

A.2 Full Operating Capability

A.2.1 Coil Set Definition

A.2.1.1 Current Centroid Locations

Coil centroids are defined by the c08r00 coil set.

A.2.1.2 Turns per Coil

	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
Turns	22	22	20	72	72	72	80	24	14	12	1

A.2.2 Coil Inductance Matrix (Henries)

	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
M1	1.50E-02	3.42E-03	1.53E-03	-6.07E-05	1.01E-05	4.16E-05	1.34E-04	-2.52E-04	-3.10E-04	9.54E-03	-1.79E-05
M2	3.42E-03	1.12E-02	2.84E-03	2.44E-05	-1.14E-05	-5.58E-06	-1.40E-05	-4.97E-05	-6.89E-05	7.35E-03	-1.19E-05
M3	1.53E-03	2.84E-03	9.76E-03	1.14E-04	-9.45E-06	-3.87E-05	-1.84E-04	-2.26E-04	-6.88E-05	5.19E-03	-9.55E-06
PF1	-6.07E-05	2.44E-05	1.14E-04	2.99E-03	4.82E-04	7.20E-05	1.47E-04	1.67E-04	1.18E-04	0.00E+00	8.92E-06
PF2	1.01E-05	-1.14E-05	-9.45E-06	4.82E-04	2.58E-03	4.33E-04	3.22E-04	1.75E-04	1.14E-04	0.00E+00	6.78E-06
PF3	4.16E-05	-5.58E-06	-3.87E-05	7.20E-05	4.33E-04	2.57E-03	1.14E-03	1.81E-04	1.04E-04	0.00E+00	4.40E-06
PF4	1.34E-04	-1.40E-05	-1.84E-04	1.47E-04	3.22E-04	1.14E-03	1.52E-02	1.14E-03	5.90E-04	0.00E+00	1.82E-05
PF5	-2.52E-04	-4.97E-05	-2.26E-04	1.67E-04	1.75E-04	1.81E-04	1.14E-03	1.28E-02	3.49E-03	0.00E+00	4.81E-05
PF6	-3.10E-04	-6.89E-05	-6.88E-05	1.18E-04	1.14E-04	1.04E-04	5.90E-04	3.49E-03	6.24E-03	0.00E+00	3.97E-05
TF	9.54E-03	7.35E-03	5.19E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.90E-02	1.51E-06
Plasma	-1.79E-05	-1.19E-05	-9.55E-06	8.92E-06	6.78E-06	4.40E-06	1.82E-05	4.81E-05	3.97E-05	1.51E-06	2.68E-06

A.2.3 Reference Scenario Data

A.2.3.1 Reference Equilibria (amp-turns per coil)

Equilibrium ID	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma	Comment
1	7.63E+05	7.10E+05	6.38E+05	0.00E+00	0.00E+00	3.05E+05	2.40E+05	2.03E+05	-1.05E+05	-4.26E+04	0	iota>0.5
2	6.95E+05	7.06E+05	6.21E+05	0.00E+00	0.00E+00	1.60E+05	-1.92E+05	2.42E+04	1.07E+04	-1.33E+04	0	iota<0.5
3	6.95E+05	7.06E+05	6.21E+05	0.00E+00	0.00E+00	1.60E+05	-1.92E+05	2.05E+04	7.53E+04	-1.33E+04	-120000	120kA, zero beta
4	6.59E+05	6.54E+05	5.43E+05	0.00E+00	0.00E+00	1.05E+05	-3.54E+05	5.58E+04	9.00E+04	4.53E+04	-179000	179kA, full beta
5	6.82E+05	6.40E+05	5.78E+05	0.00E+00	0.00E+00	-1.30E+06	-1.50E+06	1.07E+05	6.12E+04	2.62E+04	-320000	320kA, zero beta
6	6.69E+05	6.44E+05	5.57E+05	0.00E+00	0.00E+00	-1.14E+05	-2.09E+05	-3.27E+05	2.60E+05	3.77E+04	-160000	160kA, zero beta
7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E+05	0	0.5T TF
8	5.18E+05	5.24E+05	4.48E+05	0.00E+00	0.00E+00	0.00E+00	8.07E+04	3.30E+03	-5.78E+03	1.64E+05	0	iota = 0.19, Bt=1.7T
9	8.14E+05	8.12E+05	6.77E+05	0.00E+00	0.00E+00	0.00E+00	4.20E+05	6.22E+04	9.72E+03	-1.07E+05	0	iota = 0.65, Bt=1.7T
10	6.20E+05	9.03E+05	5.66E+05	0.00E+00	0.00E+00	0.00E+00	-7.24E+05	-1.82E+04	4.11E+04	-3.55E+04	0	Δ shear = +0.20
11	6.02E+05	8.72E+05	5.52E+05	0.00E+00	0.00E+00	0.00E+00	9.44E+05	1.50E+05	-1.58E+05	-1.44E+04	0	Δ shear = -0.10

