TD-03-026

Fermi National Accelerator Laboratory
Technical Division
Development and Test Department
Mail stop 316
P.O. Box 500
Batavia, Illinois • 60510

HFDB-03 TC-I Test Results & Preload Plan for TC-II

S. Bhashyam, G. Ambrosio

Abstract:

This note presents, in the form of Power Point slides, the analysis of strain gauge measurement performed during the first cold test of HFDB-03, a FEM analysis of the coil, and the preload to be used for the second cold test. The analysis of the strain gauge data showed large discrepancies with respect to the predicted values. In the FEM analysis here presented the value of the thermal contraction of G10 (3.06 mm/m from 300 to 4.2 K) is larger than the one previously used (2.75 mm/m from 300 to 4.2 K). The correspondence with the values measured during the first test improved significantly. The values of the preload to be used for the second test were based on the FEM analysis here presented.

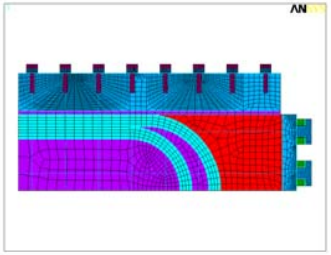
HFDB-03 TC-I Test Results & Preload Plan for TC-II

HFM Engineering Meeting

06/10/03

HFDB-03 TC-I Test Results and FEA Correlation (300 K preloads as per original preload plan)

Bolt	Pre-Load FEA (300K)	Pre-Load Test (300K)	Cool-down (4.2 K) FEA	Cool-down (4.2K) Test	Delta (4.2K-300K) FEA	Delta (4.2K-300K) Test	Excitation @ 10 kA (4.2 K) FEA	Excitation @ 10kA Test	Delta (10 kA - 0 kA) FEA	Delta (10 kA - 0 kA) Test
End Bullet 1	14560		12209		-2351		13668		1459	
End Bullet 2	13103	9525	9891	4417	-3212	-5108	11438	4417	1547	0
Side Bolt 1	3828		655		-3173		762		107	
Side Bolt 2	12218		9578		-2640		9877		299	
Side Bolt 3	11806	11542	9754	7548	-2052	-3994	10109	7255	355	-293
Side Bolt 4	12909	11369	11599	9218	-1310	-2151	11660	8672	61	-546
Side Bolt 5	3757		3188		-569		2637		-551	
Side Bolt 6	3763		3612		-151		2501		-1111	
Side Bolt 7	3890		3920		30		2565		-1355	
Side Bolt 8	3932	4309	4017	3738	85	-571	2627	3391	-1390	-347
Main Bolt-outer	10150	8455	276	0	-9874	-8455	15266	11650	14990	11650
Main Bolt - Inner	22930	15558	0	0	-22930	-15558	16714	17630	16714	17630

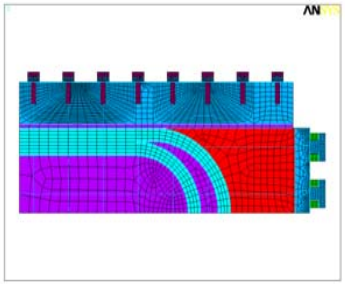


Model assumed α = 2.75 mm/m for G-10 island and inserts
This value appears to be low based on FEA/Test correlation (Delta 4.2K-300K)

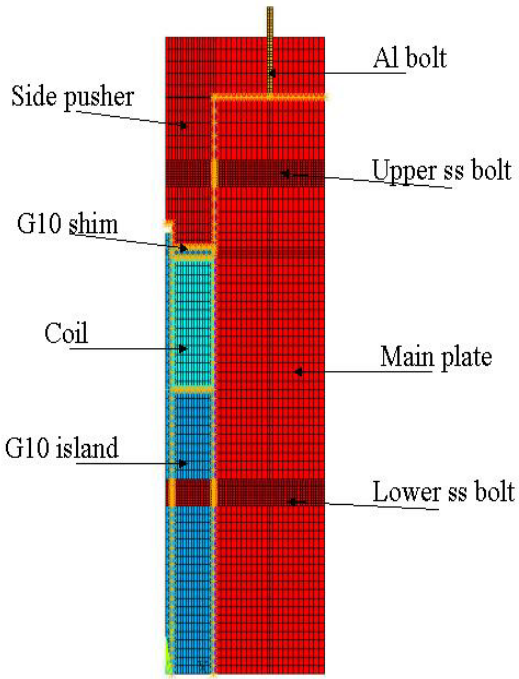
HFDB-03 TC-I Test Results and FEA Correlation

α = 3.02 mm/m of G-10 island and inserts gives reasonably good correlation (further refinement possible)

Bolt	Pre-Load FEA (300K)	Pre-Load Test (300K)	Cool-down (4.2 K) FEA	Cool-down (4.2K) Test	Delta (4.2K-300K) FEA	Delta (4.2K-300K) Test	Excitation @ 10 kA (4.2 K) FEA	Excitation @ 10kA Test	Delta (10 kA - 0 kA) FEA	Delta (10 kA - 0 kA) Test
End Bullet 1	9812		5890		-3922		7289		1399	
End Bullet 2	9335	9525	4523	4417	-4812	-5108	6044	4417	1521	0
Side Bolt 1	3682		358		-3324		505		147	
Side Bolt 2	11252		8146		-3106		8436		290	
Side Bolt 3	10122	11542	7175	7548	-2947	-3994	7399	7255	224	-293
Side Bolt 4	10961	11369	8351	9218	-2610	-2151	8002	8672	-349	-546
Side Bolt 5	2158		112		-2046		73		-39	
Side Bolt 6	2631		868		-1763		568		-300	
Side Bolt 7	3036		1437		-1599		940		-497	
Side Bolt 8	3197	4309	1684	3738	-1513	-571	1101	3391	-583	-347
Main Bolt-outer	10150	8455	276	0	-9874	-8455	15266	11650	14990	11650
Main Bolt - Inner	22930	15558	0	0	-22930	-15558	16714	17630	16714	17630



HFDB-03 FEA Transverse X-section



Vertical bolt load	N	2634	1602	638
Upper-horizontal bolt load	N	10150	276	43596
Lower-horizontal bolt load	N	22930	0	48303
Vertical stress in the coil (average on the top surface of the coil)	MPa	-2.9	-1.75	-3.9
Horizontal stress in the coil (average on the right surface of the coil)	MPa	-6.1	0	-37.2
Horizontal coil displacement (average on the right surface of the coil)	mm	-0.011	-0.069	-0.014

Low pre-stress solution

Vertical bolt load	N	14020	13524	12094
Upper-horizontal bolt load	N	12853	3935	42919
Lower-horizontal bolt load	N	37355	3784	48993
Vertical stress in the coil (average on the top surface of the coil)	MPa	-15.3	-14.8	-16.5
Horizontal stress in the coil (average on the right surface of the coil)	MPa	-8.6	-1.9	-37.2
Horizontal coil displacement (average on the right surface of the coil)	mm	-0.012	-0.069	-0.017

