FIRE Vacuum Vessel
Disruption effects

With input from B. Nelson, H.M. Fan, C. Kessel, M. Ulrickson, J. Wesley

FIRE engineering meeting

PPPL
May 31, 2000

Disruption Effects

Disruptions will cause high loads on theVV due to induced current and conducting (halo) currents flowing in structures (No thermal effects are expected for VV)

- Direct loads on vessel shell and ribs
- Direct loads on passive plates
- Reaction loads at supports for internal components
  - Divertor assemblies and piping
  - FW tiles
  - Port plugs

Dynamic effects should be considered, including:

- Load reversal during the event
- Shock loads due to gaps in load paths

All loads should be considered in appropriate combinations

e.g. Gravity + coolant pressure + VDE + nuclear / PFC heating + Seismic + …

Vacuum Vessel Loading conditions

Load	Value, July 99	Value, May 00	Comment
Gravity load	~3 MN	~3.5 MN	VV ~130 tons, FW,div. ~35 tons, port plugs ~ 185 tons
Vertical displacement event (VDE) load			
Vertical	20 MN	16 - 32 MN	Based on J. Wesley guidance [1]
Lateral, net	7 MN	6 - 11 MN	
Seismic load (assumed)			
Vertical acceleration	0.2 g	0.2 g	
Lateral acceleration	0.2 g	0.2 g	
Maximum total vertical load	~27 MN	~22-41 MN	Gravity + VDE * 1.2 (dyn load factor)
Maximum total lateral load	~9 MN	~8-14 MN	VDE * 1.2 (dyn load factor)
Maximum local EM load			
Local pressure on vacuum vessel from internal components	~4 MPa	~8 MPa	Rough estimate from halo currents
EM load from TF ramp	~0.3 MPa	~0.75 MPa	Poloidal conductivity of vessel increased due to Cu stabilizers
Coolant pressure			
Normal operation	<10 atm	<10 atm	
Bakeout	<10 atm	<10 atm	

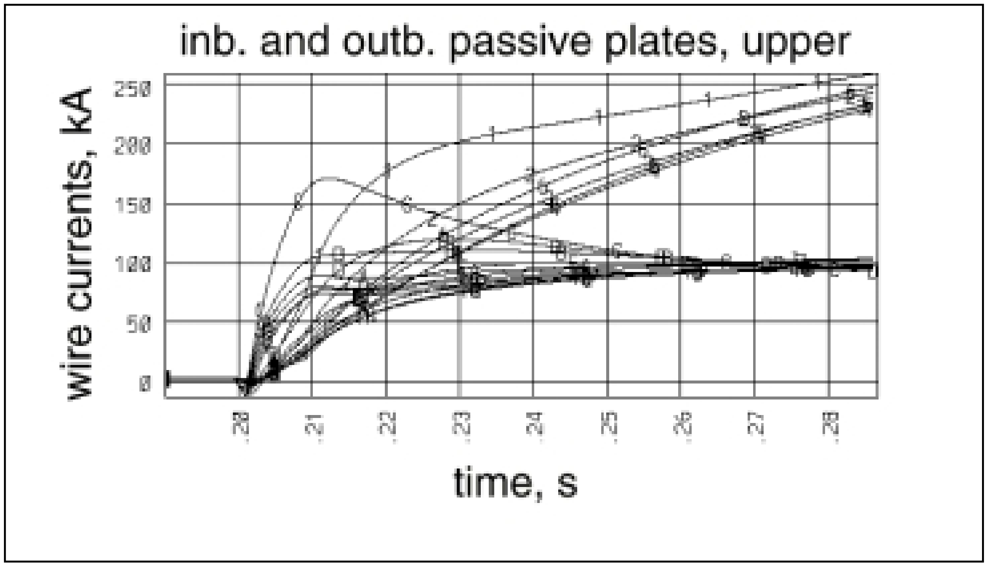
[1] Disruption loads per Wesley, based on 10T, 50% halo current or 12 T, 40% halo current

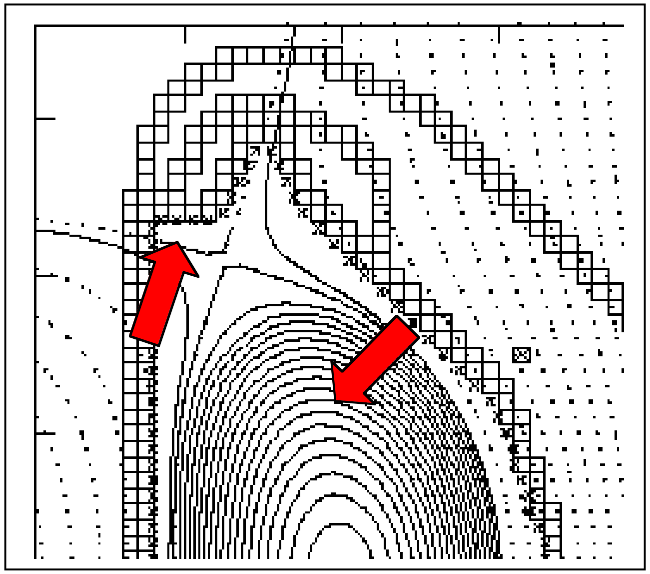
Disruption Load Status

- **Disruption currents estimated by Kessel for centered disruption, and these can be used to estimate loads**
- **Maximum disruption loads estimated by Wesley for VDE**
- **Distribution of loading for VDE case is uncertain, but current is expected to flow in passive plate regions**
- **ITER studies are useful as a guide, but load distribution will be different due to lower elongation, less passive structure**
- **Divertor loads estimated by Ulrickson**

Loads from induced toroidal currents will appear primarily in passive stabilizing structure

