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Evaluation of GE-167 Silicone Rubber (RTV) For Possible Service As A Moisture-Barrier For Certain Strain Gage Applications

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April 2000

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Evaluation of GE-167 Silicone Rubber (RTV) For Possible Service As A Moisture-Barrier For Certain Strain Gage Applications

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Abstract

The Langley Research Center uses strain gages in a wide variety of demanding test environments. Strain gage installations, depending on the testing scenario, may see high temperatures, cryogenic temperatures, moisture accumulation, mechanical abuse, or any combination of these conditions. At Langley, there is often a need to provide protection for strain gages against moisture and mechanical abuse, especially when large-scale, harsh environment testing is to be encountered. This technical memorandum discusses the evaluation of a room-temperature curing silicone rubber sealant manufactured by the General Electric Company for consideration as a moisture-barrier for certain strain gage installations.

Introduction

In-service performance of a General Electric Company silicone rubber sealant, type: GE-167, by a private sector firm, indicated that this material excelled as a moisture-barrier for a strain gaged structural component. The component was an instrumented railroad wheel that was exposed to nature's elements during long-term testing in a high-humidity environment in South America. This RTV sealant was applied over the strain gages and wiring on the face of the wheel. The strain gage installations have survived for several years with no gage failures reported. Now, this sealant has been evaluated under various laboratory test conditions in Langley's Strain Gage Test and Development Laboratory for consideration as a strain gage moisture-barrier for future test programs at Langley. The testing that was conducted is presented with accompanying test results.

Instrumenting the Beams for Testing

Three laboratory-type constant strain test beams were instrumented with one "four-active-arm" strain gage bridge on each beam. Figure 1 is representative of the gaging plan that was used on the three beams. Note #1 in the figure references NASA Technical Memorandum 110327 for applying and wiring gages. A temperature sensor (platinum RTD) was installed on each beam beside the strain gages for monitoring and recording temperature. The three beams were ultimately moisture-proofed with a General Electric Company silicone rubber sealant (RTV) type: GE-167.

Materials Involved in Testing

The three test beams were standard Langley constant strain test beams made of a nickel-based maraging steel (the industry trade name is "Vascomax"). Each beam was strain gaged to respond to bending loads using typical transducer-type application procedures (Figure 1). The strain gages were Measurements Group, type: WK-06-125AD-350. The gaging adhesive was Measurements Group, type: M-BOND 610. Strain gage wiring was Tensolite Wire, size AWG 32, stranded copper with teflon insulation. The wiring insulation was treated to promote bonding of the RTV. The temperature sensors were HyCal platinum RTD's, type: EL-700T. The silicone rubber sealant was General Electric, type: GE-167.

Test Apparatus and Data Acquisition

Load tests were performed on the strain gaged test beams using a standard laboratory-type cantilever loading fixture and dead weights. The environmental test chamber was a Delta 9000 Series temperature chamber with cryogenic and elevated temperature capabilities. The data acquisition system consisted of a HP 3457A multimeter, a Fluke Hydra 2625A data logger, and a HP 6113A DC power supply. The HP 3457A multimeter was used to read strain gage Wheatstone bridge outputs. The bridge outputs were nulled to zero at the onset of data acquisition. The Fluke Hydra 2625A data logger read the PRT temperature outputs, and the HP 6113A DC power supply powered the strain gage bridges. These instruments were linked with a PC AT 6x86 120 MHz computer through GPIB and RS-232 connections. The system was controlled using a commercially available Labview (Labview Graphical Programming Language for Instrumentation) program that received and plotted the data in real time during data acquisition. The data were organized into spreadsheet format and saved as text files at the conclusion of a given test cycle. Data reduction and permanent plots were achieved using Microsoft Excel.

Types of Tests

Three distinctly different types of tests were performed on the strain gaged test beams. These tests consisted of water-soak testing, apparent strain characterization runs, and cantilever dead weight loadings. The tests were conducted in a particular sequence in order to maximize the amount of data obtainable with each beam. The water-soak testing consisted of a series of tests in which the moisture-proofed beams were placed in a tray of tap water and resistance leakage to ground measurements were made over a specified period of time. The apparent strain characterization runs were performed prior to, and following, the application of the moisture-barrier in order to determine the effects on the apparent strain curves due to the addition of the sealant. Dead weight loadings were performed on the beams, again, prior to and following the application of the moisture-barriers. This was done in order to determine the amount of reinforcing (or stiffening) of the beam caused by the addition of the RTV. A decrease in the sensitivity of the strain gage signals would indicate such a reinforcing effect.

Initial Room Temperature Load Testing Configuration

Once the beams were instrumented (prior to moisture-proofing), room temperature bending load testing was conducted on each of the three beams that was to ultimately receive the RTV-167 sealant. Each beam was placed in a standard laboratory cantilever load fixture using a knife-edge type load hanger. The beams were then incrementally loaded and unloaded using dead weights. Baseline load data at room temperature were recorded. Also, prior to applying the RTV-167, apparent strain characterization runs were performed at temperatures up to 180°F. Subsequently, the RTV was applied to the test beams and the baseline loading tests were repeated. Individual loadings were repeated in order to determine the level of data repeatability, hysteresis, and zero shifts.

Room Temperature Load Data Results for Test Beam #250-3

The load data from Test Beam #250-3 revealed that after the RTV-167 was applied to the beam the full-scale output of the bridge was reduced from 4.819mV to 4.742mV. This was a 1.59% reduction in sensitivity (Figure 2). Following this testing, a series of apparent strain characterization runs were conducted. These runs subjected the beam to temperatures ranging from room temperature to 400°F, down to -150°F, and return to room temperature. The baseline loading schedule was then repeated. The data indicated a slight increase in the full-scale output from 4.742mV to 4.756mV. Although the temperature cycles had a tendency to restore the output to its original sensitivity, the data still reflect a total reduction in sensitivity of 1.29% following the apparent strain runs. This is also shown in Figure 2.

Room Temperature Load Data Results for Test Beam #200-4

The load data from Test Beam #200-4 revealed that after the RTV-167 was applied to the beam the full-scale output of the bridge was reduced from 4.877mV to 4.805mV. This was a 1.50% reduction in sensitivity (Figure 3). Following this testing, a series of apparent strain characterization runs were conducted. These runs subjected the beam to temperatures ranging from room temperature to 400°F, down to -150°F, and a return to room temperature. The baseline loading schedule was then repeated. The data indicated a slight increase in the full-scale output from 4.805mV to 4.819mV which was a .29% increase in sensitivity following the apparent strain runs. This is also shown in Figure 3.

Room Temperature Load Data Results for Test Beam #200-CVM

The load data from Test Beam #200-CVM revealed that after the RTV-167 was applied to the beam the full-scale output of the bridge was reduced from 5.020mV to 4.987mV. This was a 0.67% reduction in sensitivity (Figure 4). Following this testing, a series of apparent strain characterization runs were conducted. These runs subjected the beam to temperatures ranging from room temperature to 400°F, down to -275°F, and a return to room temperature. This extreme cold temperature caused the RTV-167 to produce macro-cracking large enough to jeopardize its usefulness as a moisture-barrier. This cracking is shown in the photo in Figure 10. Due to the fact the RTV had been compromised, no repeat loadings were conducted.

