NCSX
Short Race-Track Coil Test
At LN2 Temperature

13-May-2004

Test Objective

- Performed cyclic fatigue test of short race-track coil sample SRT3 at liquid nitrogen temperature.
- Goal:
  - 130,000 fatigue cycles at 2X expected strain.
  - Maintain sample at LN2 temperature.
  - Measure sample parameters before, during and after fatigue cycles.

Test Procedure

- Cool down sample coil and test fixture to LN2 temperature.
- Characterize sample coil with several slow pulls before, after and at several points during fatigue cycles.
- Fatigue cycle at high cycle rate (3.8 Hz max) and 15,000 lbf peak load.

Test Sequence

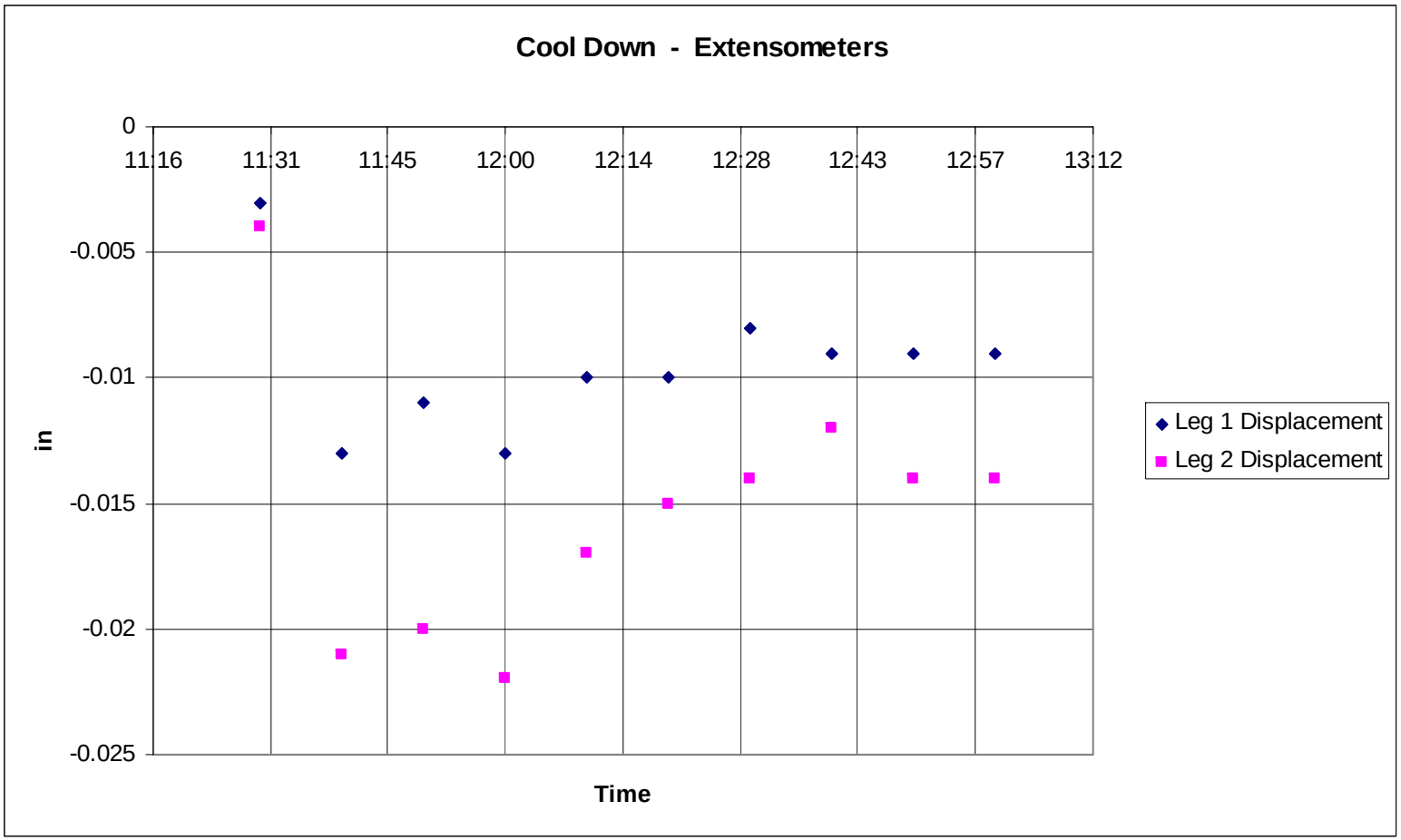
- Cool down coil and fixture
- First slow cycle to 20,000 lbf
- Second slow cycle to 20,000 lbf
- 65,000 rapid cycles to 15,000 lbf
- Slow cycle to 15,000 lbf
- 35,000 rapid cycles to 15,000 lbf (100,000 cycles total)
- Slow cycle to 15,000 lbf
- 50,000 rapid cycles to 15,000 lbf (130,000 cycles total)
- Slow cycle to 15,000 lbf
- First slow cycle to 20,000 lbf
- Second slow cycle to 20,000 lbf
- 20,000 rapid cycles to 15,000 lbf (150,000 cycles total)
- Warm up coil and fixture

Test Data

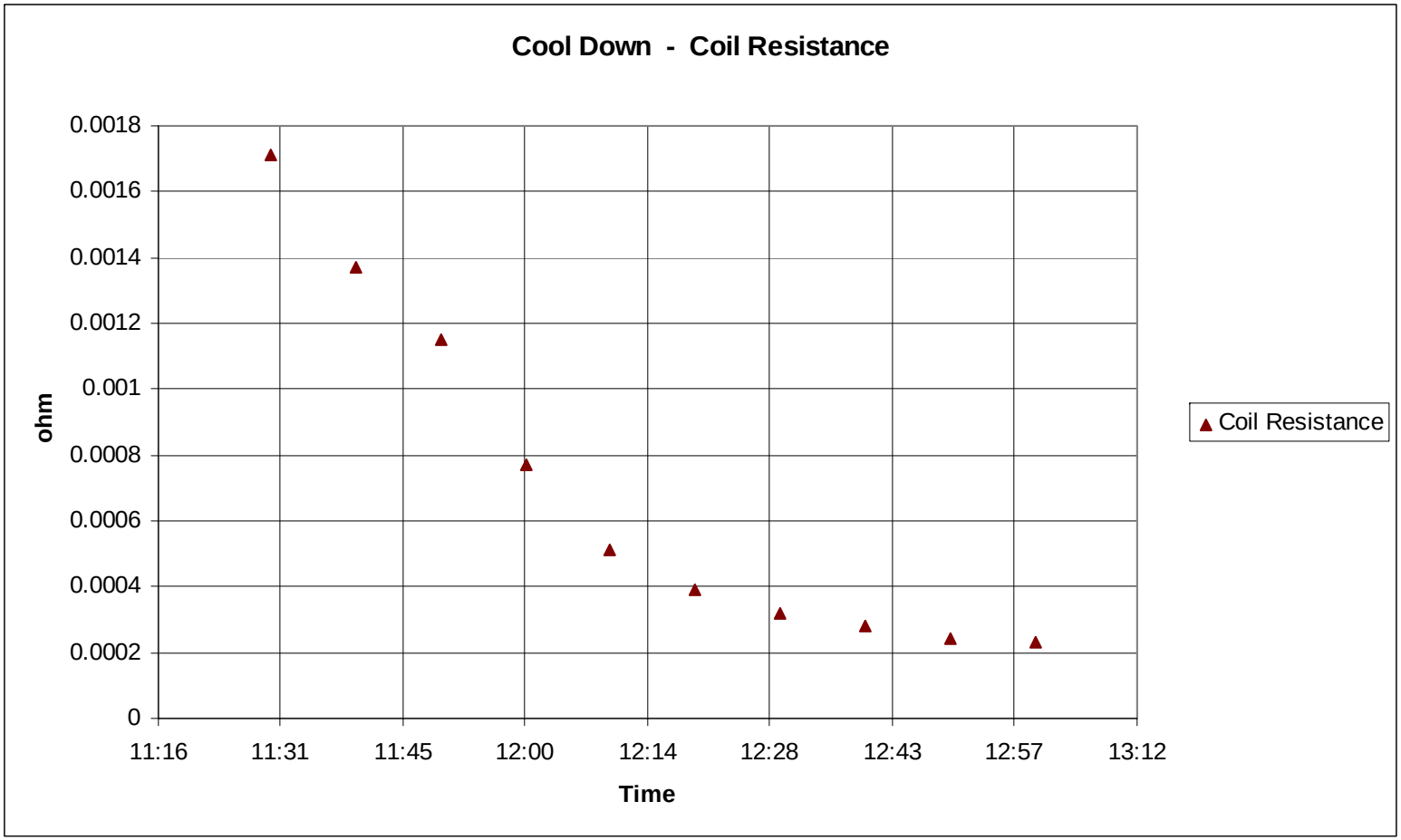
- For stress and modulus calculations used area equal to copper core area plus two layers of 0.007” glass on all sides of core.
- Single conductor area = 0.130 sq in
- Total sample coil area = 1.040 sq in

