NSTX

Center Stack Casing Disruption Inductive and Halo Current Loads

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Prepared By:

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Peter Titus, Branch Head, Engineering Analysis Division

Approved By:

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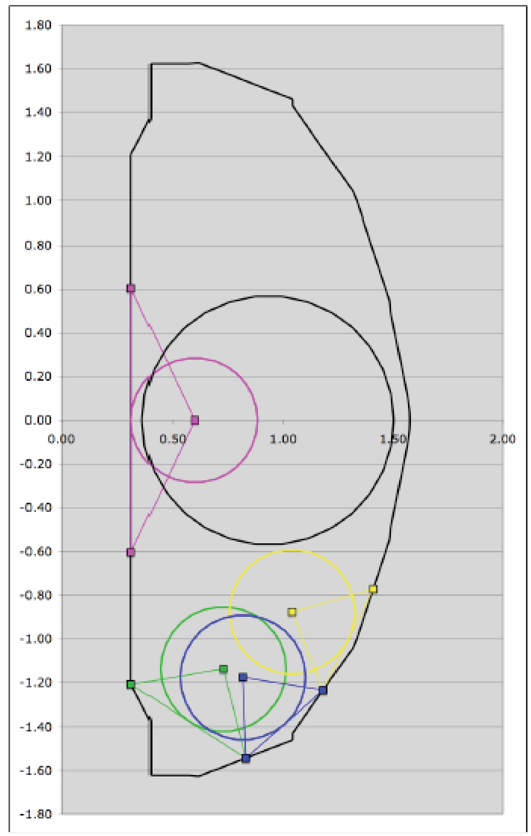
Phil Heitzenroeder, Head, Mechanical Engineering

Memo to Charlie Neumeyer and the NSTX Team
From: Peter Titus
Subject: Center Stack Casing Disruption Inductive and Halo Current Loads

Summary:

With only one halo entry and exit point considered and only one inductive disruption case considered, and only the static stress analysis performed, the stress results are acceptable, but dispacements are large – up to 8 mm laterally. Dynamic analyses are in progress .

Criteria from the GRD:



Current and field directions (referring to Figure 2.2-2) shall be as follows:

□ Plasma current Ip into the page (counter-clockwise in the toroidal direction, viewed from above)

□ Halo current exits plasma and enters the structure at the entry point, exits the structure and re-enters the plasma at the exit point (counter-clockwise poloidal current, in the view of the figure)

□ Toroidal field into the page (clockwise in the toroidal direction, viewed from above)

For the halo currents a toroidal peaking factor of 2:1 shall be assumed in all cases. Thus the toroidal dependence of the halo current is [1 + cos (⎞ - ⎞0)], for ⎞ = 0 to 360o where ⎞ is the toroidal angle.

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Table 2-2 - Plasma Disruption Specifications

	Centered	Offset, Midplane	Offset, Inboard	Offset, Central	Offset, Outboard
Center of plasma (r,z) [m]	0.9344	0.5996	0.7280	0.8174	1.0406
	0.0000	0.0000	-1.1376	-1.1758	-0.8768
Minor radius of plasma [m]	0.5696	0.2848	0.2848	0.2848	0.2848
Current Quench					
Initial plasma current [MA]	2	2	2	2	2
Linear current derivative [MA/s]	-1000	-1000	-1000	-1000	-1000
VDE/Halo					
Initial plasma current	2	0	0	0	0
Final plasma current [MA]	0	2	2	2	2
Linear current derivative [MA/s]	-200	200	200	200	200
Halo current [MA]	n.a	20%=	35%=	35%=	35%=
		400kA	700kA	700kA	700kA
Halo current entry point (r,z) [m]	n.a	0.3148	0.3148	0.8302	1.1813
		0.6041	-1.2081	-1.5441	-1.2348
Halo current exit point (r,z) [m]	n.a	0.3148	0.8302	1.1813	1.4105
		-0.6041	-1.5441	-1.2348	-0.7713