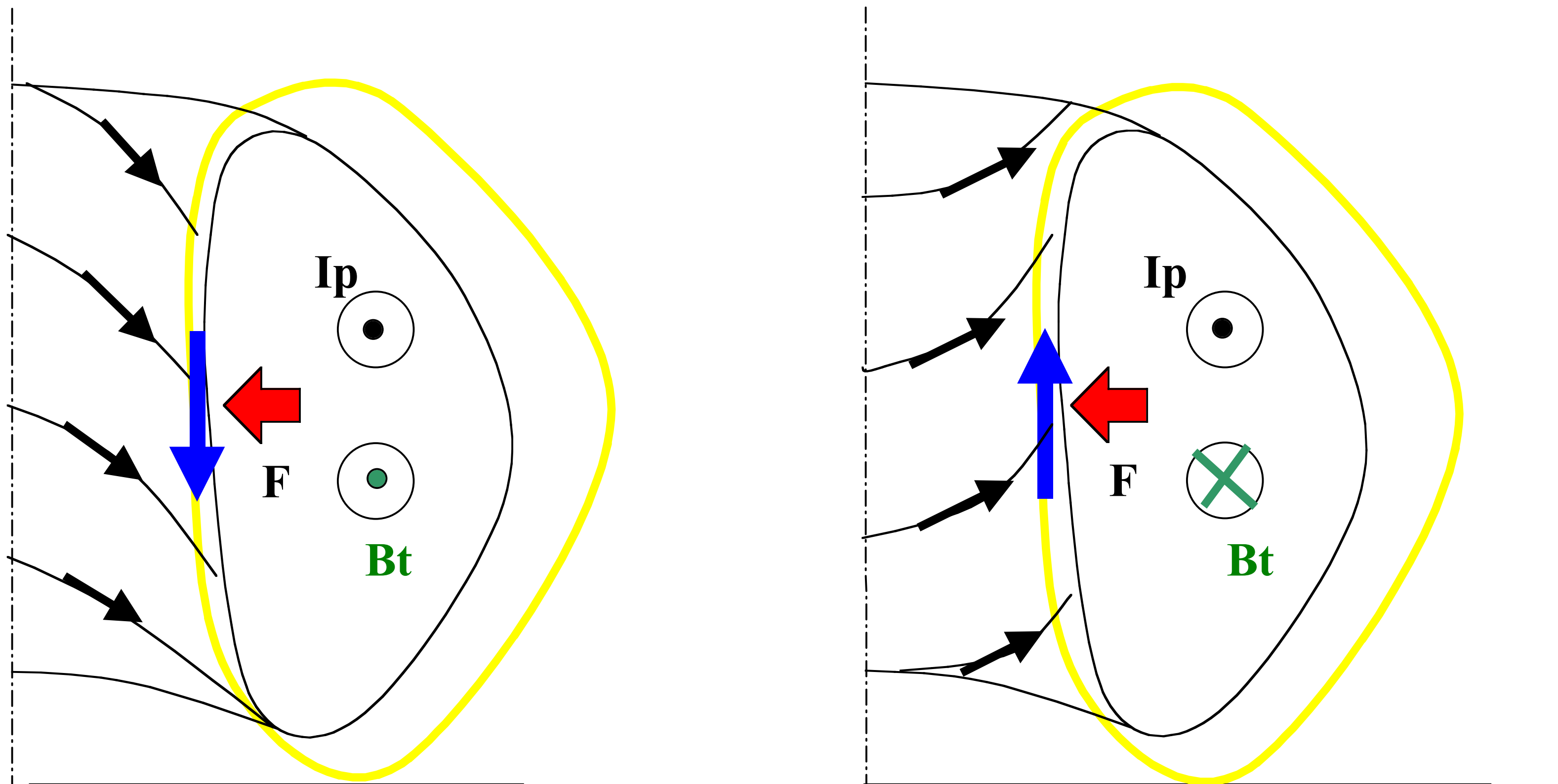
- **C. Kessel centered disruption simulation shows current and field direction**





Parameter		**IB passive plate**	**OB passive plate**
Est. induced current	(kA)	1500	800
Bpoloidal (assumed)	(Tesla)	1	1
Pressure	(Mpa)	3	1.6
Direction		“shear”	“normal to surface”

