A.1 Coil Set Definition

The coil set used in this analysis corresponds to the c07r00 coil set. This data in this section (A.1) is provided in order to define the coil geometry on which the technical data in following sections is based. This section does not define requirements for coil geometry.

A.1.1 Modular Coil Build

	M1	M2	M3
Length_m	7.35767	7.172828	6.660598
BundleHeight_mm	116.6114	116.6114	116.6114
BundleWidth_mm	42.2529	42.2529	42.2529
BundleArea_mm2	4927.17	4927.17	4927.17
BundleArea_m2	0.004927	0.004927	0.004927
EquivRadius_m	0.056007	0.056007	0.056007
GroundWrap_mm	0.762	0.762	0.762
TurnInsulation_mm	1.3716	1.3716	1.3716
InternalSeptum_mm	0	0	0
TurnsHigh	9	9	9
Turns	36	36	36
ConductorLengthPerDP_m	132.4381	129.1109	119.8908
ConductorHeight_mm	10.04429	10.04429	10.04429
ConductorWidth_mm	17.62125	17.62125	17.62125
ConductorArea_mm2	176.9929	176.9929	176.9929
CopperVolumeFraction	0.785	0.785	0.785
Area correction	-0.0552	-0.0552	-0.0552
CopperArea_mm2	131.27	131.27	131.27
Length correction	0.058425	0.058425	0.058425
Resistance correction for helical current path	0.120264	0.120264	0.120264
GeometricResistance_m-1	12814118	12492197	11600097
Tstart_K	85	85	85
Resistivity_ohm-m	2.36E-09	2.36E-09	2.36E-09
InitialResistance_ohms	0.030193	0.029434	0.027332

A.1.2 TF Coil Build

The TF conductor was modeled as a rectangular conductor of uniform thickness and width in each turn. Conductor dimensions correspond to the dimensions of the smallest turn.

	TF
Length_m	8.656783
NumberCoils	18
TurnsHigh	6
TurnsWide	2
Turns	12
ConductorLengthPerDP_m	103.8814
BundleHeight_mm	84.8868
BundleWidth_mm	100.838
BundleArea_mm2	8559.815
BundleArea_m2	0.00856
GroundWrap_mm	0.762
TurnInsulation_mm	1.2446
PancakeInsulation_mm	0.762
ConductorHeight_mm	11.4046
ConductorWidth_mm	47.752
CornerRadius_mm	2.5
CornerArea_mm2	5.365046
CoolingHoleWidth_mm	6.84276
CoolingHoleHeight_mm	19.1008
CoolingArea_mm2	120.6538
ConductorArea_mm2	418.5736
FillFactor	1
CopperArea_mm2	418.5736
Tstart_K	80
Resistivity_ohm-m	1.99E-09
GeometricResistance_m-1	4467231
InitialResistance_ohms	0.008877
Required flexibility_T	0.5
Current per turn for flexibility_kA	16.2037
Max current in reference scenario_kA	7.796296