High pre-stress solution

TC-I used loads from low pre-stress solution

TC-II loads high pre-stress solution

HFDB-03 TC-I Preload Summary

TC-I Preloads & Production Tests

Bolt	Pre-Load (300 K)	Pre-Load (300 K) Test
End Bullet 1	14560	
End Bullet 2	13103	9525
Side Bolt 1	3828	
Side Bolt 2	12218	
Side Bolt 3	11806	11542
Side Bolt 4	12909	11369
Side Bolt 5	3757	
Side Bolt 6	3763	
Side Bolt 7	3890	
Side Bolt 8	3932	4309
Main Bolt - Outer	10150	8455
Main Bolt - Inner	22930	15558

HFDB-03 TC-I Summary and TC-II Plan

❖ Analysis of strain gage data from TC-I complete and results correlated to FEA

❖ Test results indicated a much higher load loss after cool-down compared to FEA -> attributed to lower assumed thermal contraction of G-10 in the model (α=2.75 mm/m); true value is around 3.02 mm/m; rest of the results correlated fairly well

❖Main bolts completely unloaded upon cool-down; we lost half the gages during the initial few quench ramps; new gages installed for TC-II

❖No preload gain in end bolts upon excitation (end preloads too low ?)

❖End preloads will be increased by a factor of 2 in TC-II (preload table in the next slide)

❖Side pusher will be loaded uniformly, i.e. , all side bolts will have the same load (preload table in the next slide)

❖Higher preload in the main bolts so that we retain some preload @ 4.2K

(Giorgio will present the optimized results in this x-section)

❖Preload sequence will be altered:

-some preloads (25%) on the side bolts and main bolts

-next the end bullets will be preloaded to maximum load in increments

-side bolts will be then loaded to maximum load and finally the main plate

HFDB-03 TC-II Preload Plan

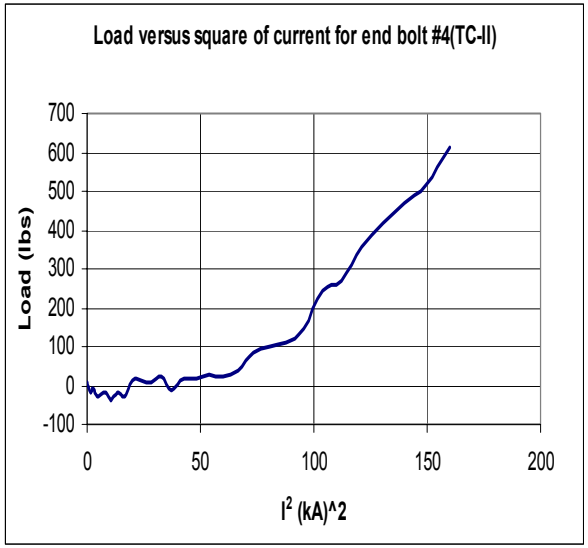
Bolts	Load (N)	Load (lbs)	Expected Torque (in-lbs)
Outer Main Bolts	13000	2921	730
Inner Main Bolts	37000	8300	2100
All Side Bolts	8000	1800	225
All End Bullets	30000	6741	800

HFDB-03 TC-II FEA Results

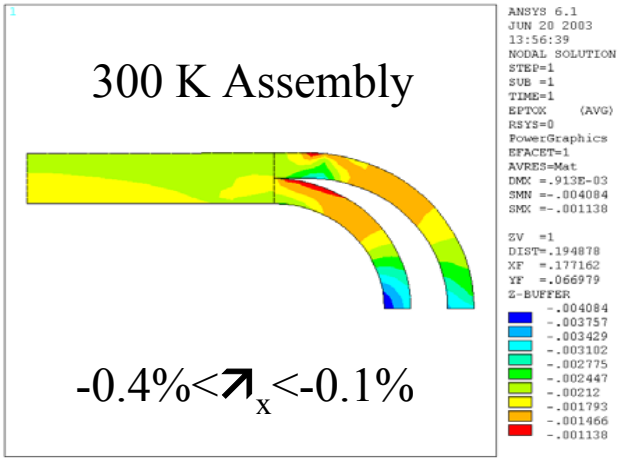
Bolt	Pre-Load (300 K) FEA	Cool-down (4.2 K) FEA	Delta (4.2K-300K) FEA	Excitation @ 17kA (4.2 K) FEA	Delta (17 kA - 0 kA) FEA
End Bullet 1	27988	23966	-4022	27605	3639
End Bullet 2	28797	24004	-4793	27913	3909
Side Bolt 1	14129	10570	-3559	10881	311
Side Bolt 2	14662	11218	-3444	11949	731
Side Bolt 3	14915	11879	-3036	12605	726
Side Bolt 4	14977	12422	-2555	12159	-263
Side Bolt 5	15570	13477	-2093	11440	-2037
Side Bolt 6	13129	11347	-1782	7841	-3506
Side Bolt 7	13186	12202	-984	7951	-4251
Side Bolt 8	12753	11237	-1516	6806	-4431
Main Bolts (avg)	29000	22950	-6050	22950	0

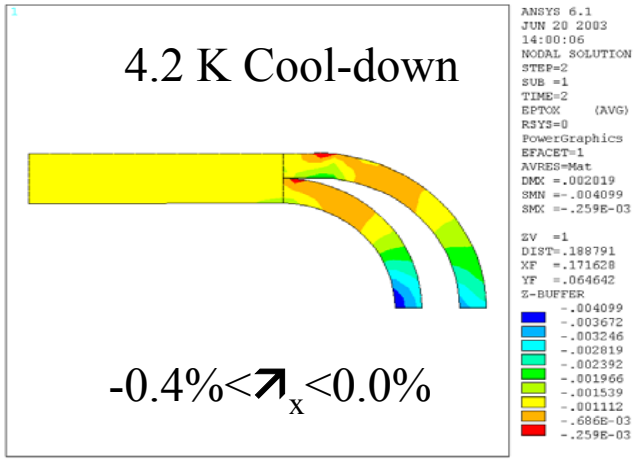
Why Higher Preloads ?