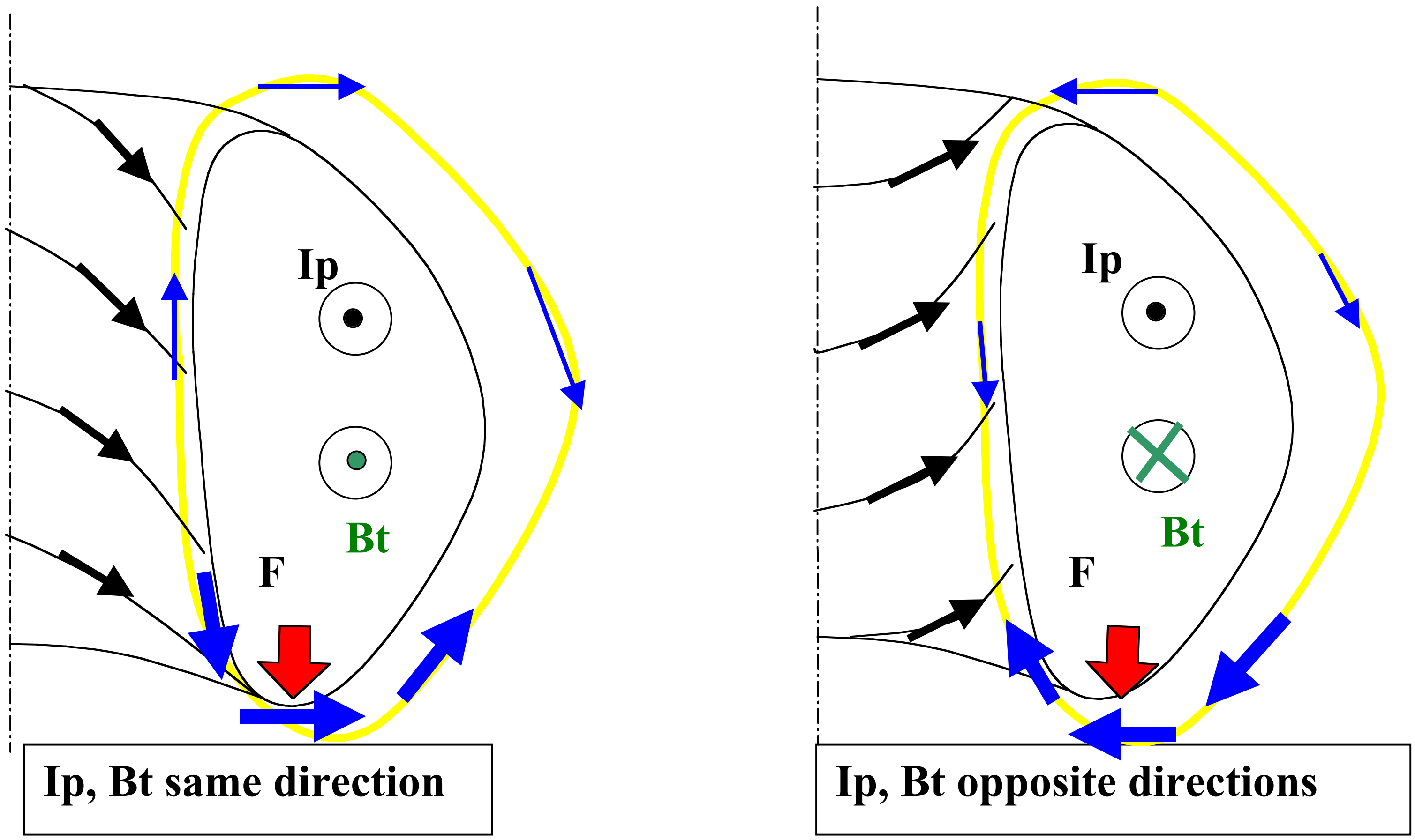
Halo load direction should be predominantly toward VV
Radial disruption



Ip, Bt same direction

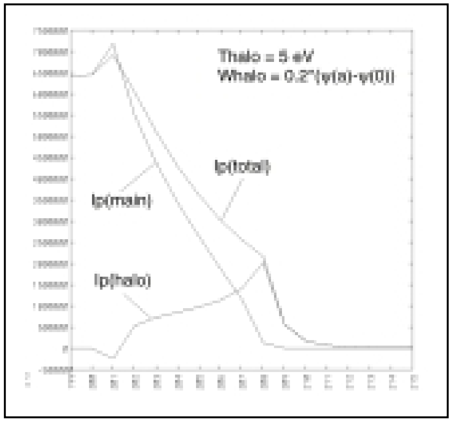
Ip, Bt opposite directions

Halo load direction should be predominantly toward VV
Vertical disruption



Halo current loads in vessel

- From C. Kessel, I halo = 2 MA
- From Wesley, I halo < 0.4 x Ip = 2.6 MA
- Toroidal peaking factor = 2



Parameter		Inboard	Outboard
Avg radius of wall	(m)	1.3	2.6
Current density, J = Ih/2*pi*R w/o TPF	(MA/m^2)	0.25	0.125
Jmax = 2 x Javg	(MA/m^2)	0.5	0.25
Btoroidal	(Tesla)	16	8
Pressure on wall	(Mpa)	8	2

Loads from internals

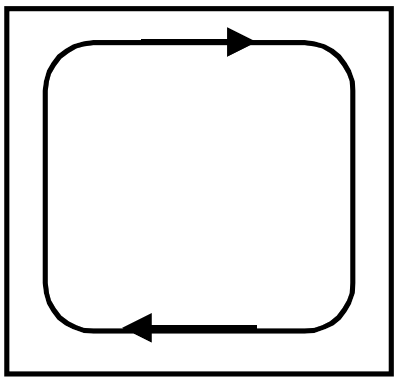
- Internals include divertors, baffles, FW tiles, and port plugs
- Loads on internals will include pressures from halo currents as well as torques from induced current loops
- Loads are strongly dependendent on configuration of electrical connections
- Forces can be estimated if current paths and field transients are known
- Divertor loads have been estimated by M. Ulrickson for

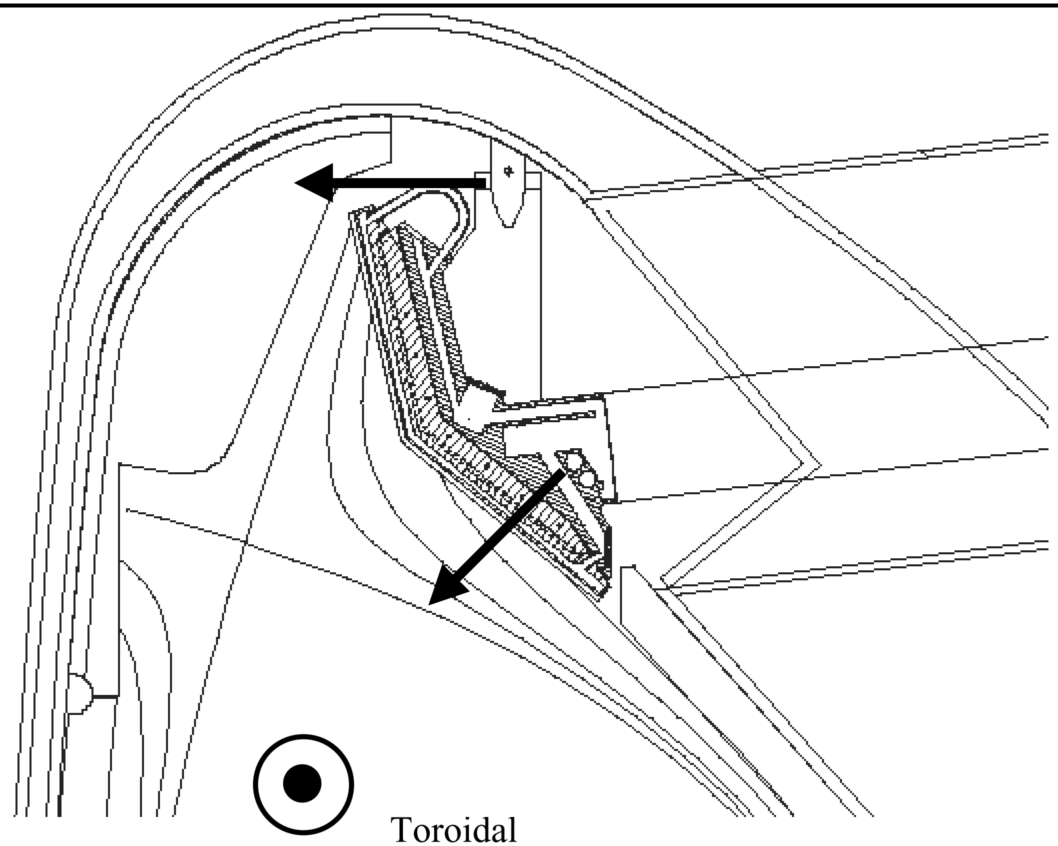
  Current loops driven by changing radial field