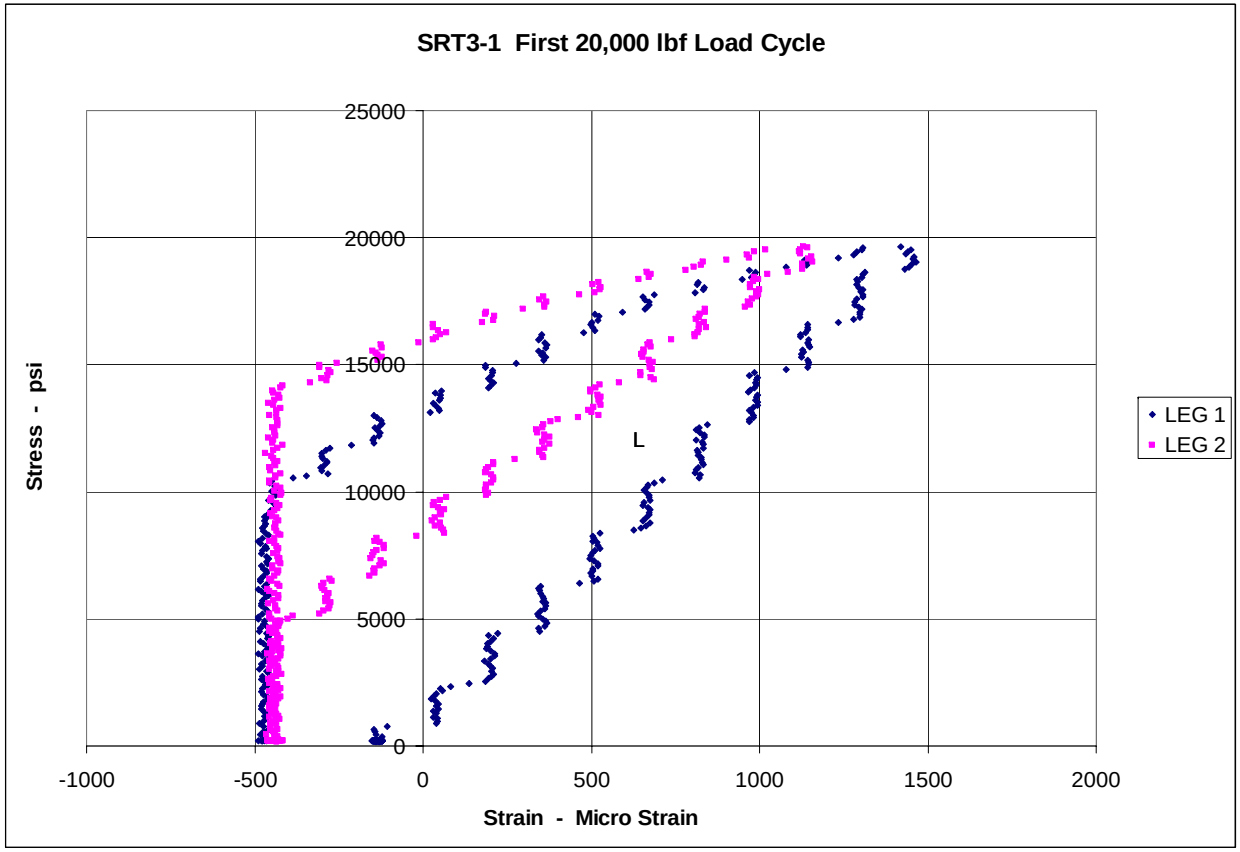
Test Fixture

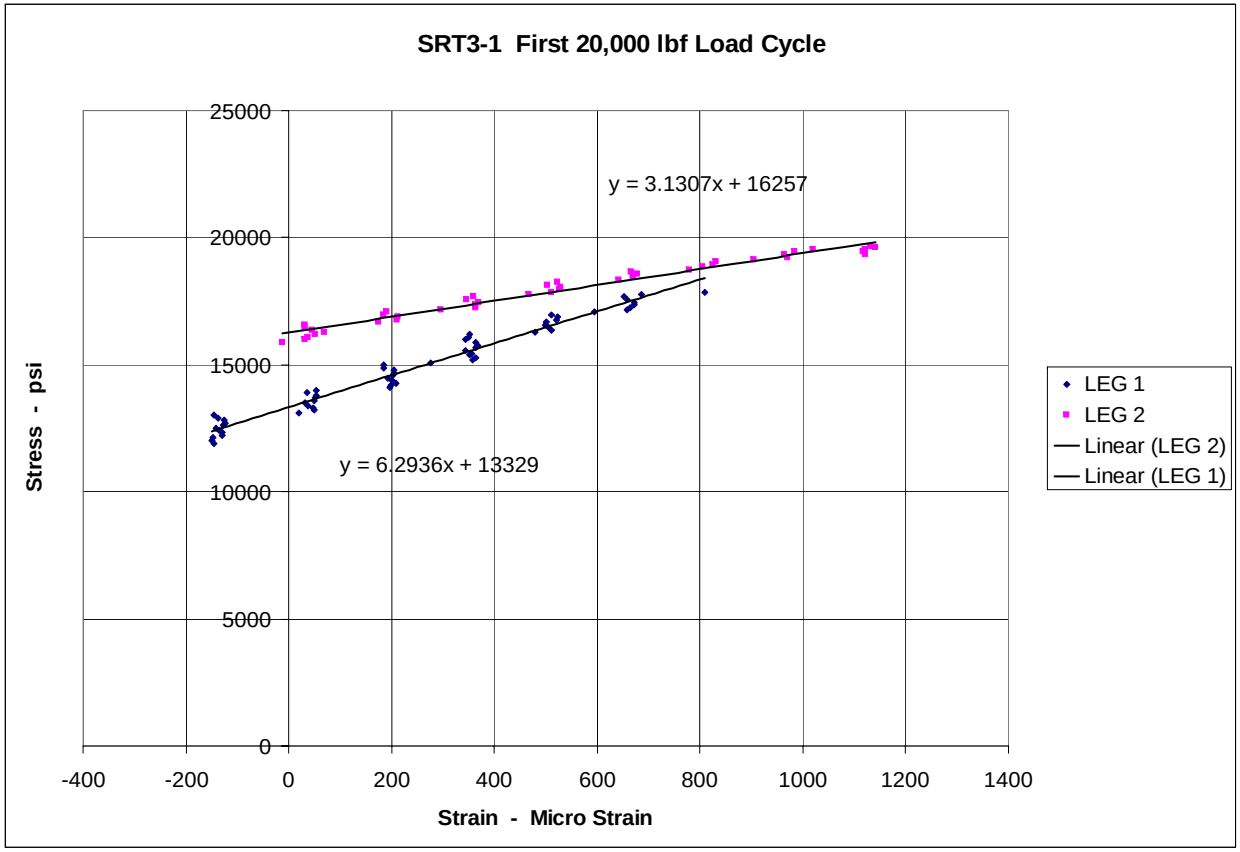
Sample Cool Down

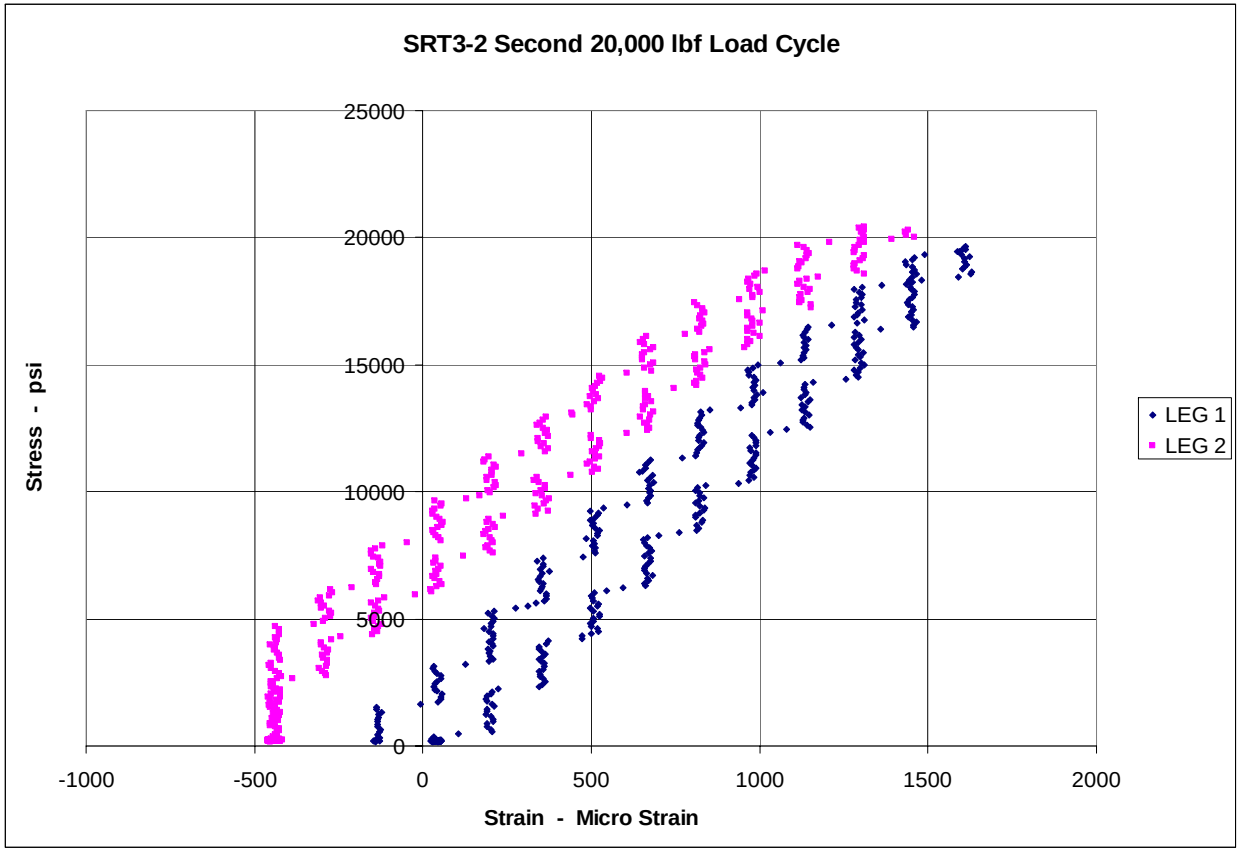