A.2.3.2 Current Waveforms

Conductor currents are given in amperes. *Maxima are shown in blue, minima in red.*

1.7T Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.700	0	0	0	0	0	0	0	0	0	0	0
	0.000	34673	32277	31908	-23438	-23438	-14478	-4495	7293	-8195	-3548	0
	0.100	34673	32277	31908	-23438	-23438	-14478	-4495	7293	-8195	-3548	0
	0.140	31611	32115	31058	-14475	-14475	-9334	-7030	135	4932	-1106	-120052
	0.240	31611	32115	31058	-10963	-10963	-6531	-5907	309	5041	-1106	-120052
	0.440	31611	32115	31058	-3941	-3941	-924	-3661	657	5257	-1106	-120052
Maximum		34673	32277	31908	0	0	0	0	7293	5257	0	0
Minimum		0	0	0	-23438	-23438	-14478	-7030	0	-8195	-3548	-120052
I ² t (A ² -s)		1.19E+09	1.11E+09	1.05E+09	3.30E+08	3.31E+08	1.36E+08	2.24E+07	2.79E+07	4.56E+07	1.07E+08	
tESW (s)		0.99	1.07	1.03	0.60	0.60	0.65	0.45	0.52	0.68	8.52	

1.7T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.700	0	0	0	0	0	0	0	0	0	0	0
	0.000	34673	32277	31908	-14660	-14660	-7469	-1688	7728	-7924	-3548	0
	0.100	34673	32277	31908	-14660	-14660	-7469	-1688	7728	-7924	-3548	0
	0.140	31611	32115	31058	-5697	-5697	-2325	-4223	570	5203	-1106	-120052
	0.240	29814	29625	27016	-6146	-6146	-3461	-6371	2009	6213	3760	-178272
	0.440	29814	29625	27016	-5444	-5444	-2901	-6147	2044	6235	3760	-178272
Maximum		34673	32277	31908	0	0	0	0	7728	6235	3760	0
Minimum		0	0	0	-14660	-14660	-7469	-6371	0	-7924	-3548	-178272
I ² t (A ² -s)		1.15E+09	1.04E+09	9.44E+08	1.25E+08	1.26E+08	3.59E+07	2.70E+07	3.25E+07	4.87E+07	1.75E+08	
tESW (s)		0.95	1.00	0.93	0.58	0.58	0.64	0.67	0.54	0.78	12.38	

2T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.850	0	0	0	0	0	0	0	0	0	0	0
	0.000	37190	37783	36538	-14615	-14615	-9054	-7498	460	453	-1301	0
	0.050	37190	37783	36538	-14615	-14615	-9054	-7498	460	453	-1301	0
	0.097	37190	37783	36538	-6931	-6931	-2919	-5041	660	6114	-1301	-141238
	0.192	35075	34852	31783	-7540	-7540	-4319	-7595	2348	7300	4424	-209732
	0.197	35075	34852	31783	-7522	-7522	-4305	-7589	2349	7300	4424	-209732
Maximum		37190	37783	36538	0	0	0	0	2349	7300	4424	0
Minimum		0	0	0	-14615	-14615	-9054	-7595	0	0	-1301	-209732
I2t (A2-s)		1.28E+09	1.27E+09	1.15E+09	1.41E+08	1.40E+08	5.74E+07	5.20E+07	2.24E+06	1.20E+07	2.36E+08	
tESW (s)		0.93	0.89	0.86	0.66	0.65	0.70	0.90	0.41	0.23	12.06	

1.2T Long Pulse Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.500	0	0	0	0	0	0	0	0	0	0	0
	0.000	24475	22784	22523	-14066	-14066	-8241	-2380	5271	-5708	-2504	0
	0.100	24475	22784	22523	-14066	-14066	-8241	-2380	5271	-5708	-2504	0
	0.128	22314	22670	21923	-7747	-7747	-4616	-4172	218	3558	-780	-84743
	0.228	21045	20911	19070	-7961	-7961	-5336	-5656	1239	4274	2654	-125839
	1.728	21045	20911	19070	-2694	-2694	-1131	-3972	1500	4436	2654	-125839
Maximum		24475	22784	22523	0	0	0	0	5271	4436	2654	0
Minimum		0	0	0	-14066	-14066	-8241	-5656	0	-5708	-2504	-125839
I2t (A2-s)		1.12E+09	1.07E+09	9.04E+08	1.05E+08	1.05E+08	3.61E+07	4.33E+07	1.36E+07	4.45E+07	9.20E+07	
tESW (s)		1.86	2.06	1.78	0.53	0.53	0.53	1.35	0.49	1.37	13.05	