A.1.3 PF Coil Builds

	PF1	PF2	PF3	PF4	PF5	PF6
Rpf_m	0.219075	0.219075	0.219075	0.521945	2.223186	2.720467
Rpf_in	8.625	8.625	8.625	20.549	87.527	107.105
Zpf_m	0.239725	0.71915	1.198575	1.583436	1.53035	0.954075
Zpf_in	9.438	28.313	47.188	62.34	60.25	37.562
Length_m	1.376489	1.376489	1.376489	3.279475	13.96869	17.0932
TurnsHigh	18	18	18	10	6	7
TurnsWide	4	4	4	8	4	2
Turns	72	72	72	80	24	14
Construction	Helically Wound	Helically Wound	Helically Wound	Helically Wound	Helically Wound	Helically Wound
BundleHeight_mm	428.8188	428.8188	428.8188	248.9052	158.9484	181.4376
BundleHeight_in	16.88263	16.88263	16.88263	9.799417	6.257811	7.143213
BundleWidth_mm	93.7668	93.7668	93.7668	186.7716	93.7668	47.2644
BundleWidth_in	3.691606	3.691606	3.691606	7.353213	3.691606	1.860803
BundleArea_mm2	40208.97	40208.97	40208.97	46488.42	14904.08	8575.539
BundleArea_m2	0.040209	0.040209	0.040209	0.046488	0.014904	0.008576
GroundWrap_mm	0.762	0.762	0.762	0.762	0.762	0.762
TurnInsulation_mm	1.2446	1.2446	1.2446	1.2446	1.2446	1.2446
PancakeInsulation_mm	0.762	0.762	0.762	0.762	0.762	0.762
ConductorHeight_in	0.787402	0.787402	0.787402	0.787402	0.787402	0.787402
ConductorHeight_mm	20	20	20	20	20	20
ConductorWidth_in	0.787402	0.787402	0.787402	0.787402	0.787402	0.787402
ConductorWidth_mm	20	20	20	20	20	20
CornerRadius_in	0.03937	0.03937	0.03937	0.03937	0.03937	0.03937
CornerRadius_mm	1	1	1	1	1	1
CornerArea_mm2	0.858407	0.858407	0.858407	0.858407	0.858407	0.858407
CoolingHoleDia_in	0.354331	0.354331	0.354331	0.354331	0.354331	0.354331
CoolingHoleDia_mm	9	9	9	9	9	9
CoolingArea_mm2	63.61725	63.61725	63.61725	63.61725	63.61725	63.61725
ConductorArea_mm2	335.5243	335.5243	335.5243	335.5243	335.5243	335.5243
FillFactor	1	1	1	1	1	1
CopperArea_mm2	335.5243	335.5243	335.5243	335.5243	335.5243	335.5243
Tstart_K	80	80	80	80	80	80
Resistivity_ohm-m	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09
InitialResistance_ohms	0.001174	0.001174	0.001174	0.003108	0.003971	0.002835
1Vs_OH_MAT	2.515329	2.515329	1.913926	0.962985	0.032436	0.019286

PF 1-6 conductor dimensions correspond to Outokumpu 8110

A.2 Coil Inductance Matrix (Henries)

	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
M1	4.01E-02	9.15E-03	4.51E-03	-9.94E-05	1.65E-05	6.81E-05	2.19E-04	-4.12E-04	-5.07E-04	1.56E-02	-2.94E-05
M2	9.15E-03	2.99E-02	8.37E-03	3.99E-05	-1.86E-05	-9.13E-06	-2.29E-05	-8.13E-05	-1.13E-04	1.20E-02	-1.94E-05
M3	4.51E-03	8.37E-03	3.16E-02	2.05E-04	-1.70E-05	-6.96E-05	-3.31E-04	-4.06E-04	-1.24E-04	9.35E-03	-1.72E-05
PF1	-9.94E-05	3.99E-05	2.05E-04	3.04E-03	4.79E-04	7.21E-05	1.47E-04	1.68E-04	1.19E-04	0.00E+00	8.92E-06
PF2	1.65E-05	-1.86E-05	-1.70E-05	4.79E-04	2.63E-03	4.30E-04	3.22E-04	1.75E-04	1.14E-04	0.00E+00	6.78E-06
PF3	6.81E-05	-9.13E-06	-6.96E-05	7.21E-05	4.30E-04	2.62E-03	1.14E-03	1.82E-04	1.04E-04	0.00E+00	4.40E-06
PF4	2.19E-04	-2.29E-05	-3.31E-04	1.47E-04	3.22E-04	1.14E-03	1.53E-02	1.14E-03	5.89E-04	0.00E+00	1.82E-05
PF5	-4.12E-04	-8.13E-05	-4.06E-04	1.68E-04	1.75E-04	1.82E-04	1.14E-03	1.29E-02	3.49E-03	0.00E+00	4.81E-05
PF6	-5.07E-04	-1.13E-04	-1.24E-04	1.19E-04	1.14E-04	1.04E-04	5.89E-04	3.49E-03	6.29E-03	0.00E+00	3.97E-05
TF	1.56E-02	1.20E-02	9.35E-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	-2.94E-05	-1.94E-05	-1.72E-05	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.3 Reference Scenario Data

A.3.1 Current Waveforms

Conductor currents are given in amperes. Maxima for all reference scenarios are shown in blue, minima in red.

