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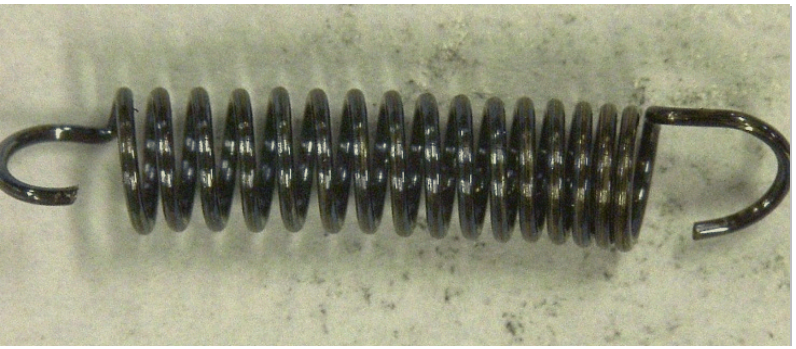

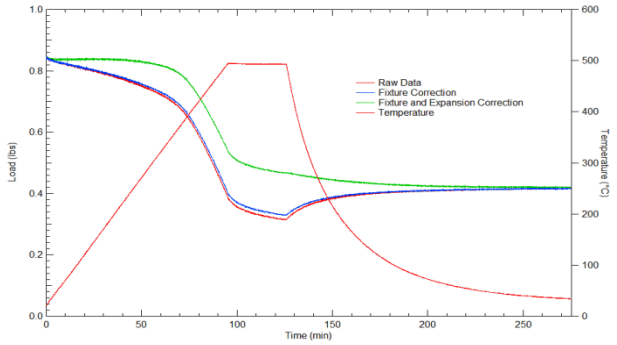

Thermal Degradation of Extension Springs

Brian T. Werner, Bonnie R. Antoun, George B. Sartor

Sandia National Laboratories, Livermore, CA

2015 SEM Annual Conference and Exposition on Experimental and Applied Mechanics,

Costa Mesa, CA, June 8-11, 2015

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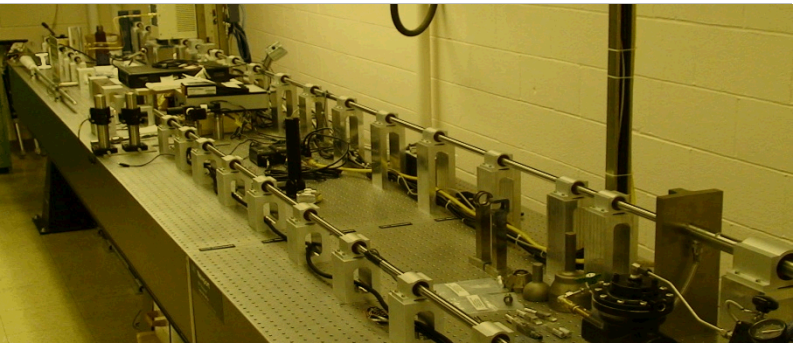
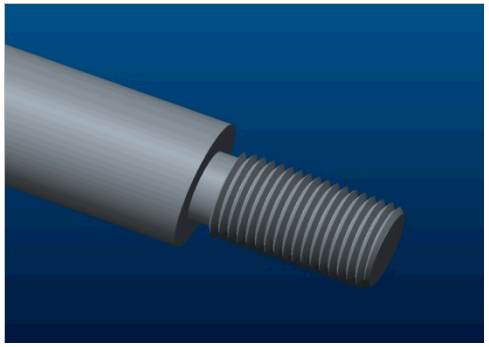
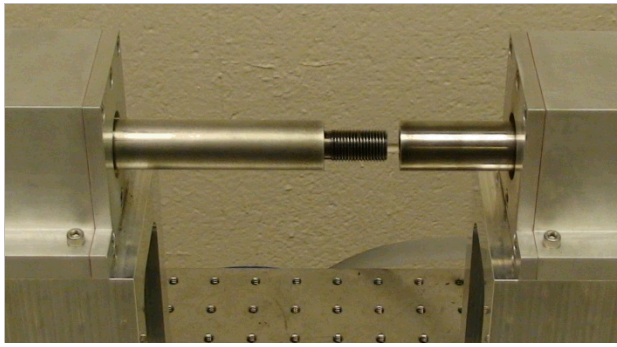

Effect of Threaded Joint Preparation on Impact Energy Dissipation Using Frequency-Based Kolsky Bar Analysis

Brian T. Werner[1], Bo Song[2], Kevin Nelson[1]

Sandia National Laboratories, [1]Livermore, CA, [2]Albuquerque, NM

2014 SEM Annual Conference & Exposition on Experimental and Applied Mechanics

Greenville, SC, June 2-5, 2014

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Thermal Degradation of Extension Springs

