Update on First Wall and Blanket Design for ARIES-AT Power Plant

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Subjects Covered

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Wisconsin

- **Poloidal flow first wall coolant routing and subsequent blanket cooling.**

- **Issues of elliptic tube shapes at the first wall.**

- **Toroidal flow first wall coolant routing and subsequent blanket cooling.**

- **Issues of circular tube shapes at the first wall.**

- **Preliminary investigation of supporting blanket modules from the weight of LiPb.**

New Blanket Design Configurations

- **The new blanket design has the first wall integrated into Cell #1.**

- **The outboard blanket has Cell #1, Cell #2 and a shield.**

- **The inboard blanket has Cell #1 and a shield.**

- **The W stabilizing shells are located on the back sides of Cell #1.**

- **All the blanket components are made of SiC and are cooled with LiPb.**

- **Both poloidal and toroidal first wall cooling have been considered.**

Outboard Blanket/Shield Schematic and Coolant Flow Direction

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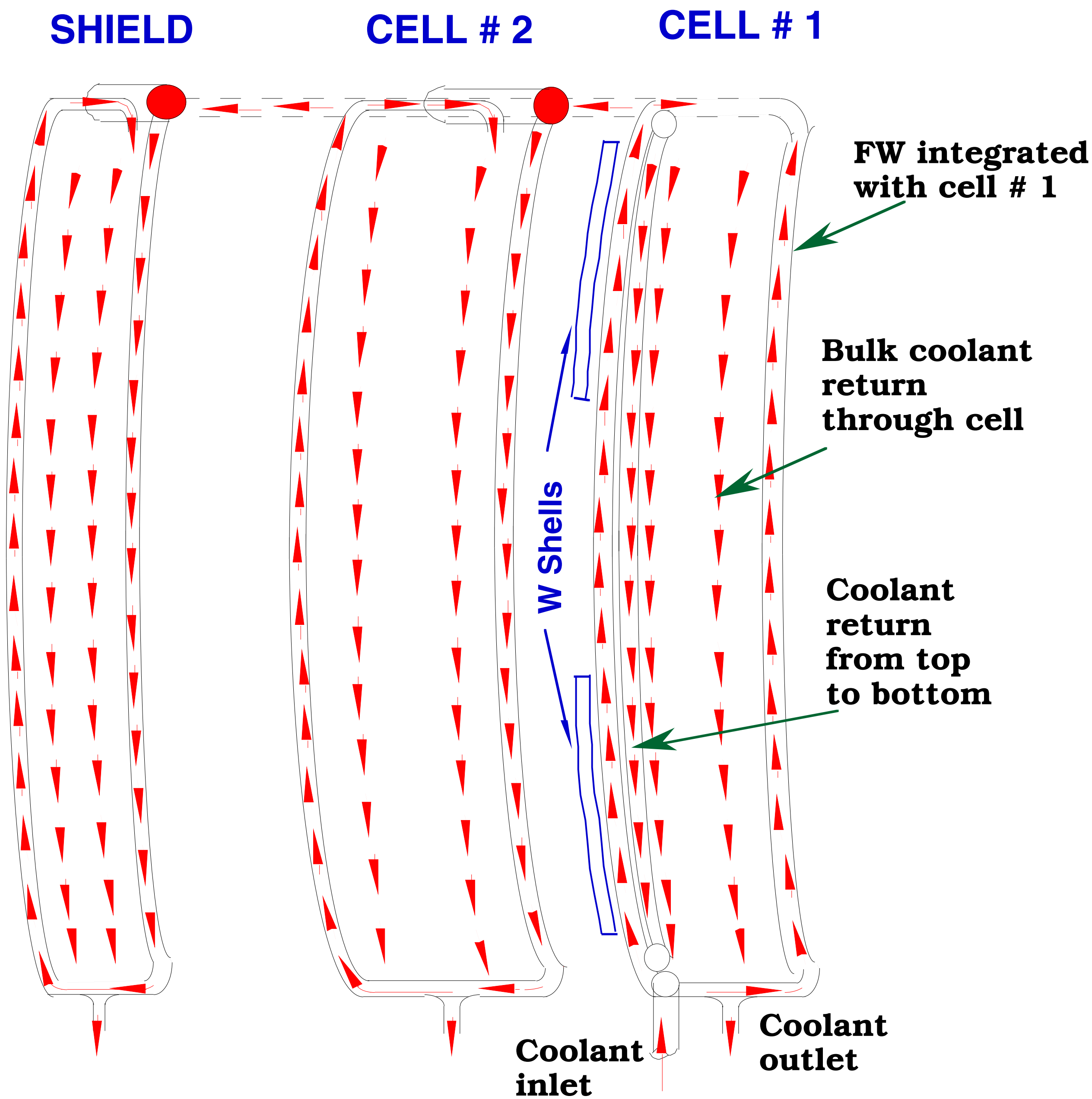

Poloidal Flow First Wall Tubes

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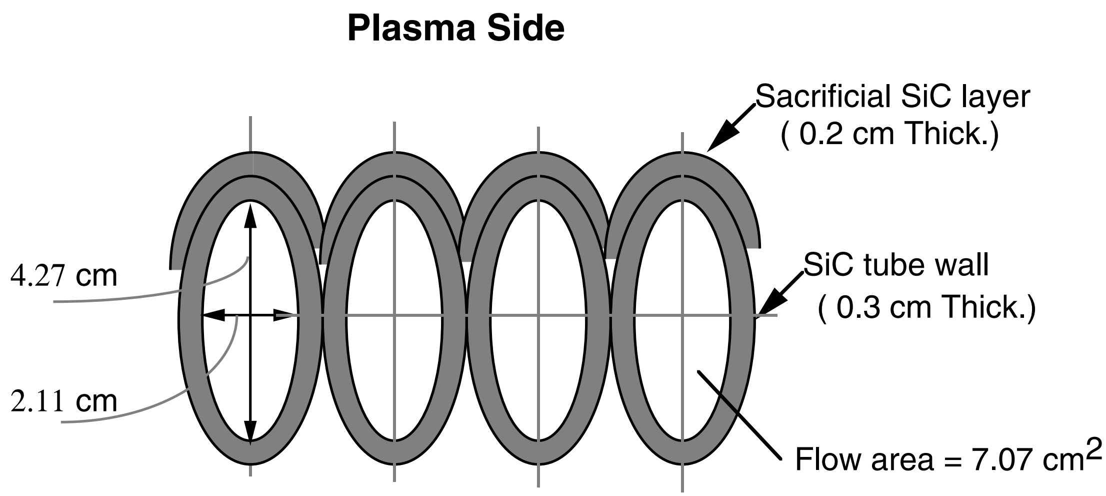
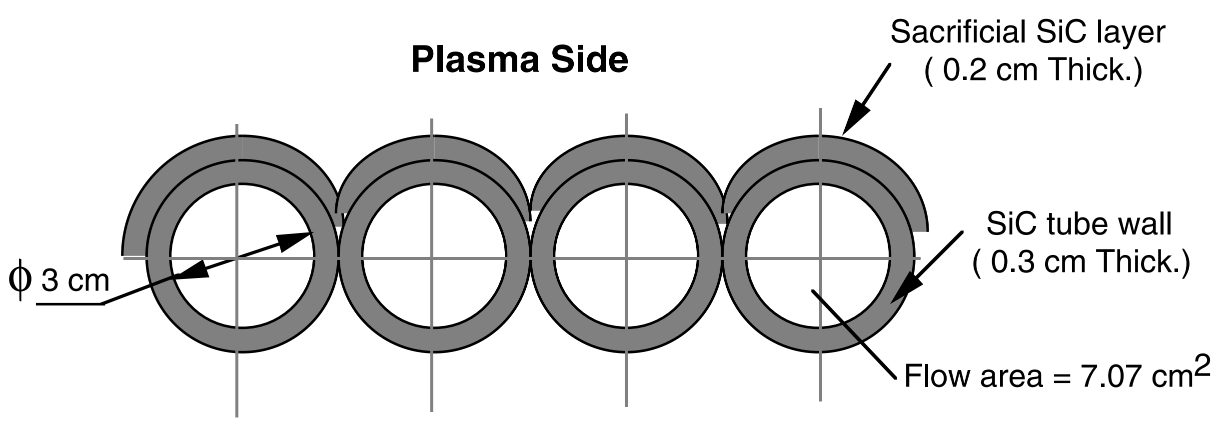