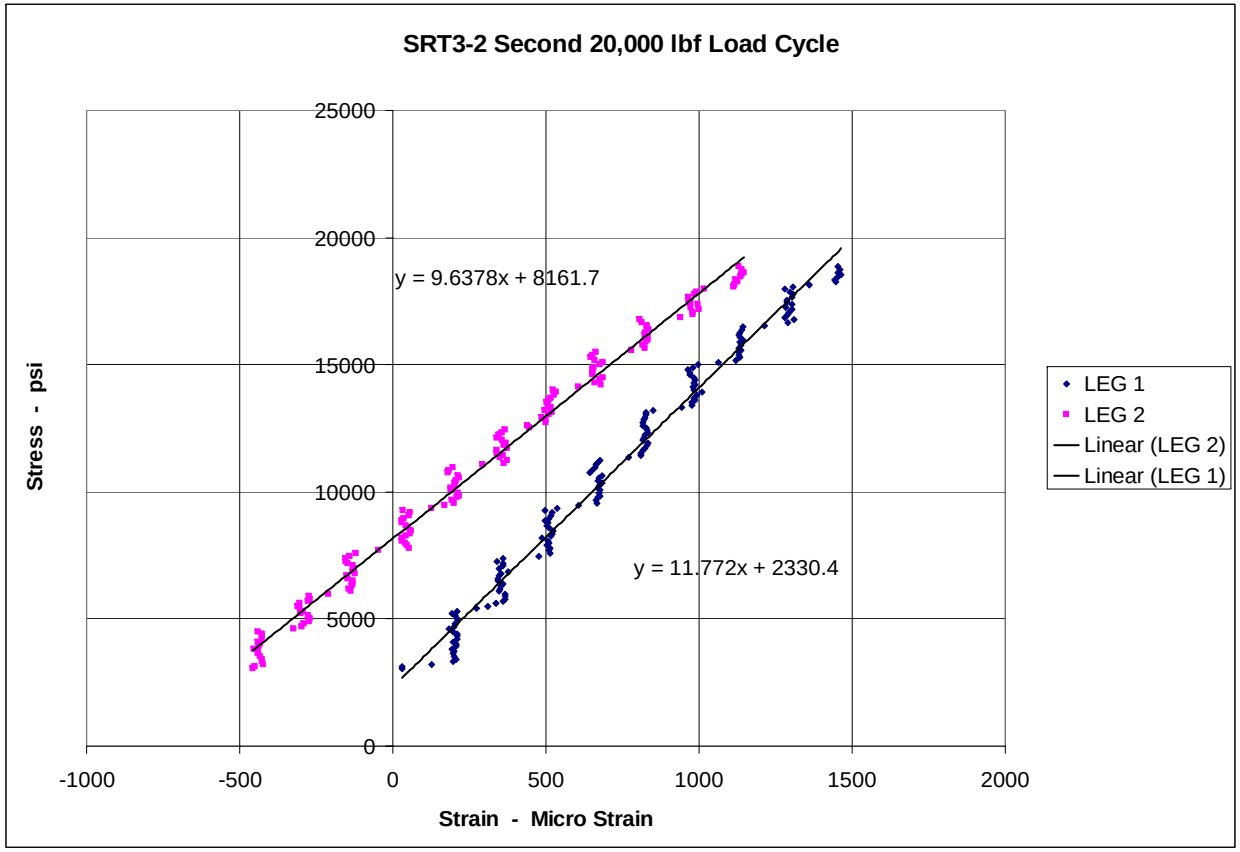
Sample Cool Down

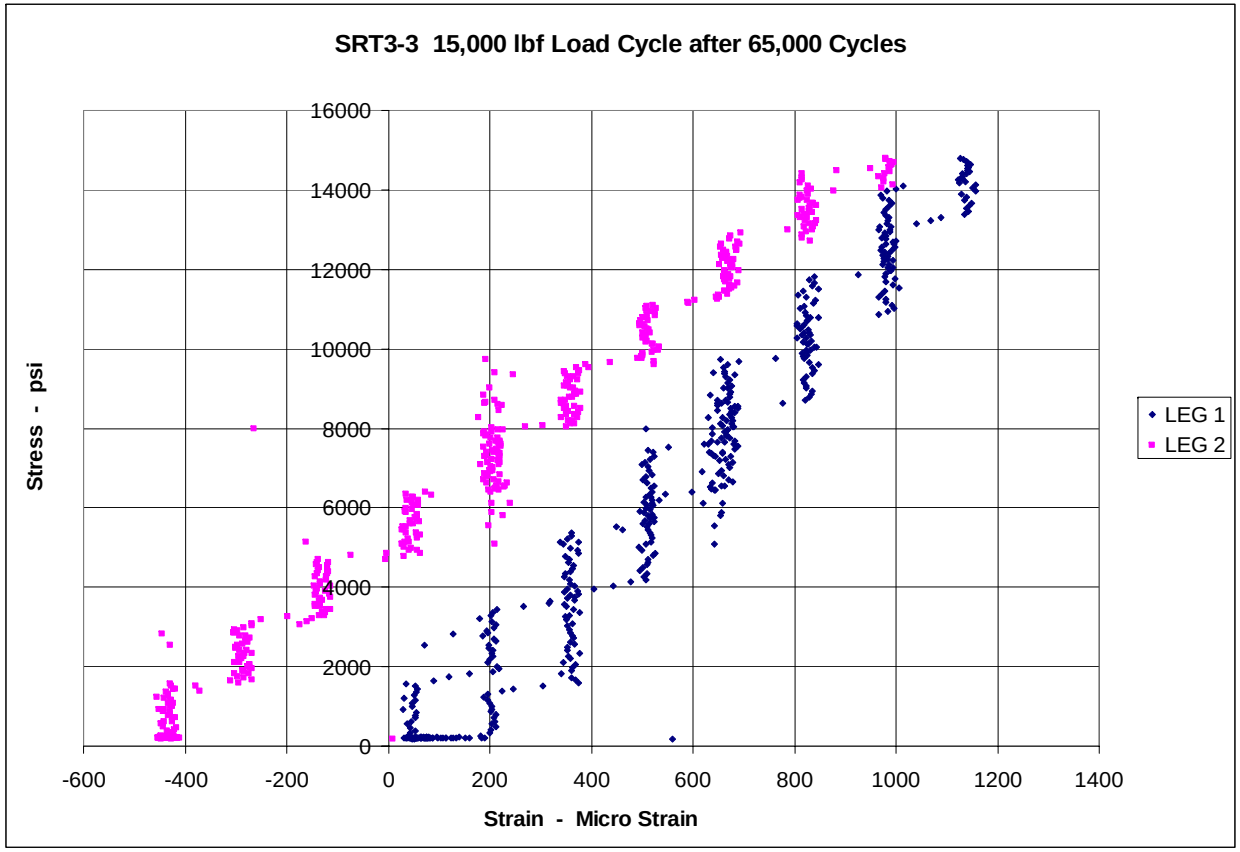


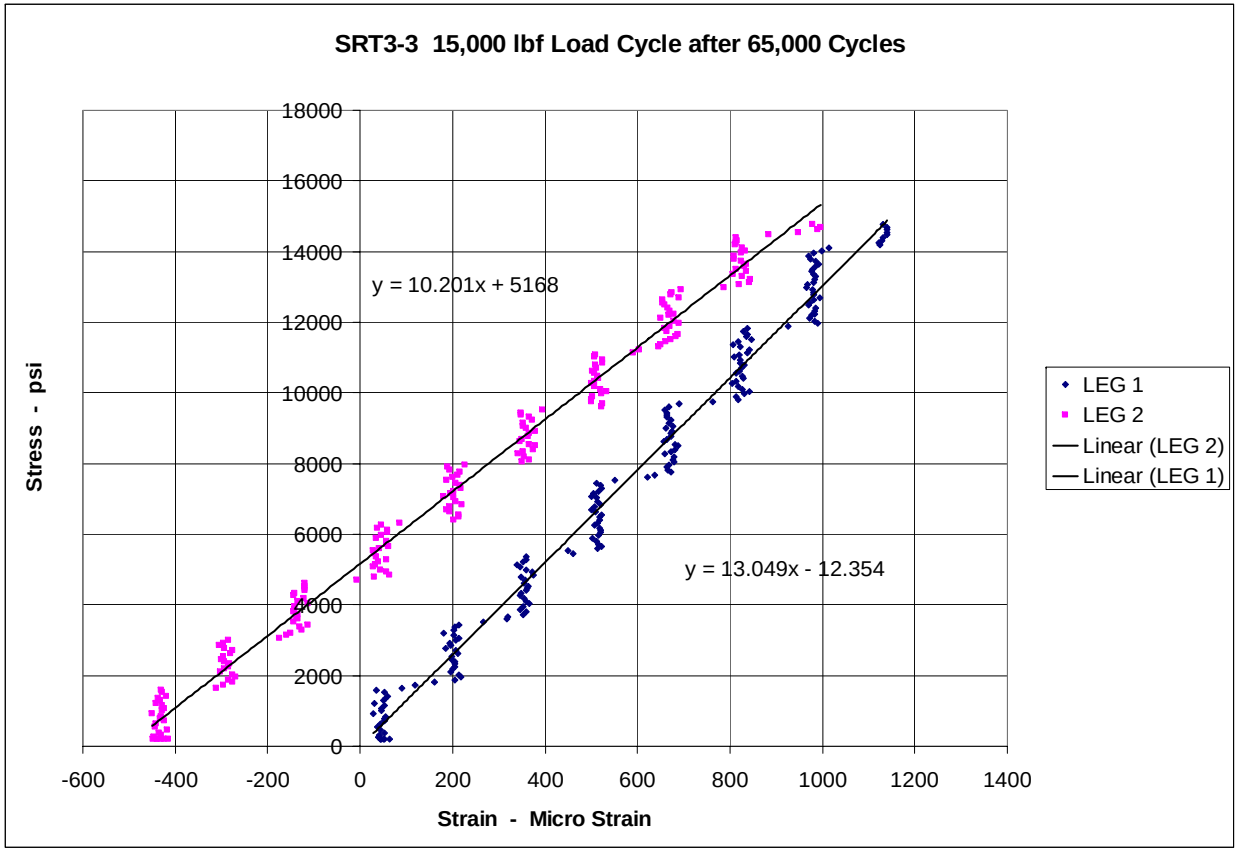

SRT3-1 First 20,000 lbf Load Cycle
Stress - psi
25000
20000
15000
10000
5000
0
-1000
-500
0
500
1000
1500
2000
Strain - Micro Strain
LEG 1
LEG 2