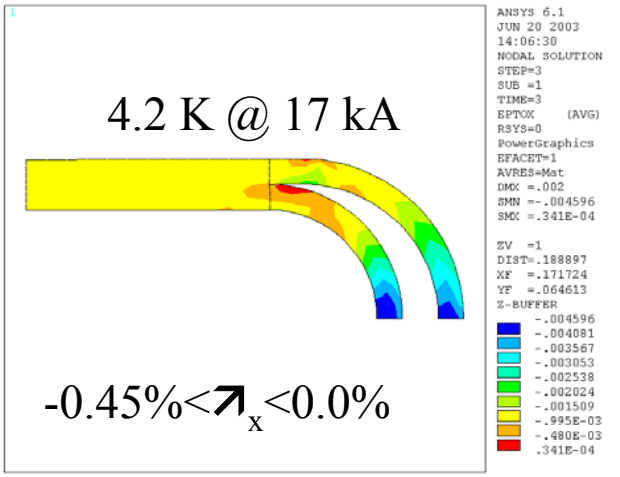
Bolt	Pre-Stress (300K)	Cool-down (4.2K)	Delta (4.2K-300K)	Excitation @ 12 kA (4.2K)	Delta (4.2K@12 kA - 4.2K)
mainL1					
mainL2	15330	21498	6168	41968	20470
mainR3	23492	14000	-9492	24457	10458
mainR4	24844	15419	-9425	21160	5741
AVG	21222	16972	-4250	29196	12224
lend1	14525	10555	-3969	10555	0
lend2	9301	4472	-4828	4472	0
rend3	15054				
rend4	17288	15330	-1958	18000	2670
AVG	14044	10119	-3924	10787	2670
sideL1	11592	12273	681	11721	-552
sideL2	9065	8201	-863	7623	-579
sideR3	9830	9416	-414	8655	-761
sideR4	10155	10974	819	10306	-668
AVG	10159	10217	58	9576	-641
	Lost strain gages				