Elliptical Tubes at ends



Circular Tubes at midplane

Poloidal Flow First Wall Coolant Routing

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- **The coolant inlet header connects to the blanket module on the bottom at the back and distributes itself in the lower rear manifold.**

- **The lower rear manifold feeds the radial tubes cooling the bottom side of the module and also the poloidal tubes cooling the sides of the module.**

- **From the bottom side of the module, the tubes make a turn upwards and flow poloidally across the first wall.**

- **At the top the first wall tubes make a bend and flow radially across the upper side of the module ending in the upper rear manifold.**

- **The side wall tubes also end up in the upper rear manifold.**

Poloidal Flow First Wall Cooling

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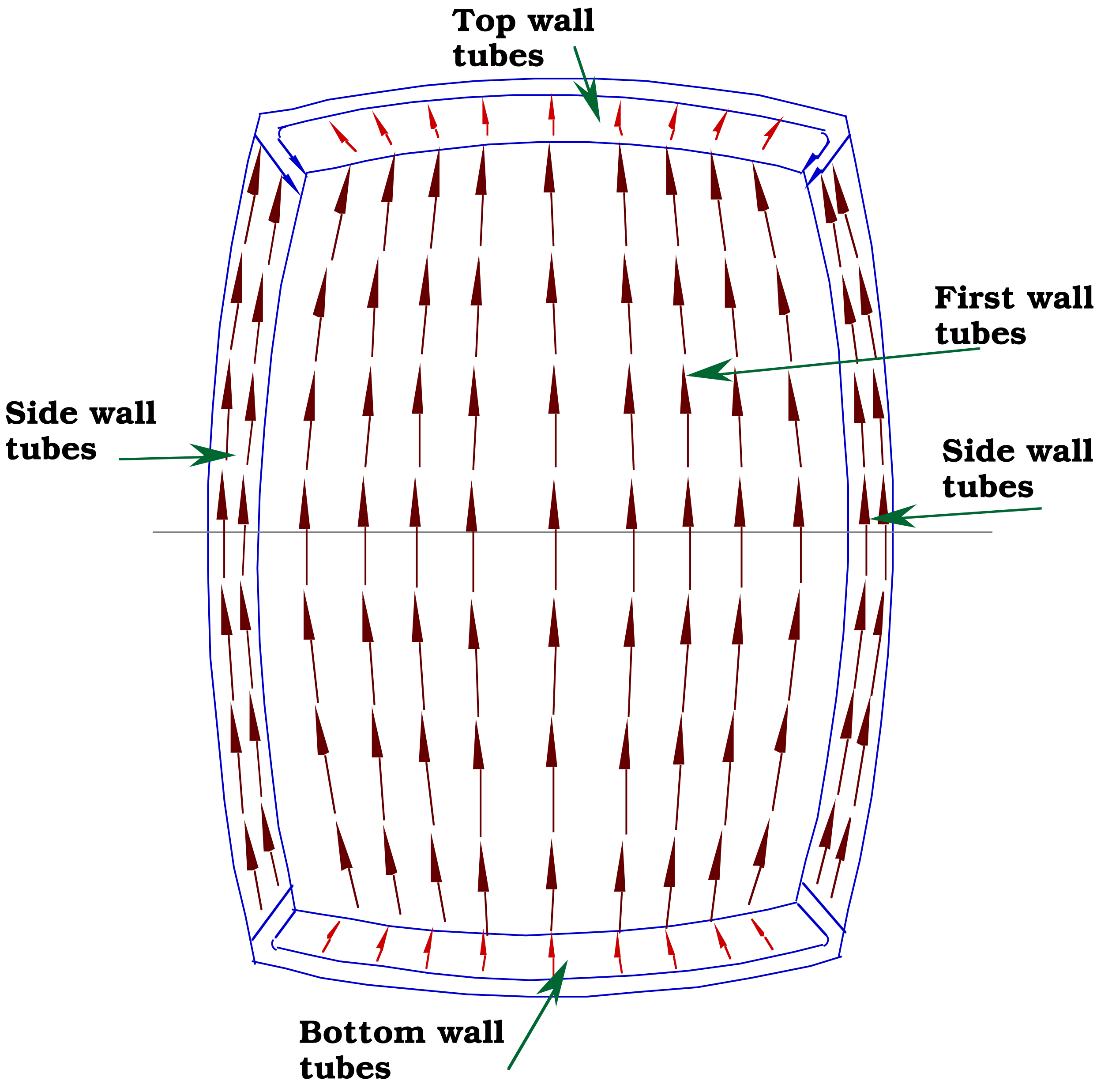

Poloidal Flow – Cooling of the Rest of the Blanket Module

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- **From the upper rear manifold, the coolant is divided into three streams:**

  1) The first stream stays in Cell #1

  2) The second stream goes to cool Cell #2

  3) The third stream goes to cool the shield.