320kA 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	19318	19626	17254	**-22649**	**-22649**	**-15010**	-10205	131	-126	-1106	**0**
	0.100	19318	19626	17254	**-22649**	**-22649**	**-15010**	-10205	131	-126	-1106	**0**
	0.206	19000	17809	16092	11328	11328	-9479	**-14892**	4924	4826	2191	**-320775**
	0.306	19000	17809	16092	14822	14822	-6821	-13688	5059	4964	2191	**-320775**
	0.506	19000	17809	16092	**21809**	**21809**	-1505	-11281	5329	5239	2191	**-320775**
Maximum		19318	19626	17254	21809	21809	0	0	5329	5239	2191	0
Minimum		0	0	0	-22649	-22649	-15010	-14892	0	-126	-1106	-320775
I2t (A2-s)		4.14E+08	3.93E+08	3.28E+08	4.55E+08	4.44E+08	1.57E+08	1.53E+08	1.59E+07	1.19E+07	1.36E+08	
tESW (s)		1.11	1.02	1.10	0.89	0.86	0.70	0.69	0.56	0.43	28.29	

1.9T 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	21591	21935	19284	1505	1505	3630	-2165	1183	917	-1236	0
	0.050	21591	21935	19284	1505	1505	3630	-2165	1183	917	-1236	0
	0.094	21591	21935	19284	8745	8745	9139	330	1292	6356	-1236	-134176
	0.189	20363	20234	16774	8186	8186	7845	-2104	2903	7478	4203	-199246
	0.194	20363	20234	16774	8204	8204	7859	-2098	2904	7479	4203	-199246
Maximum		21591	21935	19284	8745	8745	9139	330	2904	7479	4203	0
Minimum		0	0	0	0	0	0	-2165	0	0	-1236	-199246
I2t (A2-s)		4.24E+08	4.31E+08	3.30E+08	2.18E+07	2.14E+07	2.29E+07	3.22E+06	4.54E+06	1.29E+07	2.05E+08	
tESW (s)		0.91	0.90	0.89	0.28	0.28	0.27	0.69	0.54	0.23	11.60	

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	21189	19725	17727	1134	1134	5100	3391	8499	-7428	-3548	0
	0.100	21189	19725	17727	1134	1134	5100	3391	8499	-7428	-3548	0
	0.140	19318	19626	17254	10053	10053	9872	1063	1242	5774	-1106	-120052
	0.240	18220	18104	15009	9606	9606	8755	-1096	2686	6781	3760	-178272
	0.440	18220	18104	15009	10304	10304	9287	-856	2713	6808	3760	-178272
Maximum		21189	19725	17727	10304	10304	9872	3391	8499	6808	3760	0
Minimum		0	0	0	0	0	0	-1096	0	-7428	-3548	-178272
I2t (A2-s)		4.18E+08	3.80E+08	3.05E+08	5.09E+07	5.04E+07	4.94E+07	4.92E+06	4.09E+07	4.92E+07	1.69E+08	
tESW (s)		0.93	0.98	0.97	0.48	0.47	0.51	0.43	0.57	0.89	11.97	

Initial Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-1.000	0	0	0	0	0	0	0	0	0	0	0
	0.000	17450	16244	14598	1140	1140	4356	2863	7007	-6109	-2922	0
	0.100	17450	16244	14598	1140	1140	4356	2863	7007	-6109	-2922	0
	0.149	15909	16163	14209	9045	9045	8714	1139	1052	4786	-910	-98867
	0.249	15909	16163	14209	12539	12539	11372	2343	1187	4923	-910	-98867
	0.449	15909	16163	14209	19526	19526	16688	4751	1458	5199	-910	-98867
Maximum		17450	16244	14598	19526	19526	16688	4751	7007	5199	0	0
Minimum		0	0	0	0	0	0	0	0	-6109	-2922	-98867
I2t (A2-s)		3.61E+08	3.33E+08	2.68E+08	1.41E+08	1.40E+08	9.73E+07	2.18E+07	3.78E+07	4.20E+07	7.41E+07	
tESW (s)		1.19	1.26	1.26	0.37	0.37	0.35	0.97	0.77	1.12	8.68	

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	21189	19725	17727	436	436	4568	3150	8472	-7456	-3548	0
	0.100	21189	19725	17727	436	436	4568	3150	8472	-7456	-3548	0
	0.140	19318	19626	17254	9354	9354	9341	822	1215	5747	-1106	-120052
	0.240	19318	19626	17254	12848	12848	11999	2026	1350	5885	-1106	-120052
	0.440	19318	19626	17254	19835	19835	17316	4433	1620	6160	-1106	-120052
Maximum		21189	19725	17727	19835	19835	17316	4433	8472	6160	0	0
Minimum		0	0	0	0	0	0	0	0	-7456	-3548	-120052
I2t (A2-s)		4.34E+08	4.03E+08	3.40E+08	1.45E+08	1.44E+08	9.97E+07	1.96E+07	3.83E+07	4.60E+07	1.02E+08	
tESW (s)		0.97	1.04	1.08	0.37	0.37	0.33	1.00	0.53	0.83	8.10	