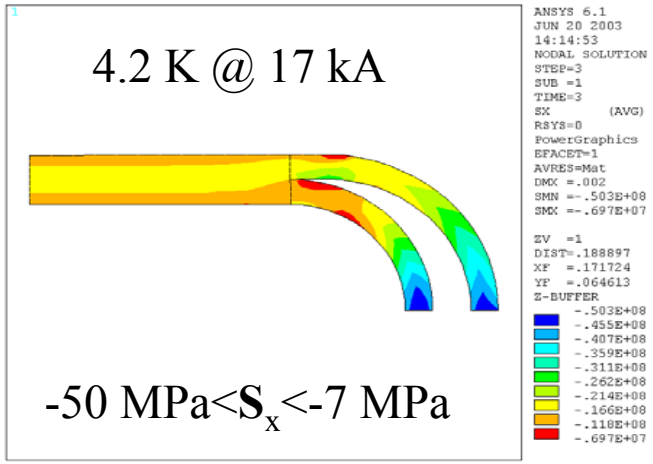


HFDB-03 Mechanical Analysis G-10 α=3.02 mm/m x-strains

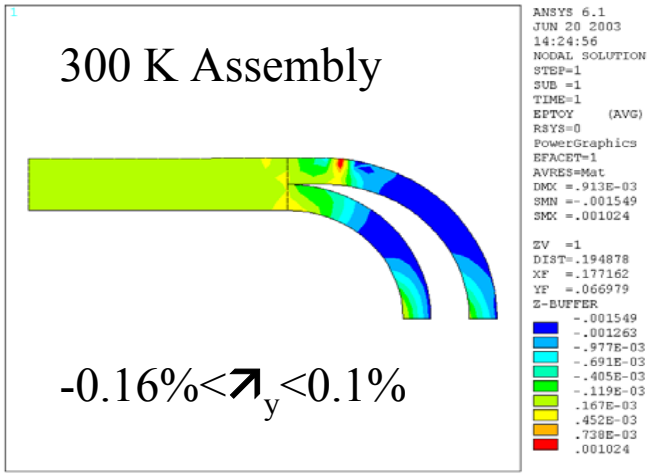


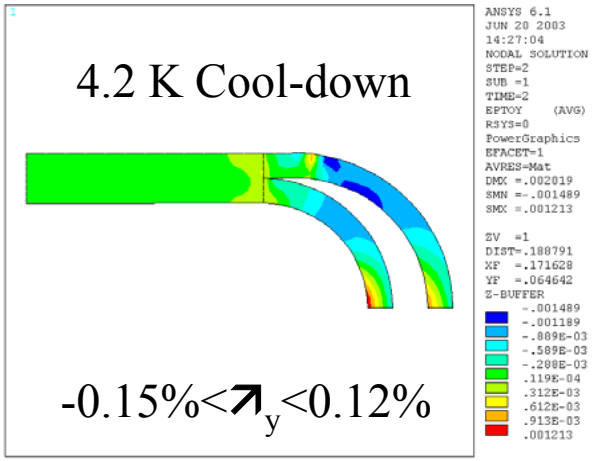


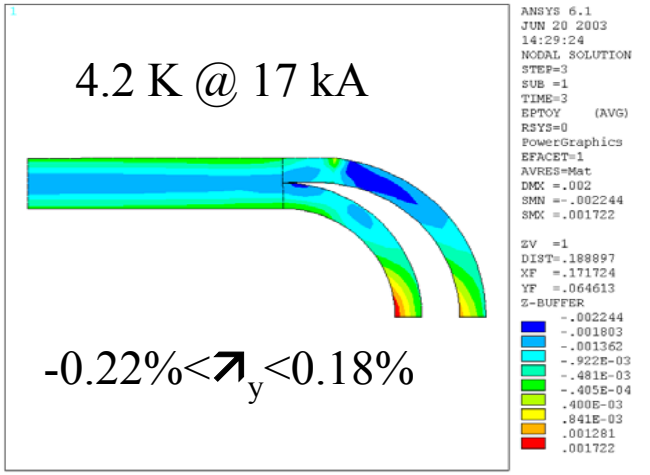


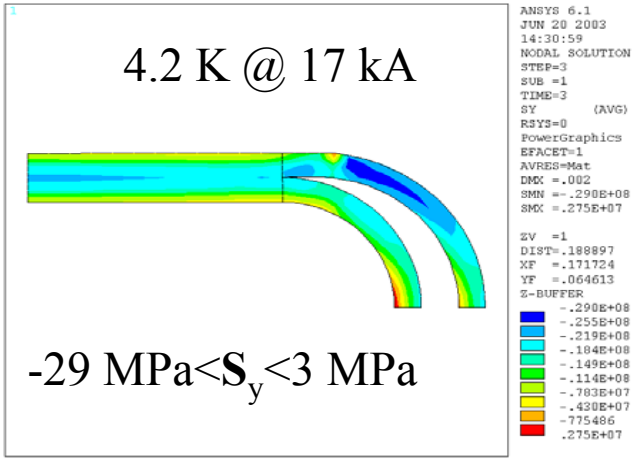


HFDB-03 Mechanical Analysis G-10 α=3.02 mm/m y-strains

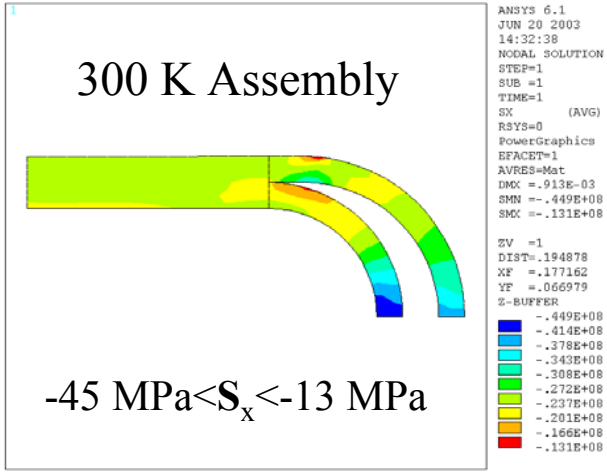


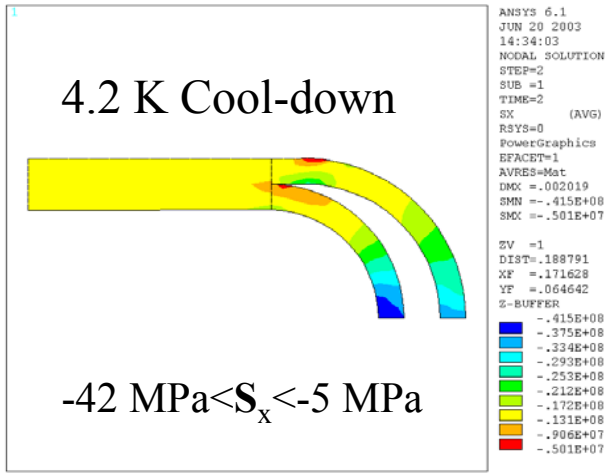


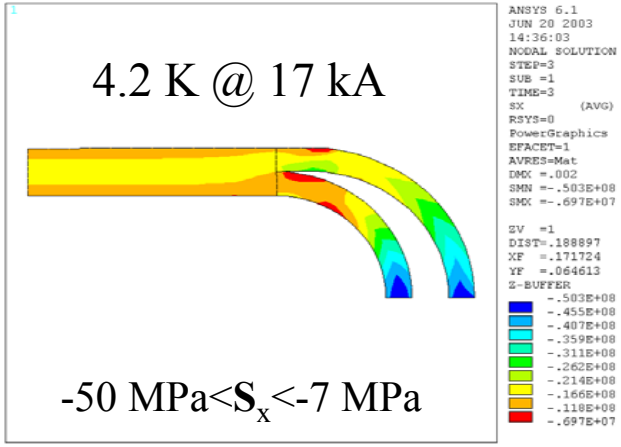




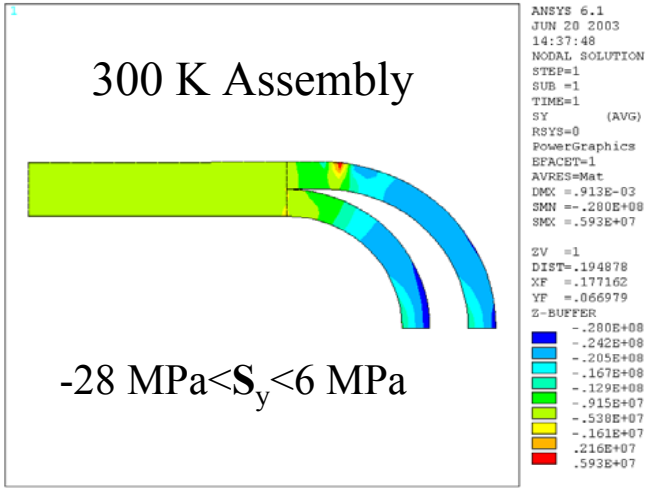
HFDB-03 Mechanical Analysis G-10 α=3.02 mm/m x-stresses

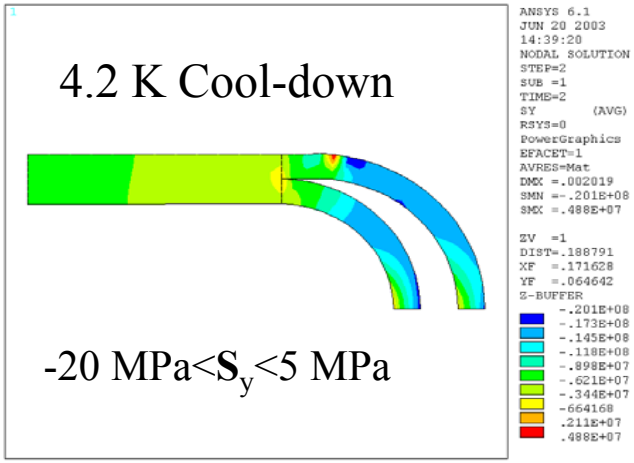


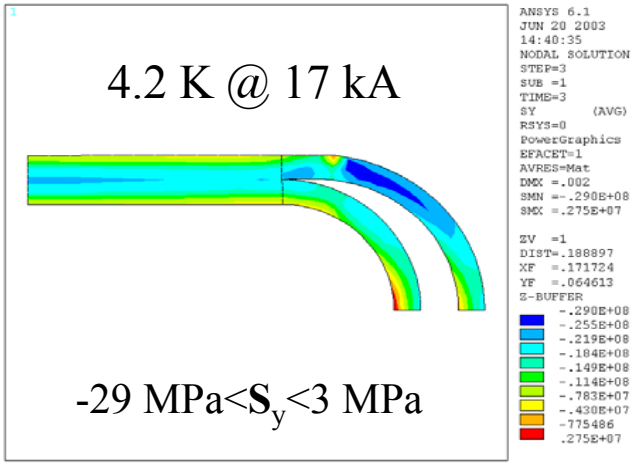




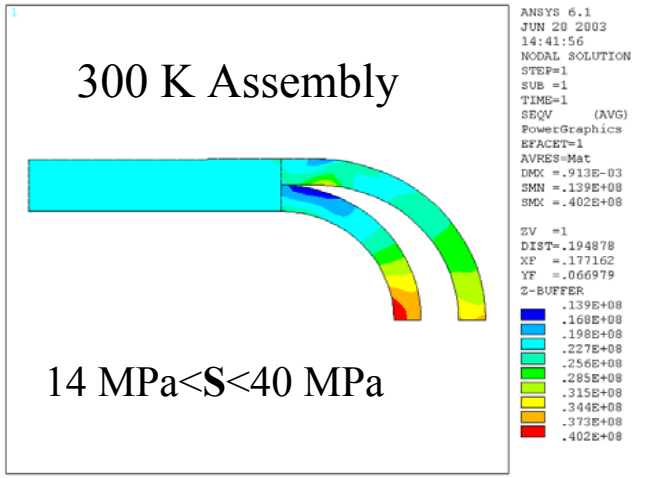
HFDB-03 Mechanical Analysis G-10 α=3.02 mm/m y-stresses