- **The function of the first stream is to cool the two W stabilizing shells on the back side of Cell #1 and to cool the back wall and radial supports of the module.**

- **The coolant is directed through a tube down to the bottom of the module connecting to a manifold which feeds the back side of the module and the radial supports.**

- **The coolant flows poloidally through the back side and radial supports of the module, and at the top enters into the cell proper.**

- **The coolant then flows down poloidally through the cell proper and exits the module on the bottom.**

Poloidal Flow – Blanket Module Cooling

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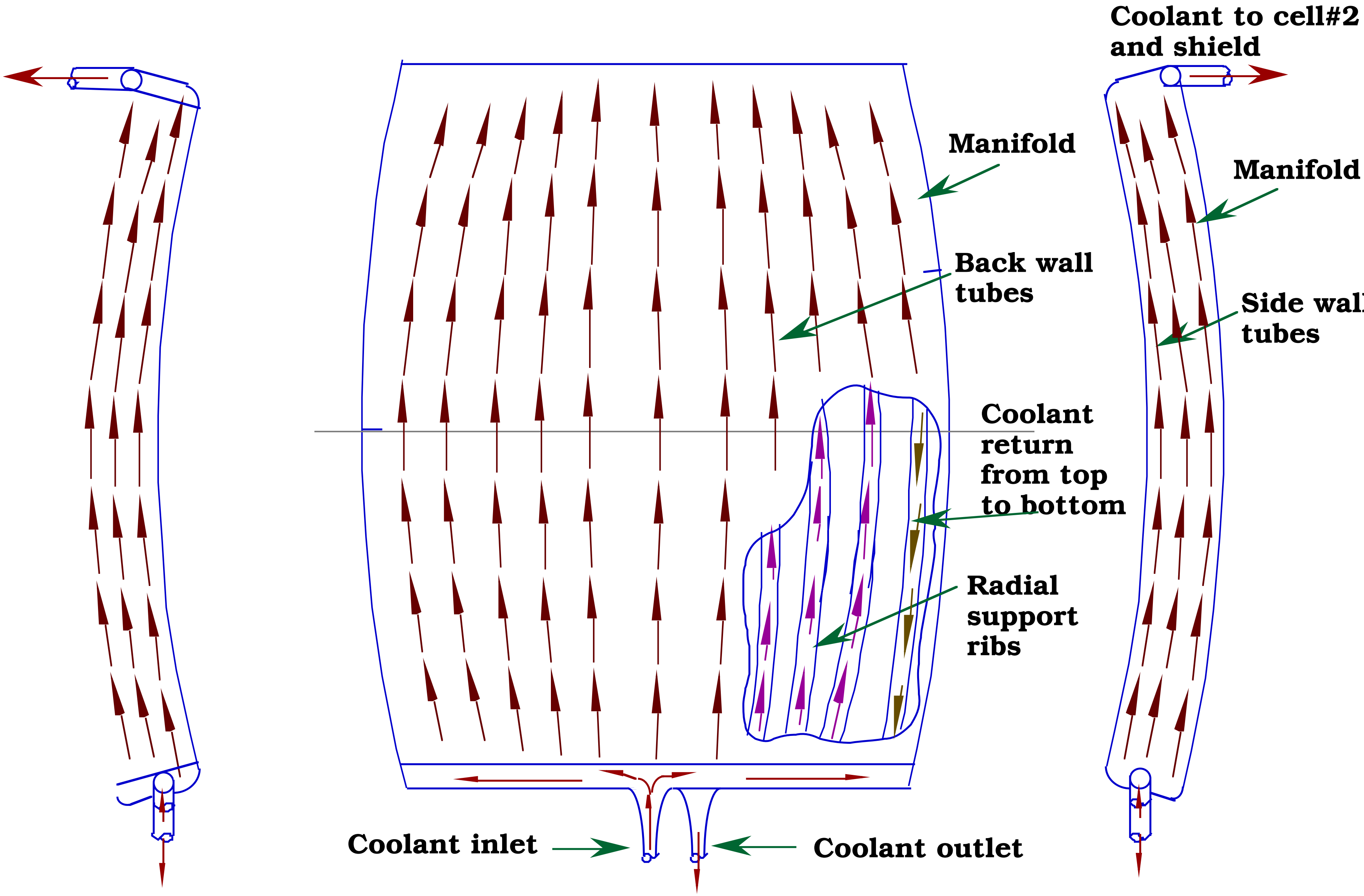

Toroidal Flow First Wall Coolant Routing

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- **The first wall is divided toroidally into six equal sections.**

- **There are two equal coolant streams, each stream cooling three sections.**

- **Each coolant stream enters manifolds at the rear midplane, one on the left side of the section above the midplane, and one on the right side below the midplane.**

- **The coolant flows along the sides of the module, then across the first wall and then across the sides on the opposite end into a manifold.**

- **The manifold then feeds the coolant to the second section which is cooled in the same way as the first section adjacent to it, but the toroidal flow across the first wall is in the opposite direction.**

- **Finally the flow cools the third section, again the same way as the first and second sections, with the flow direction the same as in the first section.**

- **The last pass of each coolant stream is across the upper side wall and the lower side of the module, respectively.**

Toroidal Flow First Wall Cooling

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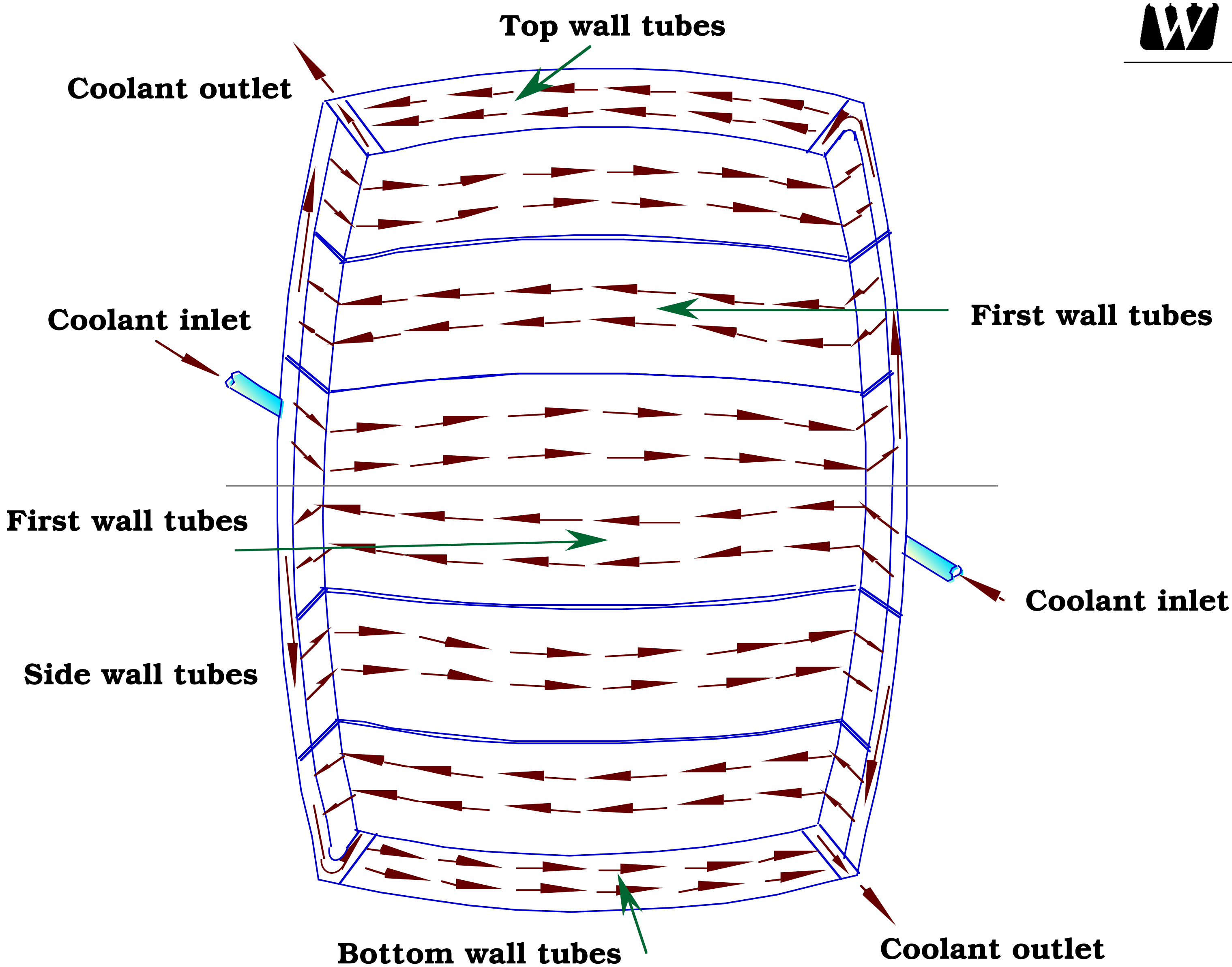