Analysis Procedure and Results

Sri Avasarala and Ron Hatcher's disruption analyses were used to provide a vector potential "environment" for a model of the center stack casing. Sri has developed a procedure which starts with Ron Hatcher's OPERA disruption simulation, and transfers the axisymmetric vector potential results into a 3 D model of the vessel and passive plates. With modest changes any of the internal components can be evaluated with this procedure. A model of the center stack casing was input to Sri's electromagnetic analysis. The results are shown in Figures 1 and 2

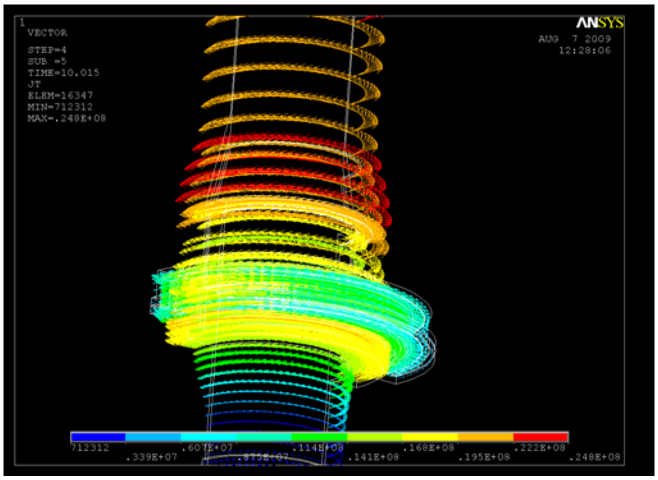

Figure 1 Inductively Driven Disruption Currents in the Casing

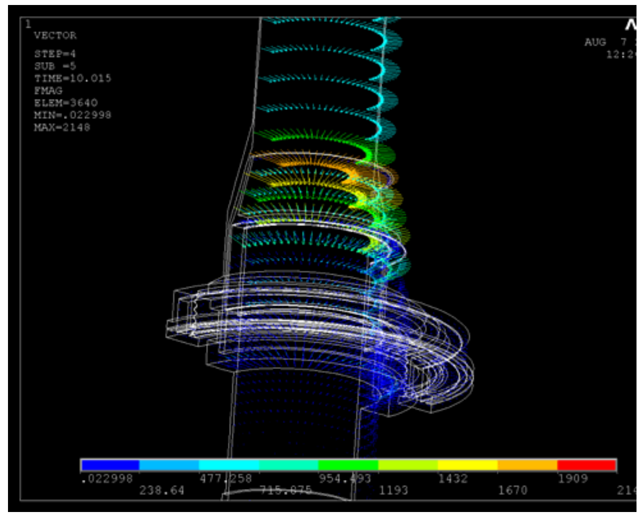

Figure 2 Inductive Disruption Lorentz Forces

Halo currents also load the vessel internals. The following spec is from the CSA Upgrade GRD:

Halo current [MA]	n.a	20%=	35%=	35%=	35%=
		400kA	700kA	700kA	700kA
Halo current entry point (r,z) [m]	n.a	0.3148	0.3148	0.8302	1.1813
		0.6041	-1.2081	-1.5441	-1.2348
Halo current exit point (r,z) [m]	n.a	0.3148	0.8302	1.1813	1.4105
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Halo loads were calculated outside of ANSYS and read in after reading the inductive loads with the LDREAD command, and with FCUM,ALL

Lorentz loads from these current entry and exit points were calculated assuming a peaking factor of 2. At present, only the equatorial plane halo current distribution has been evaluated.