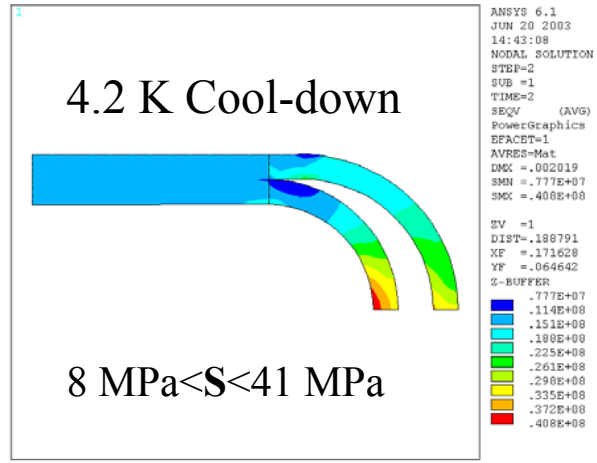


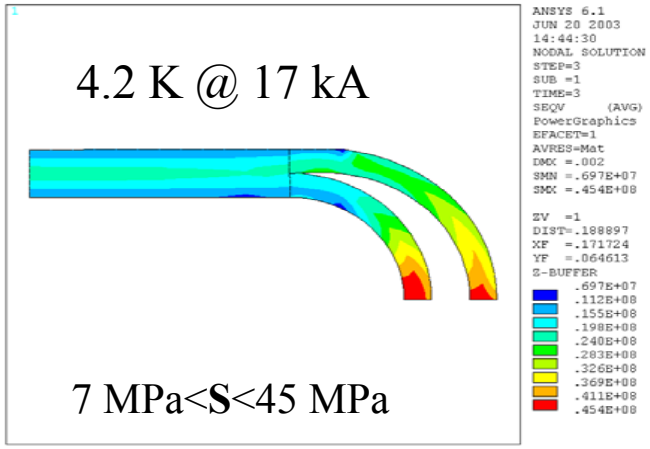




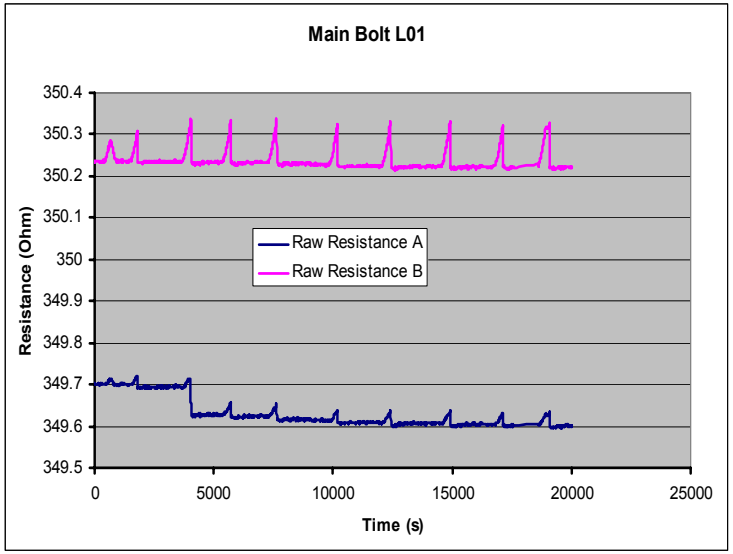
HFDB-03 Mechanical Analysis G-10 α=3.02 mm/m Von-Mises stresses