Toroidal Flow – Cooling of the Rest of the Blanket Module

- **After going through the first wall, one stream ends up at the rear upper manifold, and the second stream at the rear bottom manifold.**

- **The upper manifold flow is divided into three streams:**

  1) The first stream goes to cool the W stabilizing shells

  2) The second stream goes to cool cell #2

  3) The third stream goes to cool the shield.

- **After cooling the W shells, the first stream is combined with the lower manifold coolant and is directed into channels in the back side wall and the radial supports.**

- **This coolant flows poloidally upward through the back side and radial supports of the module, and at the top enters into the cell proper.**

- **The coolant then flows down poloidally through the cell proper and exits the module on the bottom.**

Toroidal Flow – Blanket Module Cooling

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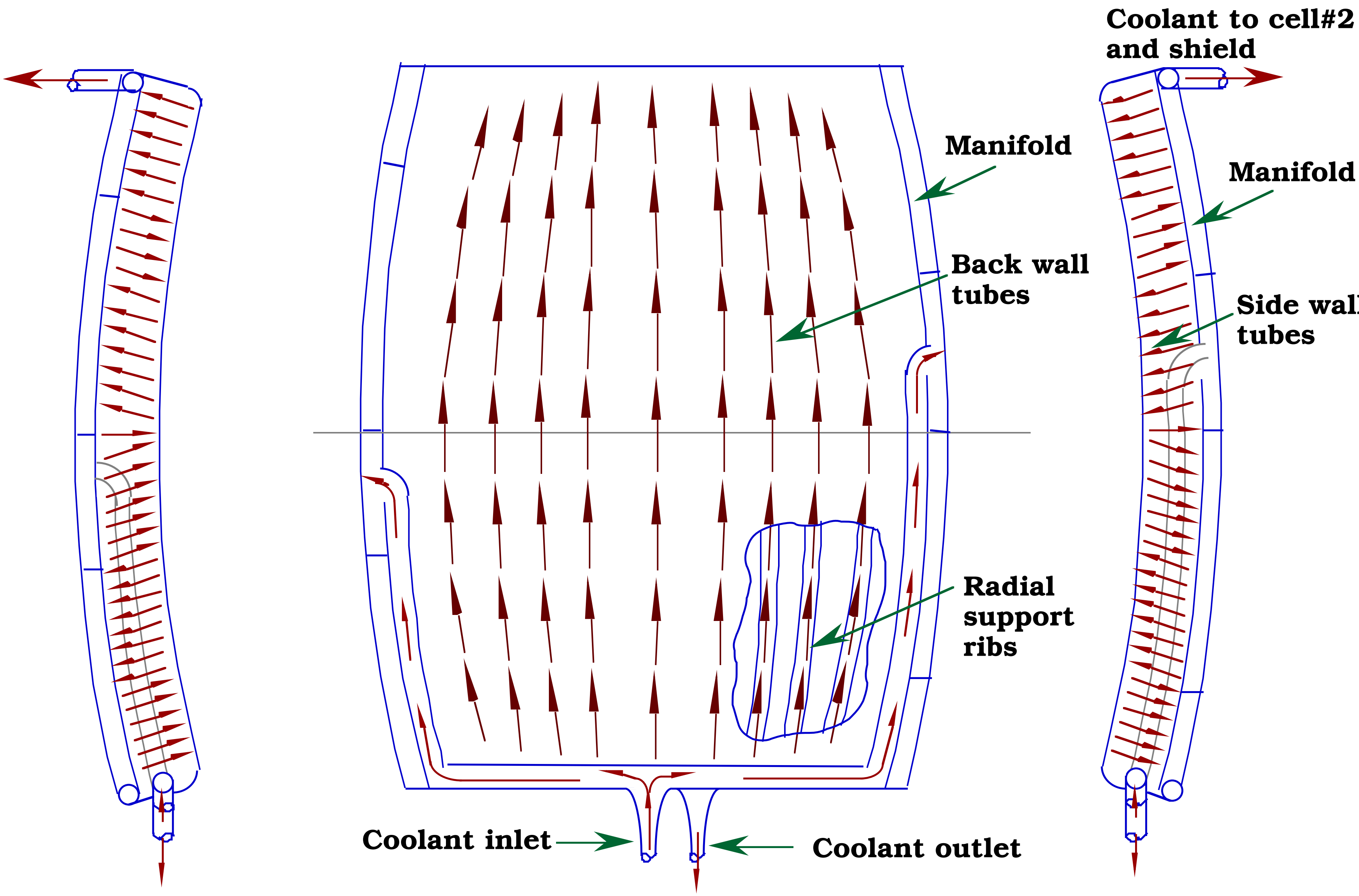