1.2T Long Pulse Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.400	0	0	0	0	0	0	0	0	0	0	0
	0.000	14957	13923	12513	1725	1725	4304	2712	6035	-5207	-2504	0
	0.100	14957	13923	12513	1725	1725	4304	2712	6035	-5207	-2504	0
	0.128	13636	13854	12179	8013	8013	7666	1066	912	4112	-780	-84743
	0.228	12861	12779	10594	7800	7800	6956	-423	1935	4827	2654	-125839
	1.728	12861	12779	10594	13040	13040	10943	1383	2138	5033	2654	-125839
Maximum		14957	13923	12513	13040	13040	10943	2712	6035	5033	2654	0
Minimum		0	0	0	0	0	0	-423	0	-5207	-2504	-125839
I2t (A2-s)		4.12E+08	3.99E+08	2.82E+08	2.65E+08	2.66E+08	1.94E+08	5.27E+06	1.93E+07	5.10E+07	8.65E+07	
tESW (s)		1.84	2.06	1.80	1.56	1.57	1.62	0.72	0.53	1.88	12.28	

Ref. Scenario Summary		M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
Maximum		21591	21935	19284	21809	21809	17316	4751	8499	7479	4203	0
Minimum		0	0	0	-22649	-22649	-15010	-14892	0	-7456	-3548	-320775
Maximum I2t (A2-s)		4.34E+08	4.31E+08	3.40E+08	4.55E+08	4.44E+08	1.94E+08	1.53E+08	4.09E+07	5.10E+07	2.05E+08	
tESW (s)		0.93	0.90	0.91	0.89	0.86	0.65	0.69	0.57	0.91	11.60	

A.3.2 Temperature History

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

320kA Ohmic	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	80	80	80	80	80	80	80
	0.000	95	96	92	82	82	81	80	80	80	80
	0.100	98	100	95	83	83	81	80	80	80	80
	0.206	102	103	97	83	83	81	81	80	80	80
	0.306	105	106	100	83	83	82	81	80	80	80
	0.506	112	112	104	84	84	82	81	80	80	80
	2.687	123	120	113	**85**	**85**	82	**82**	80	80	81
Dissipated Energy (J)		1.96E+07	1.77E+07	1.29E+07	**5.79E+05**	**5.63E+05**	1.86E+05	**4.90E+05**	6.50E+04	3.45E+04	1.22E+06
											5.33E+07

1.9T High Beta	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.850	85	85	85	80	80	80	80	80	80	80
	0.000	103	106	97	80	80	80	80	80	80	80
	0.050	105	108	99	80	80	80	80	80	80	80
	0.094	107	110	100	80	80	80	80	80	80	80
	0.189	111	114	103	80	80	80	80	80	80	80
	0.194	111	114	103	80	80	80	80	80	80	80
	2.375	124	**124**	114	80	80	80	80	80	80	**81**
Dissipated Energy (J)		2.02E+07	**2.01E+07**	1.29E+07	2.68E+04	2.65E+04	2.75E+04	9.88E+03	1.86E+04	3.86E+04	**1.86E+06**
											5.53E+07

1.7T High Beta	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	80	80	80	80	80	80	80
	0.000	98	96	93	80	80	80	80	80	80	80
	0.100	102	100	95	80	80	80	80	80	80	80
	0.140	103	101	96	80	80	80	80	80	80	80
	0.240	107	104	99	80	80	80	80	80	80	80
	0.440	113	110	103	80	80	80	80	80	80	80
	2.621	123	119	111	81	81	80	80	**80**	80	81
Dissipated Energy (J)		1.98E+07	1.69E+07	1.16E+07	6.21E+04	6.15E+04	5.90E+04	1.48E+04	**1.59E+05**	1.40E+05	1.53E+06
											5.03E+07