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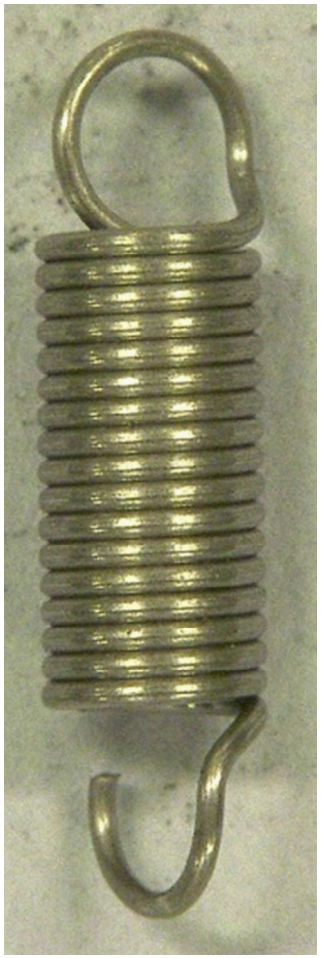
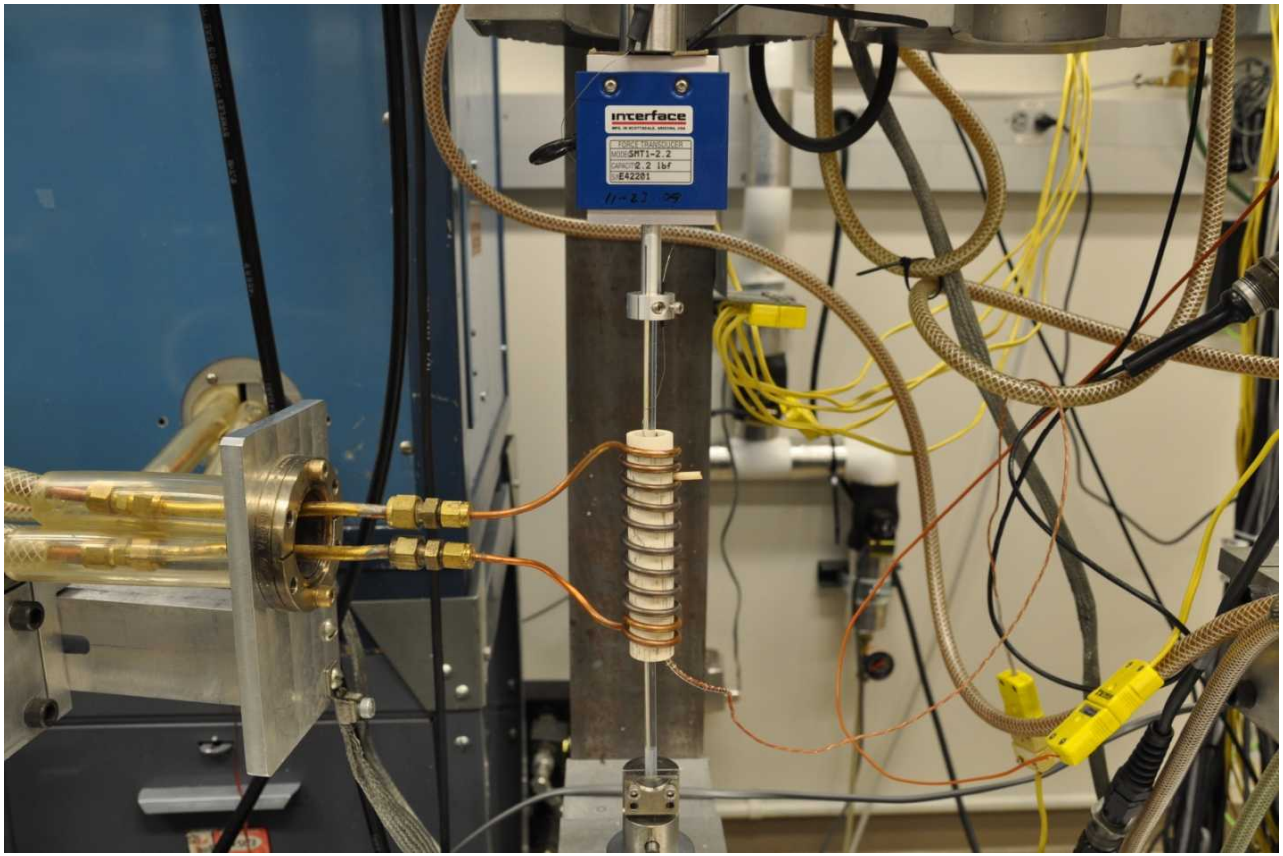
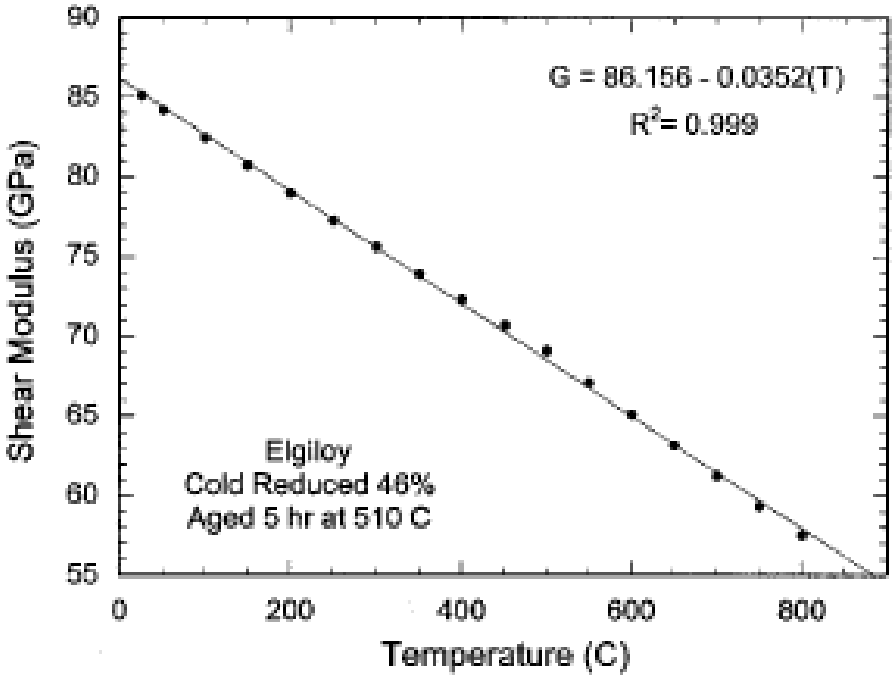
- Used in many engineering components
  - Held at fixed displacement
  - Provides constant force
- Reaction to a thermal event
  - Reliable experimental data is needed
  - Assist modeling of current components and new designs
- Two spring materials tested
  - Elgiloy – cobalt, chromium, nickel alloy
  - Stainless steel
- Relaxation testing

