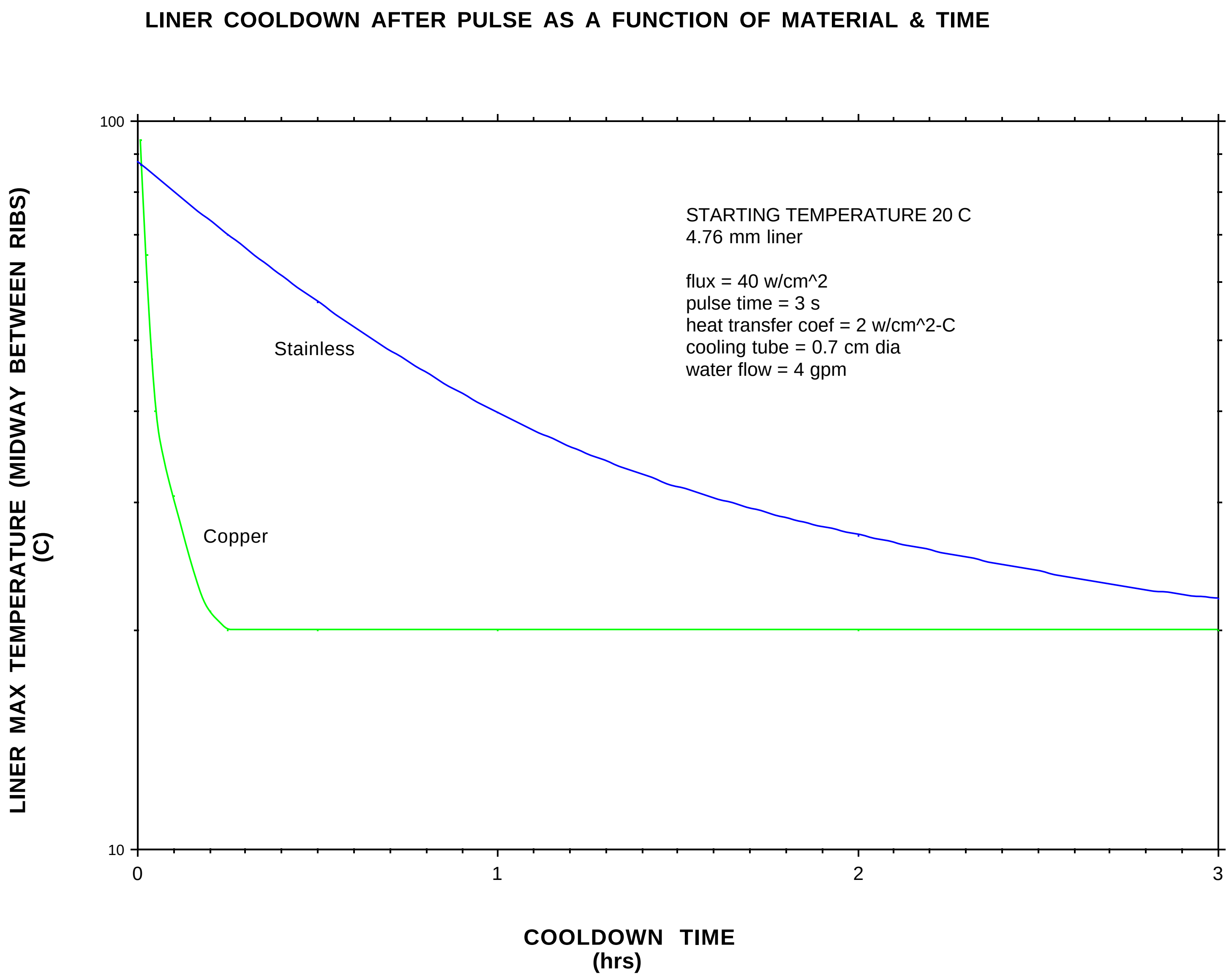
WBS 1 - VACUUM LINER & PFC COMPONENTS

P. L. GORANSON 9/24/98

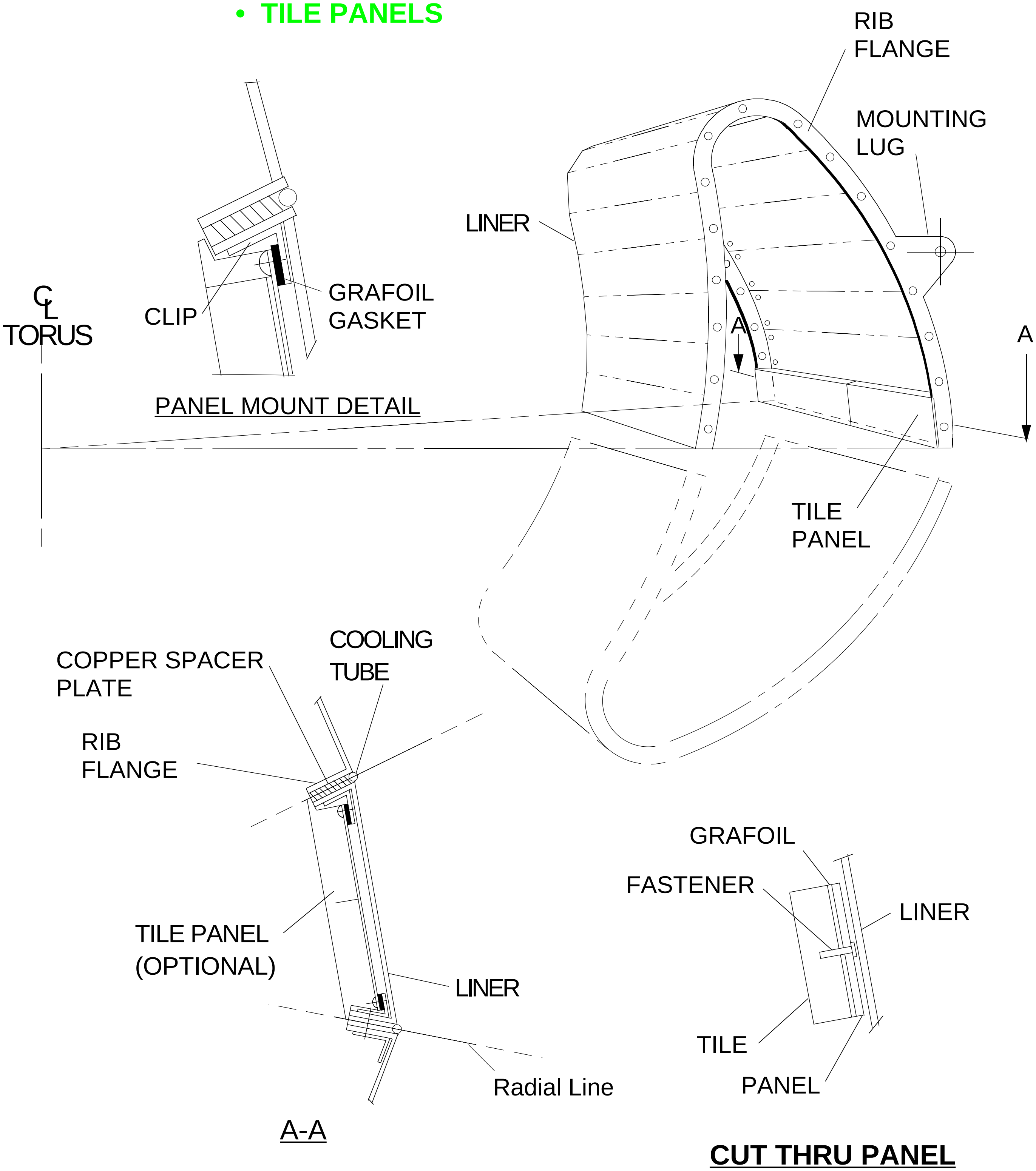
- DESIGN REQUIREMENTS
- LINER CONFIGURATION STUDY
- SEGMENTATION STUDY
- FABRICATION STUDY
- THERMAL ANALYSIS
- CONDUCTANCE ANALYSIS
- CONCLUSIONS
- DESIGN STATUS



LINER COOLDOWN AFTER PULSE AS A FUNCTION OF MATERIAL & TIME
100
10
0
1
2
3
LINER MAX TEMPERATURE (MIDWAY BETWEEN RIBS) (C)
COOLDOWN TIME (hrs)
STARTING TEMPERATURE 20 C
4.76 mm liner
flux = 40 w/cm^2
pulse time = 3 s
heat transfer coef = 2 w/cm^2-C
cooling tube = 0.7 cm dia
water flow = 4 gpm
Stainless
Copper