Initial Ohmic	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-1.000	85	85	85	80	80	80	80	80	80	80
	0.000	98	97	94	80	80	80	80	80	80	80
	0.100	101	99	95	80	80	80	80	80	80	80
	0.149	102	100	96	80	80	80	80	80	80	80
	0.249	105	102	98	80	80	80	80	80	80	80
	0.449	110	107	101	81	81	81	80	80	80	80
	2.630	117	114	107	81	81	81	80	80	80	80
Dissipated Energy (J)		1.61E+07	1.41E+07	9.82E+06	1.74E+05	1.73E+05	1.18E+05	6.86E+04	1.47E+05	1.18E+05	6.56E+05
											4.14E+07

1.7T Ohmic	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	80	80	80	80	80	80	80
	0.000	98	96	93	80	80	80	80	80	80	80
	0.100	102	100	95	80	80	80	80	80	80	80
	0.140	103	101	96	80	80	80	80	80	80	80
	0.240	107	104	99	80	80	80	80	80	80	80
	0.440	114	112	104	81	81	81	80	80	80	80
	2.621	**125**	121	**115**	81	81	81	80	80	80	81
Dissipated Energy (J)		**2.09E+07**	1.84E+07	**1.35E+07**	1.80E+05	1.78E+05	1.21E+05	6.15E+04	1.49E+05	1.30E+05	9.07E+05
											5.45E+07

1.2T Long Pulse	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.400	85	85	85	80	80	80	80	80	80	80
	0.000	88	88	87	80	80	80	80	80	80	80
	0.100	90	89	88	80	80	80	80	80	80	80
	0.128	90	89	88	80	80	80	80	80	80	80
	0.228	91	91	89	80	80	80	80	80	80	80
	1.728	117	117	105	82	82	82	80	80	80	80
	3.909	122	121	109	83	83	**82**	80	80	**81**	81
Dissipated Energy (J)		1.94E+07	1.81E+07	1.05E+07	3.21E+05	3.22E+05	**2.30E+05**	1.60E+04	7.58E+04	**1.45E+05**	7.72E+05
											4.99E+07

Ref. Scenario Summary		M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
Max Final Temperature		125	124	115	85	85	82	82	80	81	81
Max Dissipated Energy (J)		2.09E+07	2.01E+07	1.35E+07	5.79E+05	5.63E+05	2.30E+05	4.90E+05	1.59E+05	1.45E+05	1.86E+06
											5.53E+07

A.3.3 Electrical Power Requirements

Power supply requirements for the 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 seriers in a single circuit except for PF1 and PF2.
PF1 and PF2 coils are connected in series in a single circuit.

[2] All coils of the same type have a single CLR connected in series with the coils. The PF1/2 circuit has two CLRs in the circuit. 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 1000MCM cables approximately 750 feet in length. Each circuit will have 1 cable per pole with 2 poles per circuit in the initial configuration. In the upgrade configurations, the M3 circuit will have 2 cables per pole.

[4] TFTR power supply sections (PSS) will be used. Each PSS has an open circuit voltage of 1012.85V and a maximum current of 24kA.

[5] Each circuit has a maximum current rating of 24kA.

[5] NCSX research will pursue the mission in a series of phases, corresponding to the increasing capability of the facility. The planned phases are:

I. Initial Operation – initial plasma operation and system shakedown
II. Field-line Mapping – validation of the coil manufacture and assembly
III. Ohmic – operation with inductive current and ohmic heating only
IV. Auxiliary Heating – operation with 3MW of NBI, installation of PFC liner.
V. Confinement and Beta Push – operation with ~ 6MW of auxiliary heating, 2nd generation PFCs
VI. Long Pulse – plasma and heating pulse lengths of at least 1.1 sec, pumped divertor. Possible further upgrade of heating power.

Electrical power systems shall be designed and initially configured to meet the requirements of First Plasma and the Initial Ohmic Scenario and shall be capable of being upgraded to meet the requirements of all other reference scenarios.

A.3.3.1 Initial Power Supply Requirements

Initial Capability	M1	M2	M3	PF1/2	PF3	PF4	PF5	PF6	TF
Series supplies	2	2	2	2	2	2	2	2	2
Current direction	+	+	+	+	+	+	+	+/-	+
TFTR PSS	2	2	2	2	2	2	2	4	2
Total TFTR PSS									20

A.3.3.2 Upgrade Power Supply Requirements

Changes in the capability required are shown in blue

Capability at start of Phase IV	M1	M2	M3	PF1/2	PF3	PF4	PF5	PF6	TF
Series supplies	**4**	**4**	2	2	2	2	2	2	**4**
Current direction	+	+	+	+	+	**+/-**	+	+/-	**+/-**
TFTR PSS	**4**	**4**	2	**4**	2	**4**	2	4	**8**
Total TFTR PSS									**34**