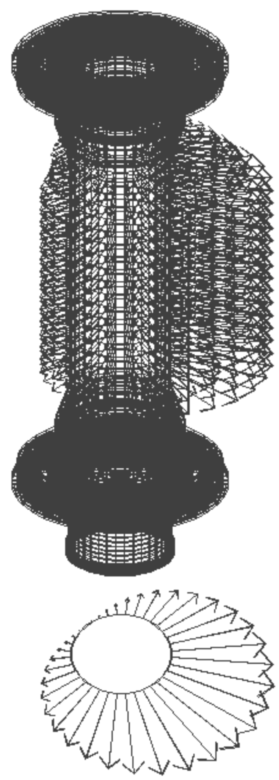


Figure Halo Loading

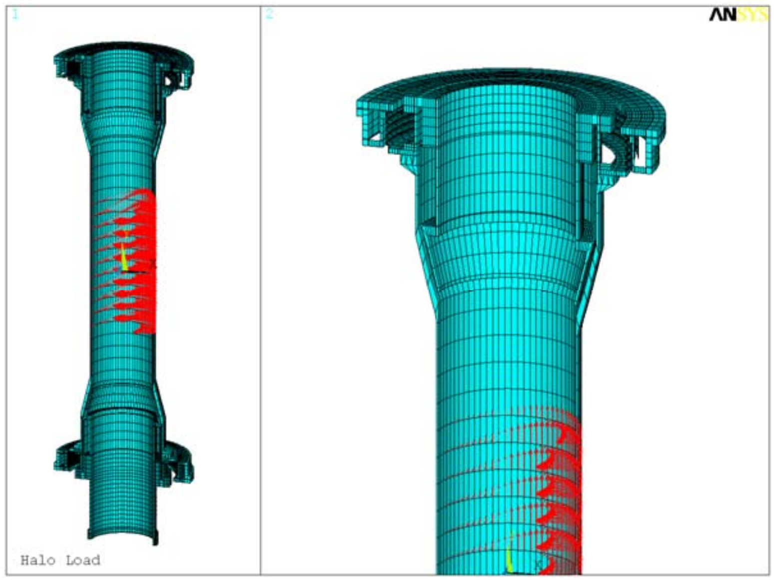
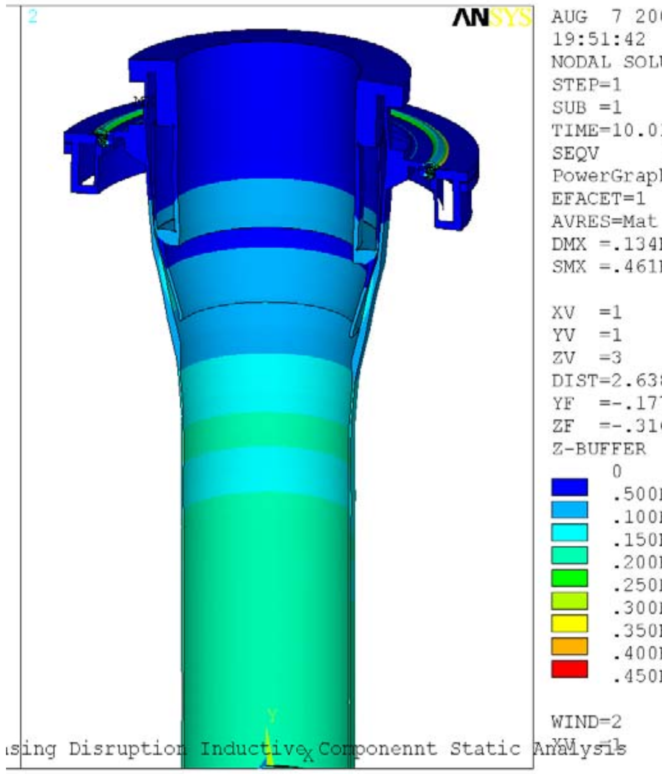