Load Data Results - Conclusions
It is evident from the load data generated with these three test beams, that the addition of the RTV-167 does have a reinforcing effect on the test beam itself. The reduction in output of the strain gage signals with the RTV-167 applied is a clear indication of a reduction in stress in the strain gaged areas of the beams. Also, the slight increase in the output signals (back toward the original outputs prior to application of the RTV) following the apparent strain characterization runs may indicate a change in the modulus of the silicone rubber. This may have occurred as a function of thermally cycling the RTV to elevated and cryogenic temperatures. It should be noted that the RTV-167 was applied to a thickness that approximated that of the test beam thickness. The RTV was applied over the exposed strain gage solder joints and extended to the shoulder of the metric end of the test beam. This was an excessive amount of RTV in the load path of a relatively thin cantilever test beam. A photo in Figure 10 shows the RTV as applied to the three beams.

Initial Apparent Strain Tests (from Room Temperature to 180°F)

Following the initial room temperature dead-weight loadings and prior to the application of the moisture-barriers, apparent strain runs were conducted on each of the three beams. An initial apparent strain characterization run was conducted for each beam. The run was from room temperature to 180°F and return to room temperature. A second run was then conducted in the same manner to determine the level of data repeatability, hysteresis, and zero shifts. The curves generated with these runs were representative of curves provided by the strain gage manufacturer.

Application of GE-167 RTV

With the initial load data and apparent strain data completed for the beams prior to the application of the moisture-barrier, the beams were ready to be "moisture-proofed". The General Electric RTV, GE-167 was applied to the three beams. Application of the GE-167 required the use of a silicone primer. Type: SS-4179 from General Electric was used. Once the primer set, the GE-167 was applied over all solder joints and leadwire insulation in the areas near the gages. None of the sealant was applied directly over the strain gage active grid convolutes. The coating, approximately 1/16" thick, was cured overnight at room temperature. Again, Figure 10 shows the RTV as it was typically applied to the beams.

Second Series of Apparent Strain Tests (from Room Temperature to 180°F)

This testing was conducted with the moisture-barriers on the beams. The purpose was to determine how much effect, if any, the addition of the sealant had on the apparent strain signatures of each bridge. The runs were made in an identical manner to the initial apparent strain tests. Figure 5 shows a typical slope for "before" and "after" the addition of the moisture-barrier to the strain gages on one of the test beams. The plot shows the "before" data as an output at discreet temperatures and the "after" data is a continuous plot of the bridge output throughout the temperature excursion. Changes in the slopes of the apparent strain curves following the application of the RTV-167 were negligible.

Extended Temperature Apparent Strain Testing

Following the initial apparent strain testing, apparent strain runs were conducted to 400°F and down to temperatures in the cryogenic range. The three beams with the GE-167 RTV sealant still in place were placed in the temperature chamber as before and apparent strain runs were conducted to 400°F. Repeatability and zero shift were of prime interest for this series of runs. The plot in Figure 6 for test beam 200-CVM shows that repeatability and zero shifts for the 400°F runs were comparable to the original 180°F runs for this beam (see Figure 5) and this degree of repeatability was representative for the other two beams. The cryogenic runs, however, revealed the inability of this RTV to serve as a moisture-barrier for strain gages at temperatures of -100°F or colder. Two of the three beams were subjected to temperature excursions down to -150°F. The third beam was subjected to apparent strain runs down to -275°F. The apparent strain signatures observed with the two test beams down to -150°F were not typical of those historically observed with this type of strain gage bridge on this type of test beam. As shown in Figure 7 and Figure 8 there was a precipitous change in slope at approximately -100°F. Additionally, repeatability was not as good as observed when going hot. Beam 200-CVM generated a more predictable curve (Figure 9) but, as shown, the second run was not repeatable. Because the slope with this beam was linear down to -150°F it was decided to continue the cryogenic run down to -275°F. Unfortunately, this temperature caused the RTV-167 to crack. This cracking is shown in the photo in Figure 10.

Wet-soak Testing

A final test of the sealant's ability to protect the strain gage installation from water damage was performed following the extended temperature apparent strain runs. Interestingly, the two beams that were subjected to -150°F excursions generated acceptable leakage to ground resistances for a few days in the tray of tap water but the coating did not provide an adequate degree of protection from the water for the entire duration of the test. Figure 11 shows the leakage to ground resistance changing on the two beams as a function of time. As shown, the leakage to ground resistance decreased rapidly in the first few days but then leveled off somewhat. The strain gage bridges for both beams were still functional after two weeks of soaking, but the resistance to ground readings had decreased to less than 90 megohms for one beam and 1.5 megohms for the other. The third beam (the beam that was subjected to -275°F apparent strain runs) showed cracking of the RTV, but in spite of the cracking, it too, provided a degree of moisture protection for a few days. The clear indication is that the RTV-167 cannot be used as a "stand-alone" moisture-barrier for strain gages in water for long-term use.

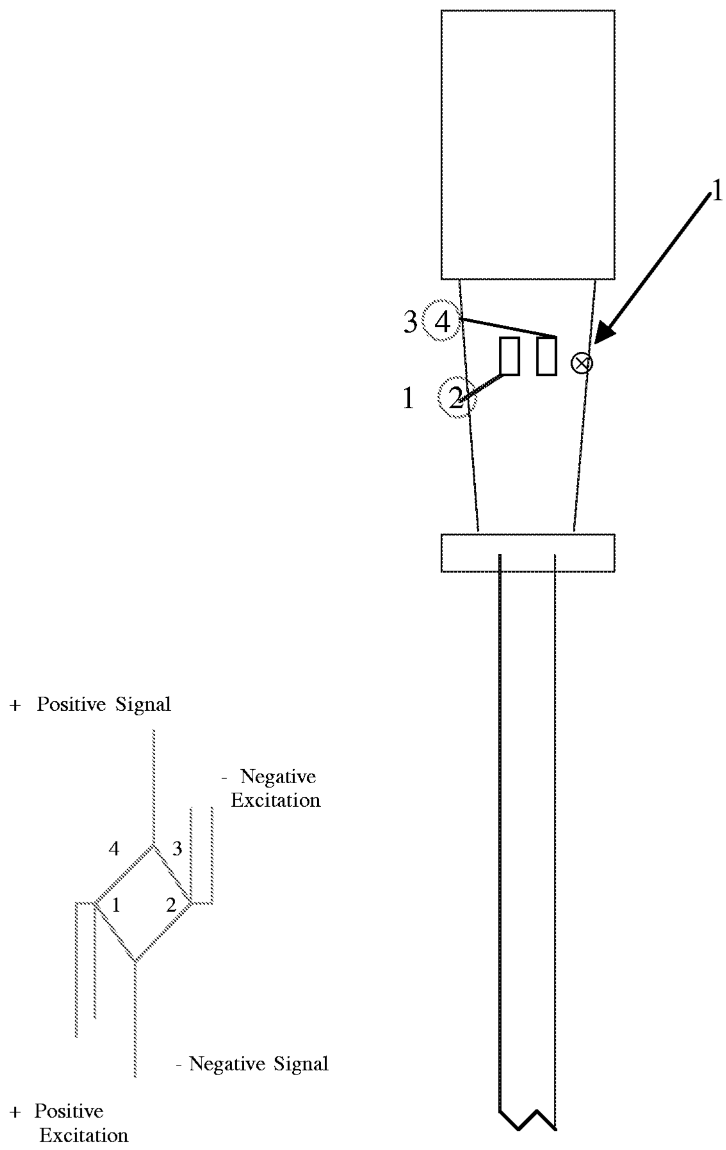
Note: It was learned following the conclusion of this evaluation testing that the private sector firm that uses the GE-167 "in the field" also uses a neoprene rubber coating over exposed solder joints and wiring prior to applying the RTV. It was therefore decided to conduct a follow-on test. A test beam was prepared for wet-testing using typical strain gage wiring terminals with strain gage wiring soldered to the terminals. One set of terminals was coated with a chloroprene rubber coating (Texas Measurements type: N-1) followed by the GE-167 coating. The other set of terminals was coated with GE-167 only. The beam was then placed in a tray of water for one month and leakage to ground readings were recorded. The combination of the two coatings provided sufficient resistance leakage to ground protection after one month in the water. The actual resistance to ground after one month was 3×10^8 ohms. The solder joints and wiring that were coated with only GE-167 had a leakage to ground resistance that was barely acceptable after one month. The actual resistance to ground was 1 x 10^7 ohms.

