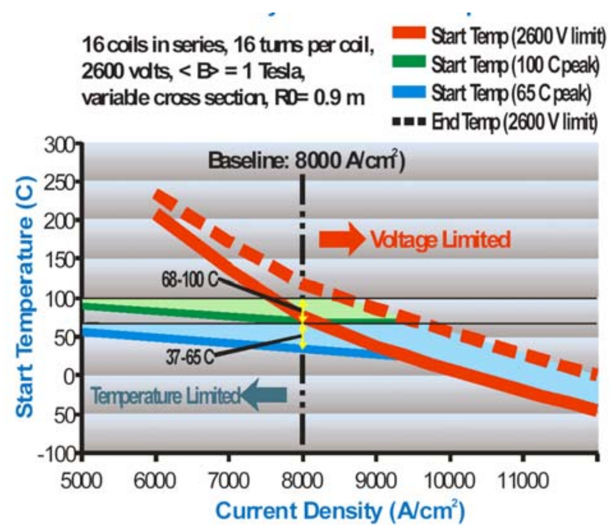

Fig. 4 Starting temperature vs. current density for 0.5 second flat-top pulse, limited by power supplies and winding temperature.

The windings are wound on and supported by the tee-shaped structural member, which is an integral part of the coil winding form. The winding form locates the coil windings within the +/- 1.5 mm tolerance and supports them against the electromagnetic loads. The forces on the winding packs tend to push them radially outward against the form and clamp them laterally against the central member of the "tee". A compliant layer is provided in the outboard region between the structure and windings to reduce thermal stresses. Plates are welded around both winding packs to provide a vacuum-compatible coil. Some development will be required to insure that no distortion of the coil occurs during the welding process. In local areas requiring reinforcement, intermittent ribs are bolted to the flanges of the "I-beam" as structural retainers for the windings.

III. TOROIDAL AND POLOIDAL FIELD COILS

A set of twelve toroidal field (TF) coils is included to provide flexibility in the magnetic configuration. The outboard legs of the coils are identical and equally spaced, but the inboard are spread out to nest in the oblong opening through the center of the modular coil set. For assembly purposes the coils are demountable at the top and bottom of the inboard region. Figure 5 illustrates the TF coil geometry. The coils are formed from hollow copper conductor and insulated with glass-epoxy. They operate at room temperature and are connected in series.

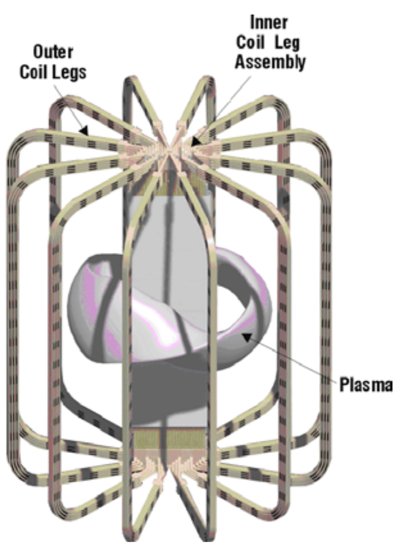

Fig. 5 TF geometry showing the oblong inboard leg assembly.

A set of poloidal field coils is provided for inductive current drive and plasma shape and position control. The coil set consists of an inner solenoid, a pair of elliptical coils, and two pairs of ring coils. Coil pairs are symmetric about the horizontal mid-plane and each coil pair is connected in an independent circuit. The solenoid is located immediately around the TF coil inner legs, and is contained in a common vacuum can that forms a center-stack assembly. This assembly is self-supporting and fills the oblong region inboard of the modular coils. All coils are of conventional construction, wound from hollow copper conductor and insulated with glass-epoxy. Existing PF coils from the ATF facility are used for the outer ring coils. All PF coils operate at room temperature. Figure 6 illustrates the PF coil geometry.

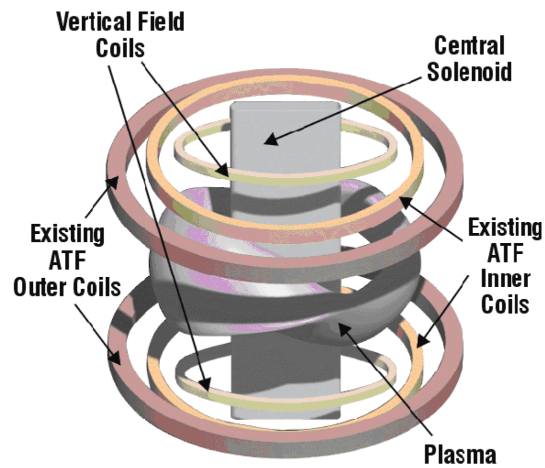

Fig. 6 PF coil geometry showing solenoid, elliptical coils and existing ATF coils

IV. EXTERNAL VACUUM VESSEL

The QPS vacuum vessel is a large bell jar based on an existing design. The vessel has numerous ports and is divided into a reinforced flat base, a lower spool piece, a middle spool piece and a dished head. All sections will be fabricated from 316L series stainless steel.. The vessel size relative to the rest of the device is illustrated in Figure 7. The large seal surfaces will accommodate double o-rings with interstitial pumping. Thermal insulation blankets and heaters will be added to provide a bake-out capability with a temperature goal of 150 C. The temperature limit will be based on the temperature limit of the solenoid winding in the center-stack The basic vessel parameters are listed in Table 3.

Table 3 Vacuum vessel parameters

Material	316L ss
Nominal outer radius	1.9 m
Maximum height	4.9 m
Inside surface area	~75 m^2
Enclosed volume (with ports)	~45 m^3
Bakout temperature	150 C
Nominal operating temperature.	20-100 C

Twelve large ports around the mid-plane of the vacuum tank are provided for heating, diagnostics, and maintenance access and numerous smaller ports are provided for coil services and instrumentation feed-throughs.