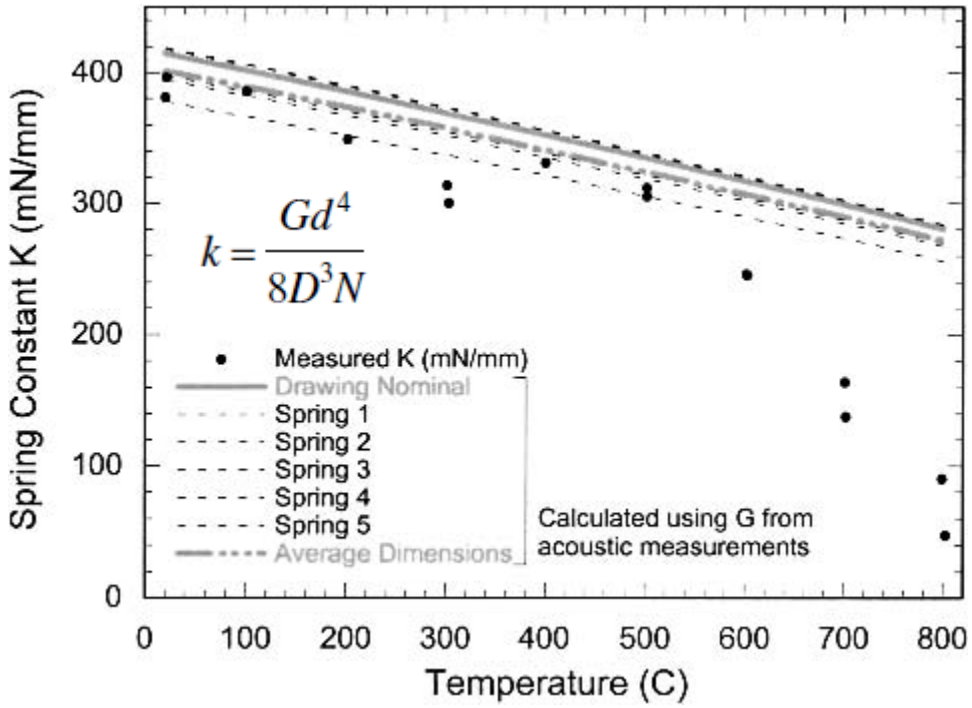


Previous Testing



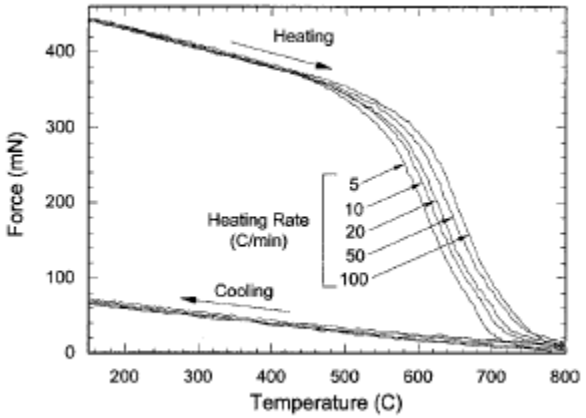
Dykhuizen and Robinho

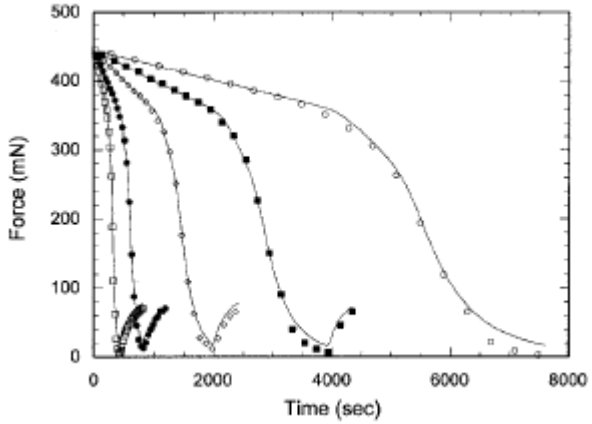


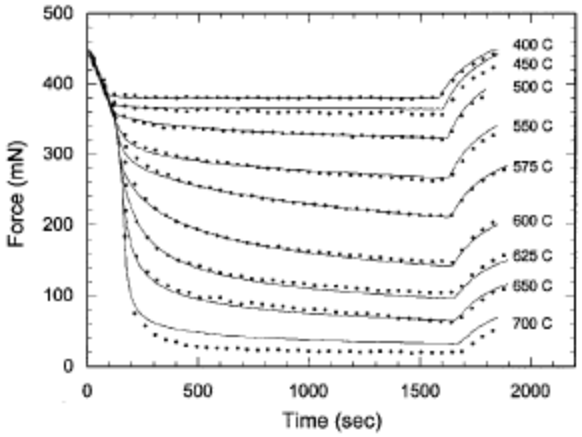


- Shear modulus linear with temperature
- Spring constant bilinear with temperature
- Reduction in spring constant cannot be explained by wire response only

Dykhuizen and Robinho

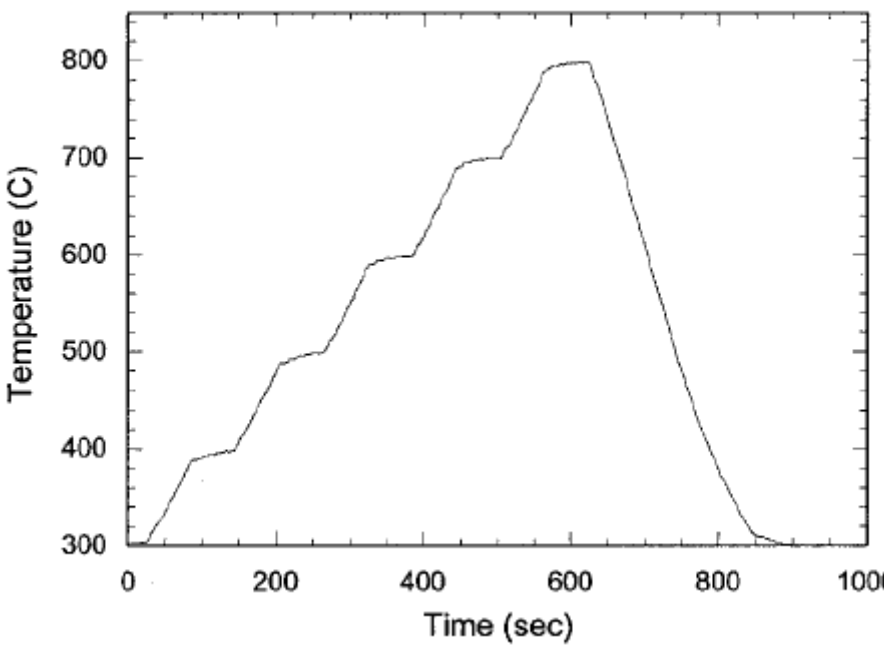


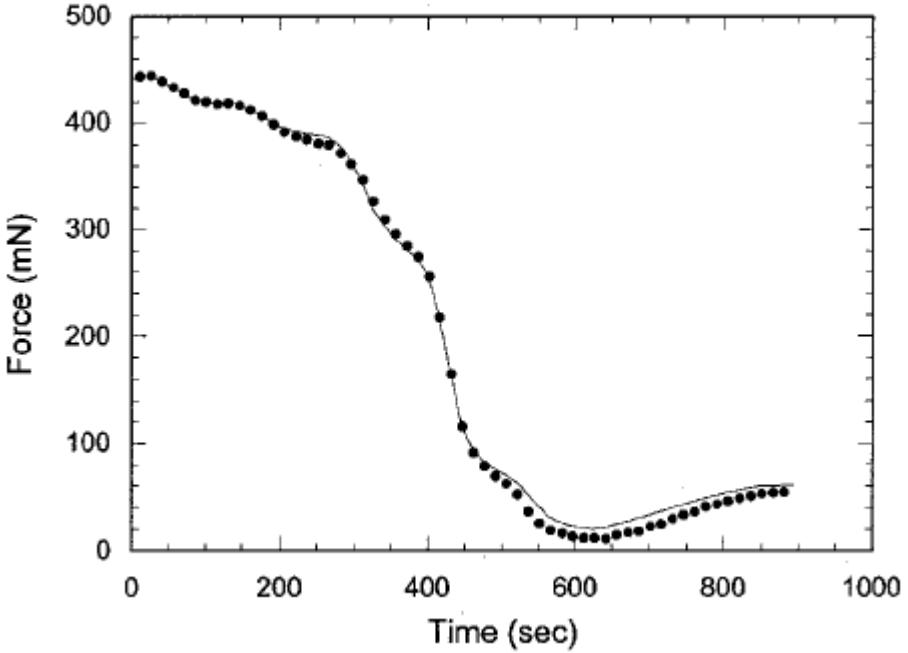




- Various heating rates
- Various dwell temperatures
- Structural model predicts response well
- Large number of tests required to determine model parameters