Summary

This testing, though limited, demonstrated that this silicone-based sealant did provide sufficient protection from water-soak damage for a period of several days but during a two-week soak test period the leakage to ground resistance decreased to an unacceptable level. The apparent strain testing showed that the RTV had negligible affect on the apparent strain signature from room temperature to 400°F but cryogenically the data contained uncharacteristic slope and repeatability anomalies. It is important to note that this RTV, as with most, is not recommended for use below -150°F. The RTV did furnish a substantial degree of mechanical protection for the strain gage installation but, importantly, the sealant did generate a reinforcing effect on the beam. This translated to a decrease in the sensitivity of the strain gage signal for a given loading scenario. It is felt that this sealant when used in conjunction with a rubber-based primary coating, could be used for long-term protection from water for structural testing where reinforcing of the test article is not a concern.

GAGING FOR MOISTURE-BARRIER TESTING

Testing of GE-167 RTV



notes:

1. Gage as per Appli. Class II, Type 2 & per notes below.
2. Install WK-06 gages in general areas shown.
3. Do not use matched gages.
4. Install one PRT where shown using EA-934
5. All leadwires to be 8 ft. in length.
6. Apply GE-167 and N-1 as per attached lab testing plan.
7. <u>Use Tetra-etch on all teflon-insulated wiring in the areas near the leadwire terminals.</u>
8. <u>Use 430-20S solder.</u>
9. Direct any questions to Tom Moore.

Beam type: VCM-200 or CVM-250 Moisture-barrier testing for GE-167 RTV T. Moore 1/5/99

Figure 1

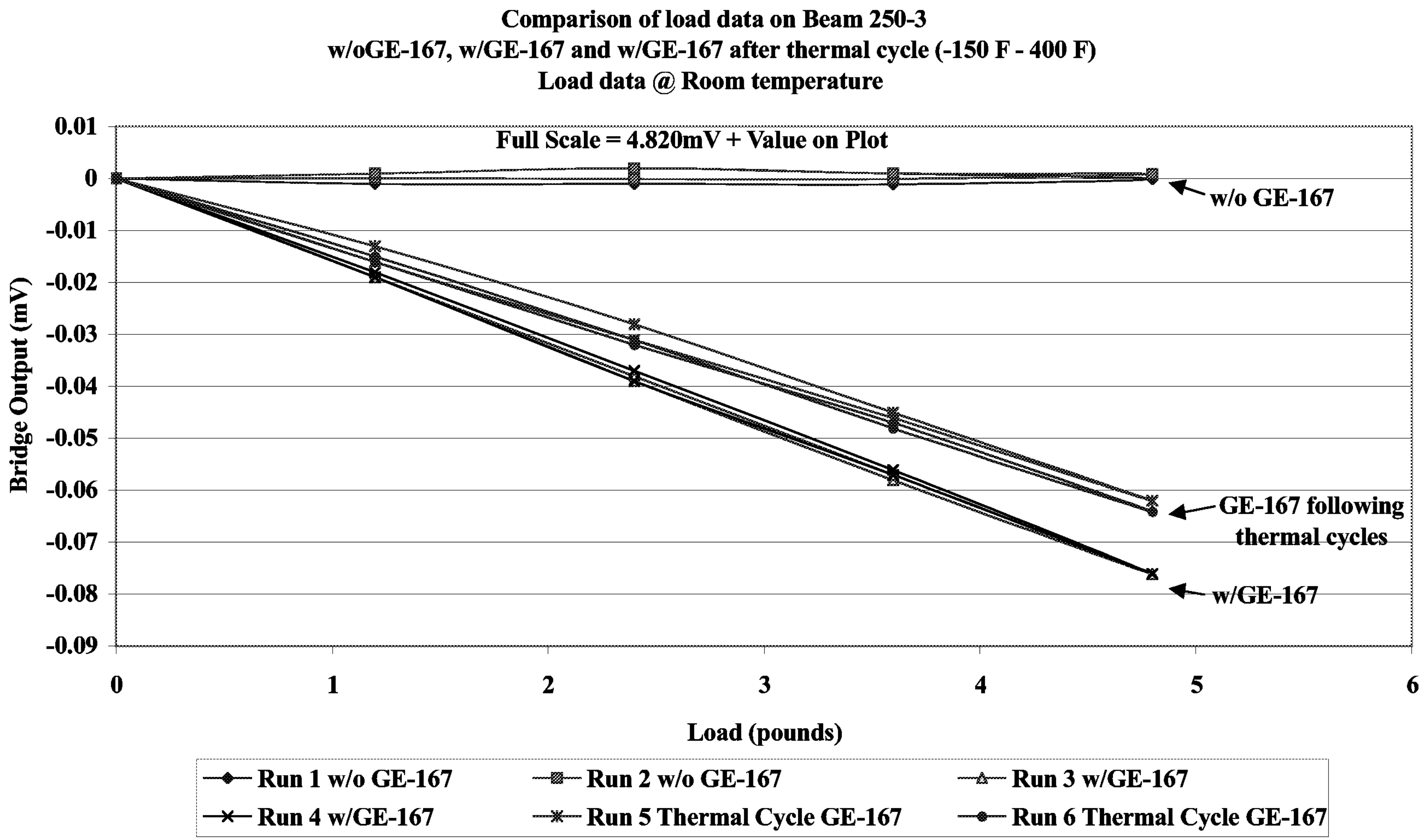

Comparison of load data on Beam 250-3
w/oGE-167, w/GE-167 and w/GE-167 after thermal cycle (-150 F - 400 F)
Load data @ Room temperature
Full Scale = 4.820mV + Value on Plot
Bridge Output (mV)
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
0
1
2
3
4
5
6
Load (pounds)
w/o GE-167
GE-167 following thermal cycles
w/GE-167
Run 1 w/o GE-167
Run 2 w/o GE-167
Run 3 w/GE-167
Run 4 w/GE-167
Run 5 Thermal Cycle GE-167
Run 6 Thermal Cycle GE-167

