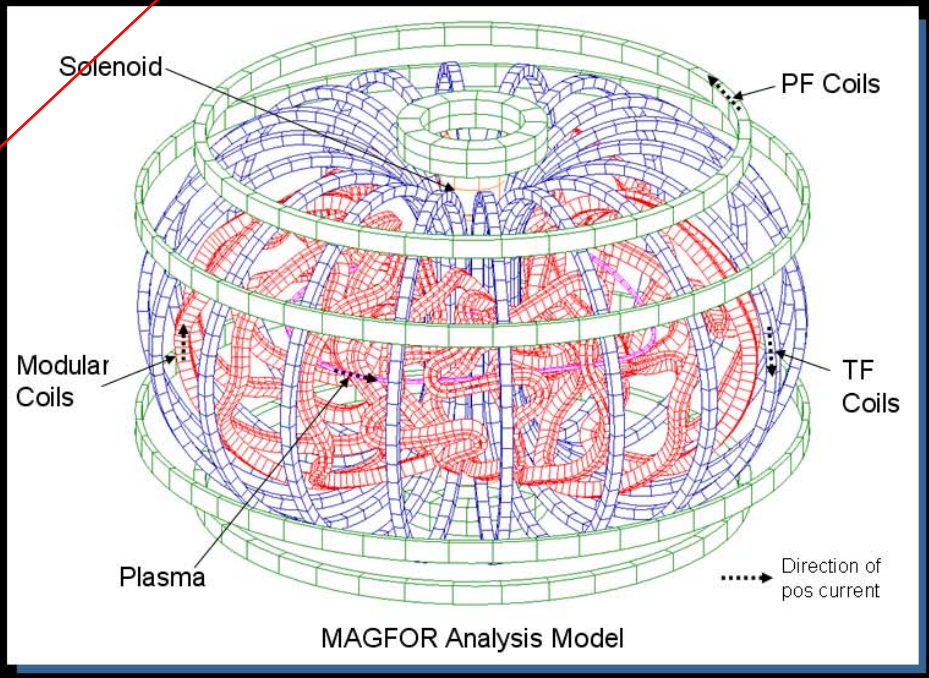
Calculation by Dennis Strickler to determine max load due to I=(+Imax, -Imax, 0) in each coil.
Background info found in email follows

Electromagnetic Loads Analysis

NCSX

- Two independent calculations have been performed using ANSYS, MAGFOR codes
- Seven reference scenarios examined at time step with maximum modular coil current
- Scan of possible coil currents for a more severe fault load condition also conducted

Maximum Current / Coil for Reference Scenarios (kA)								
Circuit	Coil Set	0.5-T	Field	1.7-T	1.7-T	2-T	1.2-T	320-kA
		1st Plasma	Mapping	Ohmic	High Beta	High Beta	L. Pulse	Ohmic
1	TF	13	13	43	45	53	30	26
2	PF1	673	0	1479	1120	1340	1191	1632
	PF2	673	0	1479	1120	1340	1191	1632
3	PF3	673	0	1286	998	1208	980	1082
4	PF4	749	734	374	416	287	313	1191
5	PF5	0	0	204	209	82	148	128
6	PF6	32	13	104	101	115	72	73
7	A	224	224	763	763	818	539	695
8	B	209	209	710	710	831	501	707
9	C	188	188	638	638	731	451	621



MAGFOR Analysis Model

Williamson, David E.

From: Dennis Strickler [stricklerdj@ornl.gov]
Sent: Thursday, September 02, 2004 11:39 AM
To: Nelson, Brad E.; Williamson, David E.; 'Art Brooks'; leonard.myatt@myattconsulting.com
Subject: Revised fault-condition loads
Attachments: Net_Loads_Rev4.doc

Brad, et. al,

Attached is yet another revision of the maximum net loads on the modular coils. All coil currents should now be in kA-t.