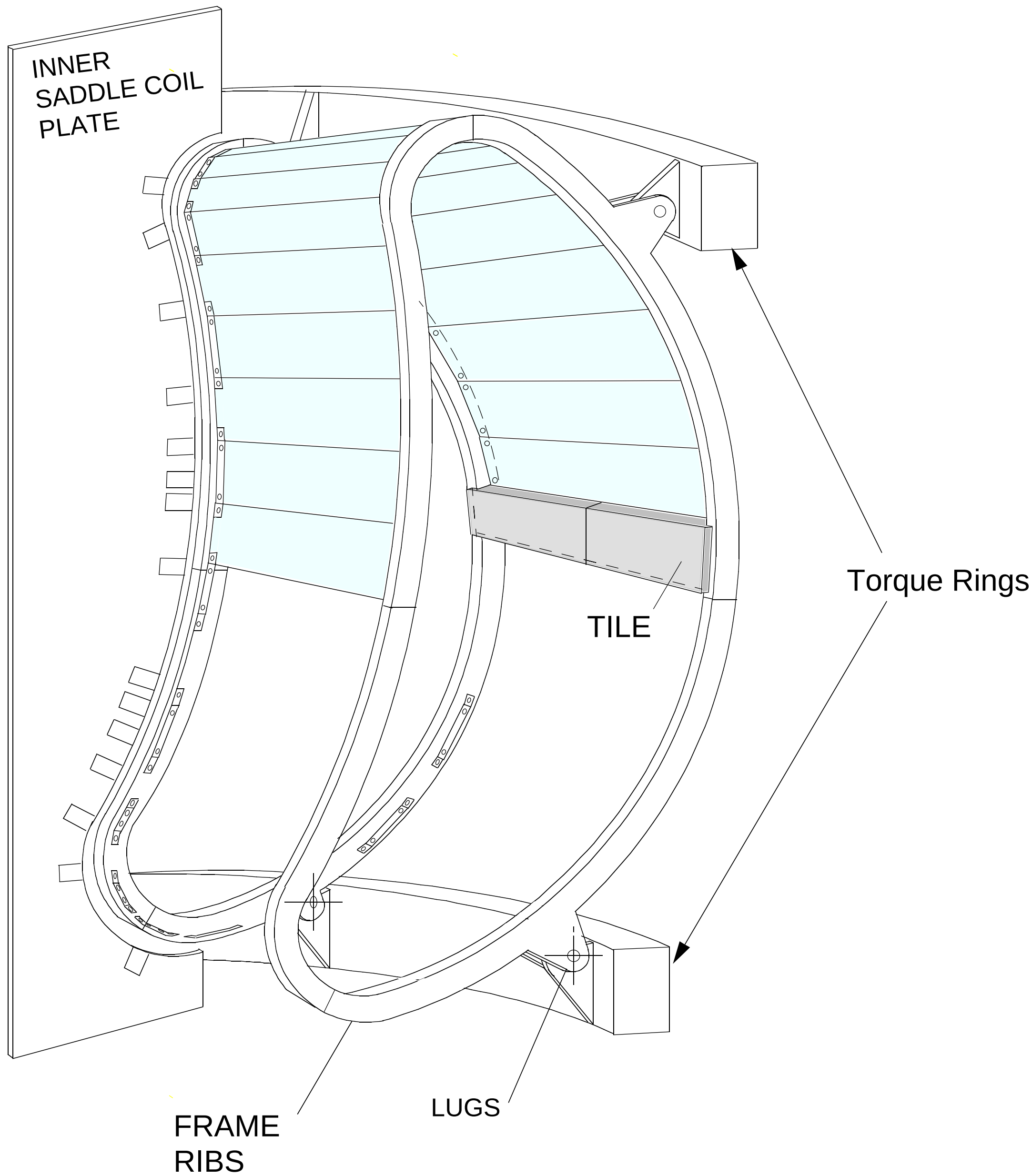
PFC FABRICATION - LINER CONCEPT

- DEVELOPED LINER, USING TRAPEZOIDAL ELEMENTS
- RADIAL RIB FLANGES
- TILE PANELS



LINER ASSY ALTERNATE MOUNTING