Toroidal vs. Poloidal First Wall Cooling

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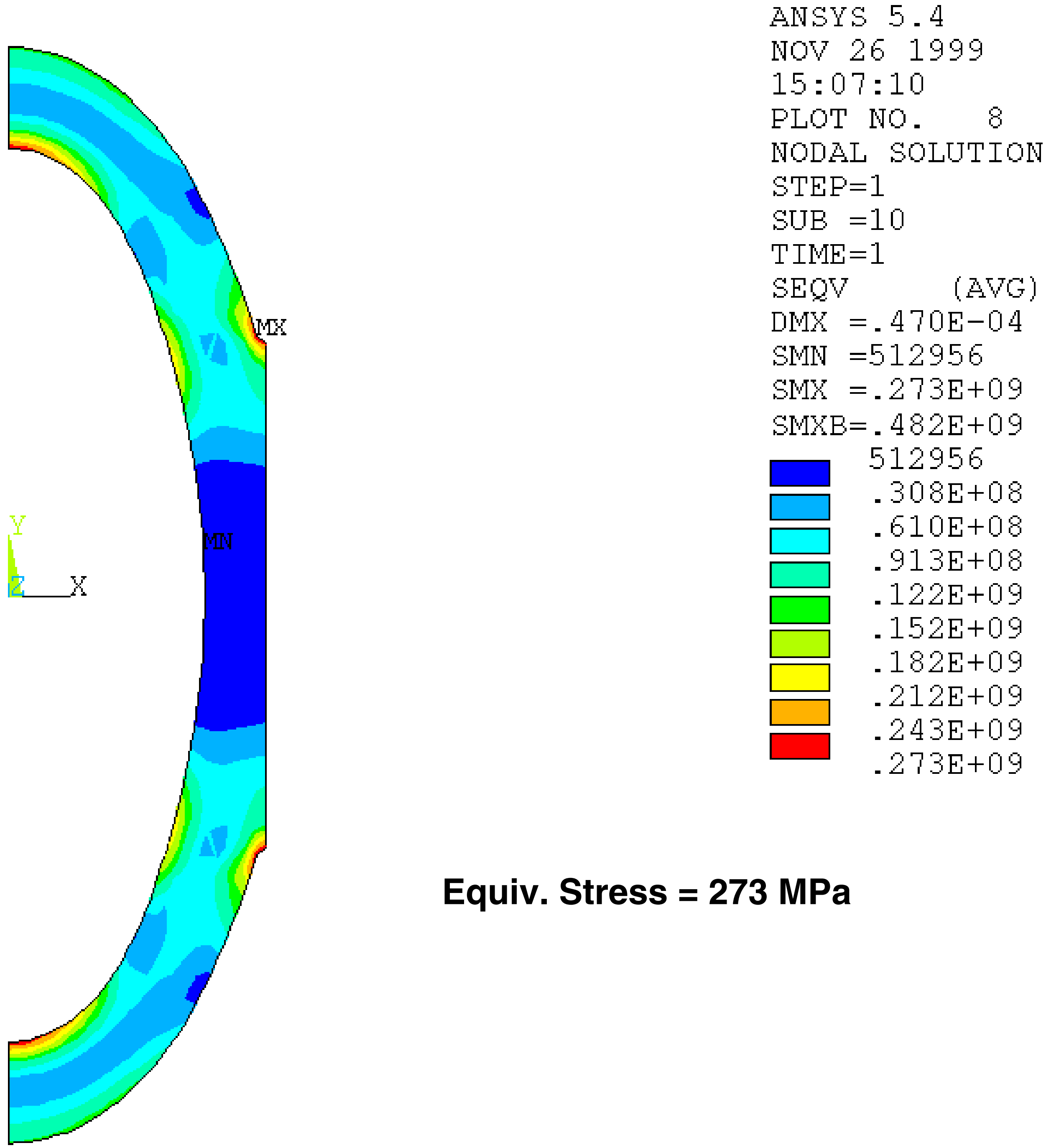
	Advantages	Disadvantages
Toroidal	• Turbulent flow • Lower pressure drop • Higher margin on temp. • Lower pressure • Lower pumping power	• More complex coolant routing
Poloidal	• Simpler coolant routing	• Laminar flow • Higher pressure drop • Higher pressure • Higher pumping power