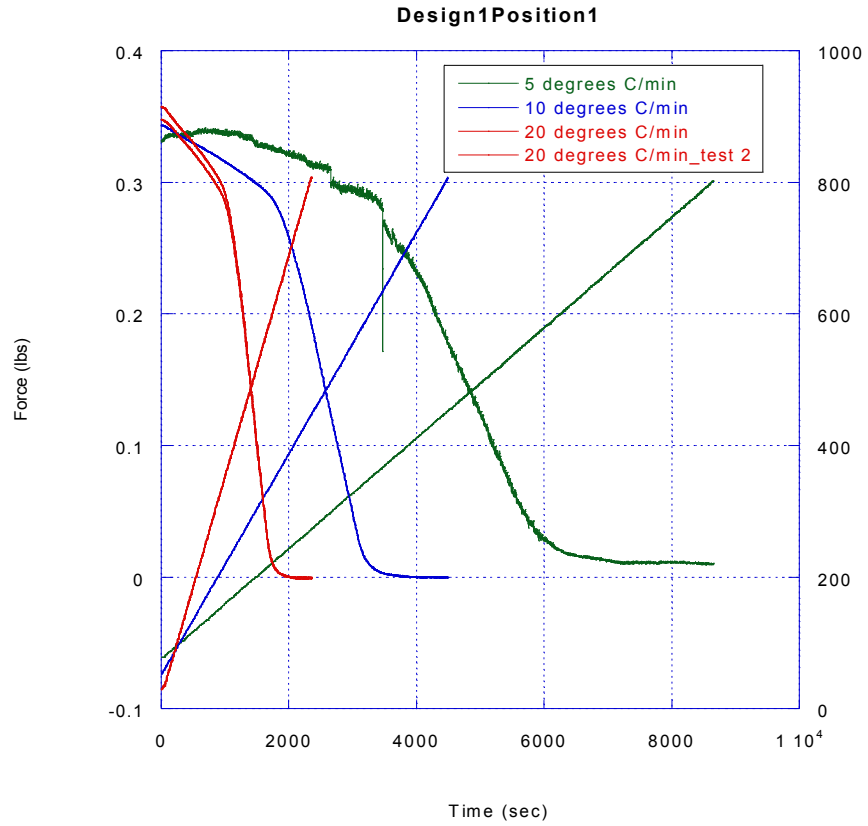
Dykhuizen and Robinho

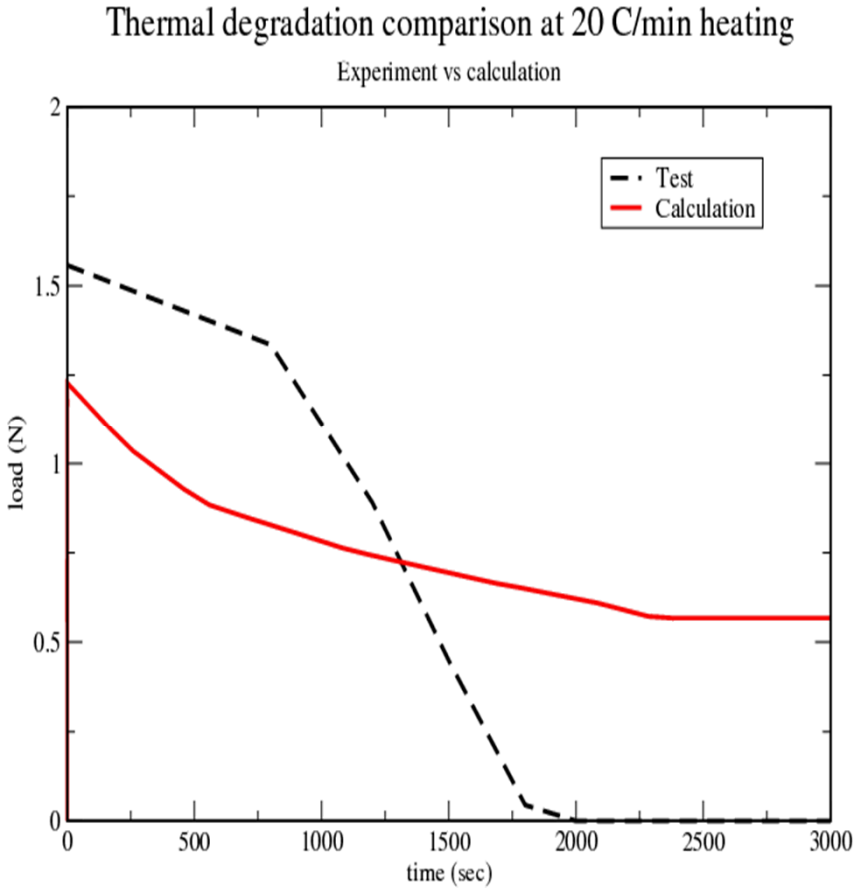




- Complicated stair-step temperature profile
- Relaxation response matched well by structural model