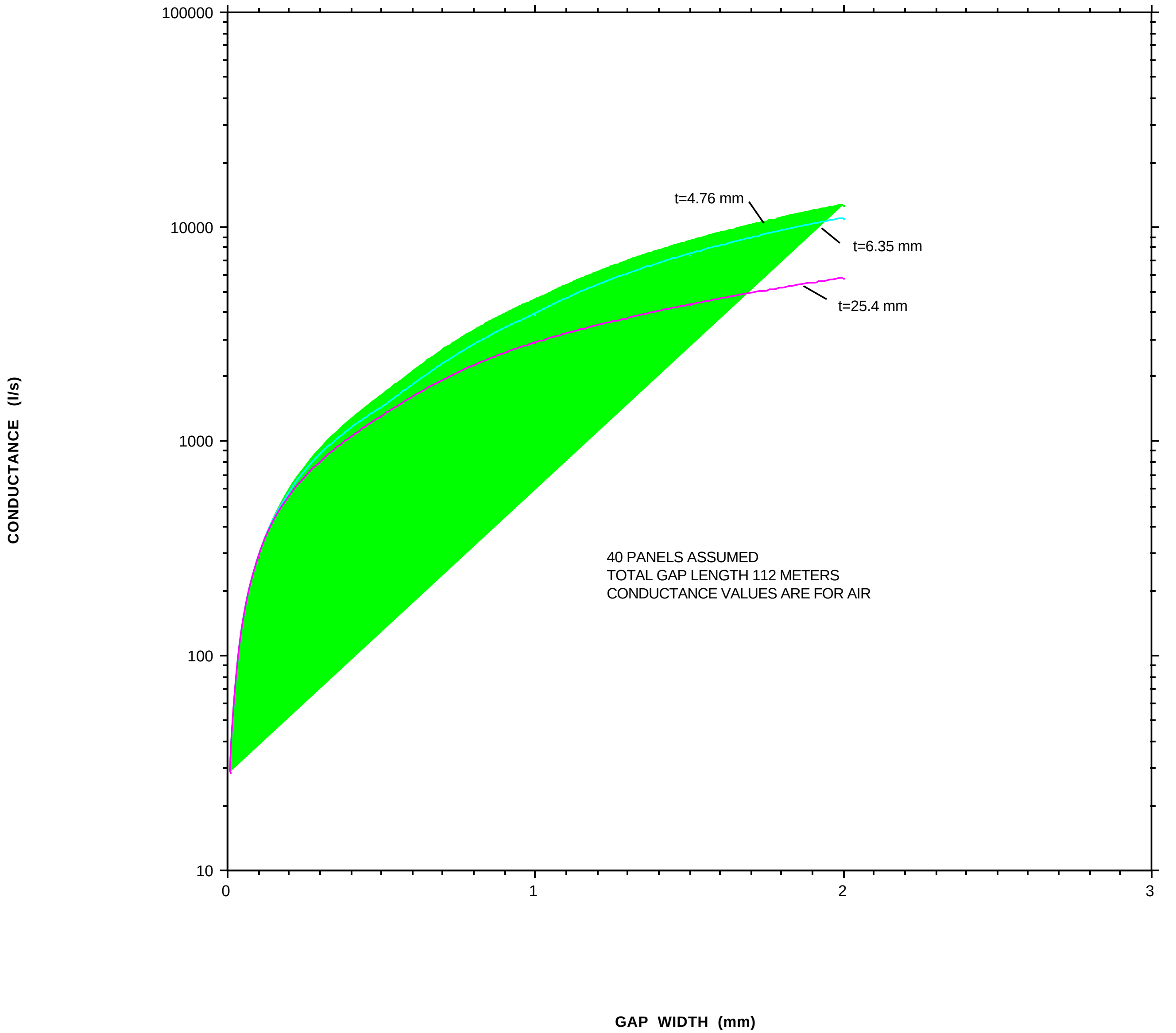
No outer saddle coil support plates



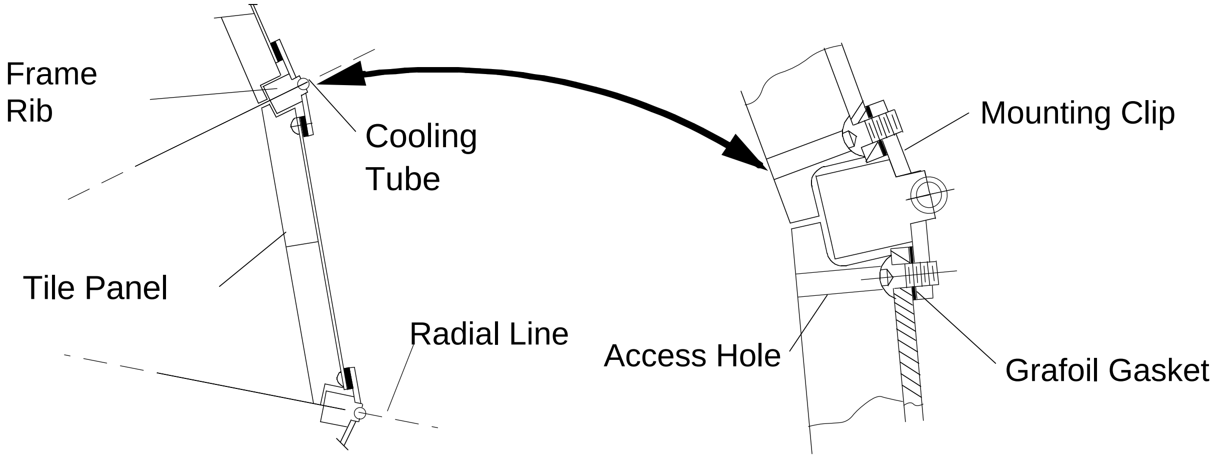
CONCERNS

Each of the lug mounts is different; a minimum of 40 unique geometries will be required.