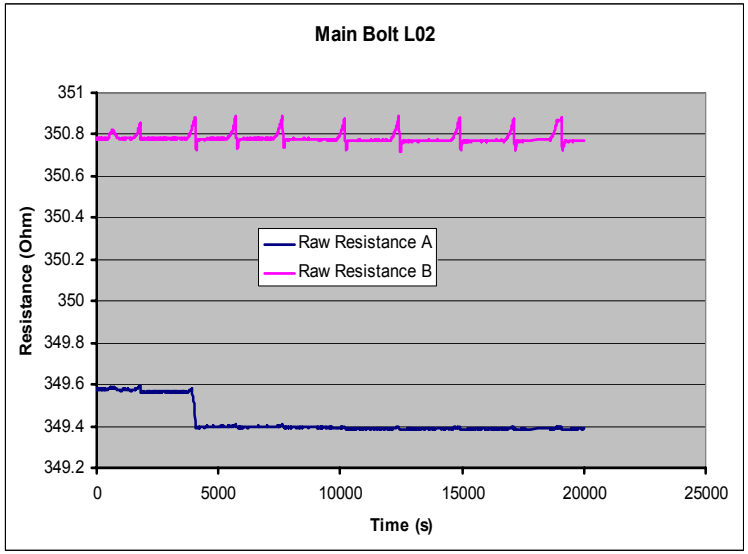


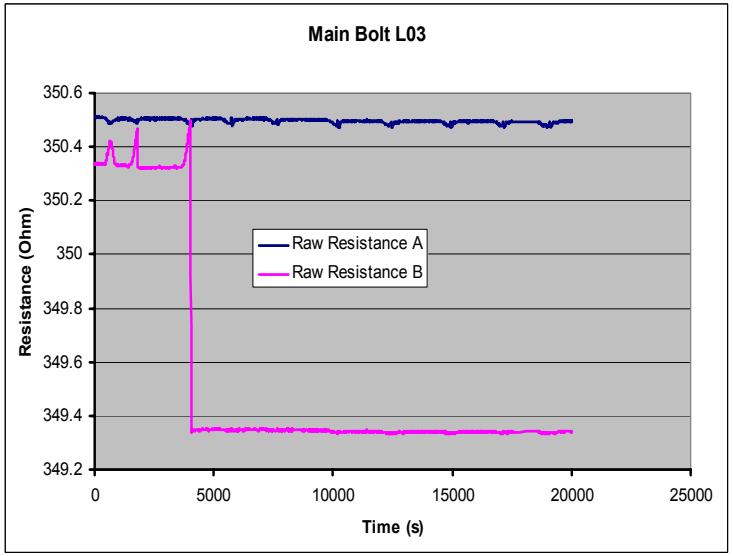


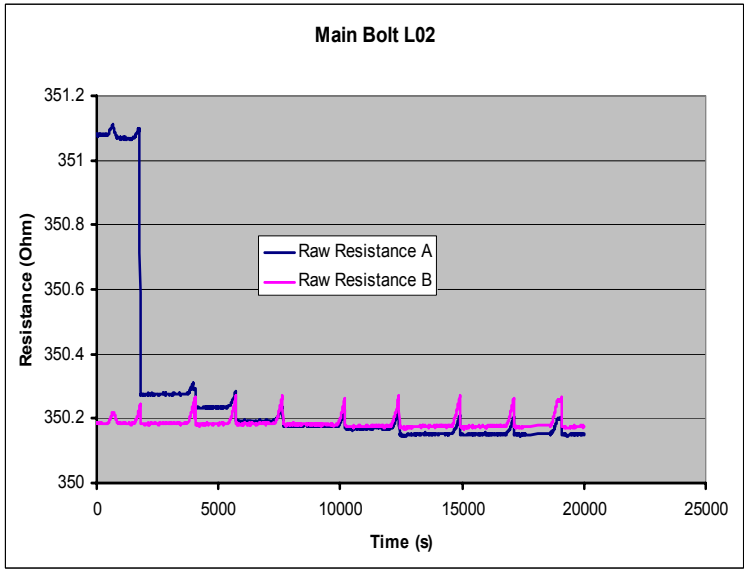


Strain Gage Data – Main Bolts

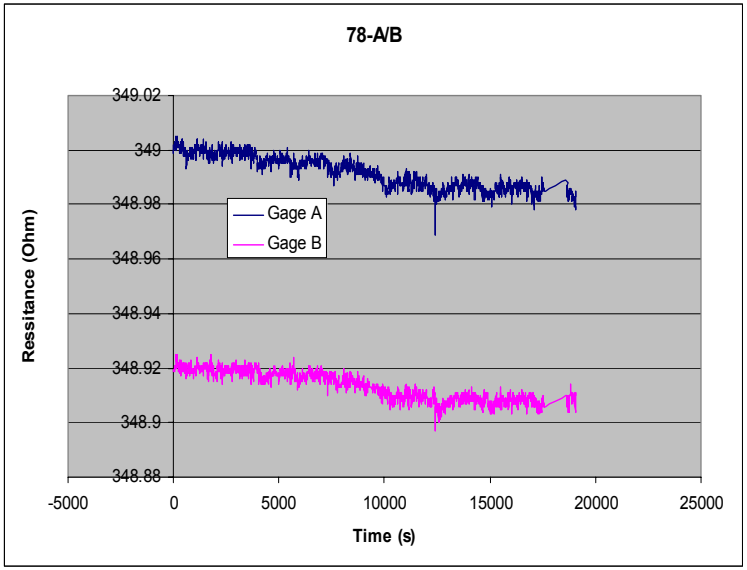


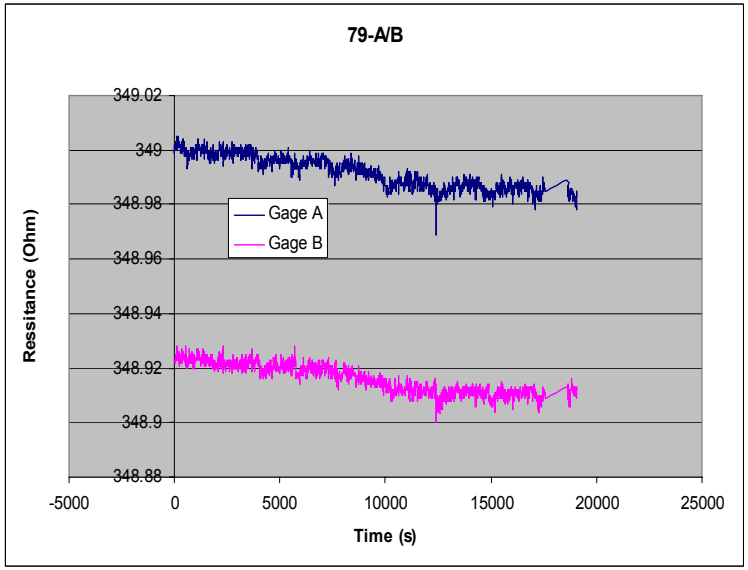


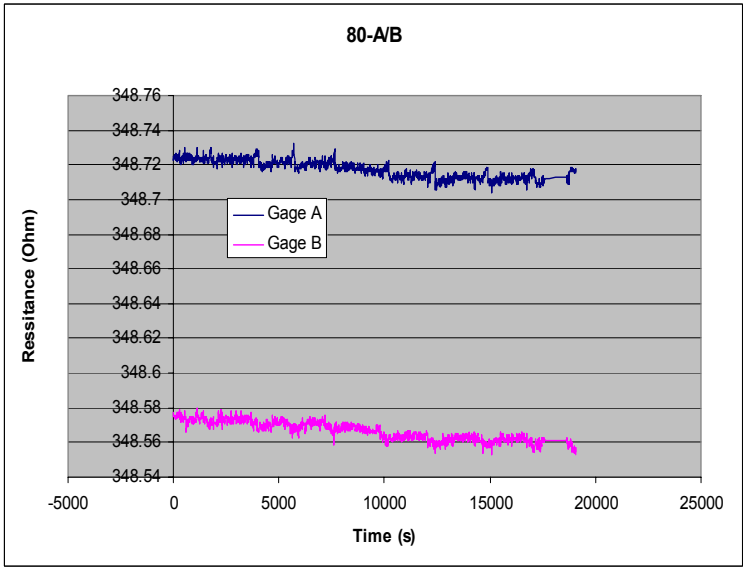