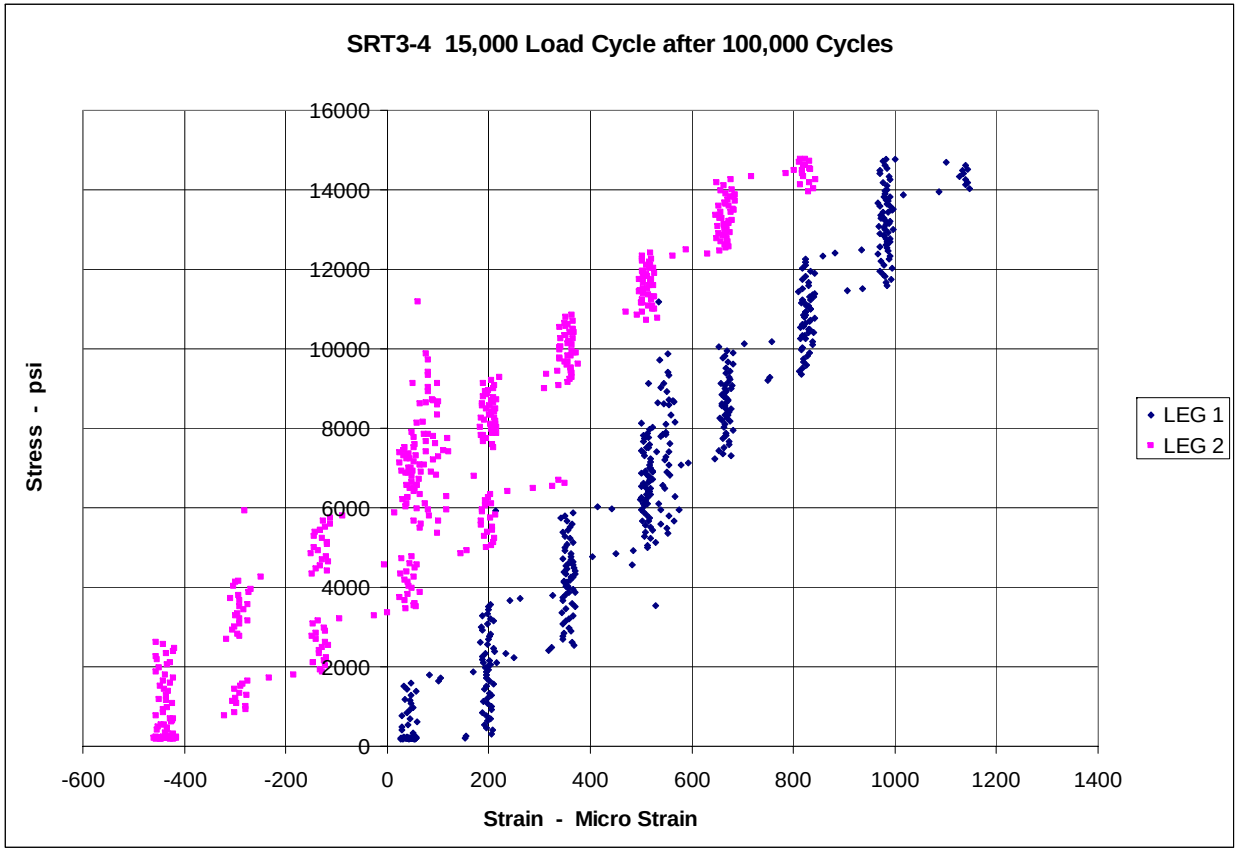

SRT3-1 First 20,000 lbf Load Cycle
Stress - psi
Strain - Micro Strain
y = 3.1307x + 16257
y = 6.2936x + 13329
25000
20000
15000
10000
5000
0
-400
-200
0
200
400
600
800
1000
1200
1400
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)

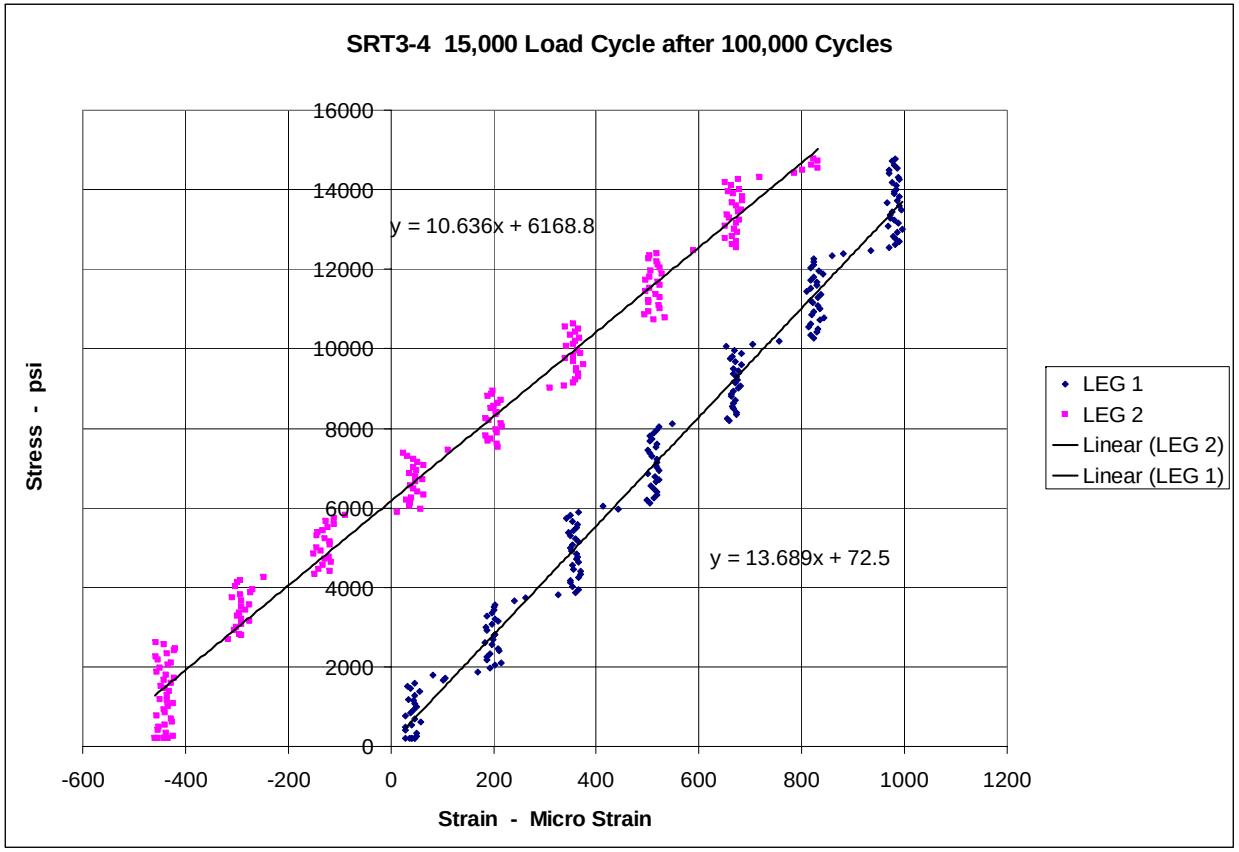

SRT3-2 Second 20,000 lbf Load Cycle
Stress - psi
25000
20000
15000
10000
5000
0
-1000
-500
0
500
1000
1500
2000
Strain - Micro Strain
LEG 1
LEG 2

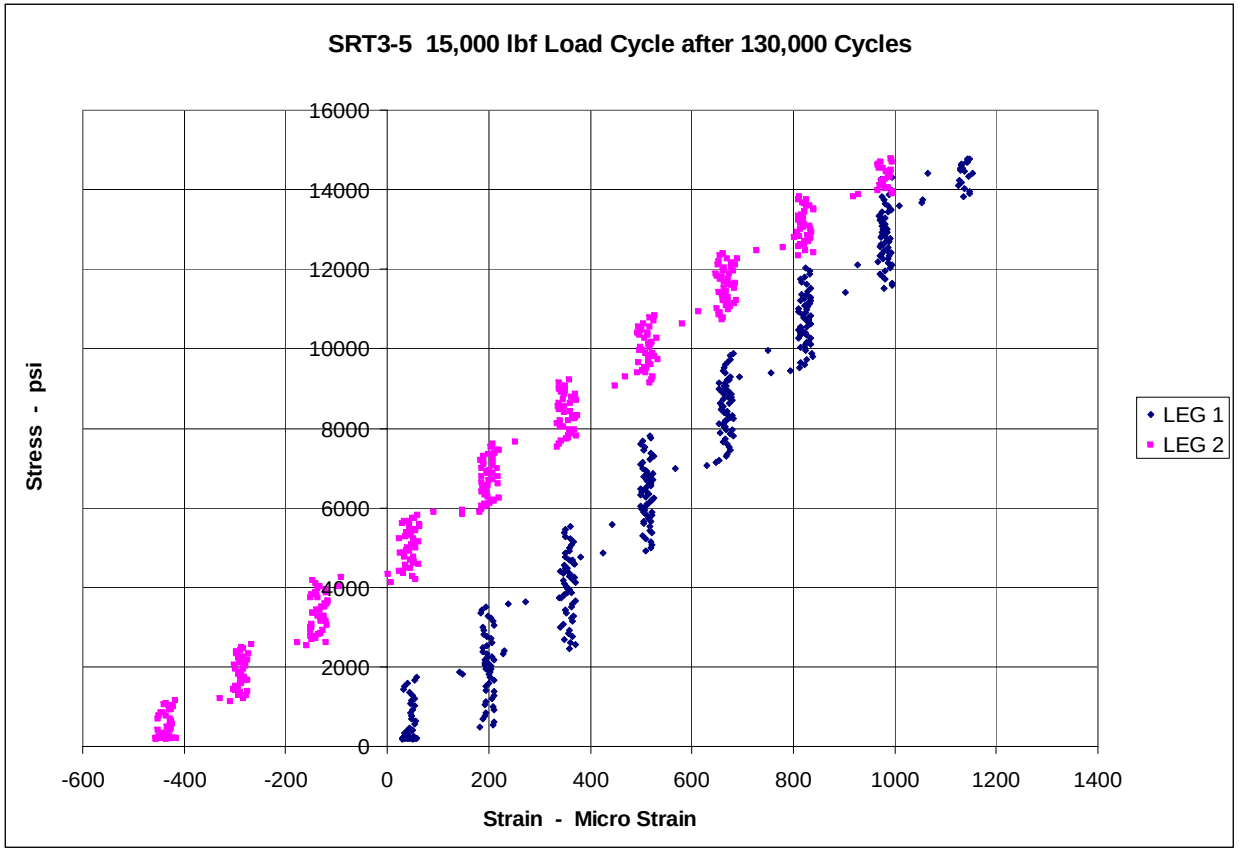

SRT3-2 Second 20,000 lbf Load Cycle
Stress - psi
Strain - Micro Strain
25000
20000
15000
10000
5000
0
-1000
-500
0
500
1000
1500
2000
y = 9.6378x + 8161.7
y = 11.772x + 2330.4
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)