LINER CONDUCTANCE AS A FUNCTION OF MATERIAL THICKNESS AND GAP BETWEEN PANELS

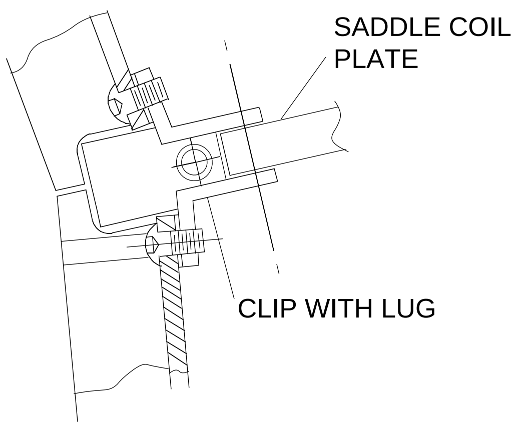


DETAILS

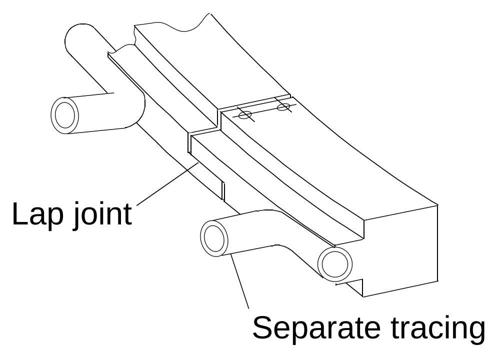


A-A
Cut thru tile

PANEL MOUNT DETAIL

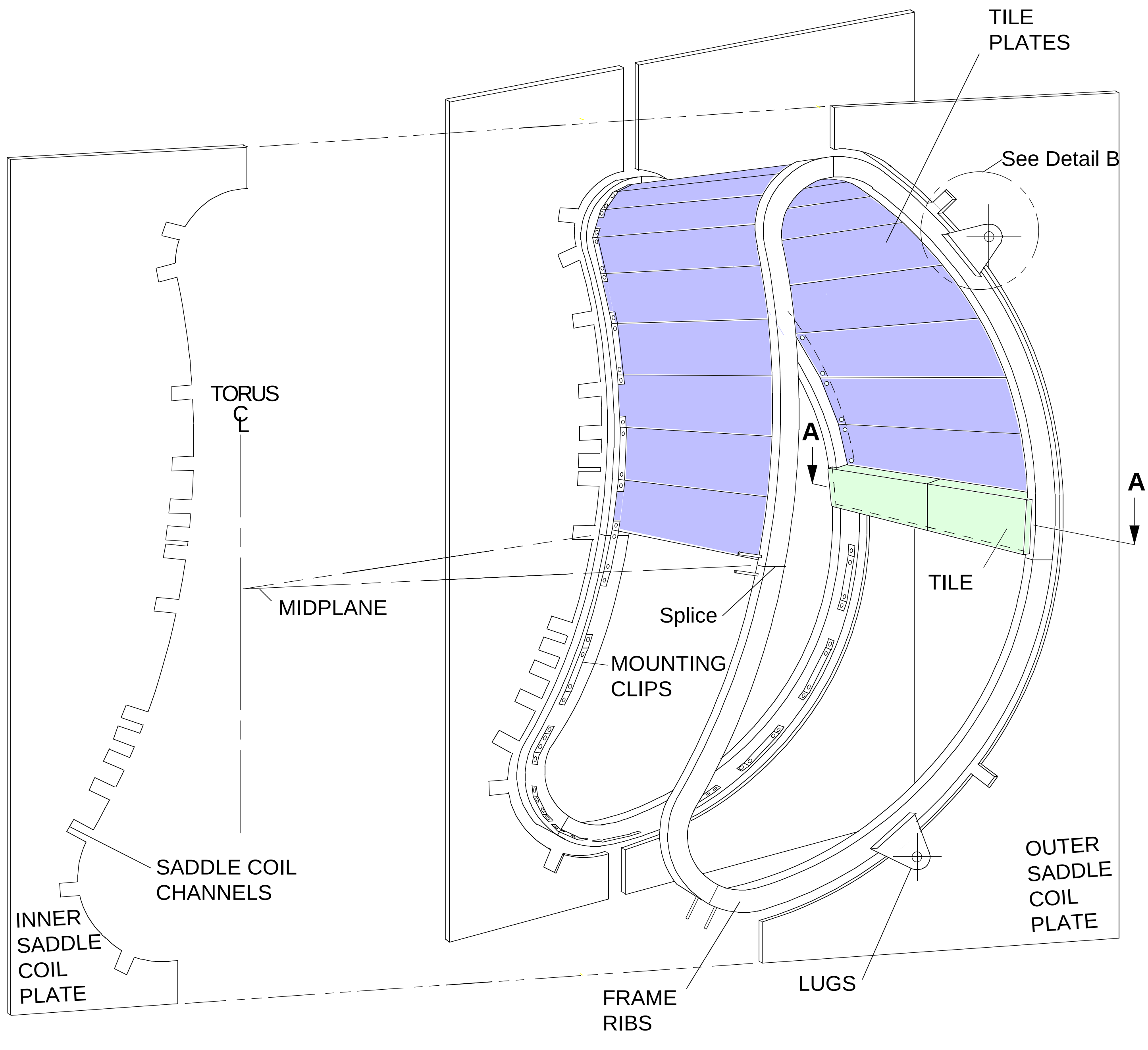


ASSY MOUNT DETAIL B



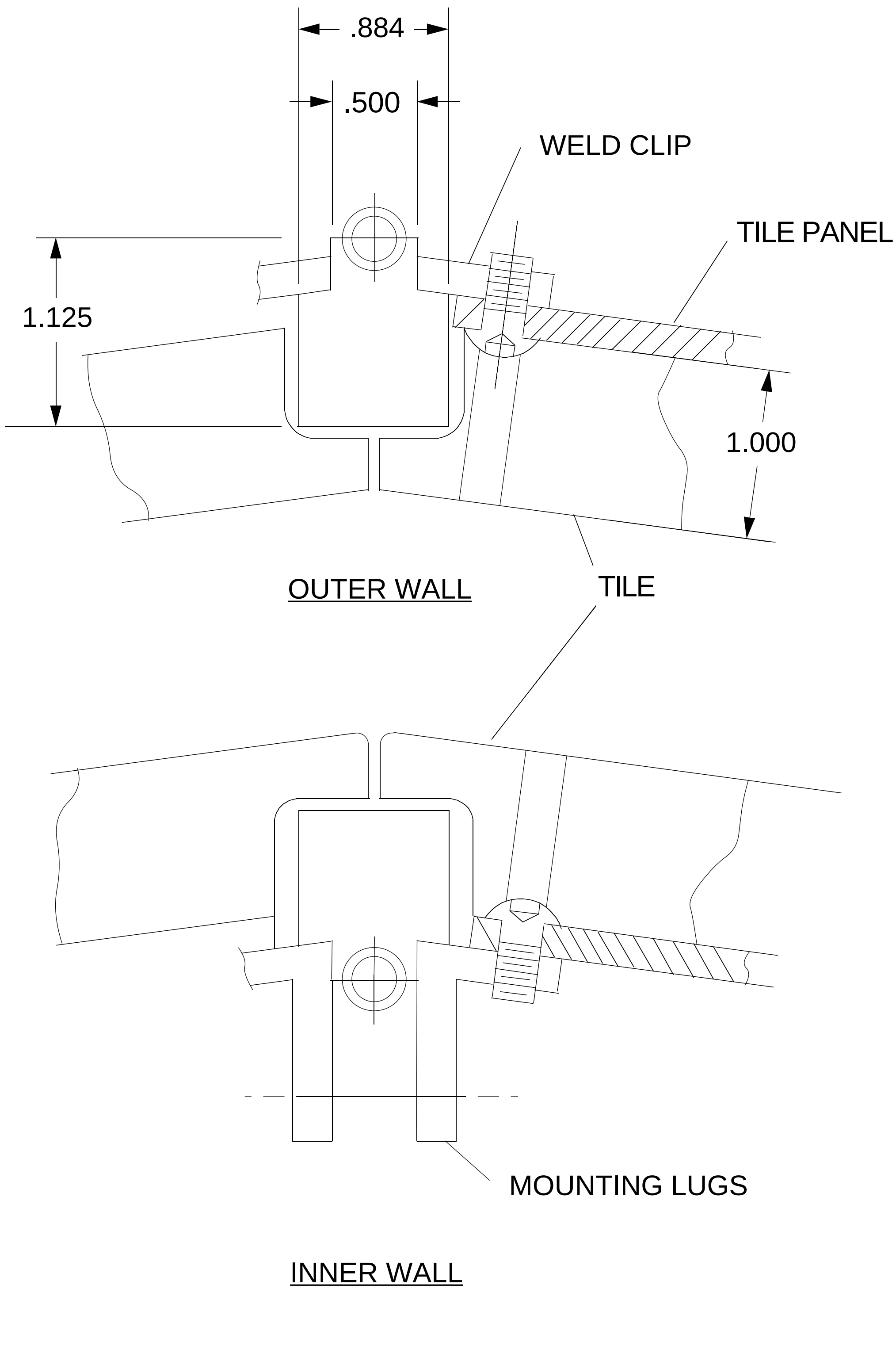
RIB SPLICE DETAIL

PFC FABRICATION - NO SEPARATE LINER

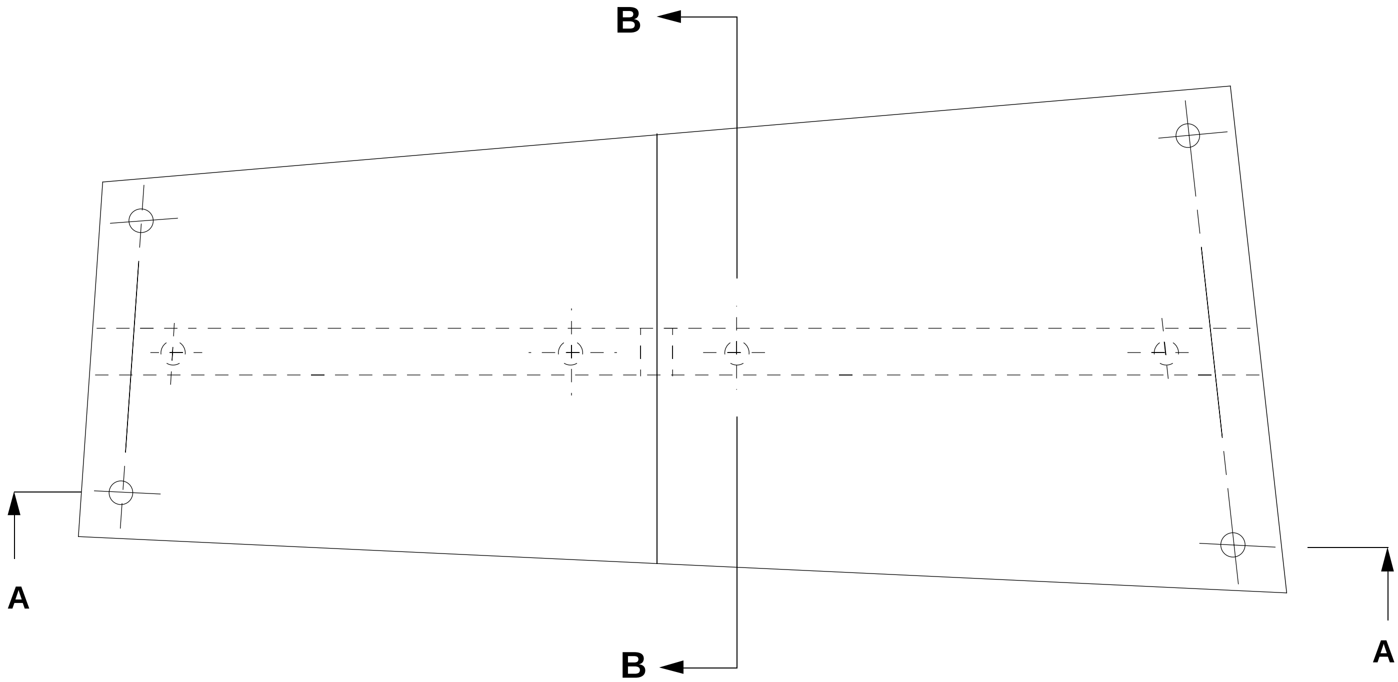


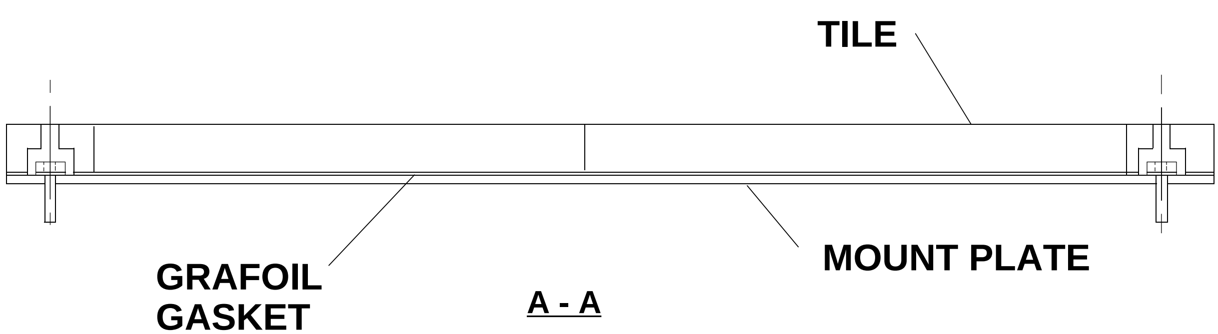
- FRAME RIBS TEMPORARILY HANG FROM SADDLE COIL PLATES DURING ASSY
- TILE PANELS / RIBS TOGETHER FORM A RIGID STRUCTURE
- TILE PANELS SERVE AS CONDUCTANCE LIMITER
- RIBS ARE TRACED TO COOL/HEAT PFC'S
- RIBS ASSEMBLED INSIDE TORUS FROM 2 0R MORE SECTIONS

LINER INTERFACE FLANGE - BASELINE

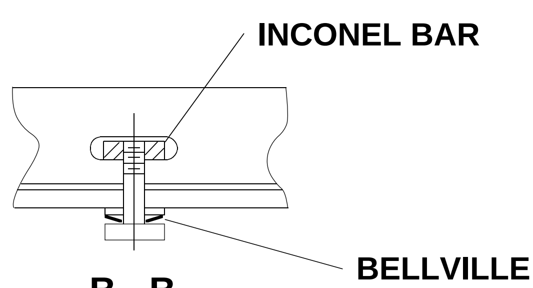


TYPICAL TILE PANEL