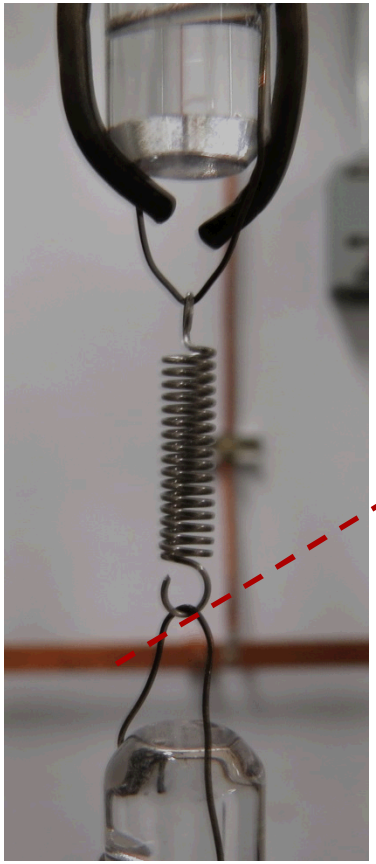
Previous Testing



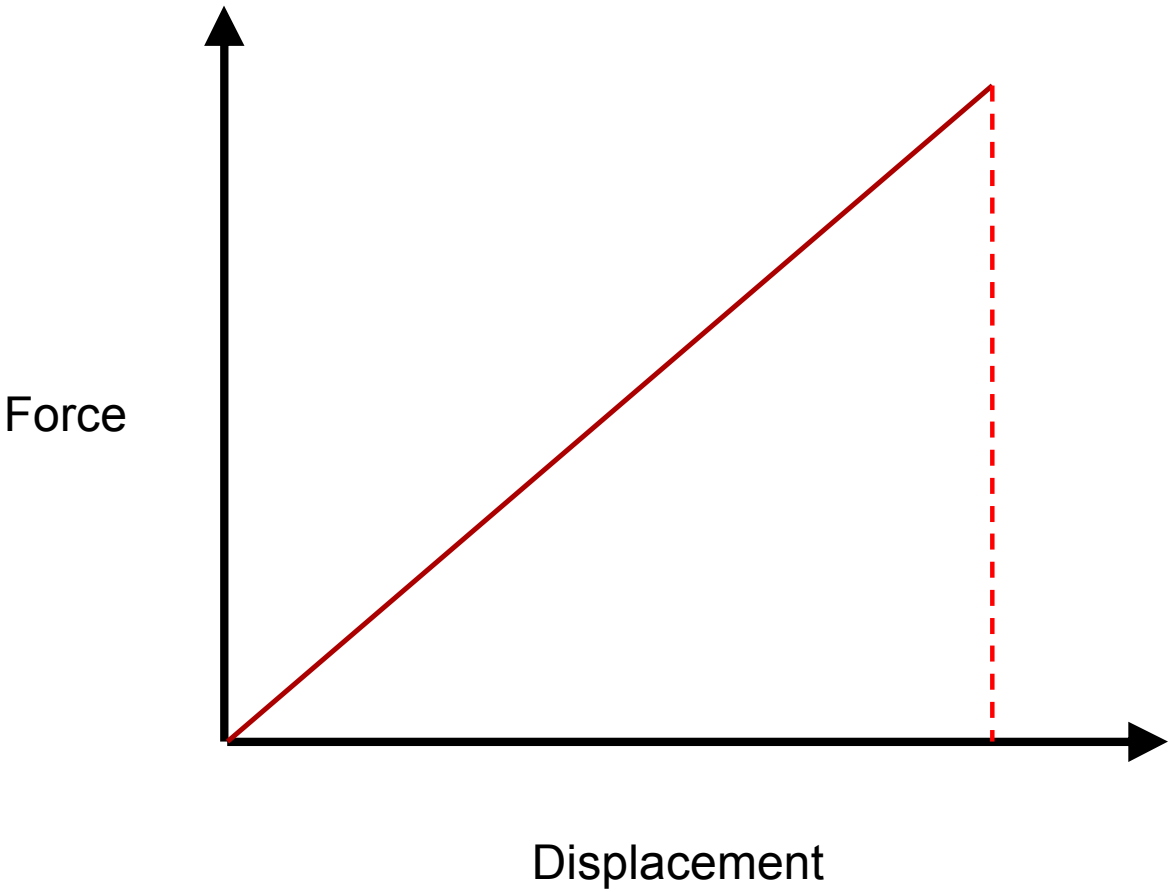


- Dwell temperature too high
- Raw data does not account for relaxation from fixture/spring expansion