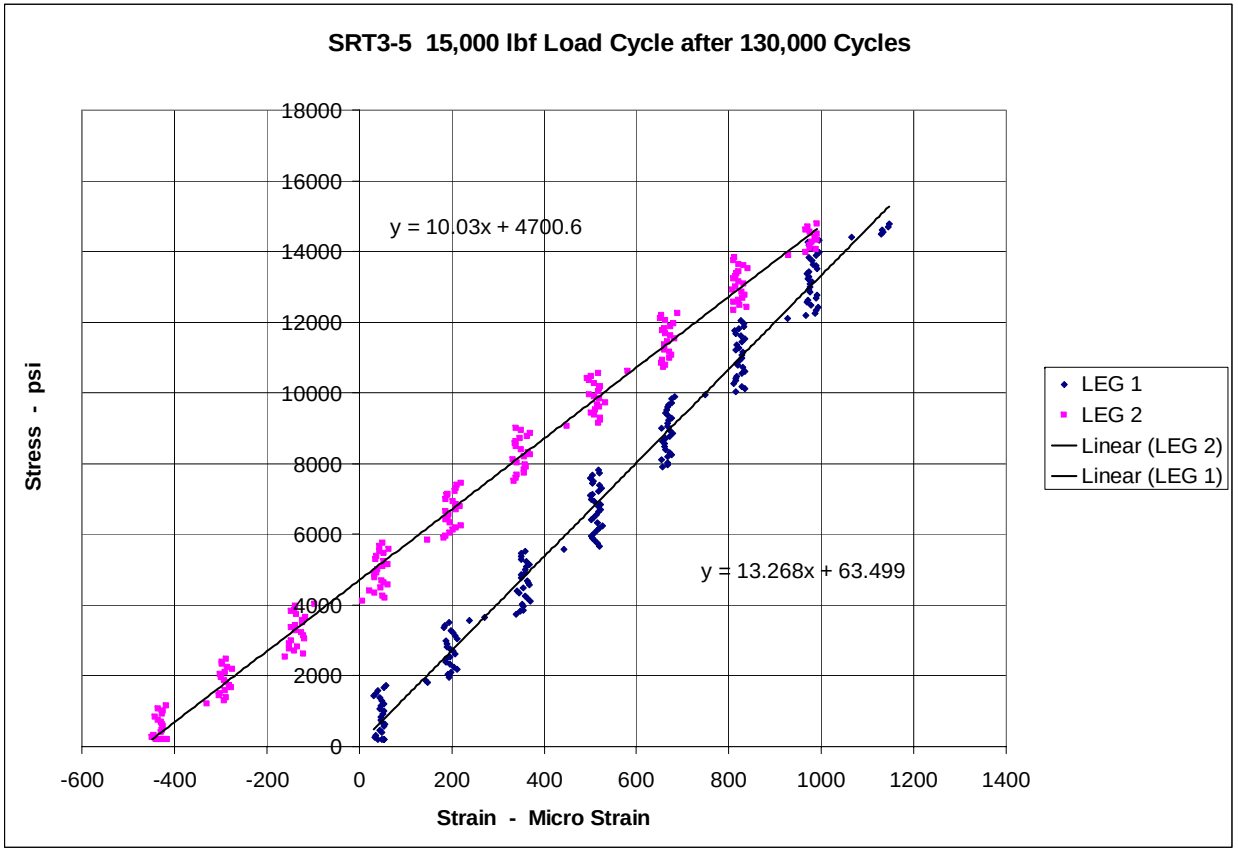

SRT3-3 15,000 lbf Load Cycle after 65,000 Cycles
Stress - psi
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
1400
Strain - Micro Strain
LEG 1
LEG 2

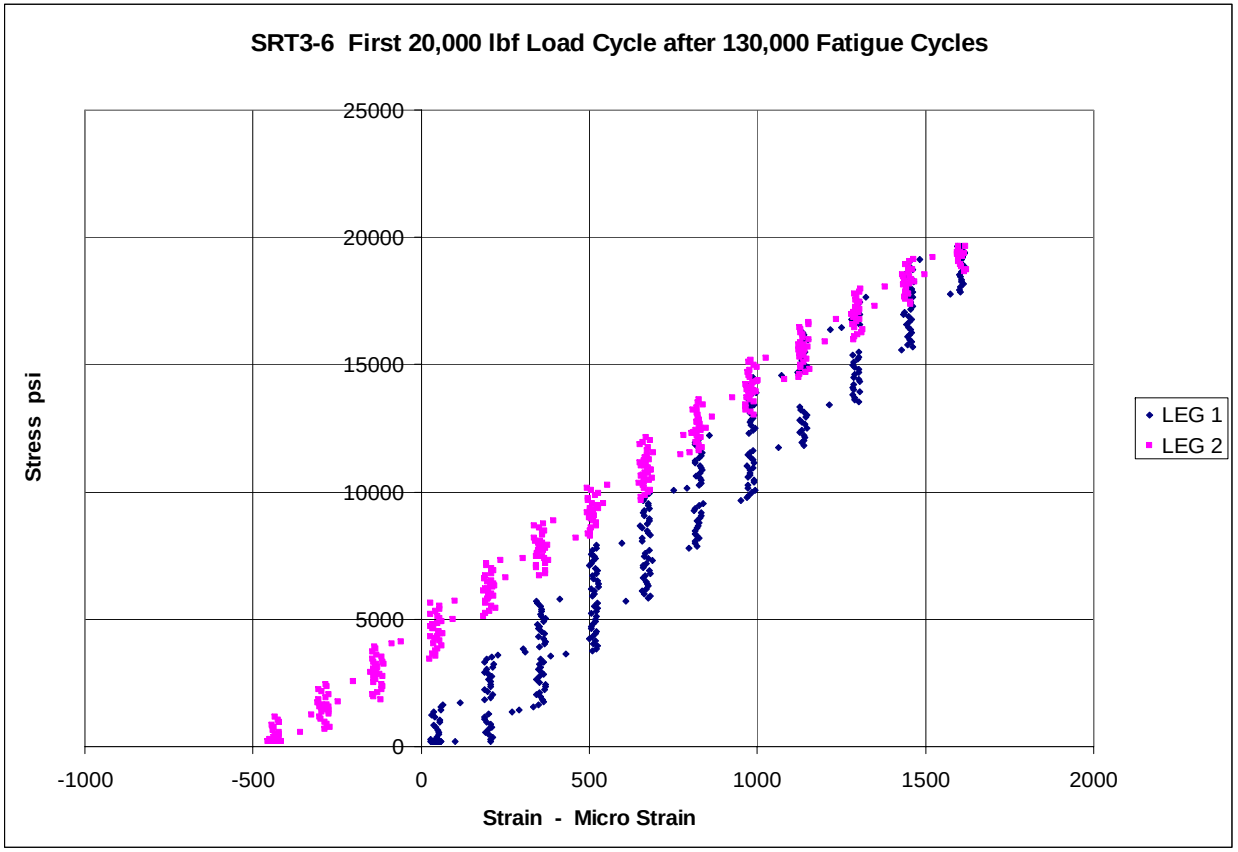

SRT3-3 15,000 lbf Load Cycle after 65,000 Cycles
Stress - psi
Strain - Micro Strain
y = 10.201x + 5168
y = 13.049x - 12.354
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
1400

