DESIGN DESCRIPTION OF THE VACUUM VESSEL FOR THE ADVANCED TOROIDAL FACILITY*

K. K. Chipley, B. E. Nelson, L. M. Vinyard, and D. F. Williamson

Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee 37831

Abstract: The Advanced Toroidal Facility (ATF) will be a stellarator experiment to investigate improvements in toroidal confinement.[1] The vacuum vessel for this facility will provide the appropriate evacuated region for plasma containment within the helical field (HF) coils. The vessel is designed to provide the maximum reasonable volume inside the HF coils and to provide the maximum reasonable access for future diagnostics.

The vacuum vessel design is at an early phase and all of the details have not been completed. The heat transfer analysis and stress analysis completed during the conceptual design indicate that the vessel will not change drastically.

Design Criteria

The design of the vacuum vessel for the Advanced Toroidal Facility (ATF) is dictated by the criteria established by the project team and listed in the ATF Design Criteria document.[2] Some of the more important criteria are listed in Table 1.

Table 1. Design criteria

Major diameter (m)	4.2
Minor diameter (m)	1.2
Coil-to-shell standoff (cm)	2.0
Beam line tangential access size (cm)	25
Toroidal loop resistance (mΩ)	0.5
Heat input (MW)	4.5
Pulse length (s)	0.3
Repetition period (s)	600

There are several other characteristics mentioned in the criteria that are not as quantifiable. The vacuum system must be a metal system compatible with physics experiments requiring high purity plasmas. The primary vacuum seals will be metal-type seals. All of the flanges will be designed to withstand the higher loads associated with metal seals. Wherever possible, standard ISO flanges will be utilized.

Design Description

The vacuum vessel will closely fit the helical field (HF) coils to minimize interference with the plasma and to maximize the vacuum volume. This concept results in a heavily contoured shape as shown in Fig. 1. Clearances between the vessel and the HF coils are about 2 cm in most areas. There are relieved areas near the joints that allow the vessel and the HF coils to be assembled vertically.

Access for diagnostics and beam lines has been provided by the extensive port configuration as shown on Fig. 1. The vertical ports are standard ISO 400 NW port size. The inner ports will be standard ISO 250 NW port size. The flanges will be somewhat thicker to allow the greater sealing forces for the metal seals. The vertical ports and the inner ports will be the Multifastener Configuration using external clamps instead of bolts (Fig. 2). This will allow for some rotational freedom between the vessel and the attachments. The large outer flange will be a special design flange to accommodate beam line access and to provide the maximum diagnostic access. The dimensions of this flange opening are shown in Fig. 3.

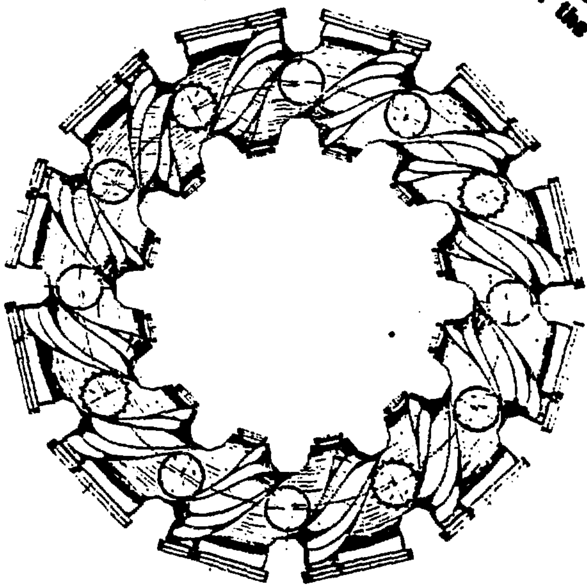


Fig. 1. ATF vacuum vessel plan view.

There will not be any active cooling of the vacuum vessel during initial operation, so the pulse length of the beam lines will be limited. Provisions for adding water-cooled panels to the interior walls have been made. Mainly these provisions provide access for the water-cooling lines and the concept design for a means of attachment (see Fig. 4). Limiters will be used as required to reduce the heat load in critical areas of the vessel.