A - A



B - B

TWICE SCALE

VACUUM LINER DESIGN REQUIREMENTS - STAGED OPERATION OPTIONS

LINER OPTIONS REQD	OPERATIONAL MODE INITIAL SHORT PULSE no bake ohmic heating low rep rate	SHORT PULSE no bake ohmic heating high rep rate	SHORT PULSE bake NB heating high rep rate	LONG PULSE >2 seconds
RIBS	NO	YES 2,3,7,8	YES 2,3,5,7,8	YES 2,3,5,7,8
PLATES	NO	YES 3,6,7,8	YES 2,5,7,8	YES 1,2,5,6,7,8
FULL TILE COVERAGE	NO	NO	NO	YES 3,4,6
TILES ONLY IN HIGH HEAT ZONES	NO	YES	YES	NA
BAKEOUT AT 350 C	NO	NO	YES	YES 1
COIL INSULATION	NO	NO	YES 5	YES 5
NO LINER	YES 9	NA	NA	NA

NA - non applicable

LINER REQUIREMENTS

1 SERVE AS CONDUCTANCE BARRIER

2 SUPPORT PLATES, LIMITERS, NB ARMOR

3 PROVIDE RADIAL AND VERTICAL THERMAL EXPANSION

4 MOUNT DIAGNOSTICS

5 PROVIDE POSSIBLE BAKEOUT AT 350 C

6 INTERCEPT PLASMA HEAT

7 WITHSTAND DISRUPTIONS

8 PROVIDE COOLING

9 SPECIAL(LOCAL) COIL PROTECTION REQD

VACUUM LINER DESIGN REQUIREMENTS

- SERVE AS CONDUCTANCE BARRIER
- SUPPORT TILES, LIMITERS, NB ARMOR
- PROVIDE RADIAL AND VERTICAL THERMAL EXPANSION
- MOUNT DIAGNOSTICS
- PROVIDE POSSIBLE BAKEOUT AT 350 C
- INTERCEPT PLASMA HEAT
- WITHSTAND DISRUPTIONS
- PERMIT STAGED FAB & INSTALLATION

THREE POSSIBLE PFC CONFIGURATIONS

- INTEGRAL LINER
  - Separate liner skin and tile panels

- TILE PANELS ONLY
  - Serves double function as liner and tile mount

- NO LINER (INITIAL OPERATION?)
  - Torus alone supplies vacuum function

SEGMENTATION

Assumptions

- 15 3/8” inch wide by 40” high port
- No outer coils to obstruct opening
- 36 toroidal segments [72 total segments]
- Split at midplane into top and bottom pieces.