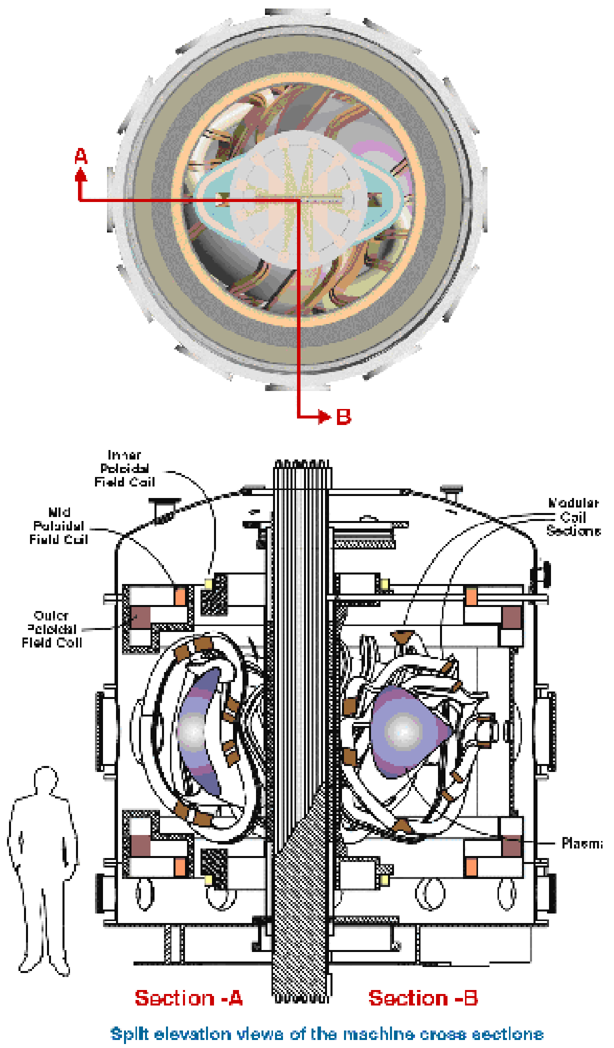

Fig. 7 QPS elevation view showing relationship of vacuum tank to internals.

VI. Core Assembly

The QPS stellarator core will be assembled from two field period sub-assemblies that are bolted together around the center-stack assembly and tank base in the test cell. Both field periods are pre-assembled in a separate area, and consist of half of the modular coils and associated inter-coil structure as well as half of the outer PF coil support rings and vacuum cans. The internal coil services will be routed through the vacuum tank base, and the main spool piece, tank lid, and outer TF legs will be added. The assembly sequence is illustrated in Figure 8.

VII. Ancillary Systems

The QPS facility will take advantage of existing infrastructure at ORNL, including plasma-heating systems (1.2 MW ECH, 3 MW ICRF), power supplies (>40 MW), de-mineralized water system, and other equipment In addition, a new building will be available to site the facility, and will include an experimental enclosure, control room, and all utility services.

VIII. Design Status and Conclusion

The QPS device is presently in the conceptual design phase. The general configuration has been selected and baseline concepts exist for most of the primary design features. Detailed analysis and concept refinement will be carried out during the remainder of the conceptual design phase.

Acknowledgment

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[1] J. F. Lyon and the QPS team, "QPS, A Low Aspect Ratio Quasi-Poloidal Concept Exploration Experiment", http://qps.fed.ornl.gov /pvr/pdf/qpsentire.pdf, April 2001.

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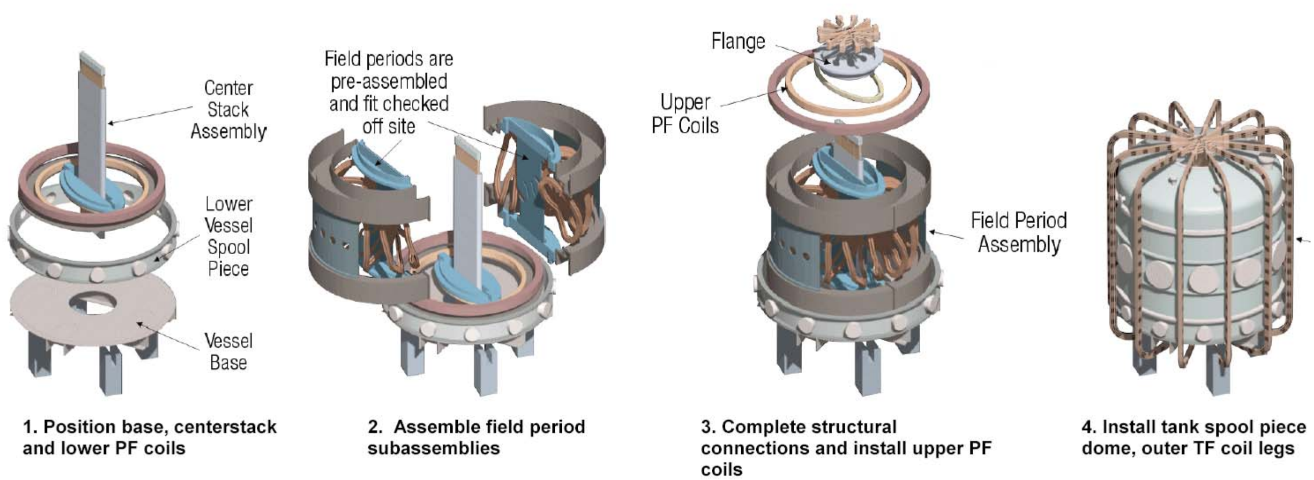

Fig. 8 Stellarator core assembly sequence