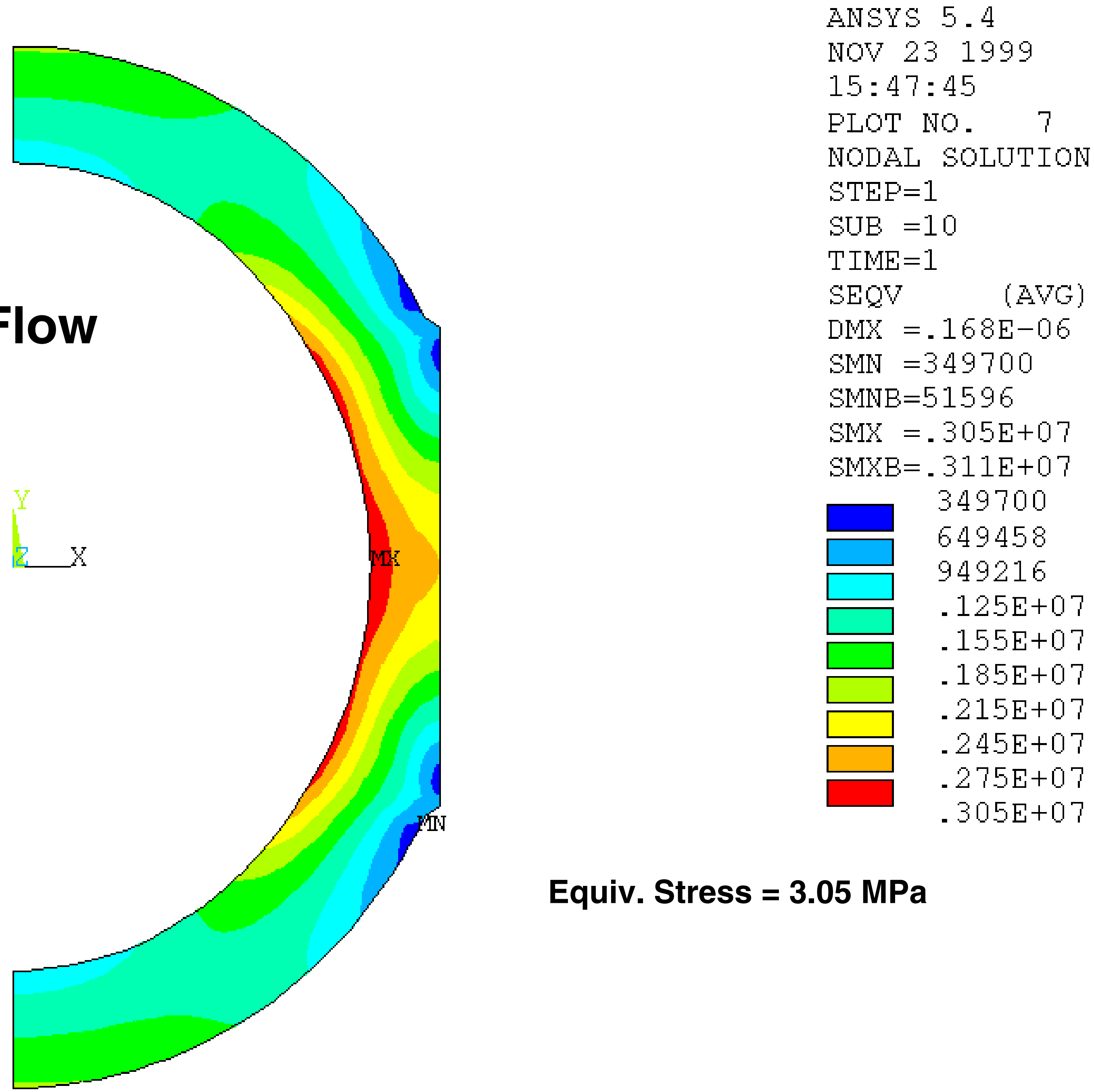
Poloidal Flow Tubes



Equiv. Stress = 273 MPa

ARIES-AT FW(Bottom),Pf=5atm,Tf=600C,SHF=0.71MW/m2,h=0.5W/cm2K,To=500C

Toroidal Flow Tubes



Equiv. Stress = 3.05 MPa

ARIES-AT FW Inlet,Pf=5atm,Tf=600C,SHF=0.71MW/m2,h=1.0W/cm2K,Tr=500C

Upper Blanket Section Represented as a Beam Built in at Midplane

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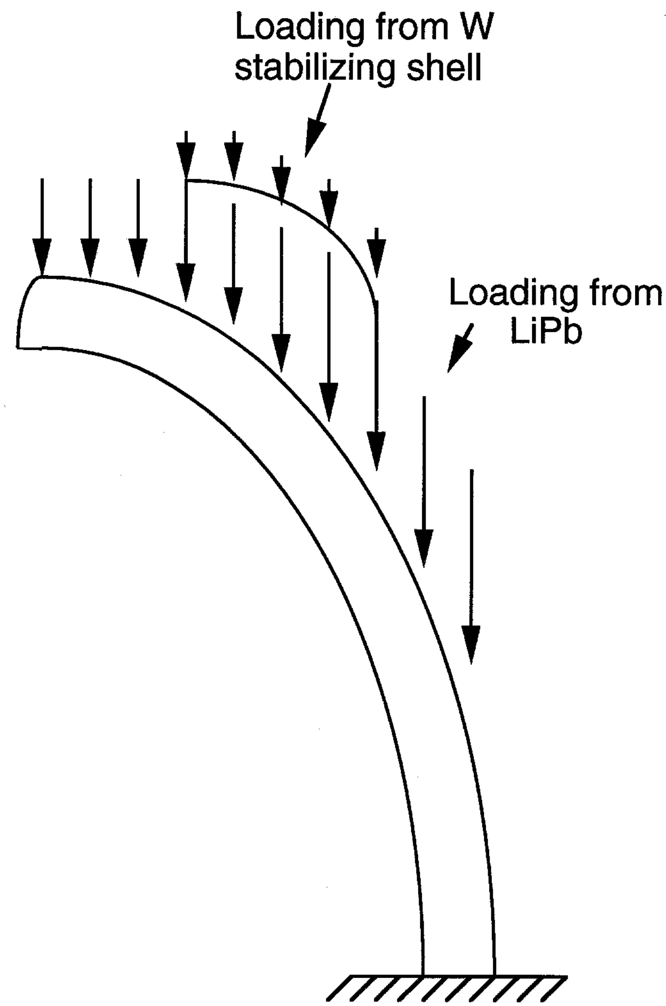

Model of a Blanket Section for Calculating the Moment of Inertia

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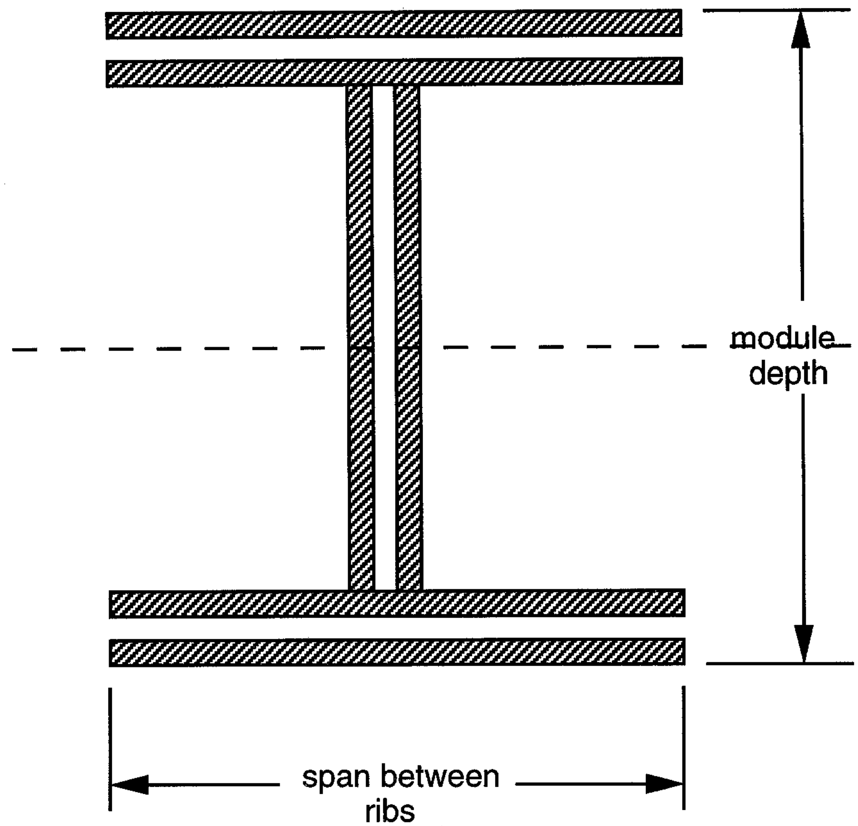

Moment of Inertia of a Blanket Section as a Function of the Spacing Between Radial Support Ribs