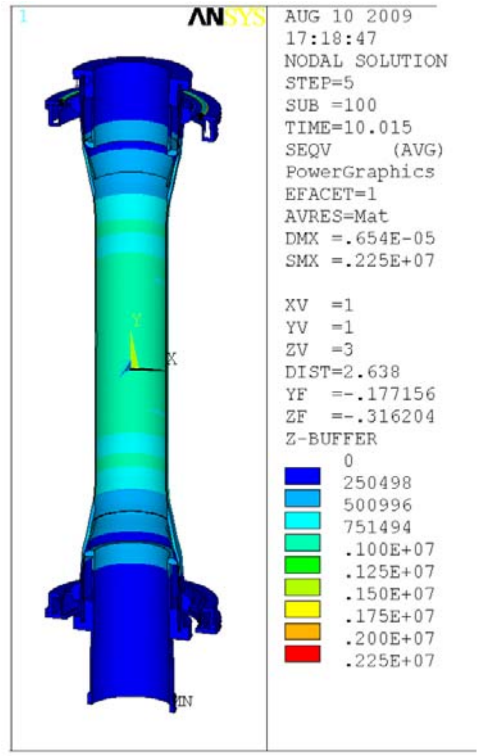
Figure _ Inductive + Halo Current Loads

INCONEL 625

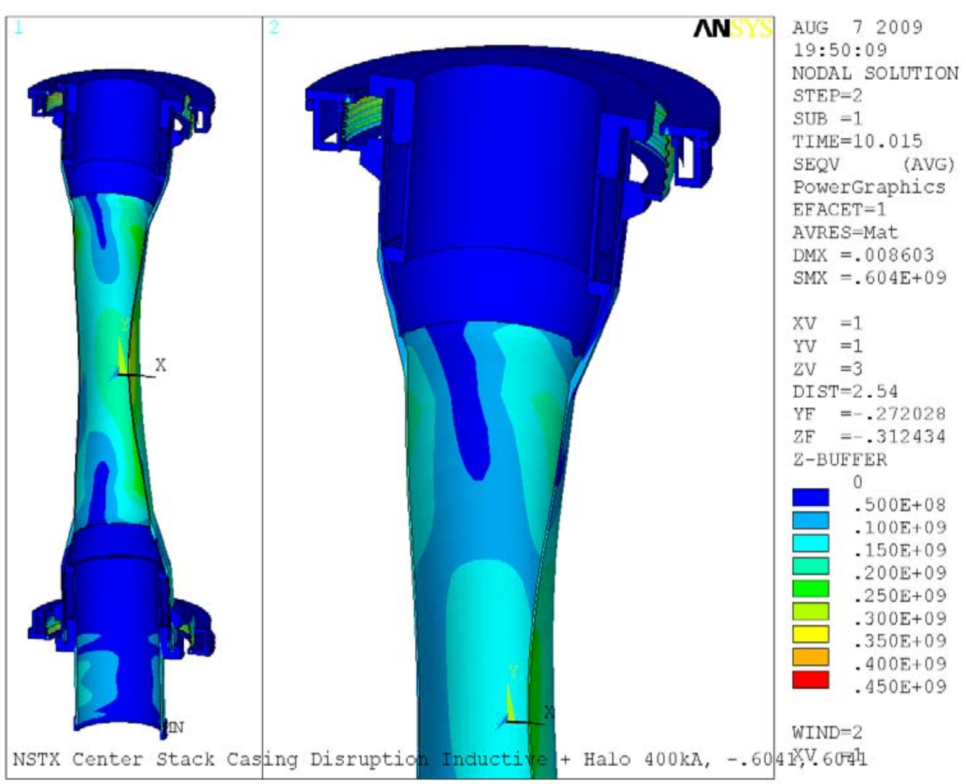
Test Temperature, °F(°C)	Ultimate Tensile Strength, ksi (MPa)	Yield Strength at 0.2% offset,ksi (MPa)	Elongation in 2" percent
Room	138.8 (957)	72.0 (496)	38
200	133.3 (919)	67.3 (464)	41
400	129.4 (892)	62.2 (429)	44
600	125.6 (866)	59.5 (410)	45
800	122.2 (843)	59.2 (408)	45
1000	119.9 (827)	58.8 (405)	46
1200	119.6 (825)	57.0 (393)	47
1400	88.4 (609)	55.3 (381)	70
1600	52.1 (359)	34.9 (241)	69
1800	25.0 (172)	10.8 (75)	108