Dennis

Dennis Strickler
stricklerdj@ornl.gov
865-574-1297

Memo follows,
last version I could find in
2004-2005 emails

Revised Magfor calculation of max net loads on NCSX modular coils
D. Strickler
9/2/2004

Comparison of M2 net force for coil current distribution:
I(kA) = [820, -830, 730, 25, 25, -13, -14, 8, 9, 4]

Analyst (code)	Fx (lb)	Fy (lb)	FR (lb)	Fφ (lb)	FZ (lb)
AB (Forces4)			262437	44219	68527
DW (Magfor)			255819	43119	68884
DS (Magfor)	201461	171457	261005	43134	69117
LM (ANSYS)	201815	170629	260895	42157	70094

Net force on modular M2 for coil current distribution corrected for no. of turns in PF, TF:
I(kA-t) = [820, -830, 730, 1800, 1800, -936, -1120, 192, 126, 48]

	Fx (lb)	Fy (lb)	FR (lb)	Fφ (lb)	FZ (lb)
DS (Magfor)	230220	179842	289973	35501	74392

Coil current distributions for max. net radial, toroidal and vertical loads on modular coils
(all currents are now in kA-t.)

Coil	**M1**	**M1**	**M1**	**M2**	**M2**	**M2**	**M3**	**M3**	**M3**
Max Net Force	FR	Fφ	FZ	FR	Fφ	FZ	FR	Fφ	FZ
FR (lb)	**-253016**	82313	107098	**-344536**	-43779	-281540	**-144318**	3124	-78108
Fφ (lb)	-9906	**-575621**	-565044	-20348	**614110**	-19109	379425	**472477**	381408
FZ (lb)	2879	-3402	**-22340**	-102021	-83470	**-106390**	-115237	-95070	**-116557**
I_{M1} (kA-t)	-820	-820	820	-820	820	820	820	820	820
I_{M2} (kA-t)	-830	830	-830	-830	-830	830	-830	830	-830
I_{M3} (kA-t)	-730	730	-730	-730	-730	730	730	-730	730
$I_{PF1/2}$ (kA-t)	1800	1800	1800	-1800	-1800	1800	1800	-1800	-1800
I_{PF3} (kA-t)	-936	-936	-936	936	936	-936	-936	936	-936
I_{PF4} (kA-t)	-1120	-1120	-1120	1120	1120	-1120	-1120	1120	1120
I_{PF5} (kA-t)	192	192	192	192	192	192	192	192	192
I_{PF6} (kA-t)	126	126	126	126	126	126	126	126	126
I_{TF} (kA-t)	-48	48	-48	-48	48	-48	48	48	-48

This table also called "Table-5" in Aug-2 memo

email exchange explores error in Table-5 found in Aug-2 version of memo

Williamson, David E.

From: Dennis Strickler [stricklerdj@ornl.gov]
Sent: Wednesday, September 01, 2004 11:18 AM
To: leonard.myatt@myattconsulting.com; Nelson, Brad E.; Williamson, David E.; 'Art Brooks'
Subject: RE: revised max net loads
Attachments: Net_Loads_Rev2.doc

As Len pointed out in a previous email, the PF and TF currents used in the max net load calculations did not represent min/max values in kA-t. The attached contains a table with PF/TF currents corrected for number of turns. Iõl re-run the search for current distributions giving max. net loads.

Thanks, Dennis

Dennis Strickler
stricklerdj@ornl.gov
865-574-1297

-----Original Message-----
From: Leonard Myatt [mailto:leonard.myatt@myattconsulting.com]
Sent: Wednesday, September 01, 2004 9:33 AM
To: 'Nelson, Brad E.'; Dennis J. Strickler; Dave Williamson; Art Brooks
Subject: RE: revised max net loads

OK, so I'm a little fresher than last night and managed the challenging task of transforming my M2 net forces into a local CS rotated 31.034784° from global X. The revised Word doc is attached (again) and shows decent agreement.

Regards,

Leonard (Len) Myatt
Myatt Consulting, Inc.
8 Eric Road
Norfolk, MA 02056

leonard.myatt@myattconsulting.com
508-520-4590 (tel.)
508-813-6843 (cell)

877-883-4961 (e-FAX & v-Mail)

www.myattconsulting.com

-----Original Message-----
From: Nelson, Brad E. [mailto:nelsonbe@ornl.gov]
Sent: Thursday, August 26, 2004 10:49 AM
To: leonard.myatt@myattconsulting.com
Subject: FW: revised max net loads

Len

Attached is a table of force comparisons for a ñworst-caseò fault condition. I know you donôt have any spare time, but if you did it would be interesting to apply this set of currents to your ANSYS model to see what ANSYS says the net forces are.