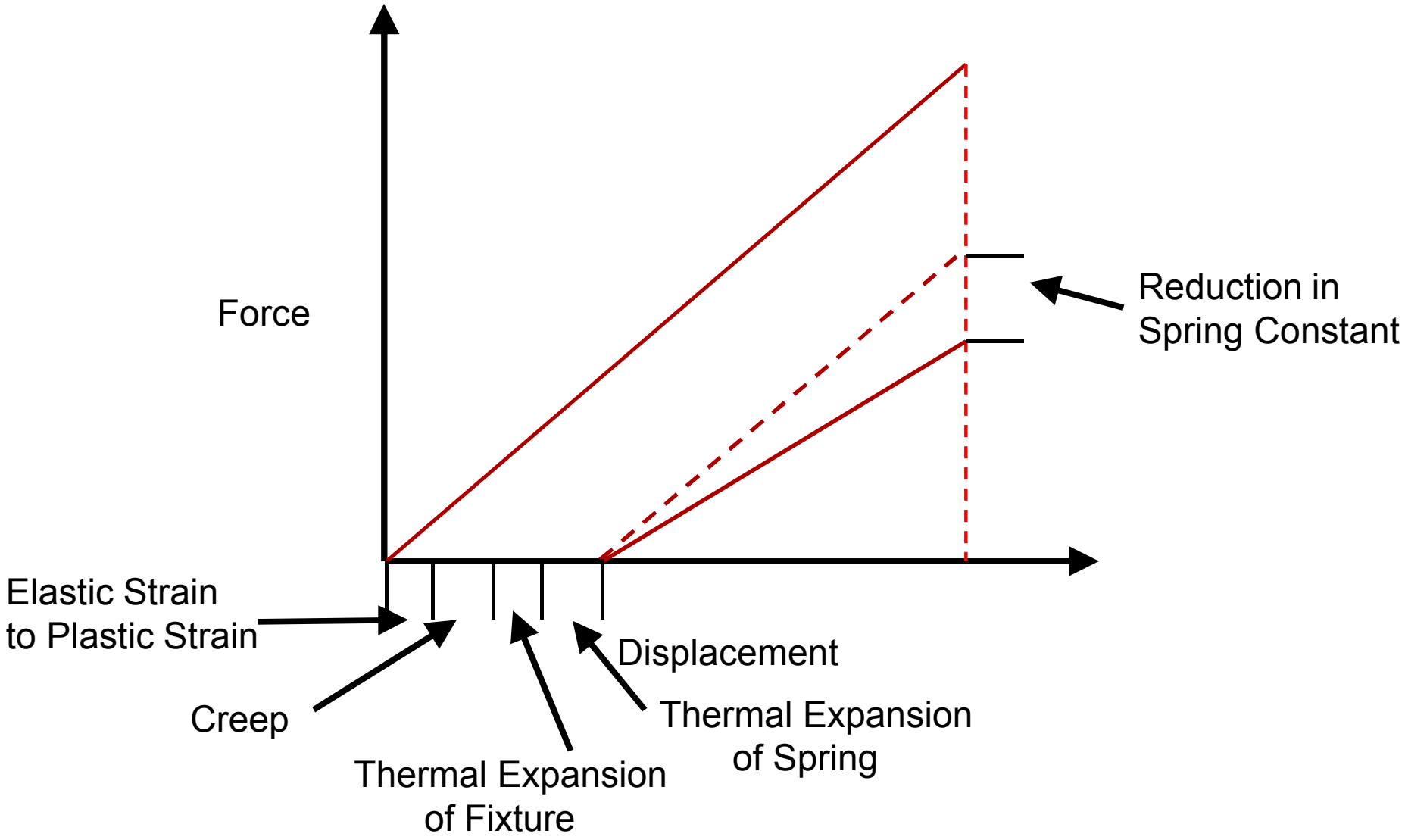
Current Experimental Setup



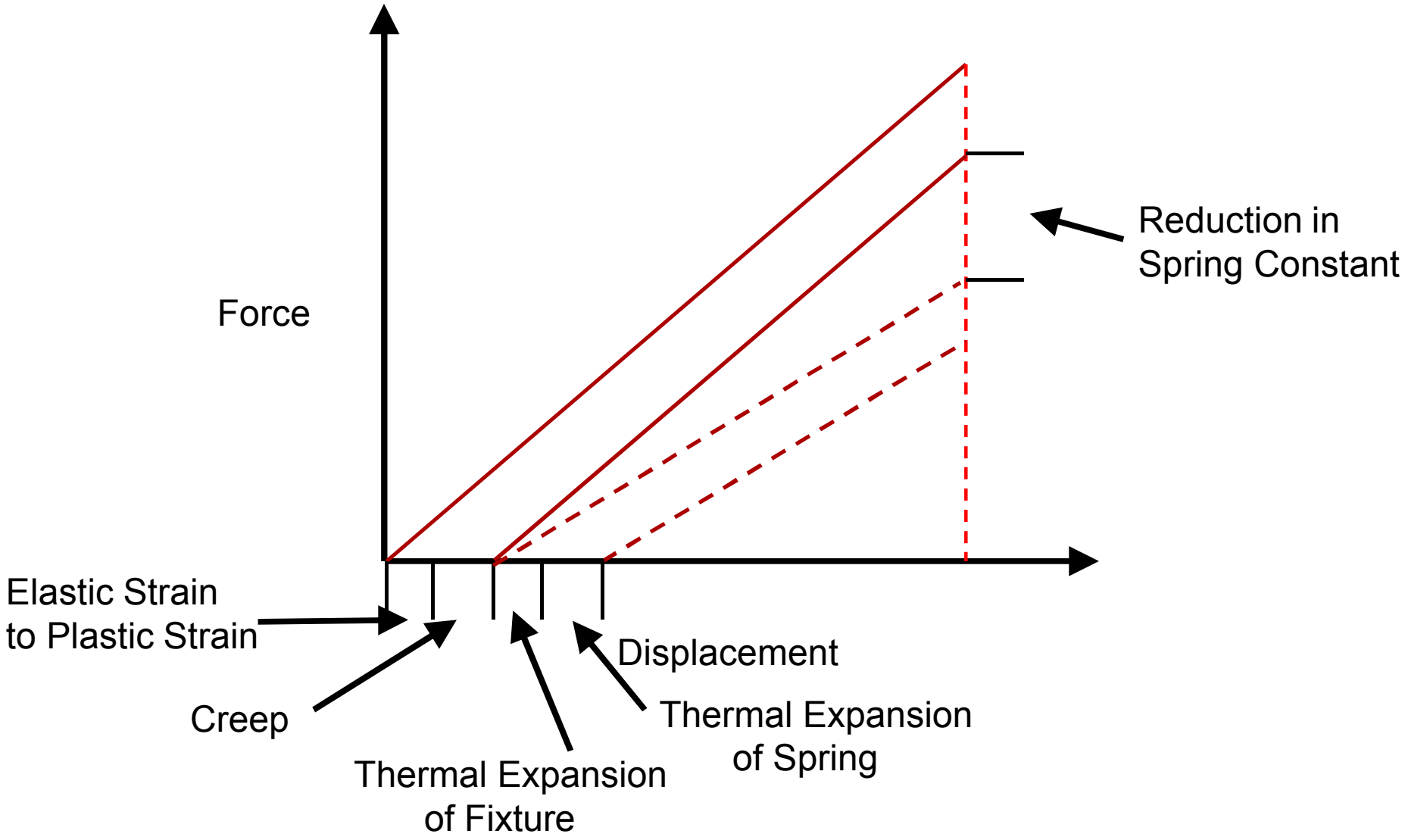
Initial Loading



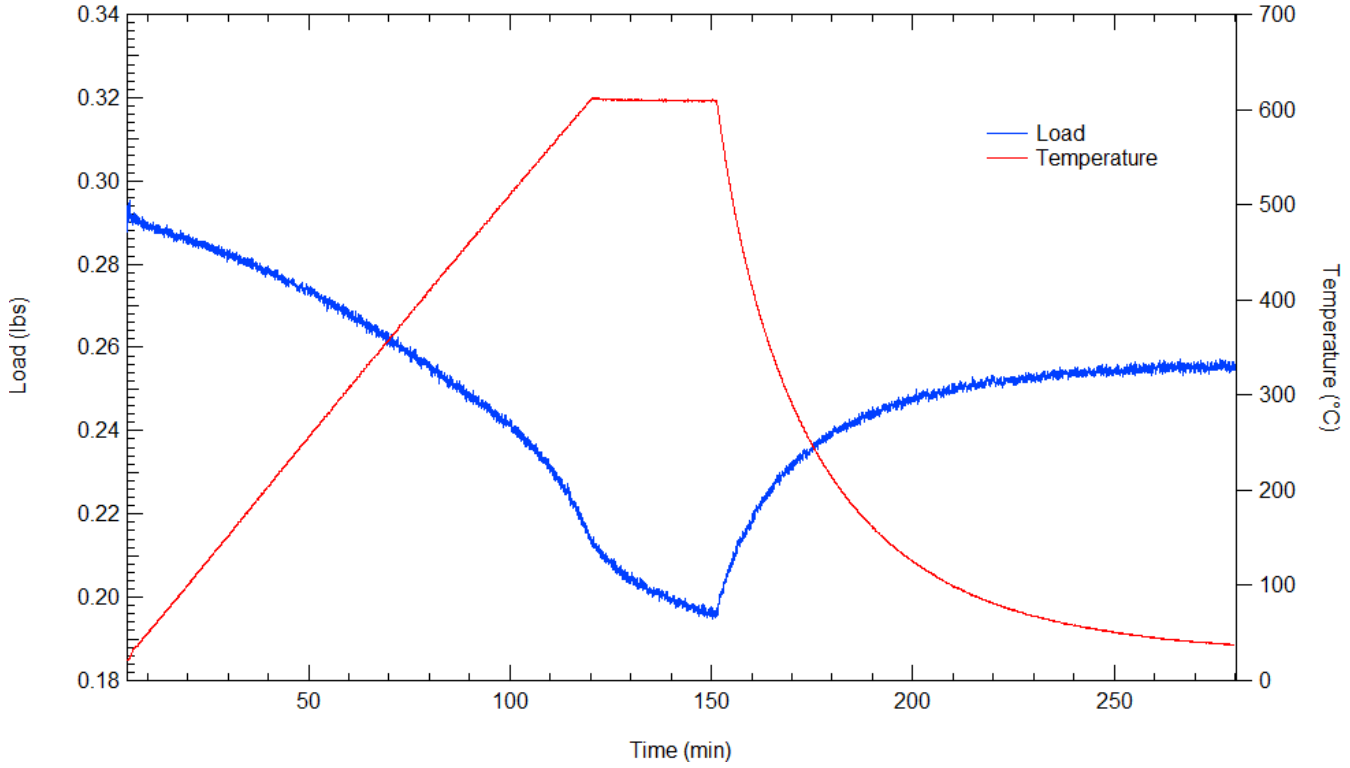
Temperature Ramp



Cool Down

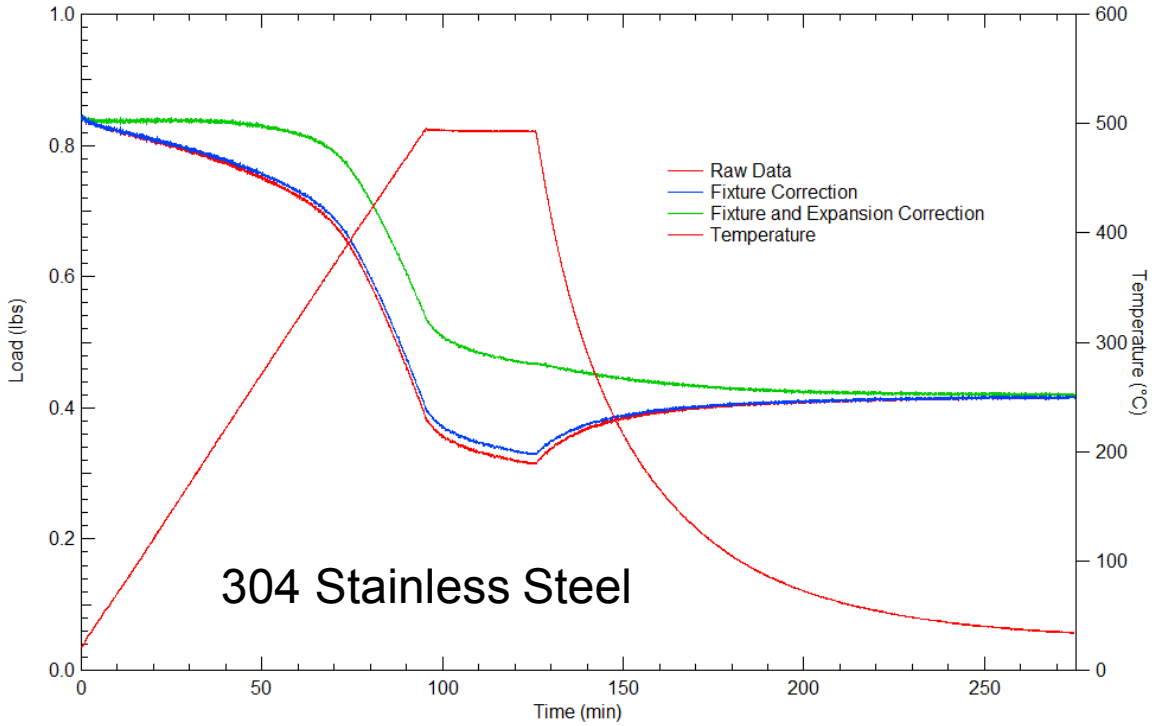

Force
Reduction in
Spring Constant
Elastic Strain
to Plastic Strain
Creep
Thermal Expansion
of Fixture
Displacement
Thermal Expansion
of Spring

Raw Data