  Halo currents

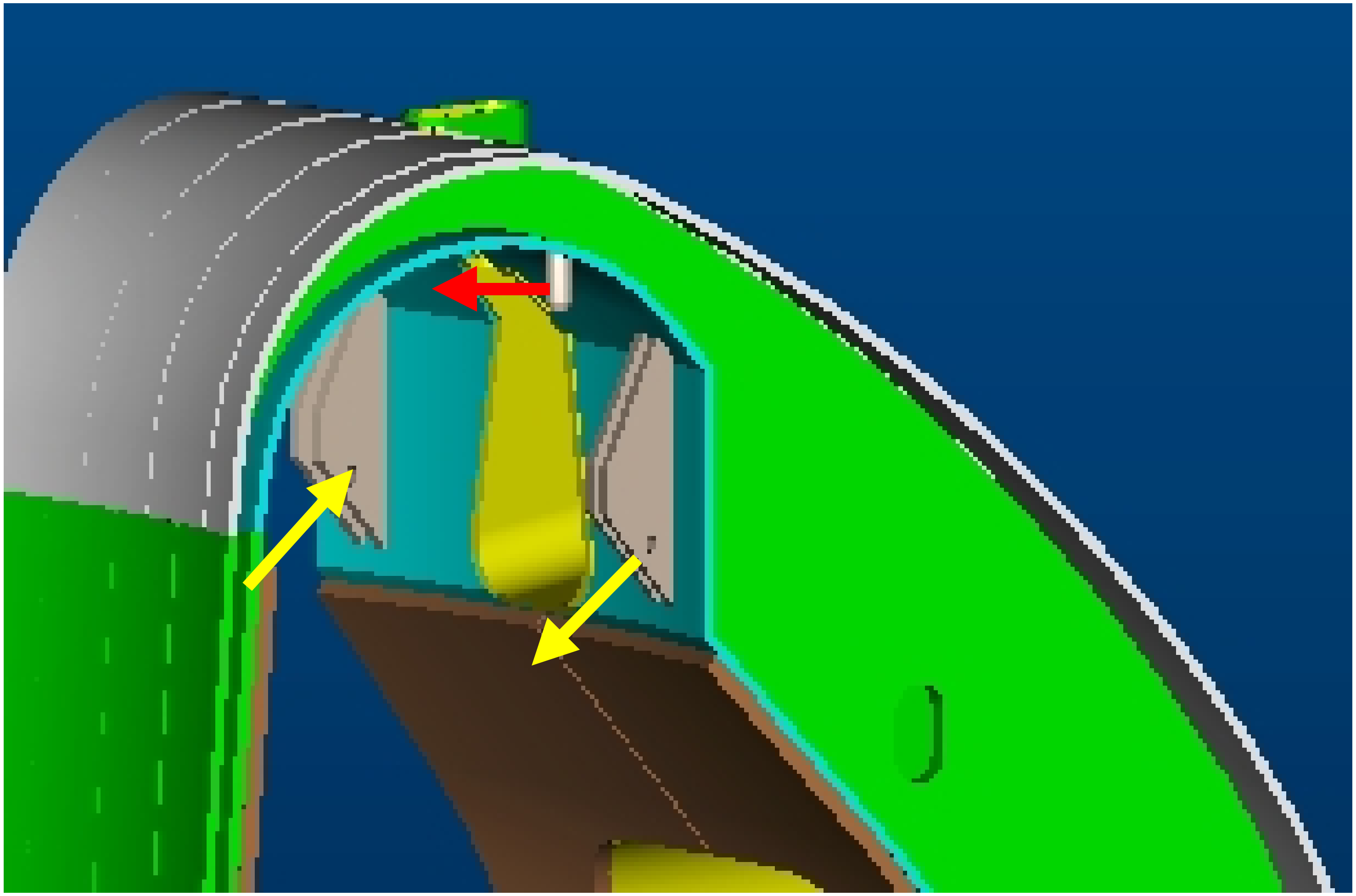
Divertor loads due to current loop in divertor assembly