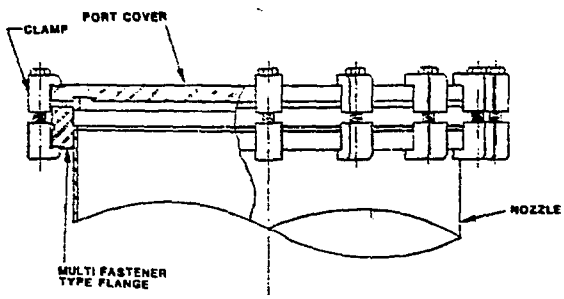


Fig. 2. ATF multifastener flange.

*Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under Contract No. W-7405-eng-26 with the Union Carbide Corporation.

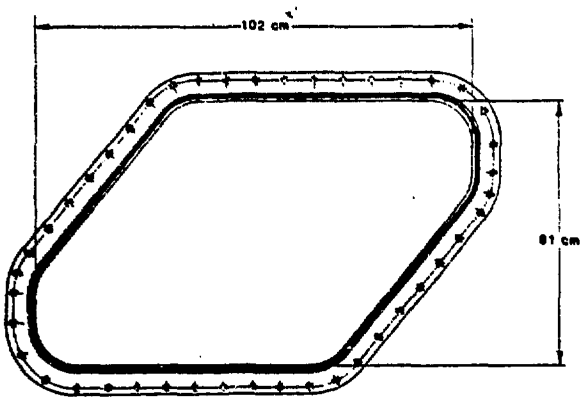


Fig. 3. ATF outer flange.

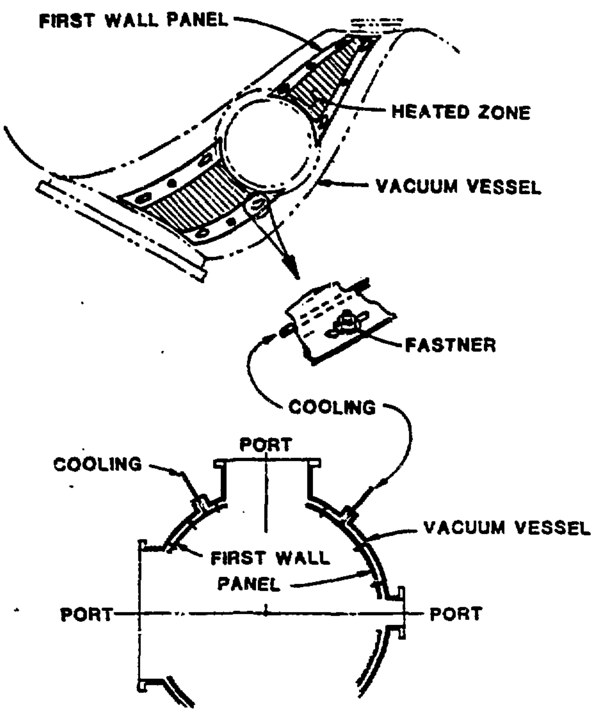


Fig. 4. Vacuum vessel cooling panels (first wall).

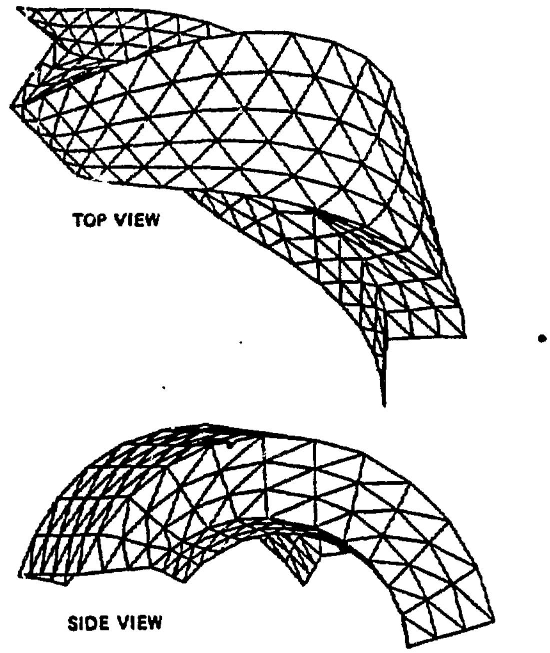


Fig. 5. Vacuum vessel finite-element model.