Results:

- To first order it appears segments would assemble thru port.
- Mockup will resolve segment sizes

LINER FABRICATION

- Liner configuration studied was Rib and Skin [Monocoque]
- Broken down into 10^{o} segments, bottom and top halves
- Segments could be pan configuration with mating rib flanges at midplane & radial interfaces
  - segments bolt together at rib flg faces

SEVERAL METHODS COULD BE USED TO FORM LINER SKIN

Form true compound curve conforming to plasma

- Pressing
- Explosive forming
- Casting

SHARE COMMON DISADVANTAGES

- Require expensive forms or dies, a minimum of 36-40 on two period machine
- Essentially the job is done twice
  - make dies
  - form skins

ALTERNATE CONCEPT - Developed liner

Approximate the shape of plasma, make parts directly from sheet stock.

- Liner segments may be a developed shape (prismatic)
  - flat patterned
  - brake bent into shape
  - mated with ribs
  - has precedence with WENDELSTEIN W VII - AS

- Series of trapezoids or triangle which approximate shape

- Ribs
  - NC machined from flat stock
  - radial, regardless of liner shape

- Requires no tooling, can be described mathematically
  - tools are in place
  - drawn full scale on ProE
  - brake bend lines included

- Method is not sensitive to number of machine periods

PFC CONFIGURATION THERMAL STUDY

Assumptions:

- 12 MW operation, distributed heat load of 40 w/cm^2
- 3 second pulse
- Cooling via tracing in copper plate sandwiched between liner ribs
- Liner relatively thin, on order of 3/16”
- Liner is composed of individual panels are fixed at ends to rigid ribs

1-D transient heat flow results - ref graph

- Stainless panels will heat very quickly, cool very slowly
  - temp will ratchet up unless cooldown on order of 2 hr

- Stresses in panels are above yield, deflections large
  - ribs must be free to expand radially

- Tiles will be not be necessary unless pulses are longer than 3-4 seconds
  - max temperature 84 C
  - pulse length is presently limited by saddle coils to less than above

- Tiles or metal shingles may be necessary in areas with severe peaking of heat distribution
  - tiles limit temperature, decrease stress
  - tiles delay heating
  - tiles distribute heat evenly into liner

PFC CONFIGURATION THERMAL STUDY - contin.

Recommendations

- Change panels to plated copper
- Increase panel thickness to reduce peak temperature
- further analysis necessary

TILE MOUNTING

- Tiles are preattached to flat panels
  - grafoil gaskets conduct heat
  - fasteners install from back side of panel (none exposed to plasma)

- Panel size corresponds to flats (facets) in liner
  - two tiles per panel may be sufficient
  - compact and installs easily from within liner

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LINER PROS AND CONS

LINER CONCEPT

Separate welded liner and tile panels

PROS:
- less conductance(factor of approx. 3 less gap)
- stronger against disruptions (effective shear web)
- easy retrofit of tiles

CONS:
- more costly, requires design, fab, and assy of both liner and tile panels
- function may be redundant, still need tile panels
- access to saddle coils not possible without partial disassembly of liner
- doubles surface area to be pumped
- more mass to bake out
- thermal stress management more difficult
- requires three piece rib assy - mating flgs and coolant spacer

TILE PANEL ONLY CONCEPT

Panel plates double as condutance limiter

PROS:
- cost savings, no design, fab, or assy of separate liner
- simple access to saddle coils
- easy retrofit of tiles
- less surface area and mass
- less thermal stress
- single piece rib with coolant tracing

CONS:
- 3 times gap length, requires lap joints in panels
- less shear resistance

VACUUM LINER STUDY CONCLUSIONS

- CONDUCTANCE VERY SENSITIVE TO GAP WIDTH
  - Lapped design probably required

- ALL CONCEPTS REQUIRE POLOIDAL RIBS (RADIAL FLANGES)
  - React magnetic loads
  - Assembly interface between sectors
  - Heat sink- cooling/bakeout tracing
  - Align other components(serves as jig)
  - Provide mount for: (no space available on inner saddle coil plates)
    - liner skin and/or tile panels
    - limiters
    - NB armor

- LINER THICKNESS - TBD
  - thermally or disruption driven ?

- LINER TO TORUS SUPPORTS - TBD
  - Must allow radial and vertical thermal expansion
  - Inner midplane preferred but not possible with present coil config

- SEPARATE LINER HAS NO REAL ADVANTAGE
  - panels provide same function, primarily as:
    - conductance barrier
    - bakeout of PFC'S

VACUUM LINER STUDY CONCLUSIONS - contin.

- BAKEOUT
  - No real cost impact on liner

  - Major concern is thermal proximity to coils and management of expansion
    all liner concepts work equally well

  - If bakeout not required then liner has only conductance function
    may not be necessary

PFC/Liner - status of liner design

- Present baseline calls for set of flat panels attached to cooled, radial support rings(ribs)
  - flat panels would be attached to the rings with bolts
  - ribs would tie to saddle coil plates

- Panels made from stainless steel/ copper laminate or nickel plated copper

- PFCs would be attached to flat panels, if needed, in regions of high heat flux
  - conductance calculations indicate that panels must overlap
  - even small gap (> 0.3 mm) between panels may result in excessive particle communication between inside and outside of liner

- Other options for liner fabrication include brake-bent assemblies instead of flat panels, or some combination of brake-bent and flat panel construction

- Design appears flexible
  - should allow high temperature bakeout
  - low conductance to the coil region
  - without much penalty in cost or complexity