Static Results ~200 MPa



Dynamic Results ~ 1 MPa



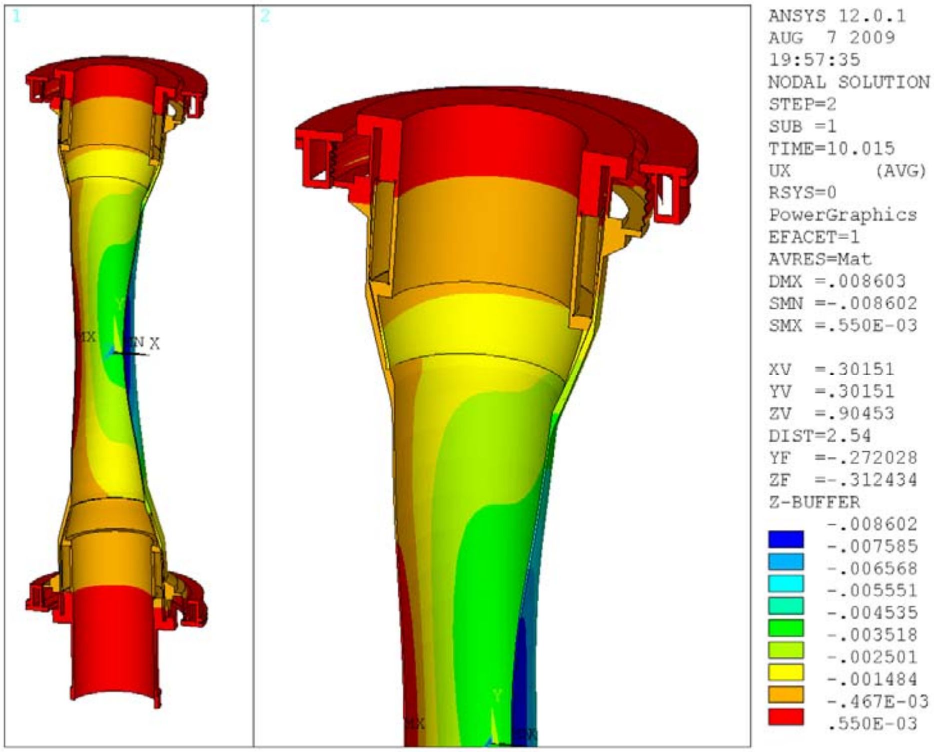


Figure Static Analysis Lateral Displacements, Mid-Height Halo + Inductive Disruption