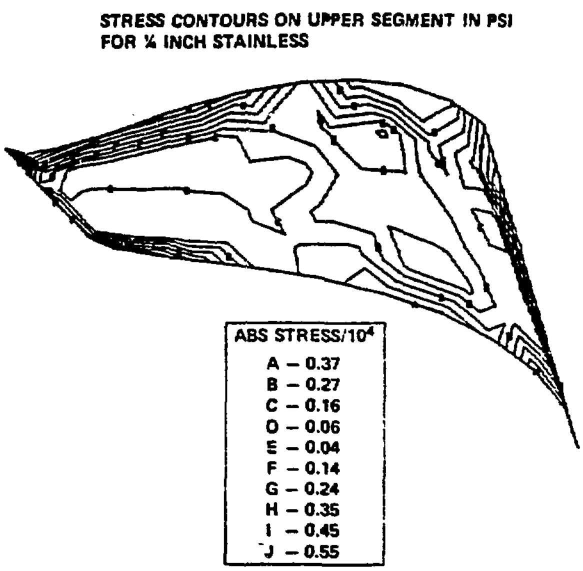


Fig. 6. PAFEC output plot.

Analysis Activities

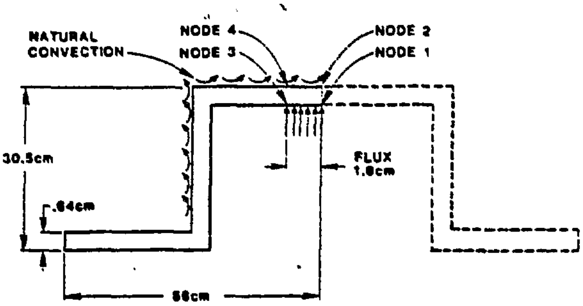
The completed analysis activities were all accomplished during the conceptual design effort, and the conclusions may change after detailed analysis has been completed.

Several simple models of sections of the vacuum vessel have been prepared for FEM analysis of stresses and deflections. A typical model is shown in Fig. 5. The results of these analysis activities for the vacuum load only indicate that the stresses will be less than 138 MPa and deflections will be less than 6 mm. A typical output of stress information is shown in Fig. 6. This preliminary analysis was accomplished using the PAFEC[3] program. A larger FEM model suitable for NASTRAN is being developed at this time.

The temperature response of the vessel and the future actively cooled panels has also been analyzed. Figure 7 shows the results of one such study for the time-temperature response of the vacuum vessel wall.

Conclusion

The vacuum vessel design is progressing at a rapid pace, and there are no expected major changes to this configuration. The vessel will be structurally adequate for the vacuum loads and for imposed loads due to electromagnetic forces and experimental attachments. The vessel will provide adequate access for experimental diagnostics and beam lines.



HEATING CYCLE

FOR 3 MW. FOR .5 SEC PULSE

FLUX = 137 W/cm^2

	0 sec	.25 sec	.5 sec	1.0 sec	10 sec
NODE 1	22	64	138	115	46
NODE 2	22	22	22	22.2	46
NODE 3	22	38	48	44	31.5
NODE 4	22	22	22	22	31.5

TIME – TEMP HISTORY (°C)

Fig. 7. Time-temperature response of the vacuum vessel wall.

References

[1] B. E. Nelson, et al., "Design Description of the Advanced Toroidal Facility (ATF)," these proceedings.

[2] Design Criteria for Advanced Toroidal Facility, DC-XCS-14770-005, Engineering Division, Union Carbide Corporation Nuclear Division, Oak Ridge, Tennessee 37831.

[3] R. D. Henshall, PAFEC Programs for Automatic Finite Element Calculations, Nottingham, England.