Thanks

Brad

-----Original Message-----
From: Dennis Strickler [mailto:stricklerdj@ornl.gov]
Sent: Thursday, August 26, 2004 9:33 AM
To: abrooks@pppl.gov
Cc: Williamson, David E.; Nelson, Brad E.
Subject: revised max net loads

Art,

Thanks for your recent calculations comparing net loads with those that I reported. Dave confirmed your results for modular M2, and I found an error in the way I had ordered coils in one of the geometry files. Attached are tables containing a comparison of our results for a specific coil current distribution, and a revised set of current distributions for max net loads.

Thanks, Dennis

Dennis Strickler
stricklerdj@ornl.gov
865-574-1297

Williamson, David E.

From: Dennis Strickler [stricklerdj@ornl.gov]
Sent: Thursday, August 12, 2004 9:01 AM
To: Williamson, David E.
Subject: FW: revised fault load analysis
Attachments: forces4x.xls

Dave,

Here's the email from Art on max. net forces.

Thanks, Dennis

-----Original Message-----
From: Arthur W. Brooks [mailto:abrooks@pppl.gov]
Sent: Thursday, August 05, 2004 11:34 AM
To: Dennis Strickler
Subject: RE: revised fault load analysis

Dennis,

Thanks for the update.

I'm having mixed results benchmarking against your results. The attached spreadsheet compares the results you report with what I'm getting from two separate modeling approaches. We check out fine for the modular 1 coil results, but not for 2 and 3. I've compare results from a multfilament approach to an ANSYS solid model for a few of the cases where we disagree, and they appear to agree. I suspect we may have some difference in convention or something. What I have assumed is modular coils 1, 2 and 3 are at ~10, 30 and 50 deg (centroids I get are are actually at 10.717, 31.035 and 51,497 deg). Coil current sign convention is such that modular and TF coils produce positive toroidal field with positive currents, and PF coils produce positive vertical field in their bore with positive currents.

Any thoughts?

Art

> -----Original Message-----
> **From:** Dennis Strickler [mailto:stricklerdj@ornl.gov]
> **Sent:** Monday, August 02, 2004 3:55 PM
> **To:** nelsonbe@ornl.gov; williamsonde@ornl.gov; Arthur W. Brooks
> **Subject:** revised fault load analysis
>
> Brad, Dave, Art,
>
> Maximum net loads have been recalculated in the attached revision of the ncsx fault load analysis.
>
> Dennis
>
> Dennis Strickler
> stricklerdj@ornl.gov
> 865-574-1297

Aug-2 version w/ description of analysis method. This is the only version of "running load table" I could find, but possibly wrong due to error in Table-5

Fault conditions analysis (D. Strickler, D. Williamson)

Forces due to combinations of extreme coil currents have been evaluated with the MAGFOR [1] code in order to assess fault-load conditions on the modular coils. In a preliminary set of calculations, field values $\mathbf{B}_{i,j}$ were obtained at each grid point $\mathbf{x}_j$ due to coil currents I_i = 1kA, I_k = 0, k≠i. Forces were then calculated for fields $\mathbf{B}(j) = \sum I_k \mathbf{B}_{k,j}$, where the I_k are minimum/maximum values from the NCSX reference scenario data. Results are presented in Tables 1 - 3 for the worst-case scenarios. Here forces are resolved into local radial (R), lateral (L), and axial coordinates, relative to the winding form structural "T". The radial coordinate is directed away from the plasma toward the shell, while the lateral coordinate is directed normal to the surface of the web structure of the "T" supporting the winding pack.

Coil currents $I_k = \pm I_{k,max}$, where the $I_{k,max}$ represent the maximum magnitude of modular and PF1-4 currents from the reference scenario data, were considered in the analysis (PF5, 6, and TF currents were fixed at maximum values). Table 1 contains forces due to the combination of coil currents for which the maximum running load occurred in modular coil M1. Similarly, Tables 2 and 3 represent forces due to the combination of currents corresponding to the maximum running loads in modular coils M2 and M3, respectively. Also included in Tables 1-3 are net radial, toroidal and vertical loads on the modular coils corresponding to the coil current distributions giving the maximum running loads. Maximum forces on the PF and TF coils were relatively small compared to those of the modular coils. The largest running load of 7679 lb/in occurs in modular coil M1.