Figure 2

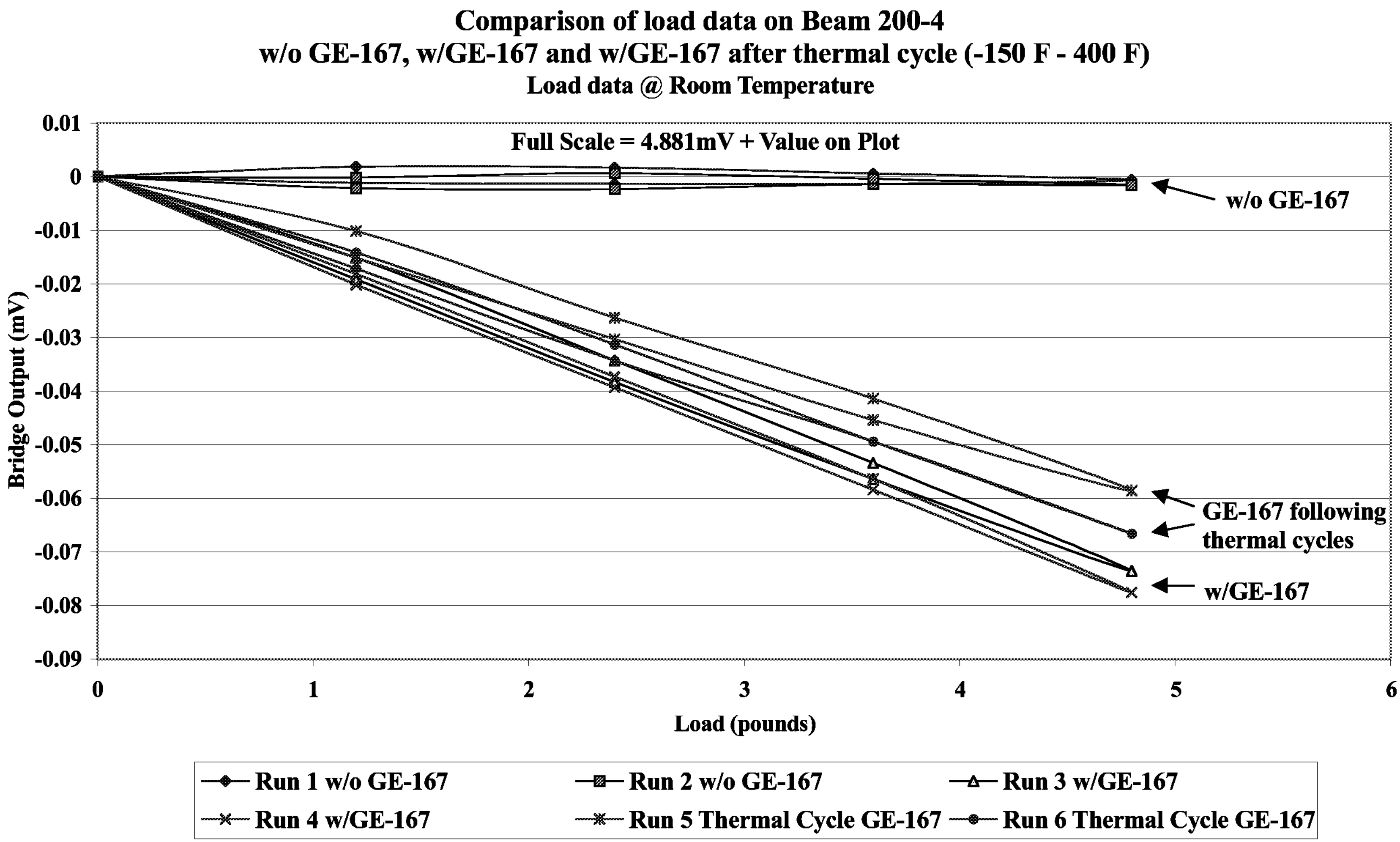
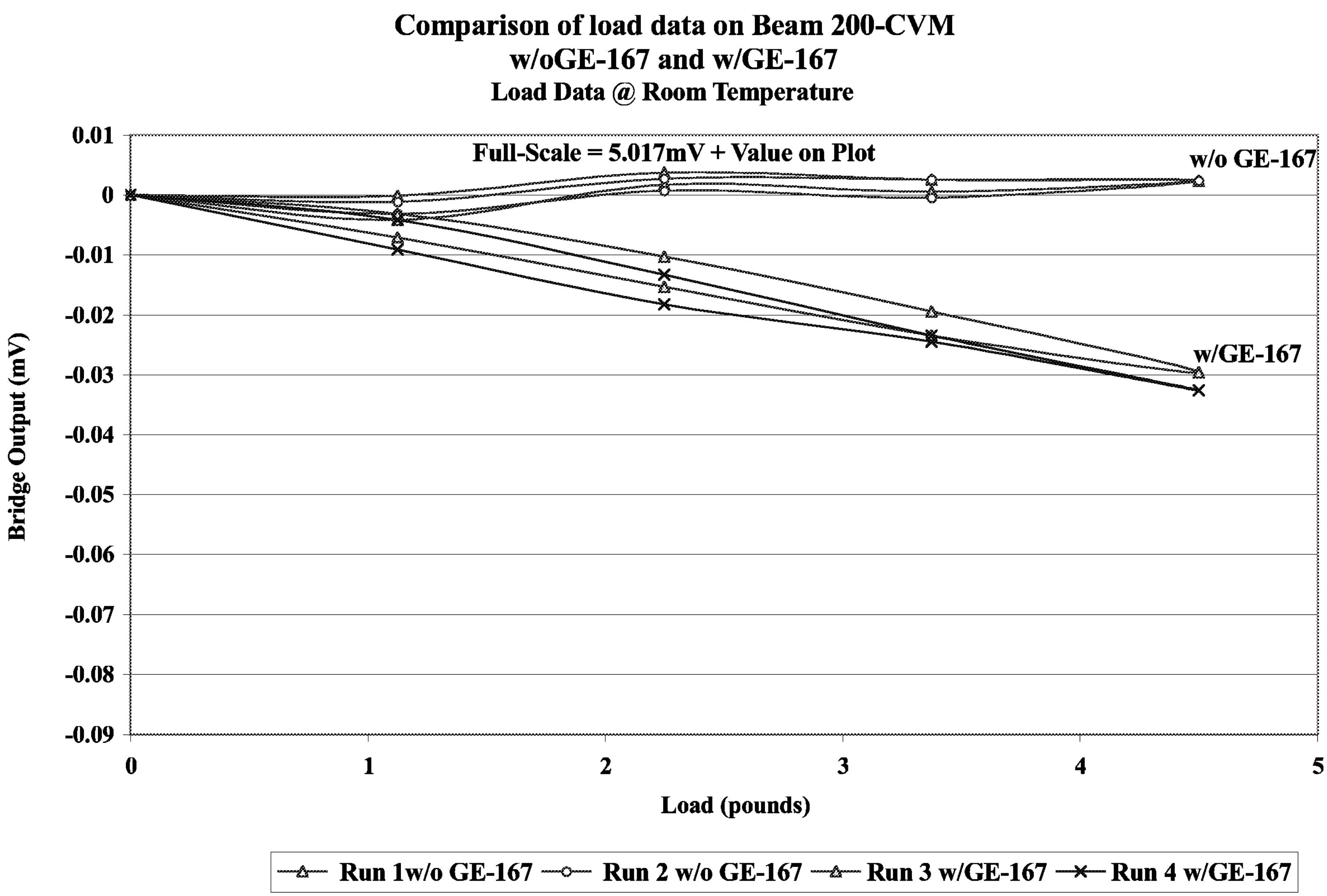