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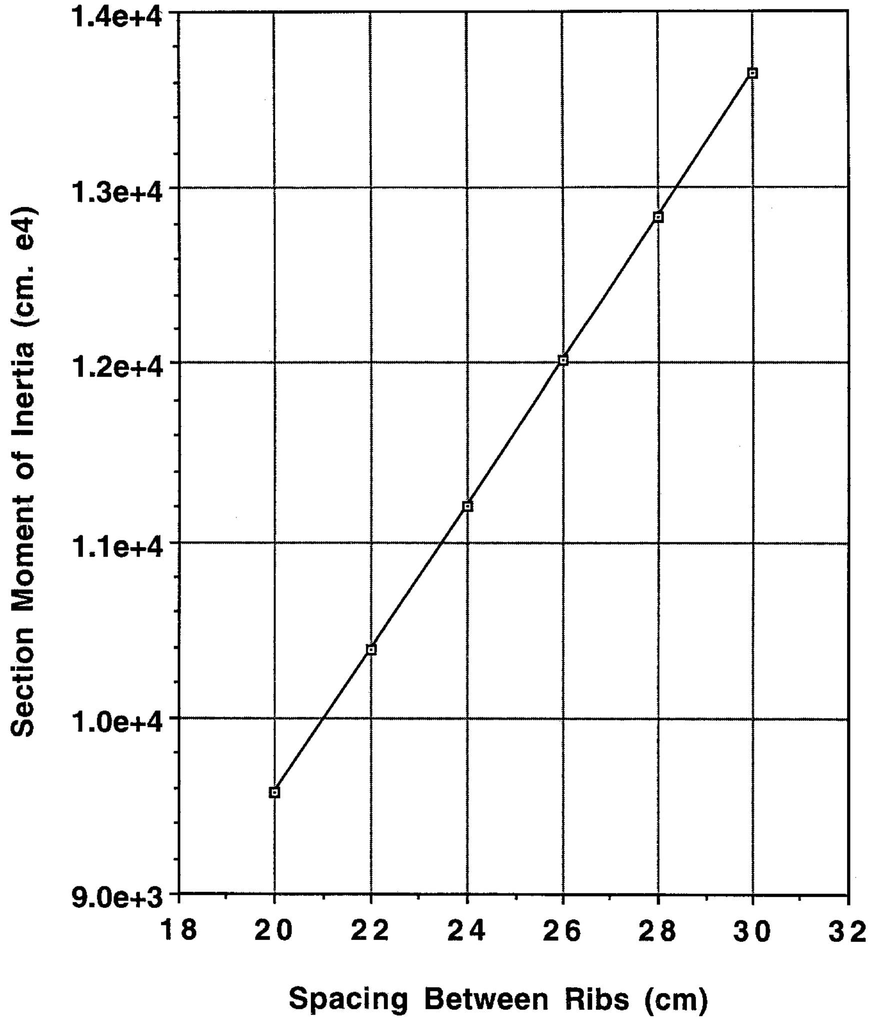

Bending Moments at the Module Midplane Due to the Mass of LiPb and the W Shell

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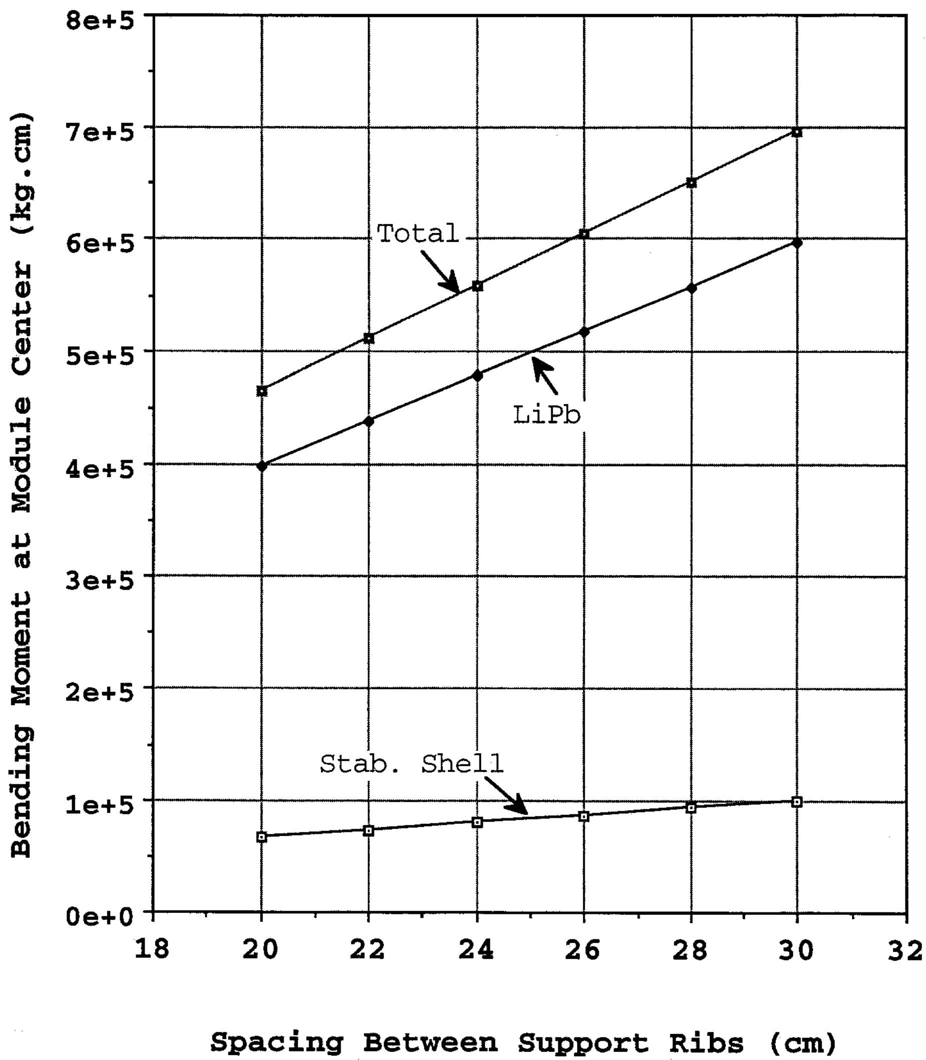