ref M.. Ulrickson FIRE physics workshop





Divertor reaction loads on VV brackets due to current loop in divertor assembly



Divertor loads due to halo currents in divertor assembly

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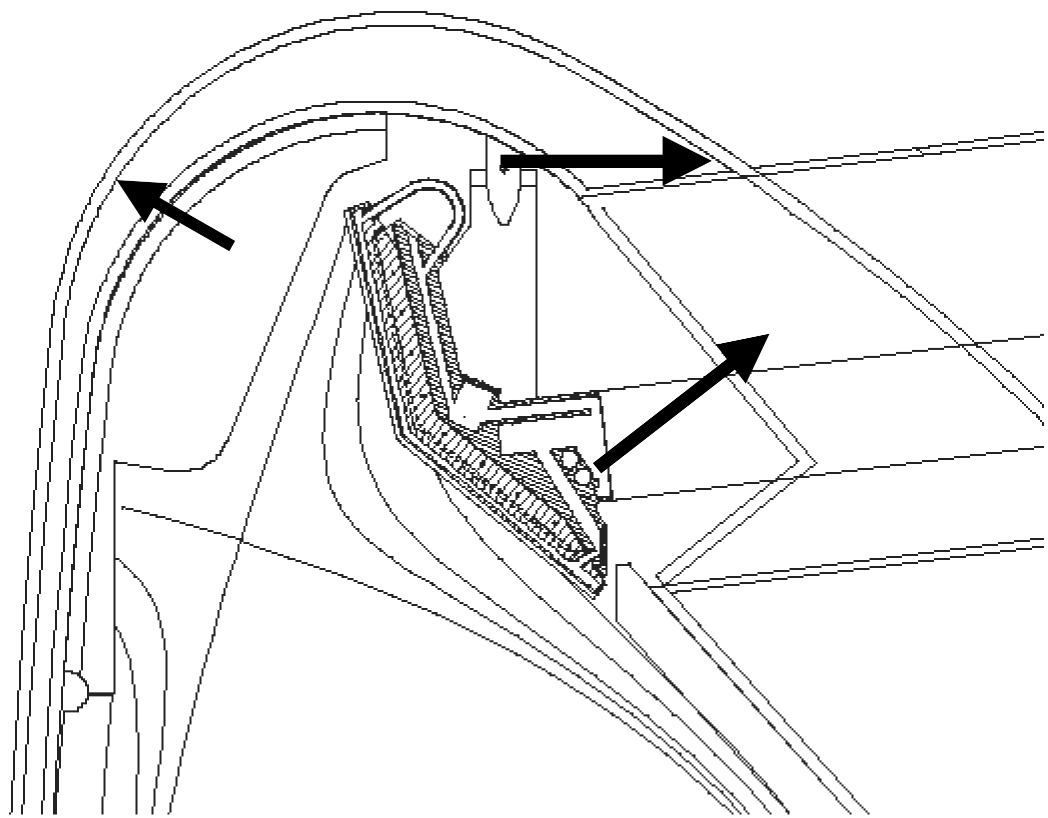
ref M.. Ulrickson FIRE physics workshop