Comparison of load data on Beam 200-4
w/o GE-167, w/GE-167 and w/GE-167 after thermal cycle (-150 F - 400 F)
Load data @ Room Temperature
Full Scale = 4.881mV + Value on Plot
Bridge Output (mV)
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
0
1
2
3
4
5
6
Load (pounds)
w/o GE-167
GE-167 following thermal cycles
w/GE-167
Run 1 w/o GE-167
Run 2 w/o GE-167
Run 3 w/GE-167
Run 4 w/GE-167
Run 5 Thermal Cycle GE-167
Run 6 Thermal Cycle GE-167

Figure 3



Comparison of load data on Beam 200-CVM
w/oGE-167 and w/GE-167
Load Data @ Room Temperature
Full-Scale = 5.017mV + Value on Plot
w/o GE-167
w/GE-167
Bridge Output (mV)
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
0
1
2
3
4
5
Load (pounds)
Run 1w/o GE-167
Run 2 w/o GE-167
Run 3 w/GE-167
Run 4 w/GE-167

Figure 4

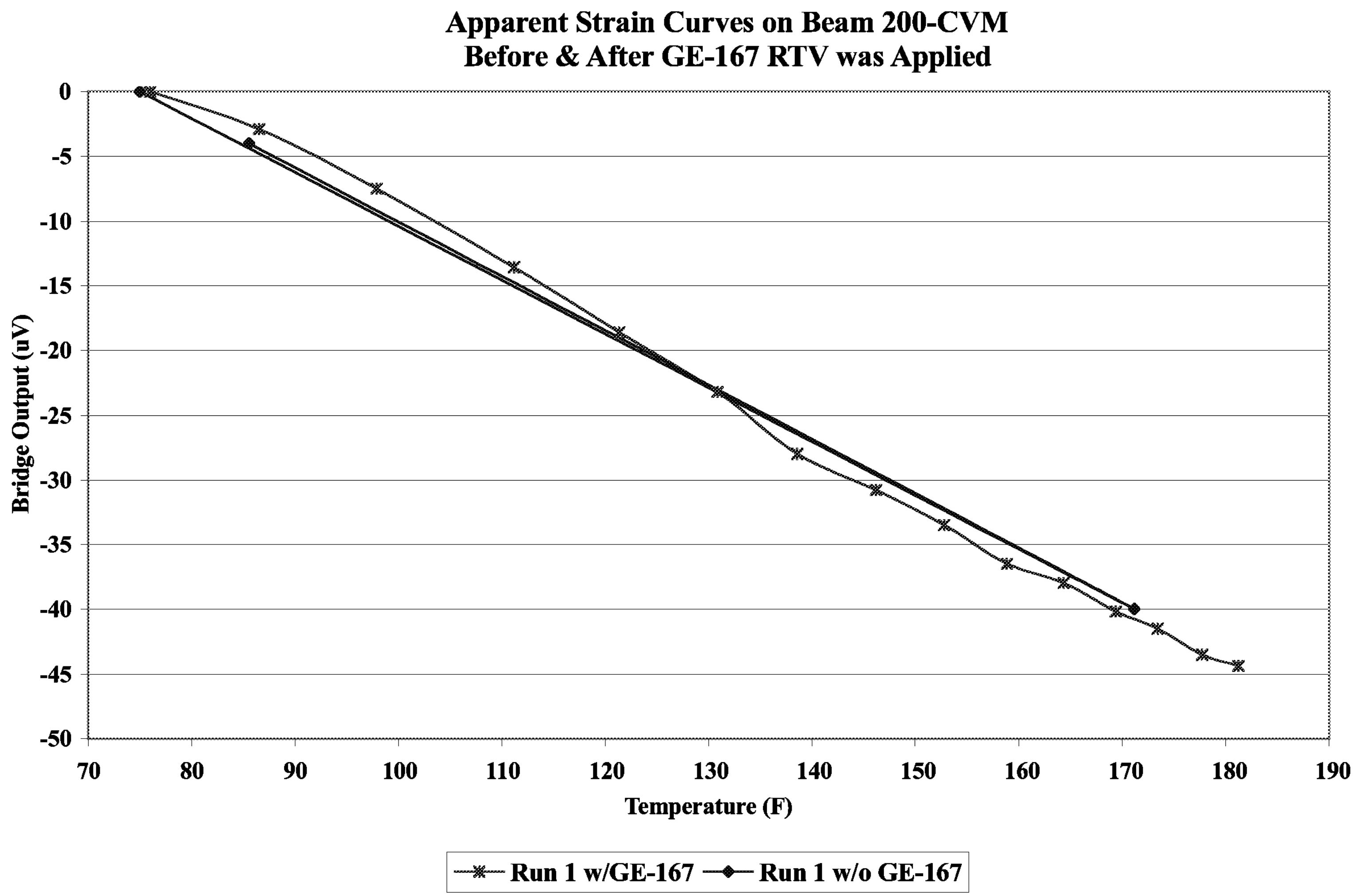
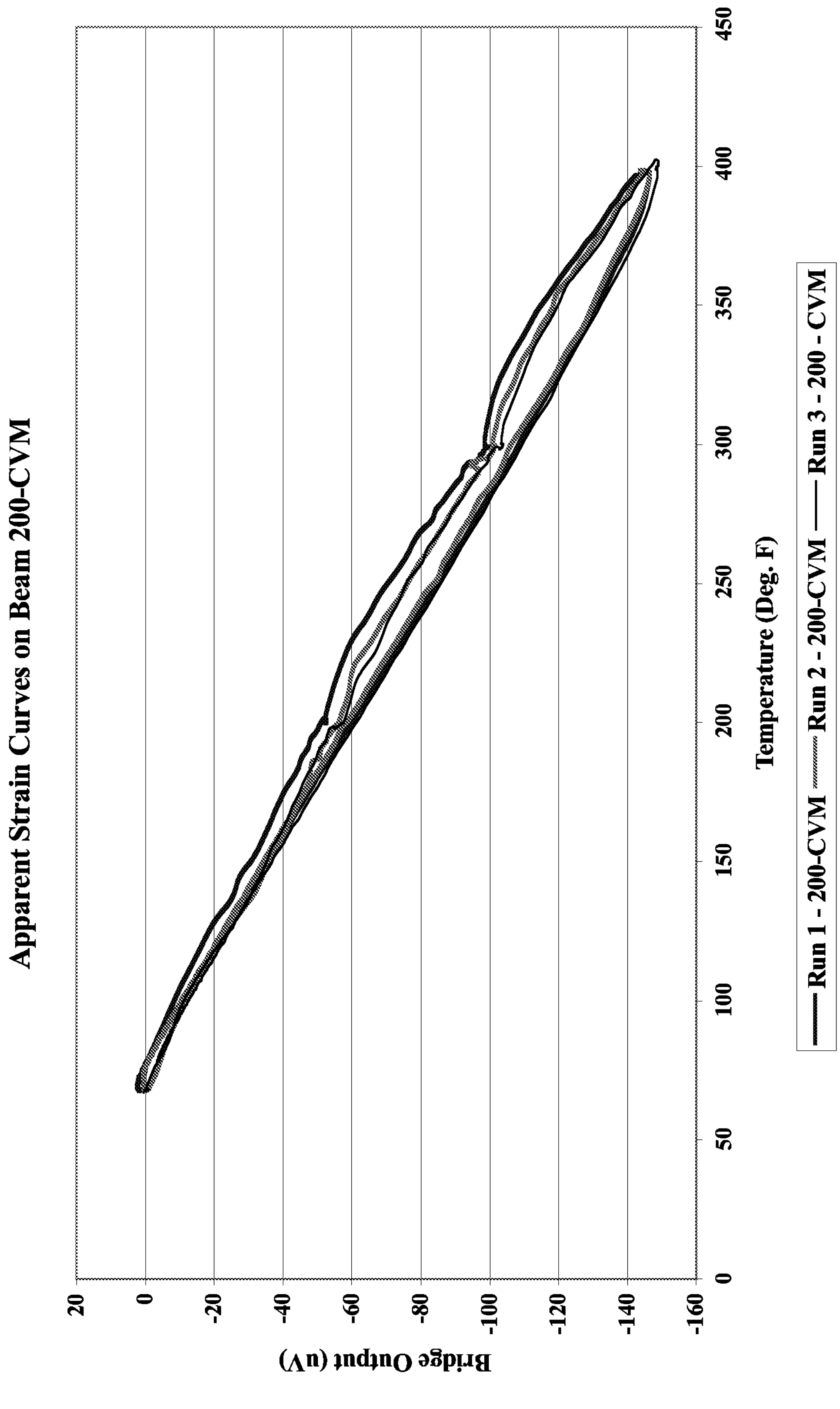