- Furnace performs well with sharp edge at dwell temperature
- Raw data includes thermal expansion
- Further reduction needed to isolate spring creep

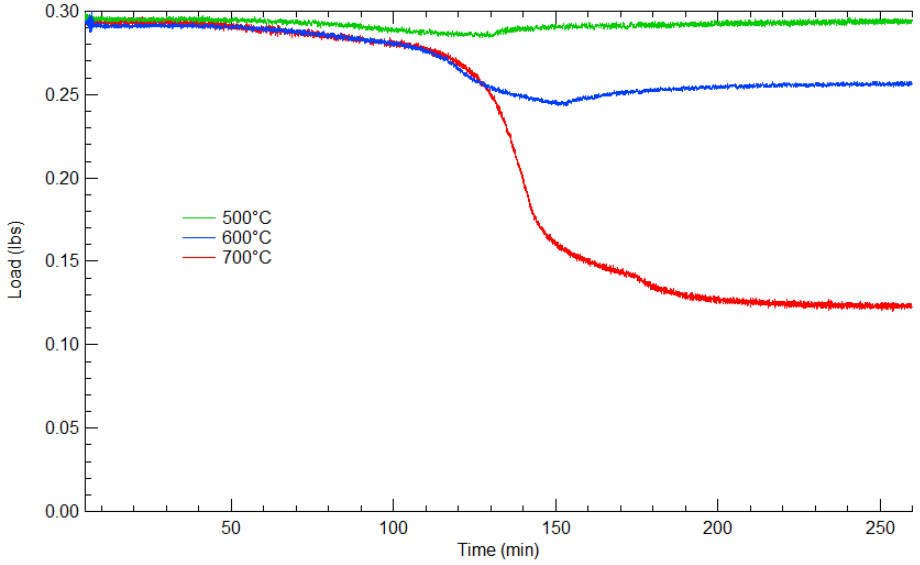
Correcting for Thermal Expansion



- Initial relaxation due entirely to expansion
- Creep sets in and speeds up during the heating
- Linear and shallow during dwell
- Spring and fixture thermal contraction produce increase in load