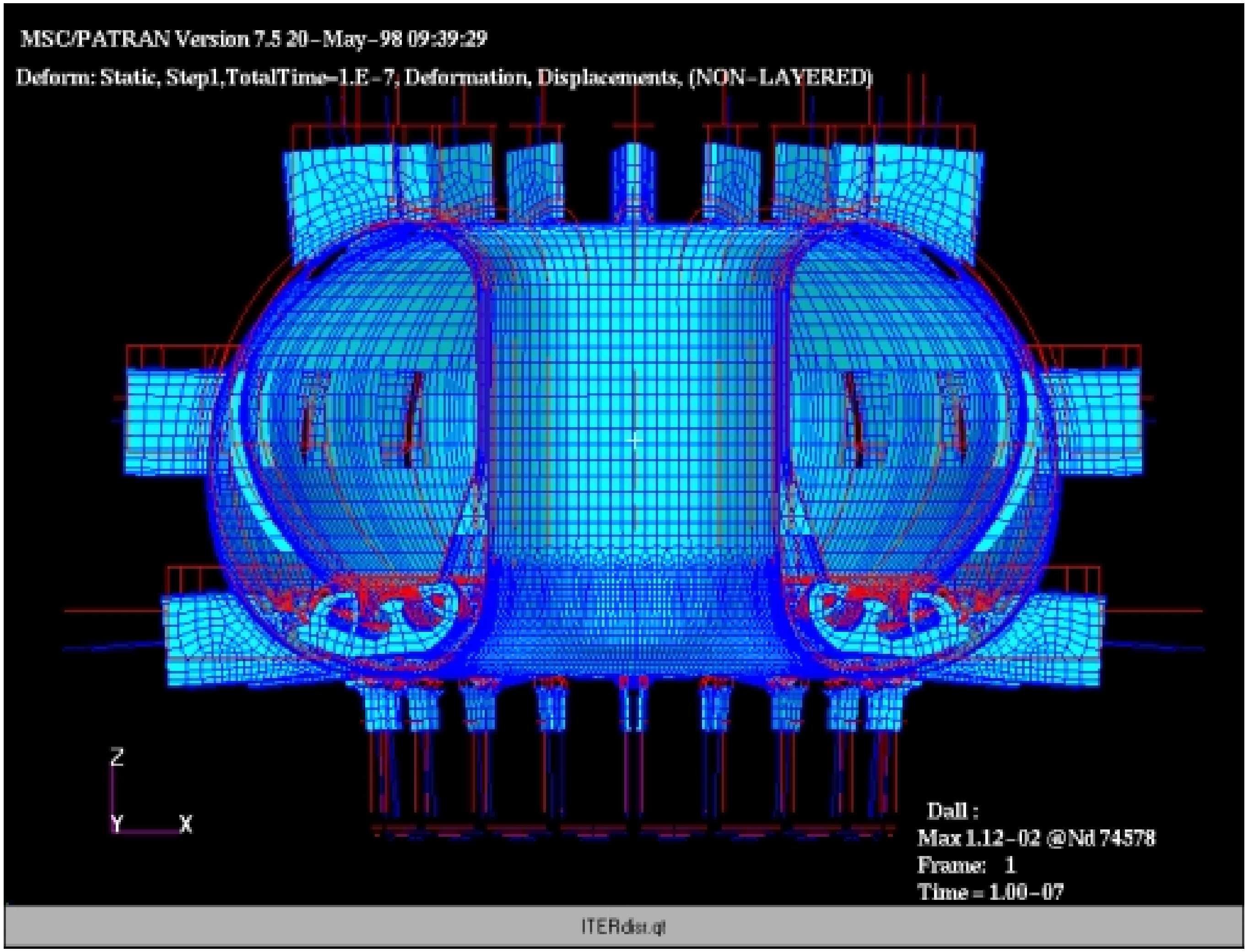
Force towards the VV on both sides,

total force = 0.8 MN outboard

= 0.3 MN inboard on baffle

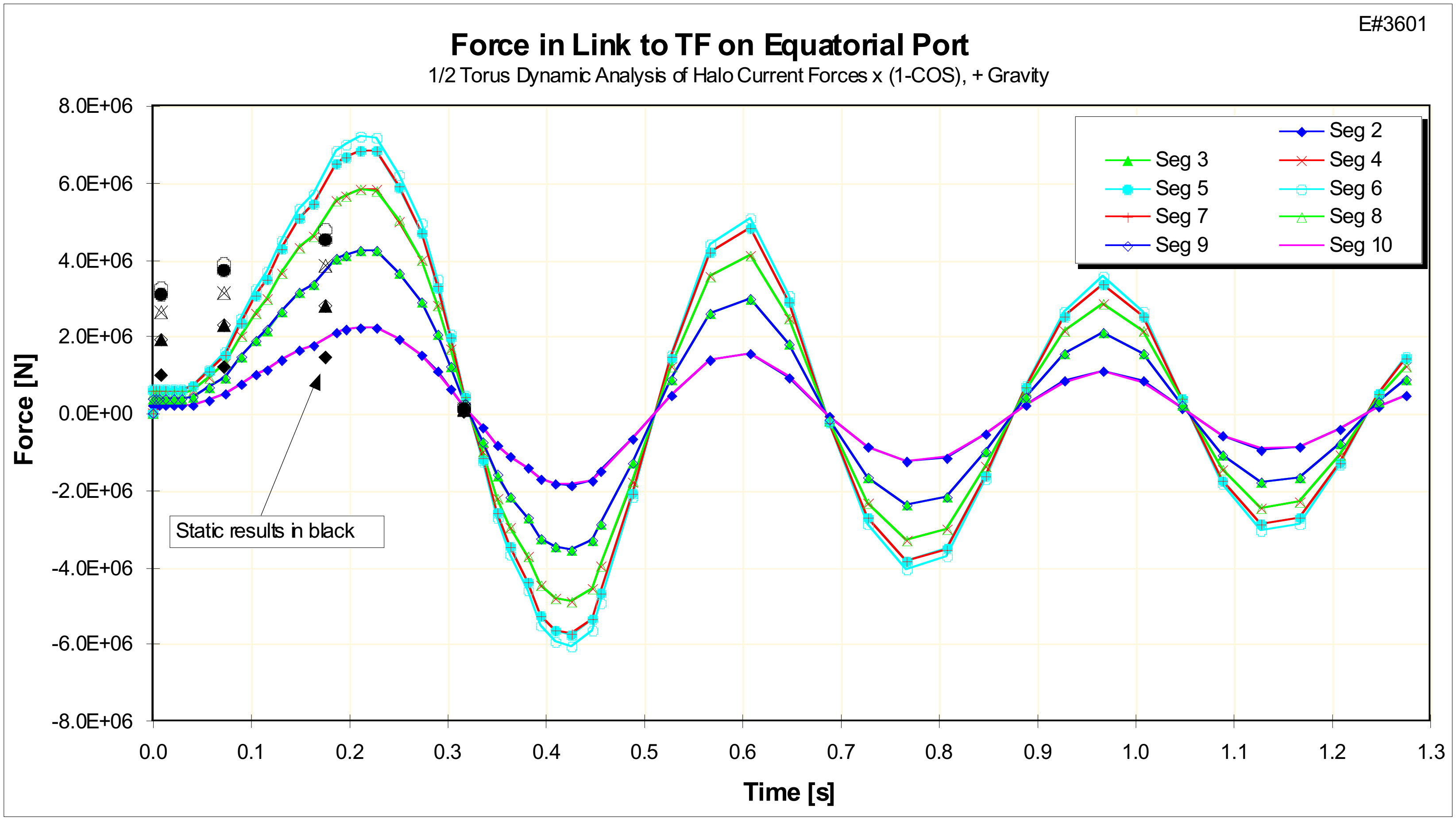


Dynamic analysis was performed for ITER



Dynamic effects were important for ITER

- Lateral links had dynamic magnification factor ~2 for some cases



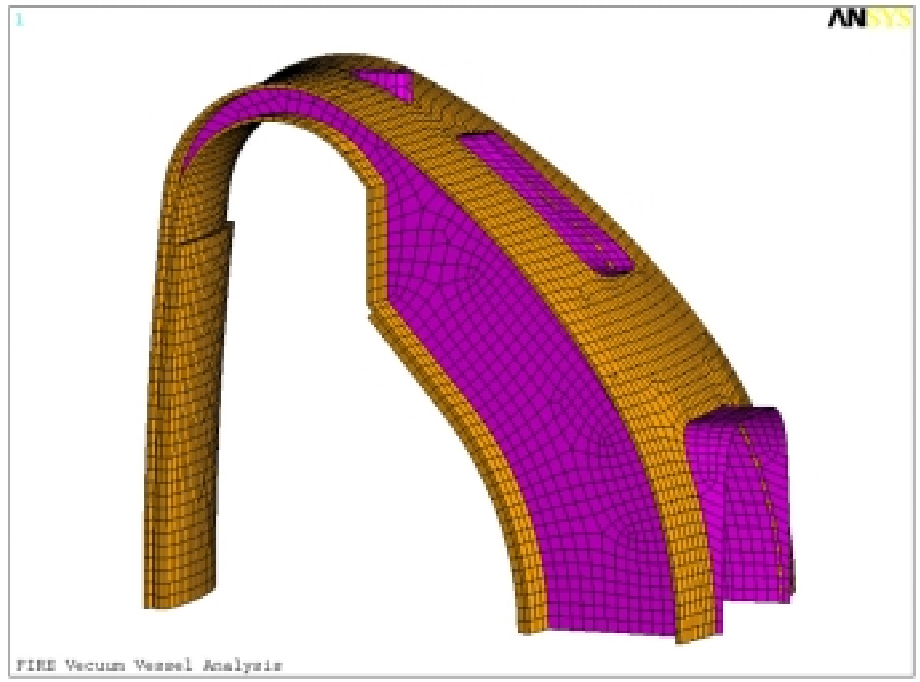
Structural analysis – ANSYS FEA model status