Apparent Strain Curves on Beam 200-CVM
Before & After GE-167 RTV was Applied
Bridge Output (uV)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
70
80
90
100
110
120
130
140
150
160
170
180
190
Temperature (F)
Run 1 w/GE-167
Run 1 w/o GE-167

Figure 5



Apparent Strain Curves on Beam 200-CVM
Bridge Output (uV)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
0
50
100
150
200
250
300
350
400
450
Temperature (Deg. F)
Run 1 - 200-CVM
Run 2 - 200-CVM
Run 3 - 200 - CVM

Figure 6

Apparent Strain Curves on Beam 200-4

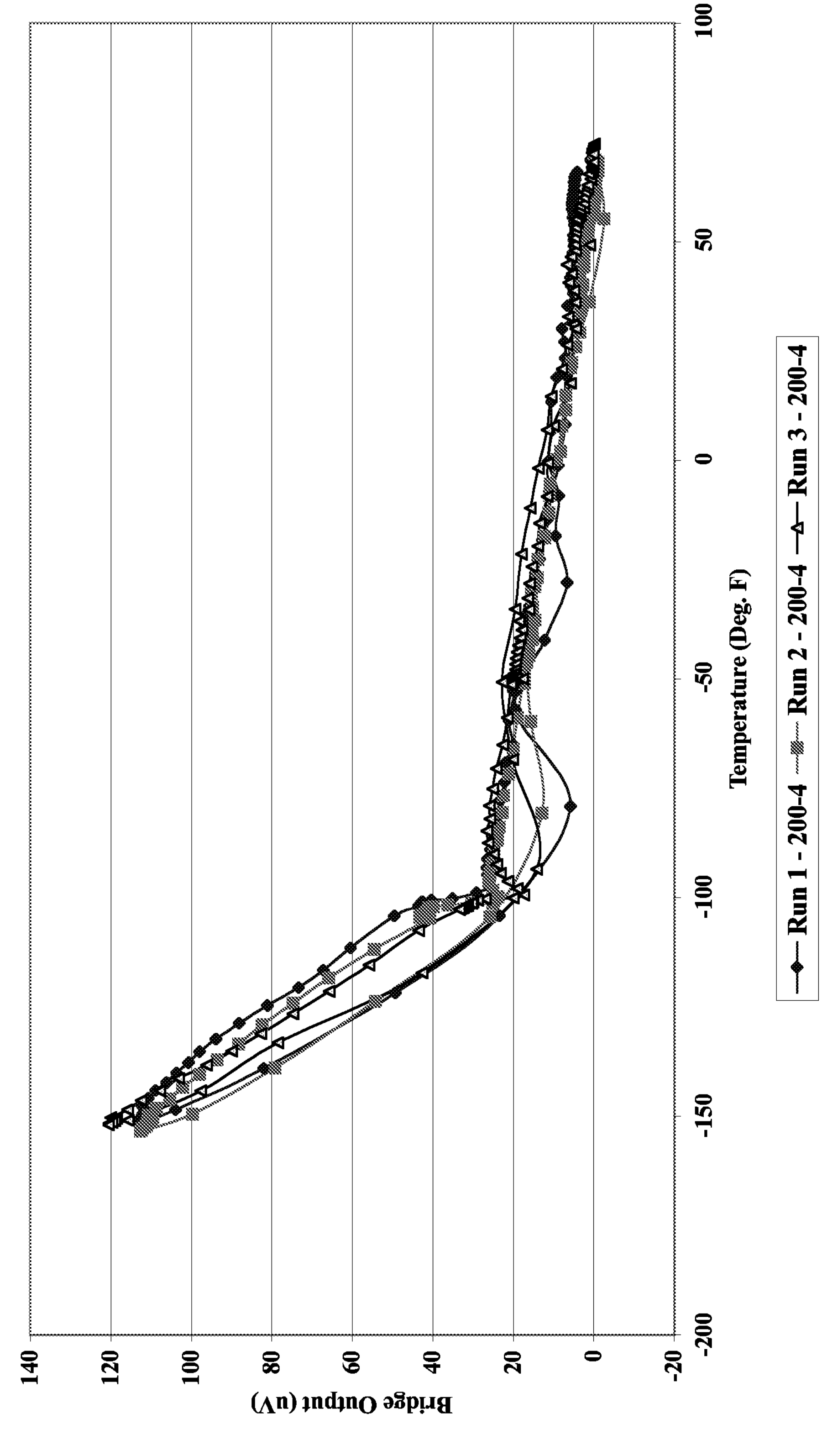


Figure 7

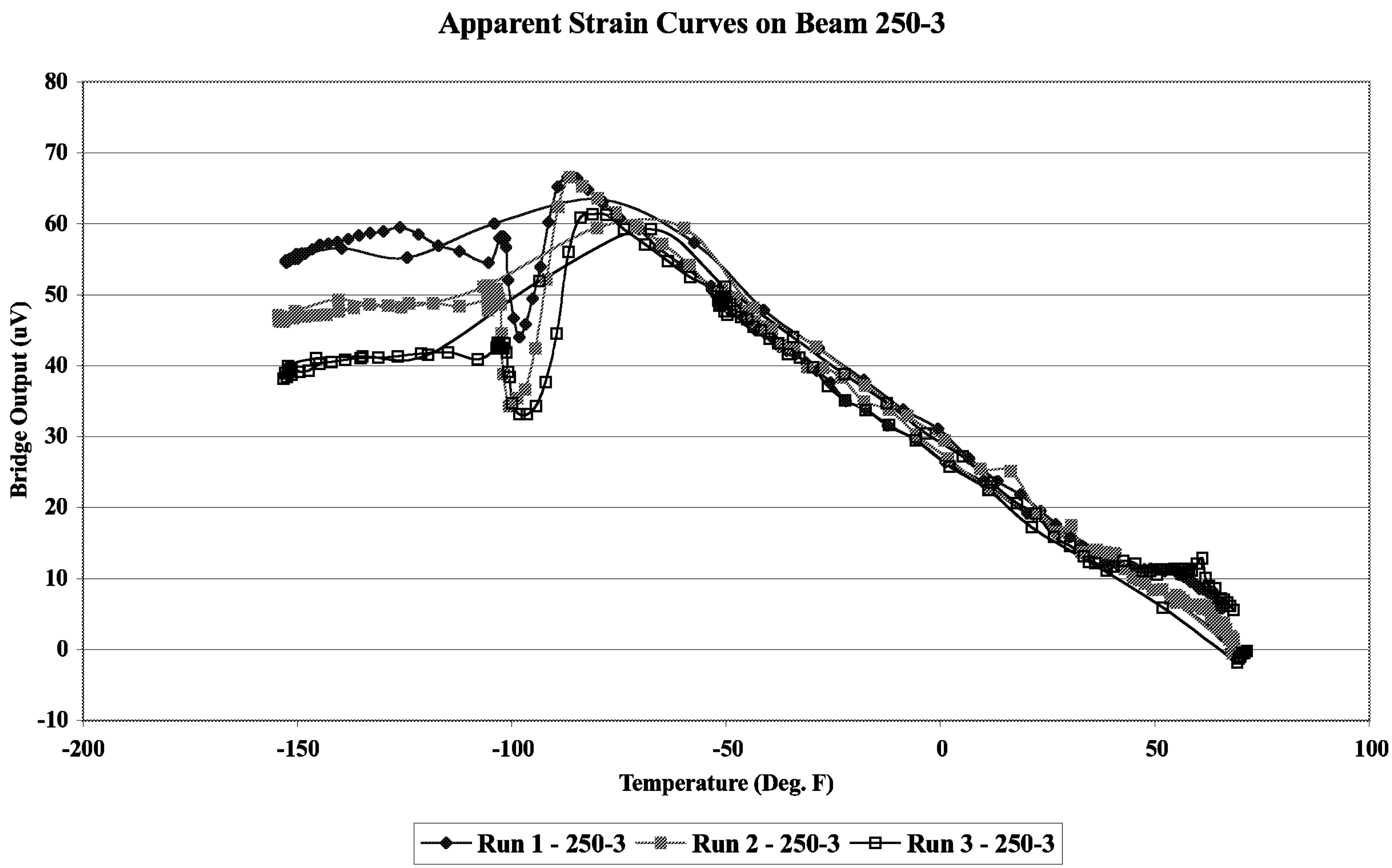

Apparent Strain Curves on Beam 250-3
Bridge Output (uV)
80
70
60
50
40
30
20
10
0
-10
-200
-150
-100
-50
0
50
100
Temperature (Deg. F)
Run 1 - 250-3
Run 2 - 250-3
Run 3 - 250-3

Figure 8

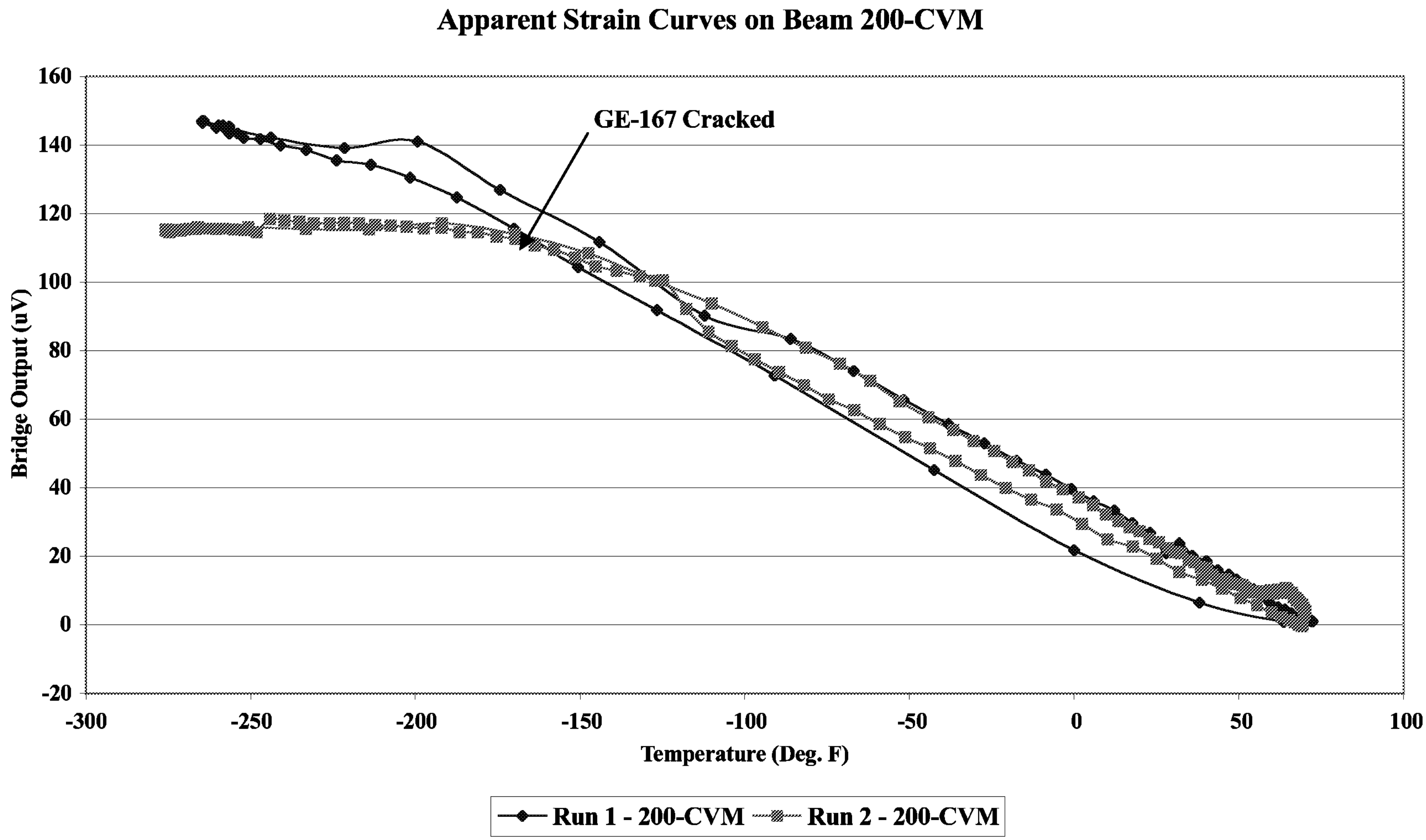

Apparent Strain Curves on Beam 200-CVM
GE-167 Cracked
Bridge Output (uV)
160
140
120
100
80
60
40
20
0
-20
-300
-250
-200
-150
-100
-50
0
50
100
Temperature (Deg. F)
Run 1 - 200-CVM
Run 2 - 200-CVM