320kA Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.600	0	0	0	0	0	0	0	0	0	0	0
	0.000	31611	32115	31058	-22763	-22763	-15953	-9680	-122	66	-1106	0
	0.100	31611	32115	31058	-22763	-22763	-15953	-9680	-122	66	-1106	0
	0.206	31091	29143	28966	11386	11386	-9008	-15155	5050	4730	2191	-320775
	0.306	31091	29143	28966	14897	14897	-6205	-14032	5224	4838	2191	-320775
	0.506	31091	29143	28966	21919	21919	-598	-11786	5572	5054	2191	-320775
Maximum		31611	32115	31058	21919	21919	0	0	5572	5054	2191	0
Minimum		0	0	0	-22763	-22763	-15953	-15155	-122	0	-1106	-320775
I2t (A2-s)		1.10E+09	1.02E+09	9.66E+08	4.18E+08	4.04E+08	1.49E+08	1.50E+08	1.71E+07	1.15E+07	1.40E+08	
tESW (s)		1.10	0.99	1.00	0.81	0.78	0.59	0.65	0.55	0.45	29.19	

0.5T TF	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.800										0	
	0.000										16204	
	0.100										16204	
	0.200										16204	
	0.300										16204	
	0.500										16204	
Maximum											16215	
Minimum											0	
Current direction											1.00E+00	
I2t (A2-s)											4.05E+08	
tESW (s)											1.54	

Summary		M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
Maximum		37190	37783	36538	21919	21919	5217	1584	7728	7300	16215	0
Minimum		0	0	0	-23438	-23438	-15953	-15155	-122	-8195	-3548	-320775
Max I2t (A2-s)		1.28E+09	1.27E+09	1.15E+09	4.18E+08	4.04E+08	1.49E+08	1.50E+08	3.25E+07	4.87E+07	4.05E+08	
tESW (s) at max current		0.93	0.89	0.86	0.76	0.74	0.59	0.65	0.54	0.73	1.54	

A.2.3.3 Temperature History

Coil temperatures are in Kelvin. *Maxima for all reference scenarios are shown in blue.*

1.7T Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	85	85	85	85	85	85	85
	0.000	93	92	92	88	88	86	85	85	85	85
	0.100	96	94	94	88	88	86	85	85	85	85
	0.140	97	95	95	88	88	86	85	85	85	85
	0.240	99	98	97	89	89	86	85	85	85	85
	0.440	104	103	102	89	89	87	85	85	85	85
	3.621	113	111	109	89	89	87	85	85	86	86
Dissipated Energy (J)		1.62E+07	1.44E+07	1.13E+07	4.87E+05	4.88E+05	1.94E+05	8.28E+04	1.32E+05	1.55E+05	1.22E+06 4.47E+07

1.7T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	85	85	85	85	85	85	85
	0.000	93	92	92	86	86	85	85	85	85	85
	0.100	96	94	94	86	86	85	85	85	85	85
	0.140	97	95	95	86	86	85	85	85	85	85
	0.240	99	97	97	86	86	85	85	85	85	85
	0.440	103	102	101	86	86	85	85	85	85	85
	3.621	112	109	106	86	86	85	85	85	86	86
Dissipated Energy (J)		1.54E+07	1.33E+07	9.81E+06	1.78E+05	1.79E+05	5.03E+04	1.00E+05	1.54E+05	1.65E+05	2.01E+06 4.13E+07

2T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.850	85	85	85	85	85	85	85	85	85	85
	0.000	98	99	98	86	86	86	85	85	85	85
	0.050	99	101	99	86	86	86	85	85	85	85
	0.097	101	102	101	86	86	86	85	85	85	85
	0.192	104	105	104	86	86	86	85	85	85	85
	0.197	104	105	104	86	86	86	85	85	85	85
	3.378	115	115	112	87	87	86	86	85	85	87
Dissipated Energy (J)		1.79E+07	1.73E+07	1.26E+07	2.01E+05	1.99E+05	8.06E+04	1.93E+05	1.05E+04	4.04E+04	2.74E+06 5.13E+07

1.2T Long Pulse Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.500	85	85	85	85	85	85	85	85	85	85
	0.000	87	87	87	86	86	85	85	85	85	85
	0.100	89	88	88	86	86	85	85	85	85	85
	0.128	89	88	88	86	86	85	85	85	85	85
	0.228	90	89	89	86	86	85	85	85	85	85
	1.728	107	106	102	86	86	85	85	85	85	85
	4.909	111	110	105	86	86	85	85	85	85	86
Dissipated Energy (J)		1.48E+07	1.37E+07	9.29E+06	1.49E+05	1.49E+05	5.05E+04	1.61E+05	6.41E+04	1.51E+05	1.05E+06 8.88E+05