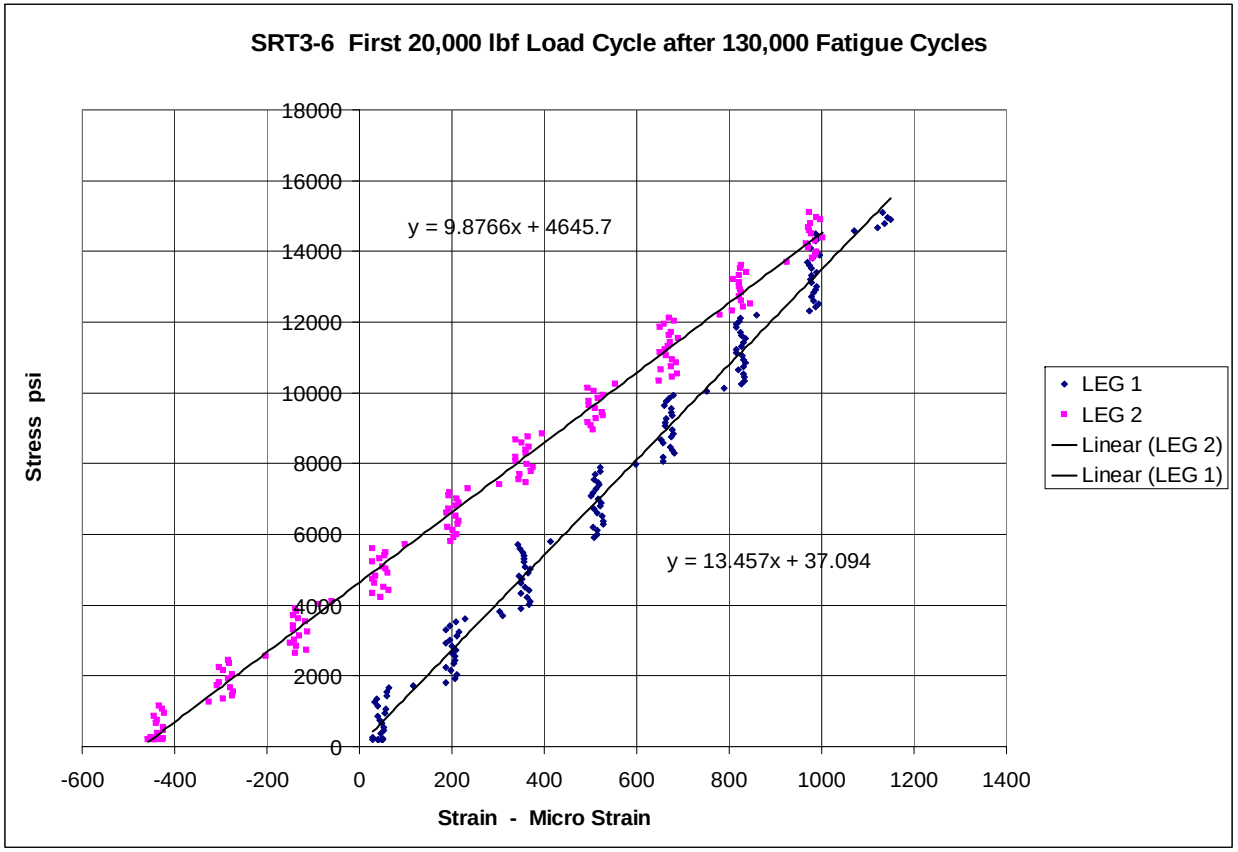

SRT3-4 15,000 Load Cycle after 100,000 Cycles
Stress - psi
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
1400
Strain - Micro Strain
LEG 1
LEG 2

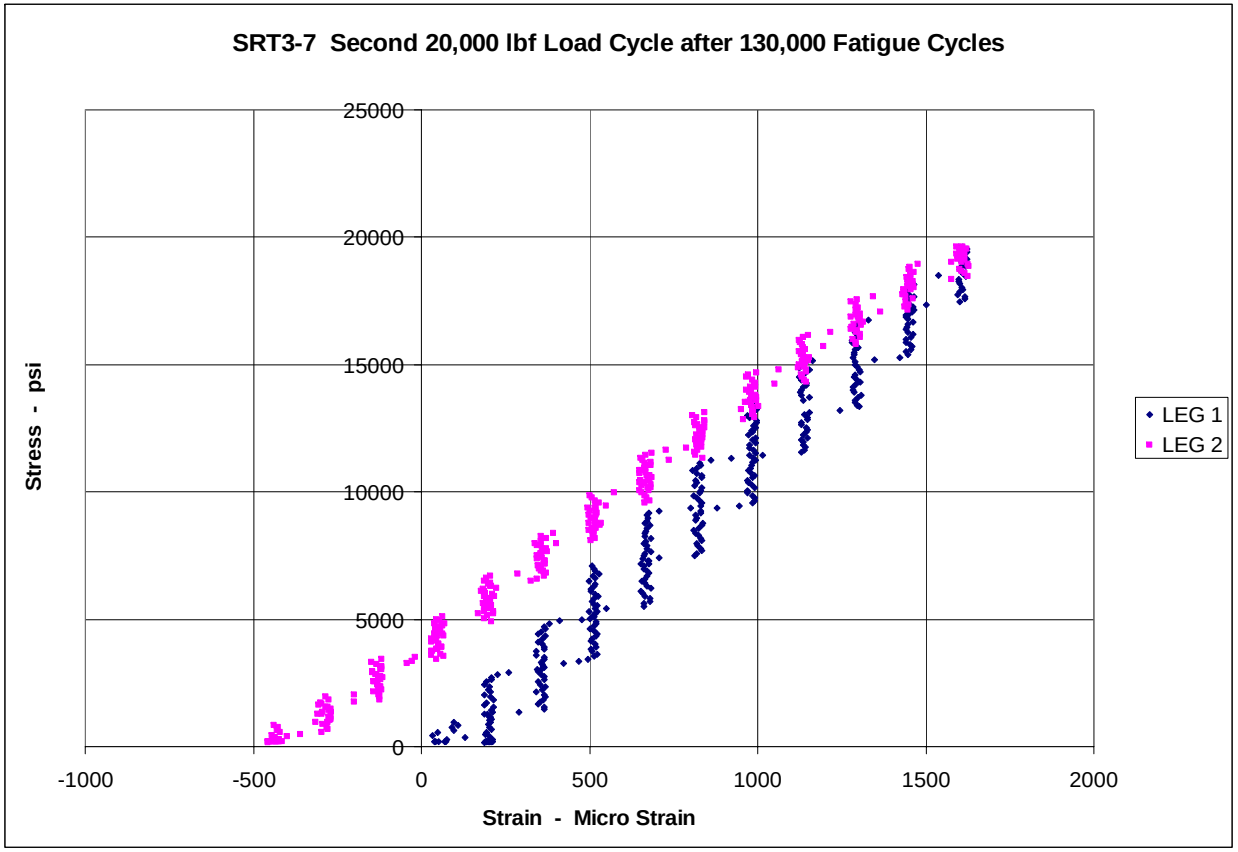

SRT3-4 15,000 Load Cycle after 100,000 Cycles
Stress - psi
Strain - Micro Strain
y = 10.636x + 6168.8
y = 13.689x + 72.5
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)