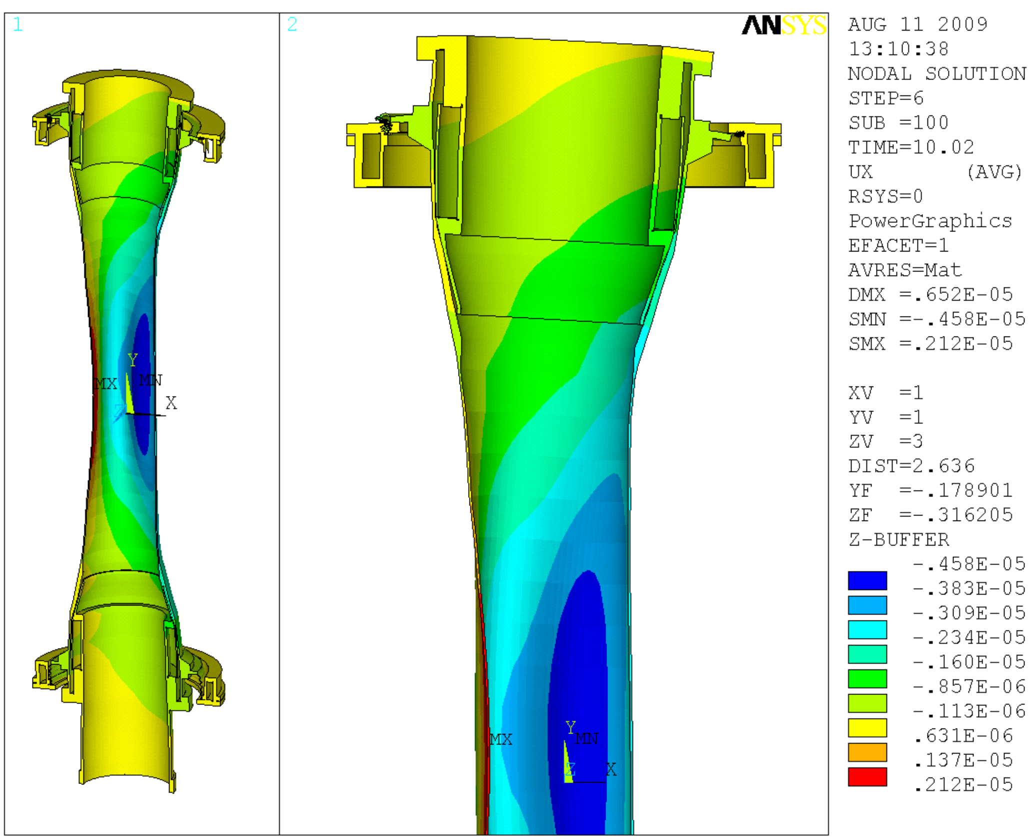


Figure Dynamic Analysis Lateral Displacements, Mid-Height Halo + Inductive Disruption

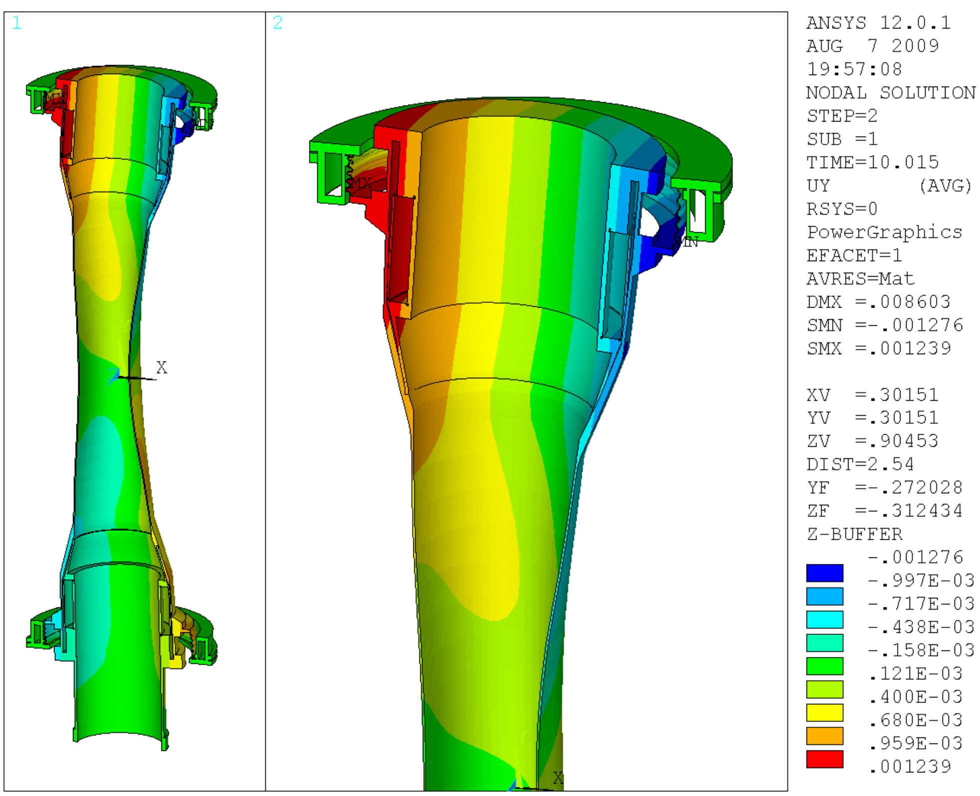


Figure Vertical Displacements, Mid-Height Halo + Inductive Disruption

Regulatory Guide 1.61 - Damping Values for Seismic Design of Nuclear Power Plants

Table 1 Damping Values[1]
(Percent of Critical Damping)

Structure or Component	Operating Basis Earthquake or 1/2 Safe Shutdown Earthquake[2]	Safe Shutdown Earthquake
Equipment and large-diameter piping systems[3], pipe diameter greater than 12 in	2	3
Small-diameter piping systems, diameter equal to or less than 12 in.	1	2
Welded steel structures	2	4
Bolted steel structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

[1] Table 1 is derived from the recommendations given in Reference 1.
[2] In the dynamic analysis of active components as defined In Regulatory Guide 1.48, these values should also be used for SSE.
[3] Includes both material and structural damping. If the piping system consists of only one or two spans with little structural damping, use values for small meter piping.