320kA Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.600	85	85	85	85	85	85	85	85	85	85
	0.000	90	91	90	87	87	86	85	85	85	85
	0.100	93	93	92	88	88	86	85	85	85	85
	0.206	95	95	95	88	88	87	86	85	85	85
	0.306	97	97	96	88	88	87	86	85	85	85
	0.506	102	101	100	89	89	87	86	85	85	85
	3.687	110	108	107	90	90	87	87	85	85	86
Dissipated Energy (J)		1.46E+07	1.29E+07	1.01E+07	6.25E+05	6.03E+05	2.13E+05	5.69E+05	8.09E+04	3.86E+04	1.61E+06 0.00E+00

0.5T TF	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.800										85
	0.000										86
	0.100										86
	0.200										86
	0.300										86
	0.500										87
	4.287										88
Dissipated Energy (J)											4.79E+06 4.79E+06

Summary		M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
Max Final Temperature		115	115	112	90	90	87	87	85	86	88
Max Dissipated Energy (J)		1.79E+07	1.73E+07	1.26E+07	6.25E+05	6.03E+05	2.13E+05	5.69E+05	1.54E+05	1.65E+05	4.79E+06 5.13E+07

A.2.3.4 Electrical Power Requirements

Upgrade Power Supply and Cabling Requirements and Modeling Assumptions

Other than for the First Plasma and Field Line Mapping Scenarios, it is assumed that DC power will be brought over from D-site. Power supply requirements for these reference scenarios have been calculated based on the following assumptions:

- [1] All coils of the same type (e.g. all M1 coils) are connected in series. All coils in the same circuit are connected in series. Circuit configurations are defined in the table below.
- [2] All coils of the same type have a single CLR connected in series with the coils. Each CLR has an inductance of 267 micro-H and a resistance of 100 milli-ohms.
- [3] DC power will be carried from D-site to the test cell via cables approximately 750 feet in length (each way). Required DC current ratings and cables per pole in each circuit are defined in the table below. An inductance of 132 micro-Henries per cable pair (supply and return) was assumed.
- [4] TFTR power supply sections (PSS) will be used. Each PSS has an open circuit voltage of 1012.85V and a maximum current of 28kA. When operated in parallel, the maximum rated current is reduced by 10%.
- [5] Required DC ratings are based on a pulse repetition time of 15 minutes.

Ultimate capability required	1.7T Ohmic 1.7T Hi Beta 2T Hi Beta 1.2T Long Pulse 320kA	M1	M2	M3	PF4	PF6	TF	PF1/2	PF3	PF5U	PF5L	
128 MW	Max I2t (A2-s)	1.28E+09	1.27E+09	1.15E+09	1.50E+08	4.87E+07	4.05E+08	4.04E+08	1.49E+08	3.25E+07	3.25E+07	
380 MVA	tESW (s)	0.93	0.89	0.86	0.65	0.73	1.54	0.74	0.59	0.54	0.54	
94 MJ	Required DC rating (A)	1193	1190	1128	409	233	670	670	407	190	190	26 Cables
	Cables per pole	2	2	2	1	1	1	1	1	1	1	
	Series PSS per branch	2	2	2	2	2	4	4	2	2	2	40 PSS
	Branches	2	2	2	1	2	2	2	1	1	1	
	Branch configuration	Parallel	Parallel	Parallel			Anti-parallel	Anti-parallel	Anti-parallel			

A.2.4 Pulsed Heat Loads

Pulsed heat loads calculated on the basis of the worst case scenario for each coil.

A.2.4.1 Maximum Temperature and Energy Deposition

Pulsed heat Loads	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
Initial Temperature (K)	85	85	85	85	85	85	85	85	85	85
Max Temperature (K)	115	115	112	90	90	87	87	85	86	88
Energy Deposited (J)	1.79E+07	1.73E+07	1.26E+07	6.25E+05	6.03E+05	2.13E+05	5.69E+05	1.54E+05	1.65E+05	4.79E+06
										5.13E+07

A.2.4.2 LN2 Consumption During Pulsed Operation

Max LN2 Consumption	Tsat (K)	Psat (MPa)	hfg (kJ/kg)	Mass per pulse (kg)	Density (kg/m3)	Volume (m3/kg)	Volume (m3)	Volume (liters)	Volume (gallons)
Per shot	78	0.109365	198.3014	258.463	805.735	0.001241	0.320779	320.7791	85 per shot
Time between shots (minutes)	15								
Hours per day	8								
Full pwr shots per day	32								2712 per day
Operating days per week	5								13559 per wk

A.2.4.2 LN2 Delivery Requirements

	Gallons per Truck 6500	Trucks
Pulsed heat loads only		
Max pulsed heat loads		2.09 per week
Field line mapping		0.05 per week
First Plasma		0.02 per week
Parasitic loads only		
Normal		2.12 per week
150C Bakeout		2.86 per week
350C Bakeout		3.52 per week
Cooldown only		1.63