Figure 9

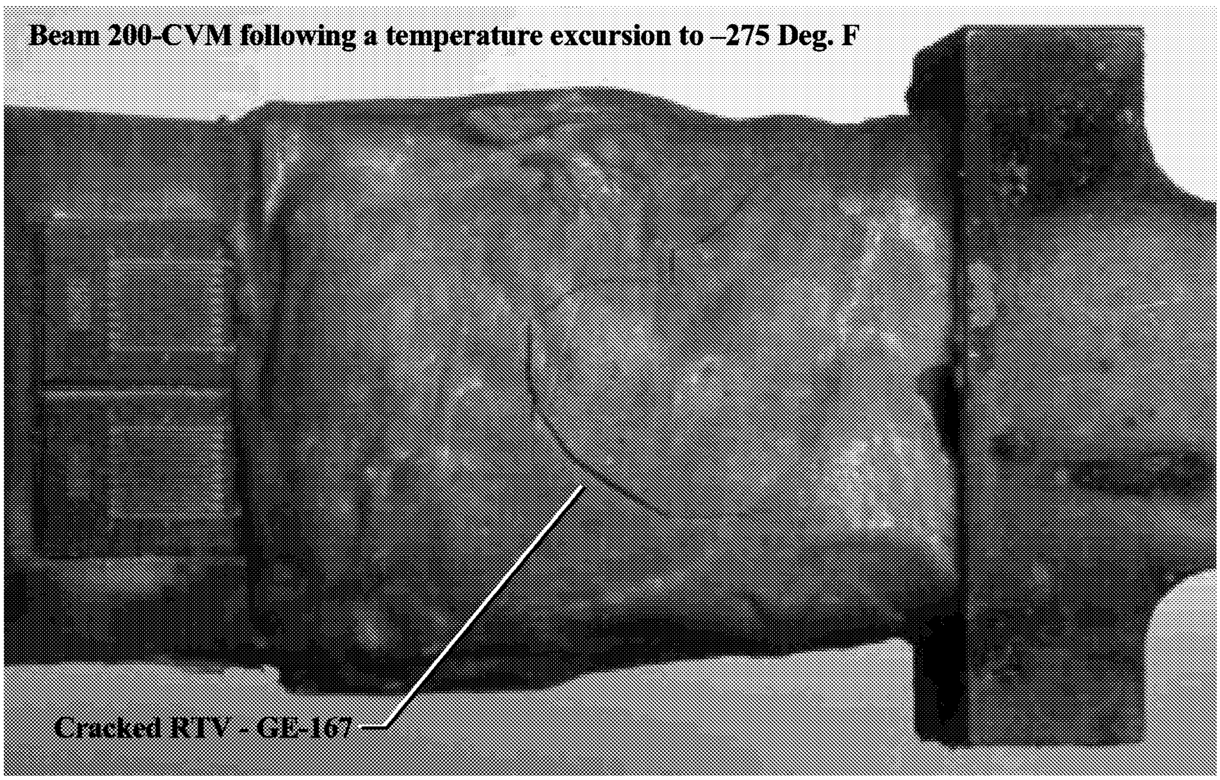

Beam 200-CVM following a temperature excursion to –275 Deg. F
Cracked RTV - GE-167

Figure 10

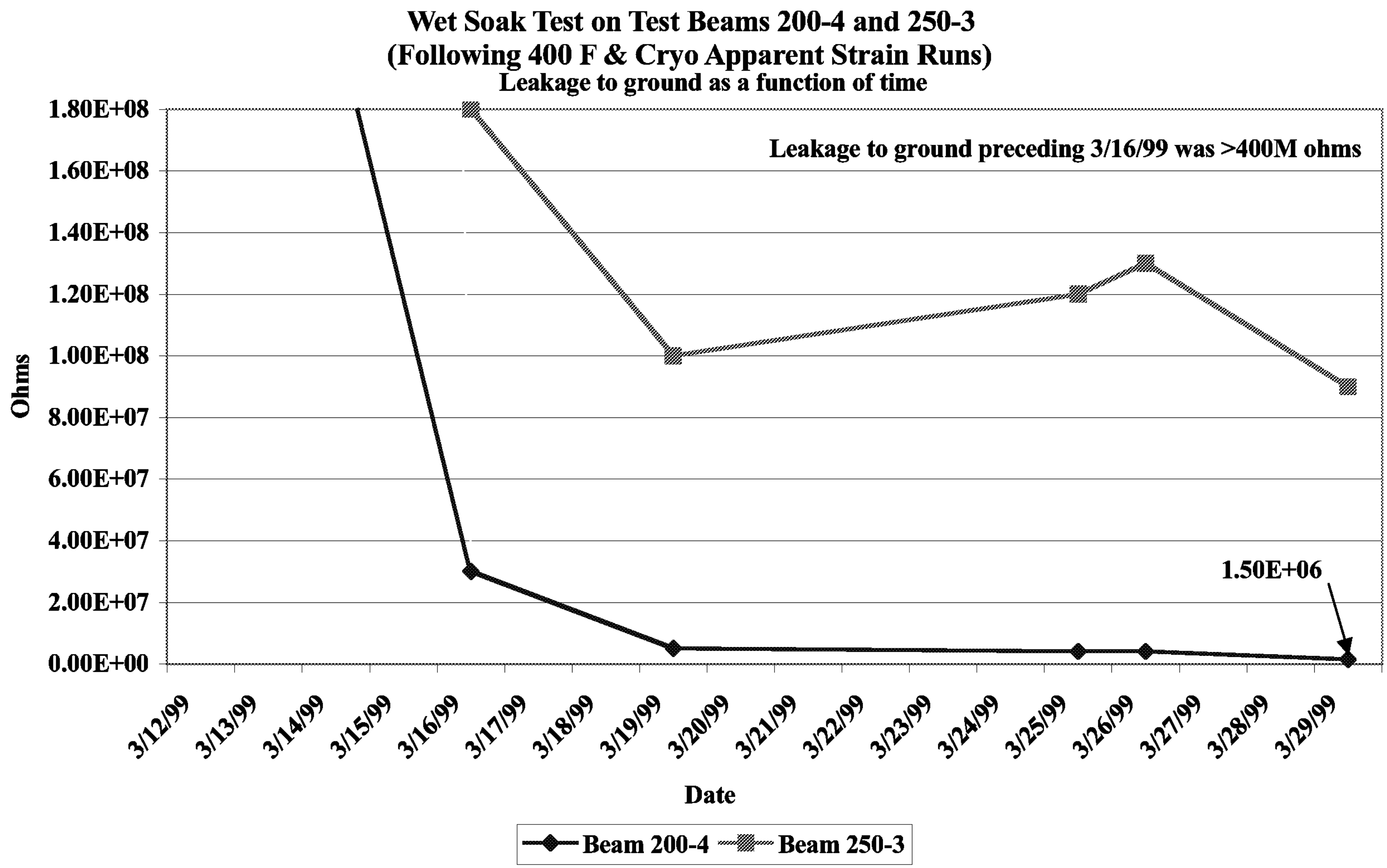

Wet Soak Test on Test Beams 200-4 and 250-3
(Following 400 F & Cryo Apparent Strain Runs)
Leakage to ground as a function of time
Leakage to ground preceding 3/16/99 was >400M ohms
1.50E+06
Ohms
1.80E+08
1.60E+08
1.40E+08
1.20E+08
1.00E+08
8.00E+07
6.00E+07
4.00E+07
2.00E+07
0.00E+00
3/12/99
3/13/99
3/14/99
3/15/99
3/16/99
3/17/99
3/18/99
3/19/99
3/20/99
3/21/99
3/22/99
3/23/99
3/24/99
3/25/99
3/26/99
3/27/99
3/28/99
3/29/99
Date
Beam 200-4
Beam 250-3

Figure 11

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