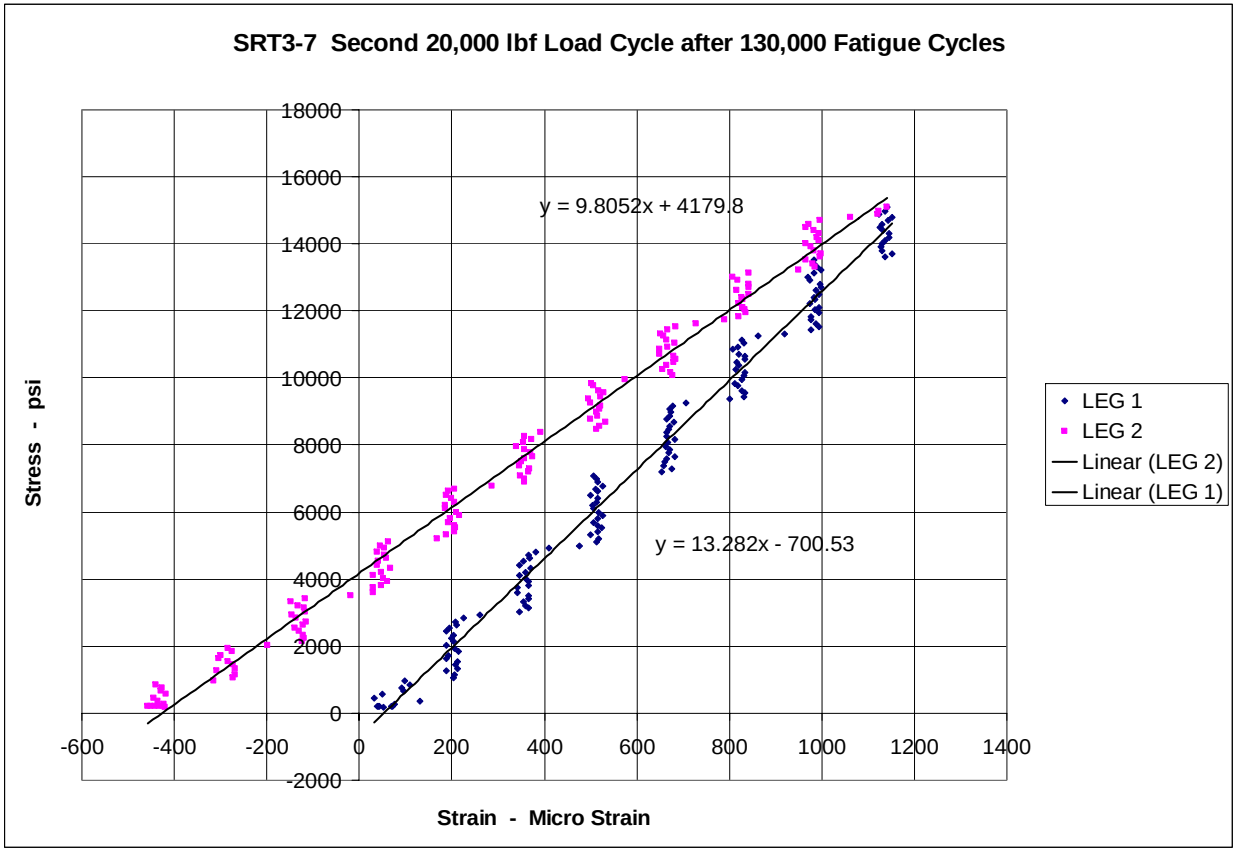

SRT3-5 15,000 lbf Load Cycle after 130,000 Cycles
Stress - psi
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
1400
Strain - Micro Strain
LEG 1
LEG 2


SRT3-5 15,000 lbf Load Cycle after 130,000 Cycles
Stress - psi
Strain - Micro Strain
y = 10.03x + 4700.6
y = 13.268x + 63.499
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
1400


SRT3-6 First 20,000 lbf Load Cycle after 130,000 Fatigue Cycles
Stress psi
25000
20000
15000
10000
5000
0
-1000
-500
0
500
1000
1500
2000
Strain - Micro Strain
LEG 1
LEG 2


SRT3-6 First 20,000 lbf Load Cycle after 130,000 Fatigue Cycles
Stress psi
Strain - Micro Strain
y = 9.8766x + 4645.7
y = 13.457x + 37.094
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-600
-400
-200
0
200
400
600
800
1000
1200
1400


SRT3-7 Second 20,000 lbf Load Cycle after 130,000 Fatigue Cycles
Stress - psi
25000
20000
15000
10000
5000
0
-1000
-500
0
500
1000
1500
2000
Strain - Micro Strain
LEG 1
LEG 2


SRT3-7 Second 20,000 lbf Load Cycle after 130,000 Fatigue Cycles
Stress - psi
Strain - Micro Strain
y = 9.8052x + 4179.8
y = 13.282x - 700.53
LEG 1
LEG 2
Linear (LEG 2)
Linear (LEG 1)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-600
-400
-200
0
200
400
600
800
1000
1200
1400

Modulus Summary

Test Cycle File	Test Cycle Peak Load lbf	Cumulative Fatigue Cycles	Leg 1 Modulus Msi	Leg 2 Modulus Msi	Average Modulus Msi
SRT3-1	20,000	0	6.3	3.1	4.7
SRT3-2	20,000	0	11.8	9.6	10.7
SRT3-3	15,000	65,000	13.0	10.2	11.6
SRT3-4	15,000	100,000	13.7	10.6	12.2
SRT3-5	15,000	130,000	13.3	10.0	11.7
SRT3-6	20,000	130,000	13.5	9.9	11.7
SRT3-7	20,000	130,000	13.2	9.8	11.5
Average (excluding first cycle)			13.1	10.0	11.6

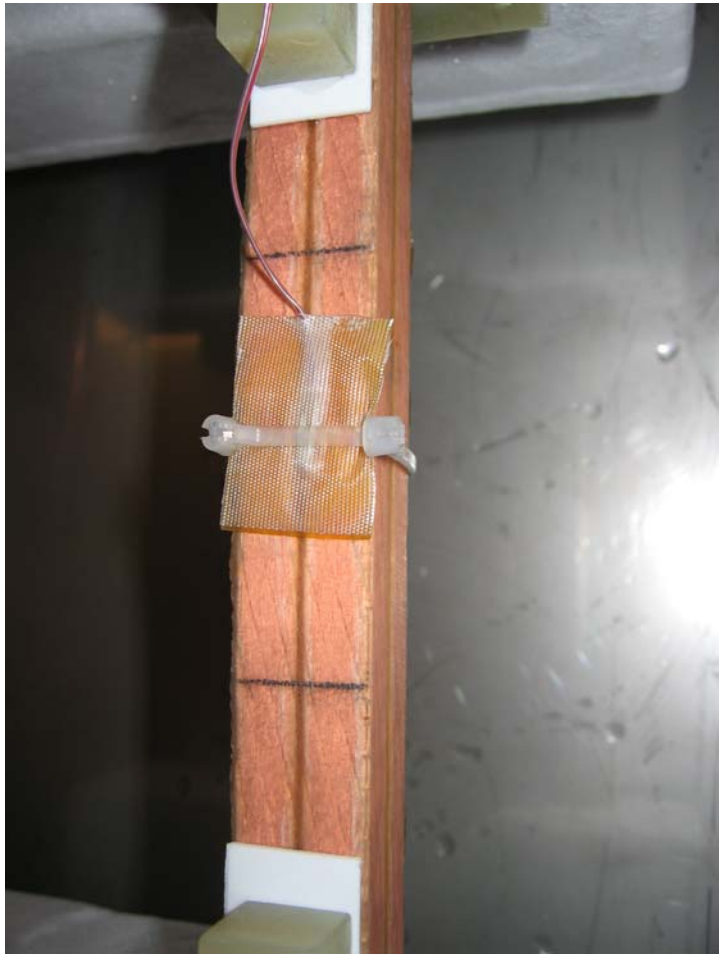
Modulus Results

- The variation in the tensile modulus between the two legs is probably the result of unequal load sharing.
- The average modulus is representative for the strain resulting from a uniform stress over the total cross-section.

Coil Condition After Fatigue Cycles

- The race-track coil legs are in excellent condition after the 150,000 load cycles.
- Leg 1 (in left picture, next slide) has a casting mark in the center from the manufacturing process, not the cycle testing.
- Leg 2 has a thermocouple attached to its front face.
- No change in coil resistance from fatigue cycling.

Coil Legs After 150,000 Cycles to 15,000 lbf



Next Tests

- This sample, SRT3, will be slow cycled at room temperature to provide comparative modulus values.
- Two more short race-track coils will be cycle tested at LN2 temperature.
- One sample will have a variation in the attachment of the pin block in an attempt to improve the leg-to-leg load equalization.