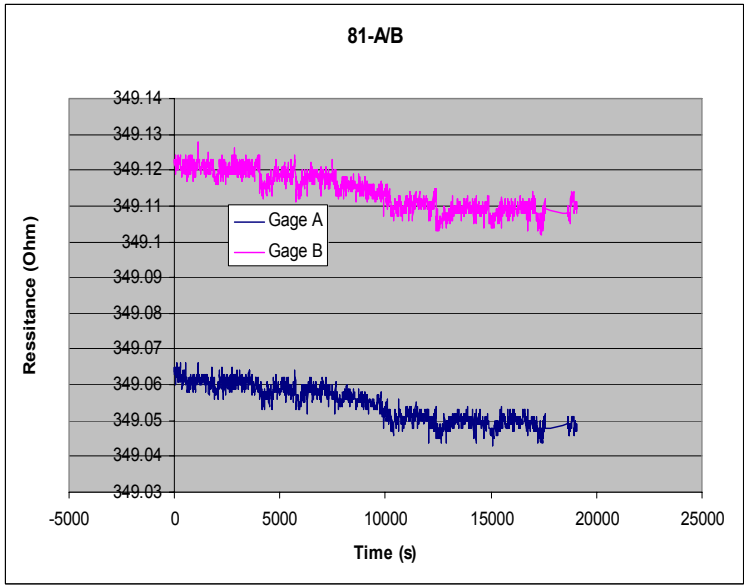


Strain Gage Data – End Bullets

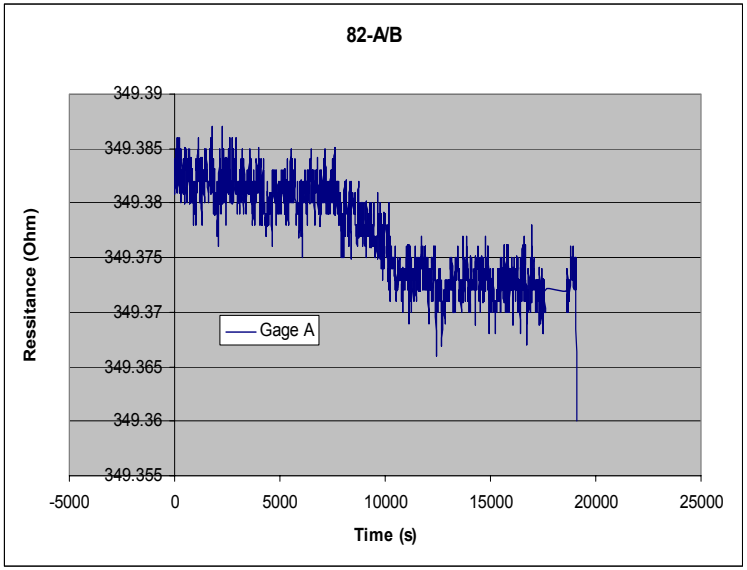


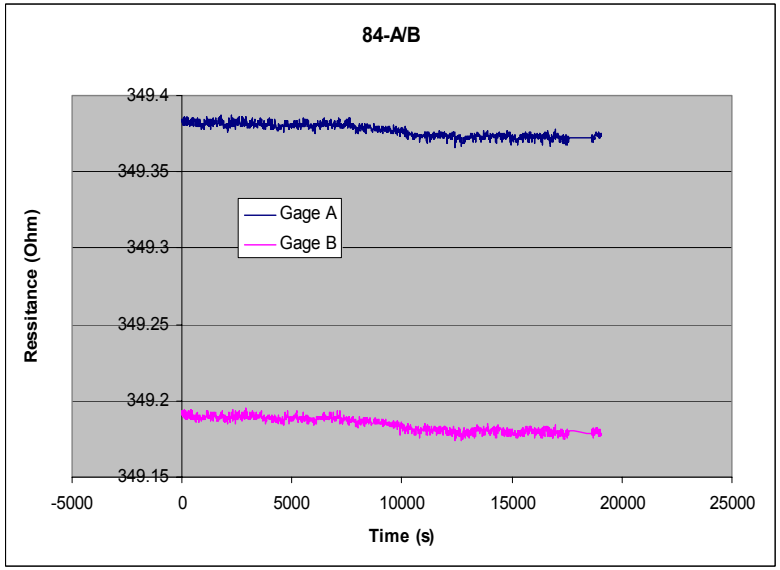


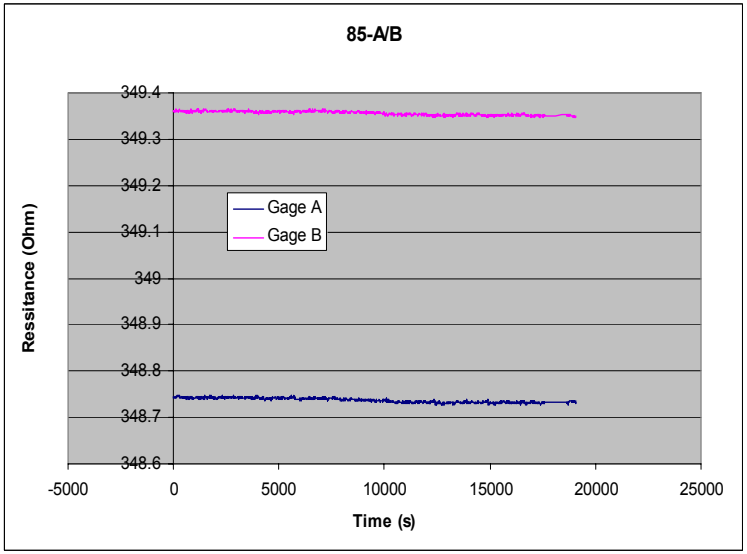




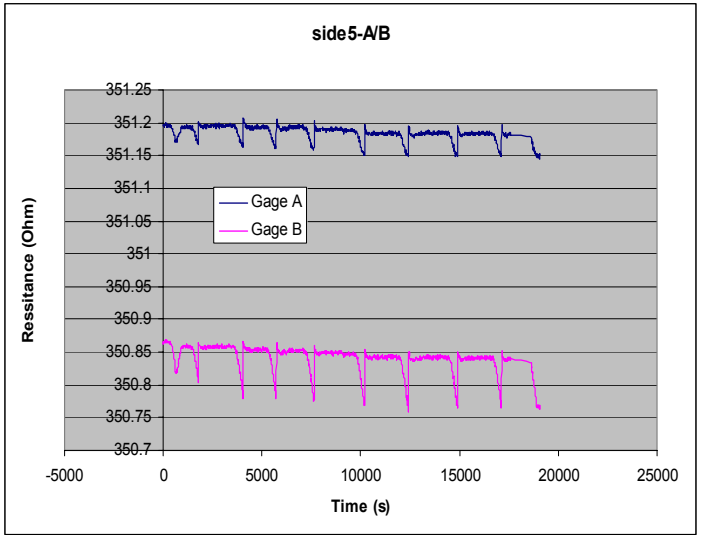
Strain Gage Data – End Bullets

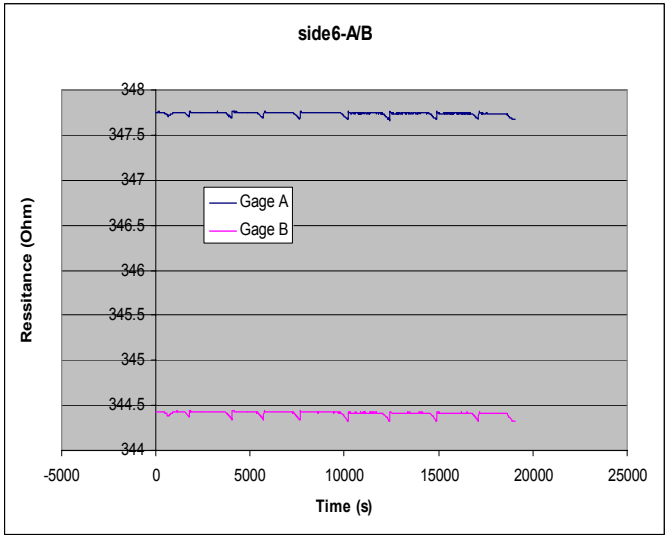