- Model being prepared by HM Fan

- 64 poloidal ribs inboard, 64 poloidal ribs outboard

- thickness of elements assumed as:

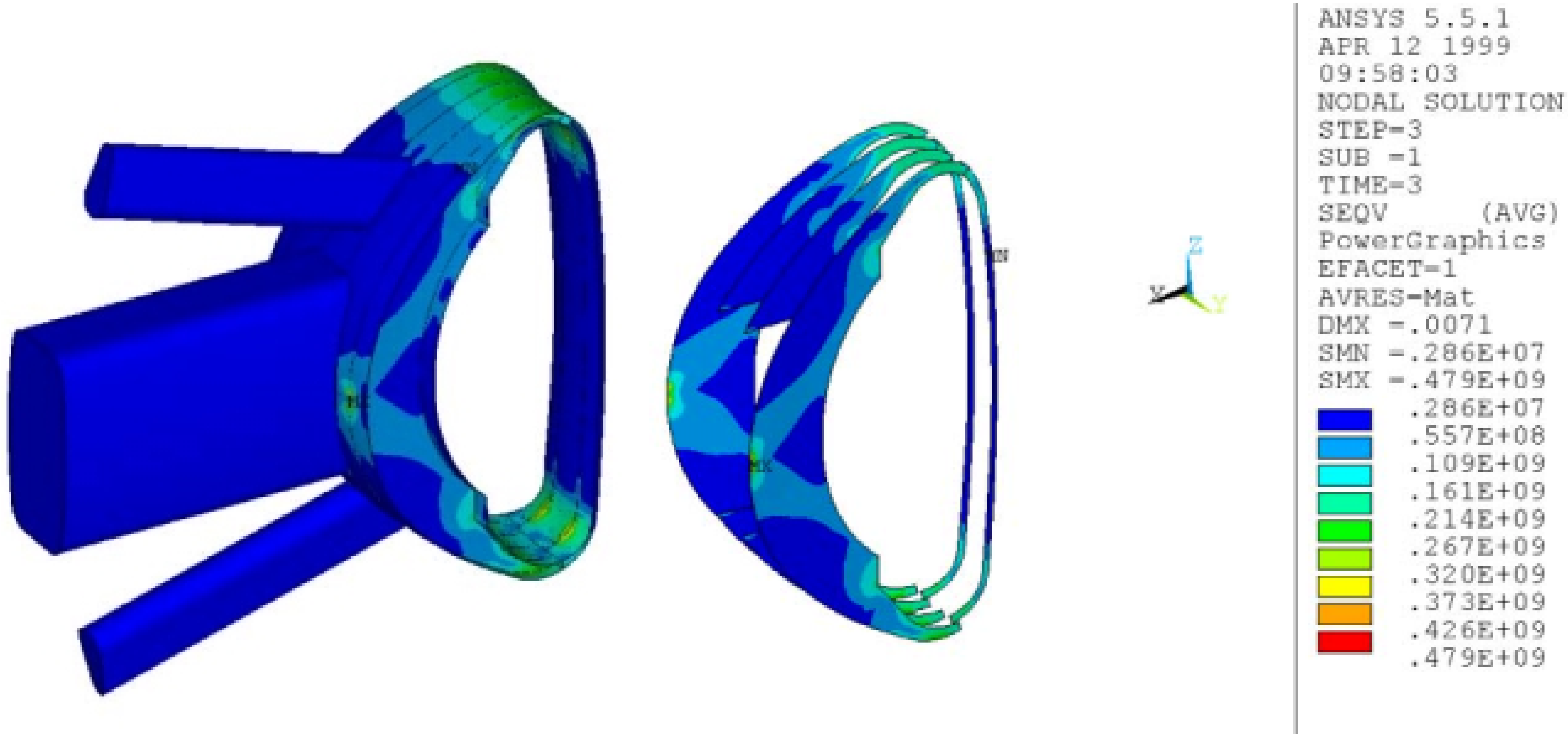
- 15 mm for vessel facesheets,
- 30 mm for port at midplane,
- 15 mm for port above/below midplane,
- 15 mm for most poloidal ribs,
- 30 mm for OB ribs at supports
- 25 mm for copper stabilizers