Maximum net radial, toroidal and vertical loads with respect to all coil current distributions considered, evaluated at the centroid of each modular coil, are summarized in Table 4, The coil currents for these maximum loads are listed in Table 5. A net toroidal load of 566687 lb on modular coil M1, for modular coil currents I_{M1} = -820 kA, I_{M2} = 830 kA, and I_{M3} = 730 kA, is maximum. The maximum net vertical load of 139009 lb is on modular M3 with modular coil currents I_{M1} = -820 kA, I_{M2} = -830 kA, I_{M3} = 730 kA. The maximum net radial load of 259368 lb also occures on modular M3, but for modular coil currents I_{M1} = -820 kA, I_{M2} = 830 kA, I_{M3} = 730 kA.

[1] W.D. Cain, "MAGFOR: A Magnetics Code to Calculate Field and Forces in Twisted Helical Coils of Constant Cross-Section," 10th IEEE/NPSS Symposium on Fusion Engineering (1983).

Table 1. Maximum running load – modular coil M1

Coil	I (kA)	F_R (lb/in)	F_L (lb/in)	|F| (lb/in)	Net Radial Load (lb)	Net Toroidal Load (lb)	Net Vertical Load (lb)
M1	820	-7269.5	-2473.9	7678.9	210326	8261	6858
M2	830	-845.0	6858.8	6993.8	-78271	195650	-32813
M3	730	-2500.4	5977.1	6485.7	178111	-357135	-135854
PF1/2	25	-5.3	-14.9	15.8			
PF3	-13	-0.1	0.9	0.9			
PF4	-14	1.8	-1.3	2.2			
PF5	8	4.1	2.1	4.6			
PF6	9	2.5	6.2	6.6			
TF	4	-2.4	-9.3	9.7			

Table 2. Maximum running load – modular coil M2

Coil	I (kA)	F_R (lb/in)	F_L (lb/in)	|F| (lb/in)	Net Radial Load (lb)	Net Toroidal Load (lb)	Net Vertical Load (lb)
M1	-820	-7219.3	-2388.6	7604.2	205134	8942	6925
M2	-830	-779.9	6880.6	7007.2	-81955	193044	-33484
M3	-730	-2445.9	5943.2	6433.4	177429	-353416	-137555
PF1/2	-25	-5.3	-14.1	15.0			
PF3	13	-0.5	0.9	1.1			
PF4	14	1.8	-1.7	2.5			
PF5	8	-4.5	-2.3	5.1			
PF6	9	-2.7	-6.1	6.7			
TF	4	2.6	9.2	9.6			

Table 3. Maximum running load – modular coil M3

Coil	I (kA)	F_R (lb/in)	F_L (lb/in)	|F| (lb/in)	Net Radial Load (lb)	Net Toroidal Load (lb)	Net Vertical Load (lb)
M1	-820	7395.4	1851.1	7623.5	-64408	566687	12608
M2	830	4112.9	-4703.6	6250.5	-134307	19000	-26483
M3	730	-1299.7	6529.6	6664.2	259368	-340136	118254
PF1/2	25	-9.6	-31.1	32.5			
PF3	-13	-5.7	1.7	5.9			
PF4	-14	-0.1	-4.4	4.4			
PF5	8	-6.5	-1.8	6.8			
PF6	9	-8.5	-6.7	10.8			
TF	4	7.1	-12.2	14.1			

Table 4. Maximum net radial, toroidal and vertical loads on modular coils.

Coil	Max. Net Radial Load (lb)	Max. Net Toroidal Load (lb)	Max. Net Vertical Load (lb)
M1	210577	566687	12842
M2	-143130	475850	-34648
M3	259368	-357153	139009

Table 5. Coil current distributions for maximum net radial, toroidal and vertical loads.

Coil	M1	M1	M1	M2	M2	M2	M3	M3	M3
Force component	R	φ	Z	R	φ	Z	R	φ	Z
Max. net load (lb)	210577	566687	12842	-143130	475850	-34648	259368	-357153	139009
I_{M1} (kA)	820	-820	-820	820	820	-820	-820	820	-820
I_{M2} (kA)	830	830	830	-830	830	-830	830	830	-830
I_{M3} (kA)	730	730	730	730	-730	730	730	730	730
$I_{PF1/2}$ (kA)	-25	25	-25	25	25	-25	25	-25	-25
I_{PF3} (kA)	13	-13	13	-13	-13	13	-13	13	13
I_{PF4} (kA)	14	-14	14	-14	-14	14	-14	-14	14
I_{PF5} (kA)	8	8	8	8	8	8	8	8	8
I_{PF6} (kA)	9	9	9	9	9	9	9	9	9
I_{TF} (kA)	4	4	4	4	4	4	4	4	4