Capability at Start of Phase V	M1	M2	M3	PF1/2	PF3	PF4	PF5	PF6	TF
Series supplies	4	4	2	**4**	2	2	2	2	4
Current direction	+	+	+	**+/-**	**+/-**	+/-	+	+/-	+/-
TFTR PSS	4	4	2	**8**	**4**	4	2	4	8
Total TFTR PSS									**40**

A.3.3.3 Total Power Requirements

Reference Scenario	Max Active Power (W)	Max Apparent Power (VA)	Stored Energy Required (J)
350kA Ohmic	1.09E+08	**3.39E+08**	**8.79E+07**
1.9T High Beta	**1.09E+08**	2.73E+08	7.94E+07
1.7T High Beta	9.79E+07	2.74E+08	7.45E+07
Initial Ohmic	6.57E+07	1.92E+08	6.59E+07
1.7T Ohmic	9.77E+07	2.97E+08	8.10E+07
1.2T Long Pulse	7.37E+07	2.08E+08	7.80E+07
Maximum	**1.09E+08**	**3.39E+08**	**8.79E+07**

A.4 Cryogenic System Requirements

A.4.1 Pulsed Heat Loads

Pulsed heat loads for the modular coils calculated on a temperature rise from 85K to 125K in each modular coil.
Pulsed heat loads for the TF and PF coils calculated on the basis of the worst case scenario for each coil.
Total heat loads calculated by summing the above.

Pulsed heat Loads	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
Initial Temperature (K)	85	85	85	80	80	80	80	80	80	80
Max Temperature (K)	125	125	125	85	85	82	82	80	81	81
Energy Deposited (J)	2.10E+07	2.04E+07	1.83E+07	5.79E+05	5.63E+05	2.30E+05	4.90E+05	1.59E+05	1.45E+05	1.86E+06
										6.38E+07

LN2 Consumption		Tsat (K)	Psat (MPa)	hfg (kJ/kg)	Mass per pulse (kg)	Density (kg/m3)	(m3/kg)	Volume (m3)	(liters)	(gallons)	
Per shot		78	0.107717	198.7357	320.7905	805.7325	0.001241	0.398135	398.1353	105	per shot
Time between shots (minutes)	15										
Hours per day	8										
Full pwr shots per day	32									3366	per day
Operating days per week	5									16828	per week

A.4.2 Parasitic Heat Loads

Heat leakages to the cold mass calculated on the basis of numbers provided by cognizant engineers based on nominal VV operating temperatures of 40C and bakeout temperatures of 150C with the cold mass at 80K.

Normal Operation	Heat Load (kW)	Flow rate (kg/s)	Vol flow rate (m3/s)	s/week	Volume (m3)	(liters)	(gallons)	
Cryostat gaseous nitrogen circulation	7.4							
Through cryostat	3.4							
Through ports	2.6							
From VV to modular coil shell	1.4							
Modular coil liquid nitrogen cooling (from VV)	3.7							
Combined	11.2	0.056189	6.97E-05	604800	42.17631	42176.31	11142	per week
VV heating required to maintain VV temperature	*7.8*							

Bakeout	Heat Load (kW)	Flow rate (kg/s)	Vol flow rate (m3/s)	s/week	Volume (m3)	(liters)	(gallons)	
Cryostat gaseous nitrogen circulation	9.6							
Through cryostat	3.4							
Through ports	4.0							
From VV to modular coil shell	2.2							
Modular coil liquid nitrogen cooling (from VV)	5.7							
Combined	15.3	0.076987	9.55E-05	604800	57.78784	57787.84	15266	per week
VV heating required to maintain VV temperature	*11.9*							

A.4.3 Heat Loads For Cooling the Cold Mass from RT to 80K

Cold mass	75000	kg
Cryogen requirements	0.43	kg of LN2 per kg of SS assuming evaporation enthalpy only per http://gperinic.home.cern.ch/gperinic/cooldown.htm
	32250	kg based on evaporation enthalpy only
	10574	gallons

A.4.4 LN2 Delivery Requirements

	gallons per truck	trucks	
Pulsed heat loads only	6500	2.6	per week
Parasitic loads only			
Normal		1.7	per week
Bakeout		2.3	per week
Cooldown only		1.6	