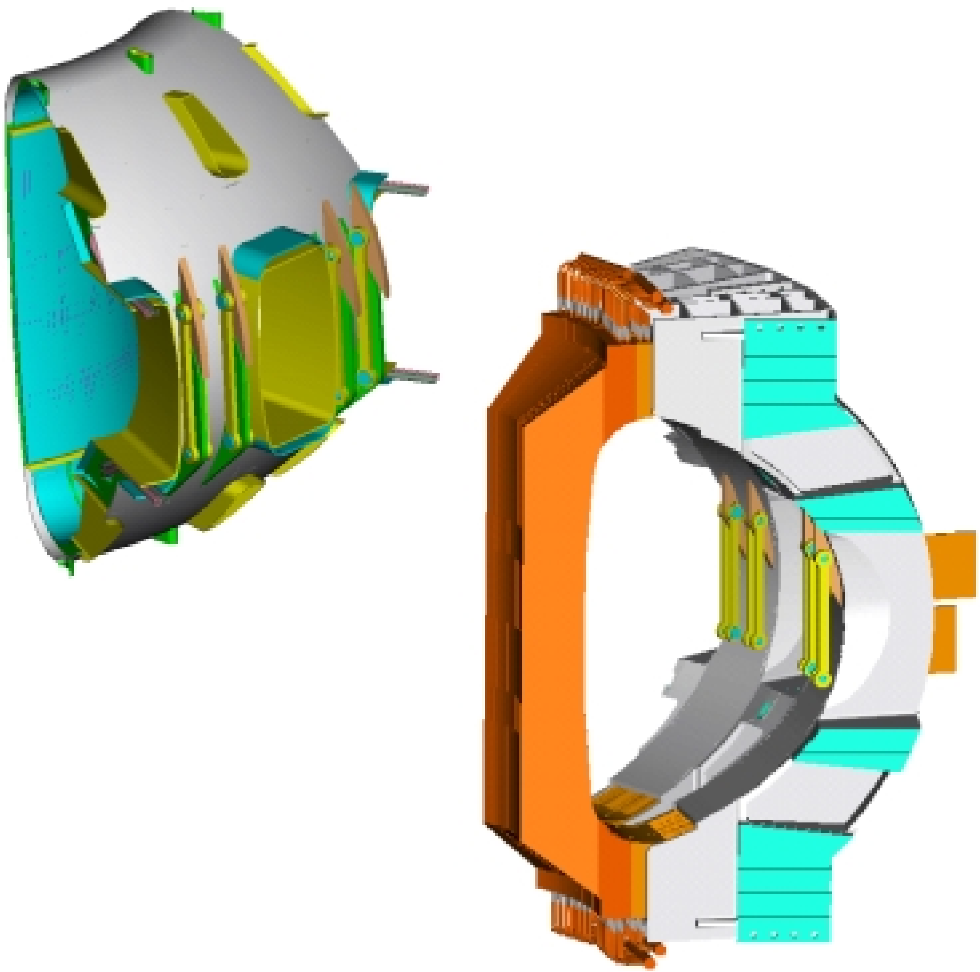
Previous analysis: VDE loads, OB midplane supports only

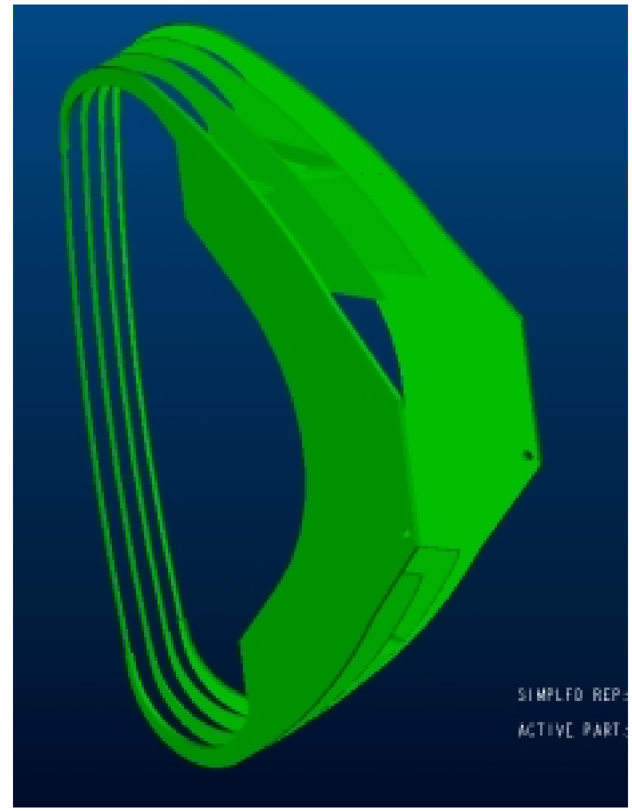
- Vertical load = 20 MN, lateral load = 7 MN, peaking factor of two

New loads = 38MN vertical, 13 MN lateral with dyn amp factor of 1.2



FIRE VV vertical supports and structure





Rib structure carries loads
directly to support links

FIRE VV stress summary 99 engr report (w/ est.revision)

Load condition	Preliminary Von Mises stress estimates for vacuum vessel			
	Torus		Ports (unreinforced values)	
	General stress (Allow. Stress = 195 Mpa)	Peak local stress (Allow. stress= 390 Mpa) [1]	General stress (Allowable stress = 195 Mpa)	Peak local stress (Allow. Stress = 260 Mpa) [1]
Vacuum load	< 60	~ 170	< 100	~ 170
Coolant pressure (1 Mpa) [note 2]	< 150	~500	< 250	~ 500
VDE [note 3]	< 400 (~350?)	~ 480	< 50	~ 400
Thermal stress from nuclear htg [note 4}	< 150	~ 340 (>400)	< 150	~ 340 (>400)
TF ramp-up [note 5]	< 15 (30)	TBD	TBD	TBD

Notes:
1. Estimated demarcation between general and peak local stress, peak primary + secondary = 3 x Sm
2. Stress values reduced from App. D calculations by ratio of applied pressure (1.0 / 2.7)
3. VDE loads applied in simplified manner as described in Appendix D, supports on outside
   Latest design has 50% thicker section at top / bottom, stress reduction should be factor of >2
4. Temperature gradient of ~ 60 C based on 10 second full power pulse, preliminary geometry
   Allowable secondary stress = 390 MPa
5. Stress estimate based on hand calculation of hoop stress in inboard facesheets

Issues and plan

- Self consistent loads from TSC simulations may not be available very soon
- Est. disruption and TF ramp loads are higher than what we used last year
- Need new est. of thermal stresses
- Load combinations have not been applied to model yet

- HM has constructed new FEA model
- Est. disruption loads, in combination with other loads, can be applied to model
- Reinforcement may be added based on est. loads
- Transient EM solver will be used eventually (EDDYCUFF, ANSYS, etc.)