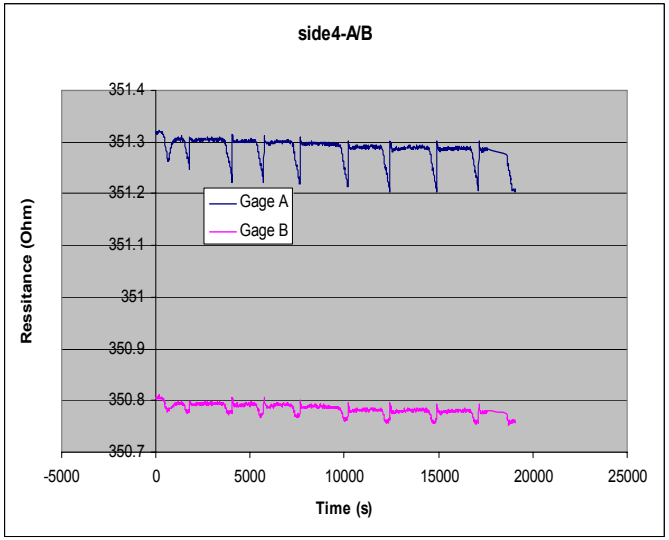


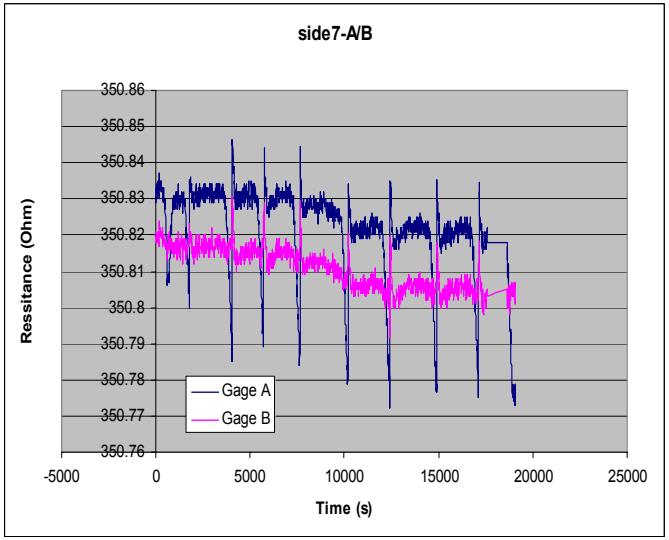
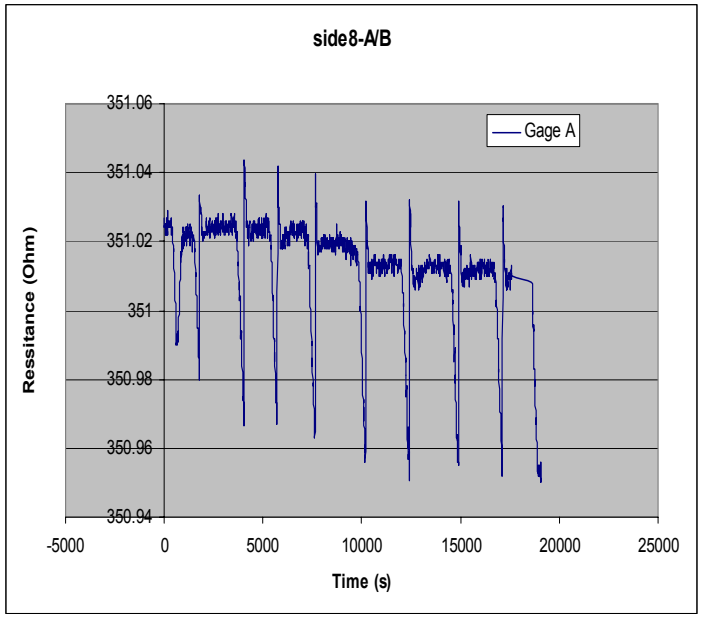
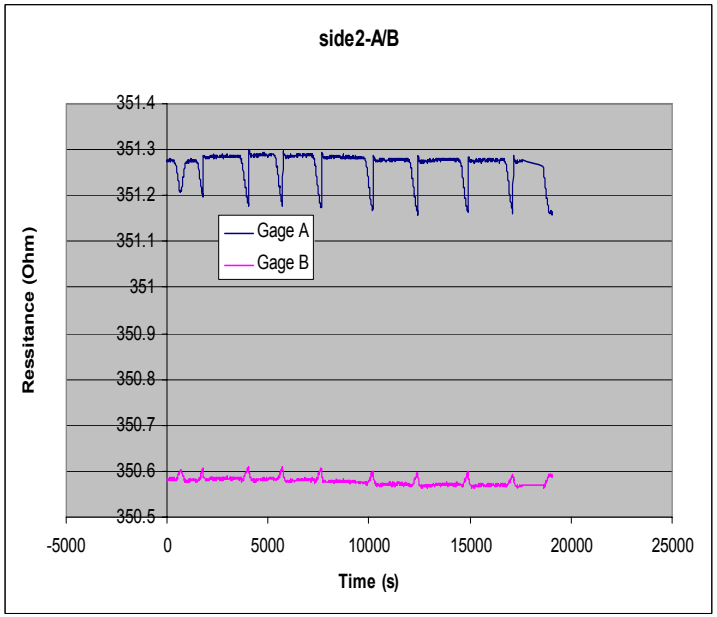
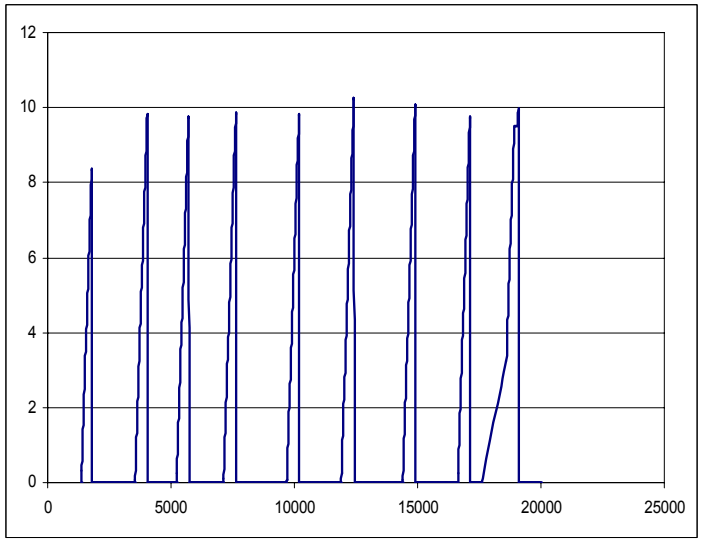


Strain Gage Data – Side Bolts









Strain Gage Data – Side Bolts