Bending Stress at the Module Midplane Due to the Mass of LiPb and the W Shell

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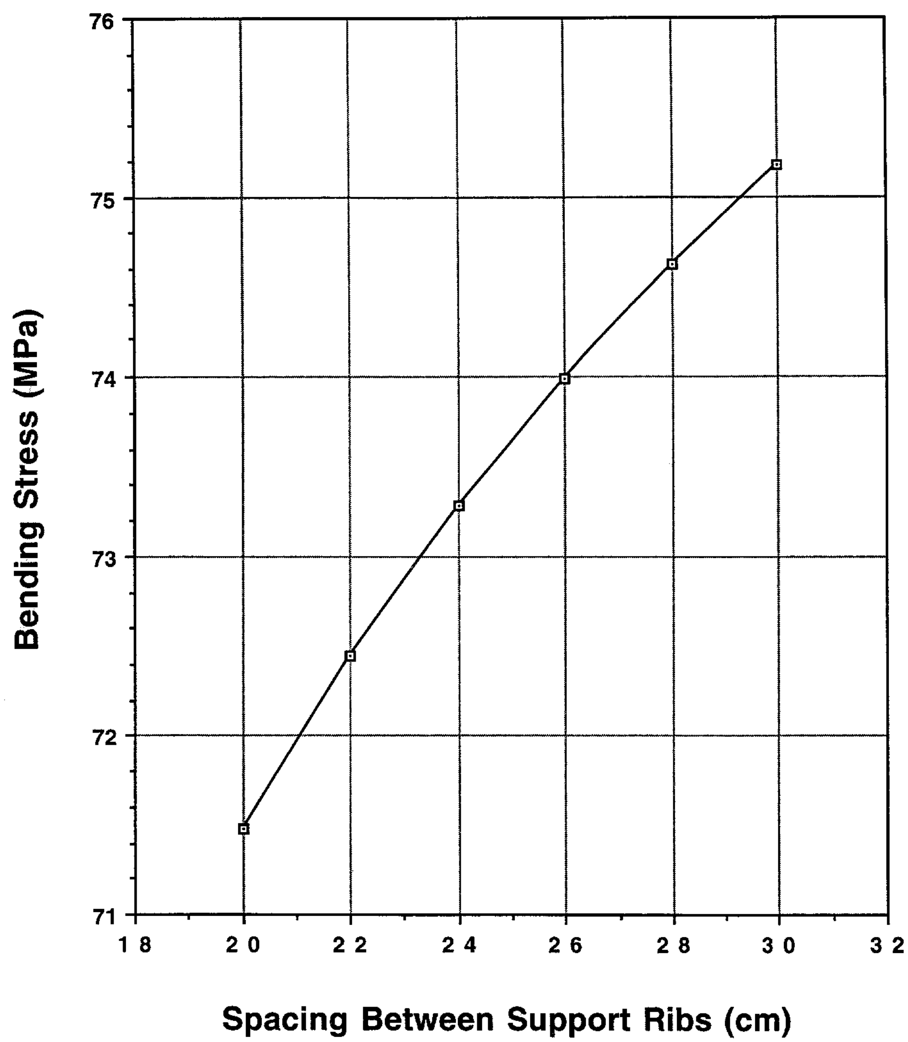

Relative Coefficients of Expansion W vs. SiC

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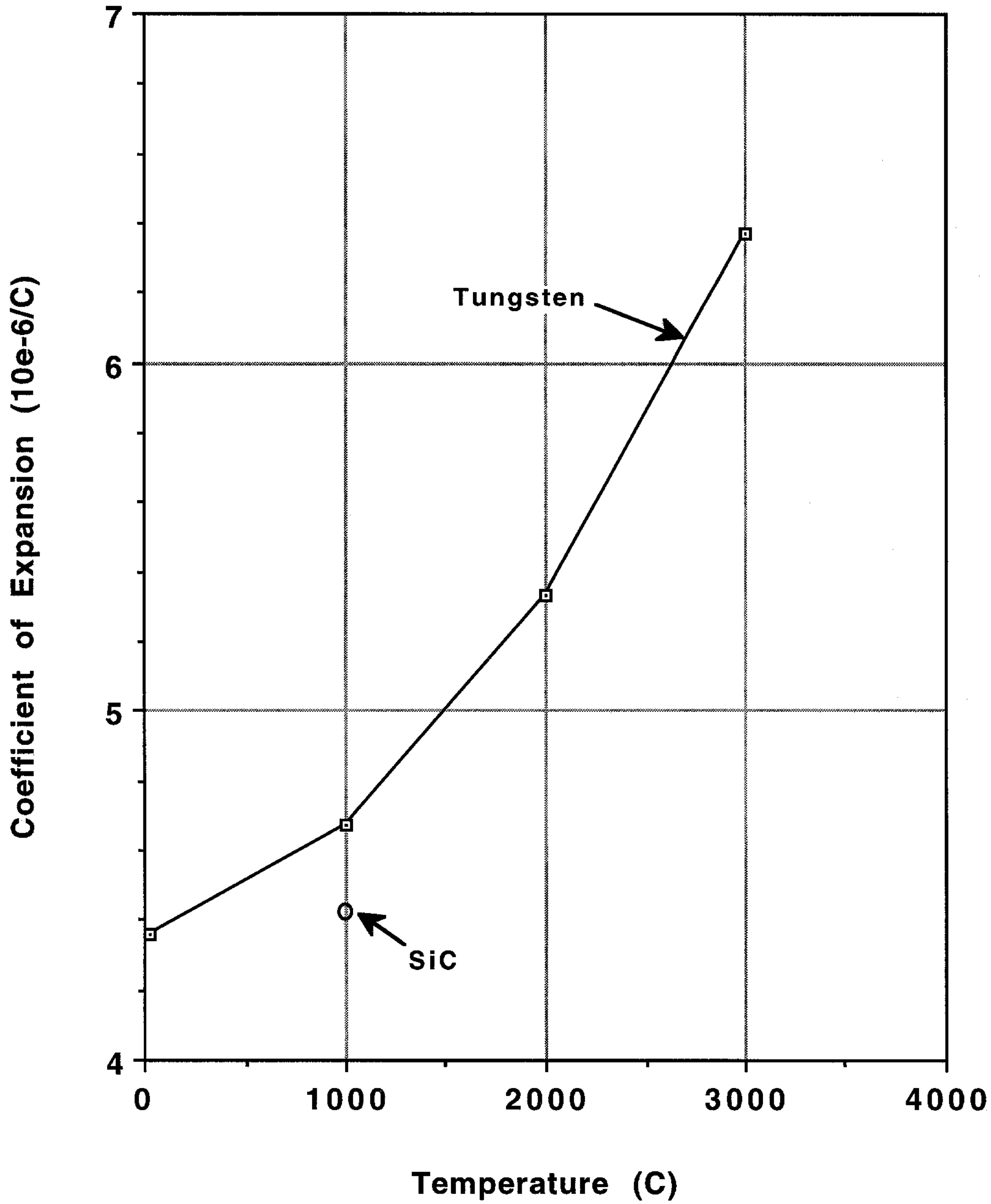

Unresolved Issues

- **External coolant lines layout to the outboard and inboard blanket modules**
- **Detailed internal coolant routing with consideration to mass flow rate**
- **Attachment of the W shells to the back of Cell #1**
- **Connections between Cells and the shield**
- **Coolant flow through the W shells**
- **Coolant connections from the SiC blanket structure to the W shells**
- **Electrical connections between W shells**
- **Overall stability and support considerations**

Conclusions

- **Elliptically shaped tubes at the first wall have much higher stresses than circular tubes.**

- **Toroidally cooled first walls have an advantage over poloidally cooled first wall by virtue of better heat transfer, lower pressure drop, thus providing a larger margin in temperature and stress.**

- **Toroidally cooled first walls have a more complex coolant routing than poloidally cooled first walls.**

- **Preliminary investigation shows that the outboard blanket modules can be self supporting with respect to the heavy LiPb load. However, the total gravity load to the ground is yet to be designed.**