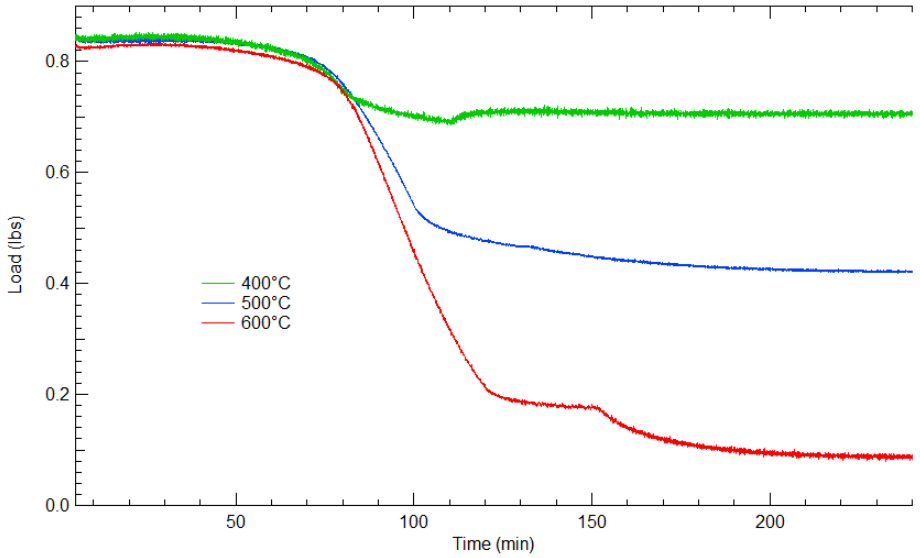
Spring Relaxation

Elgiloy



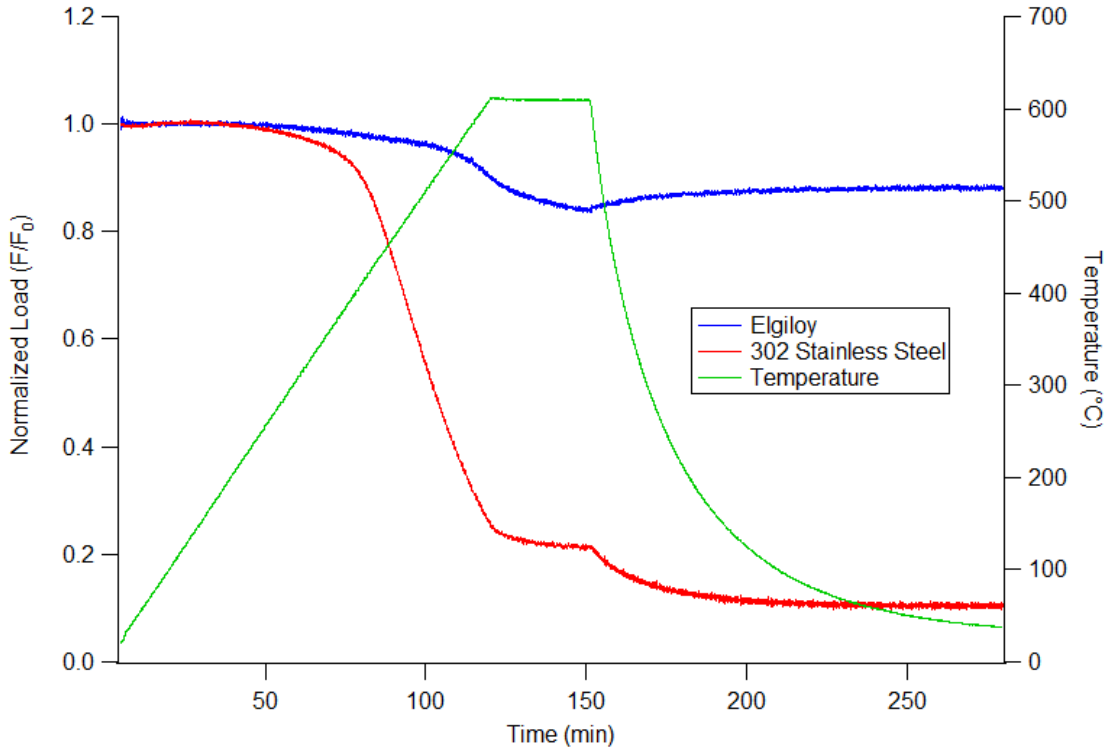
500-700C

304 Stainless Steel



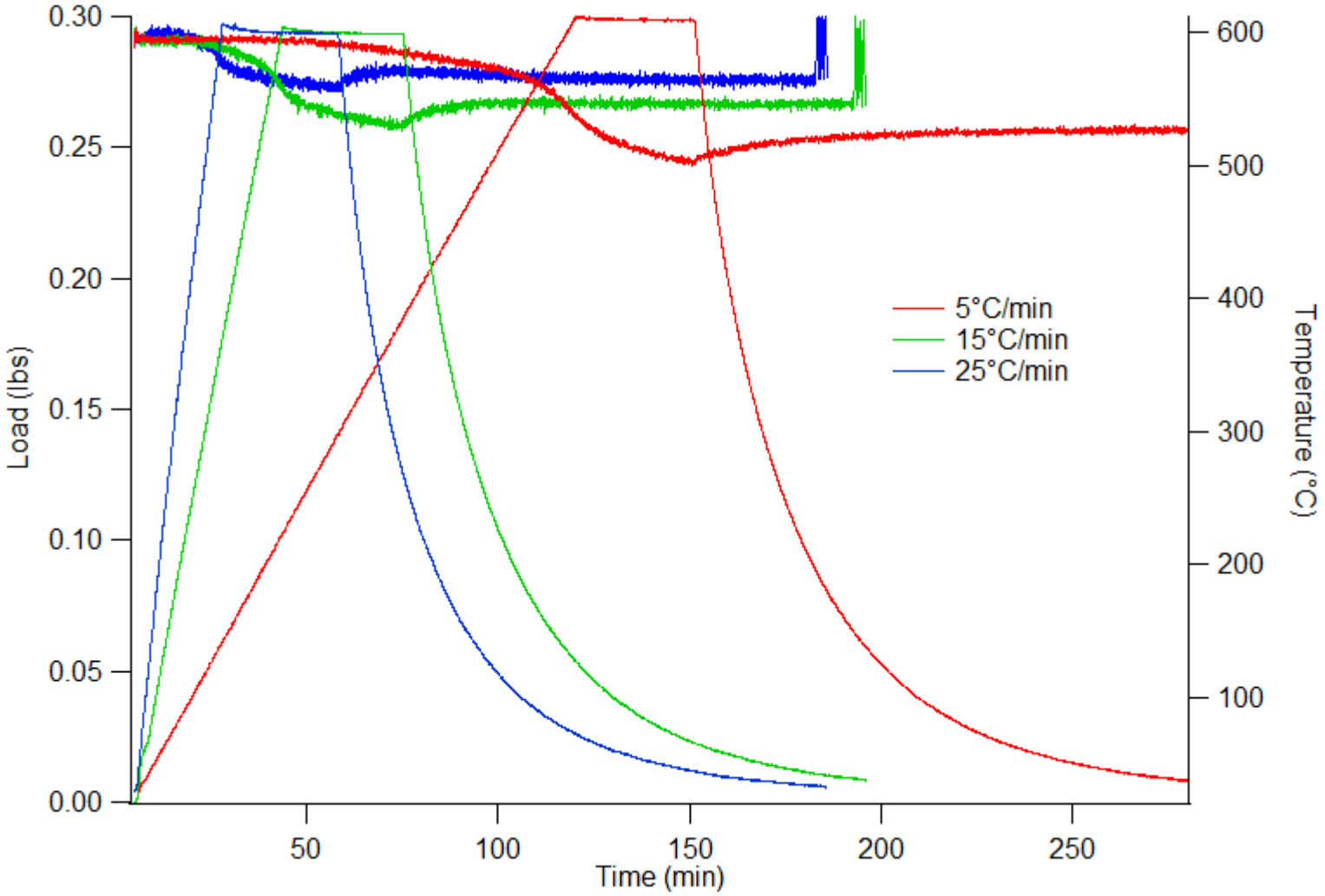
400-600C

Thermal Degradation of Each Spring Material



- Load normalized to initial load
- Both heated to 600C
- Elgiloy shows little creep while 304 loses a lot of load carrying ability

Effect of Heating Rate



Spring Deformation Due to Relaxation

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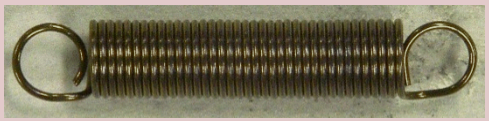
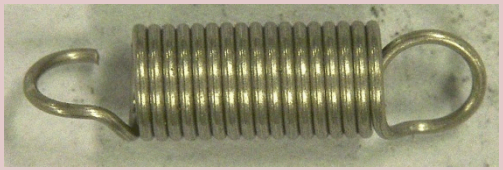
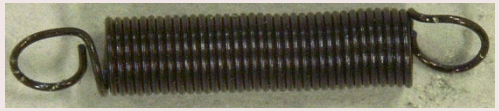
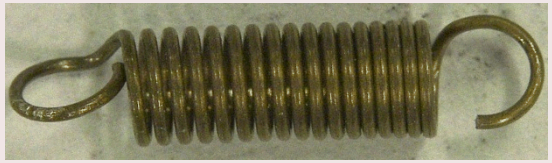
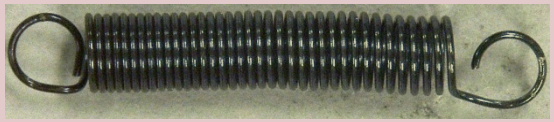
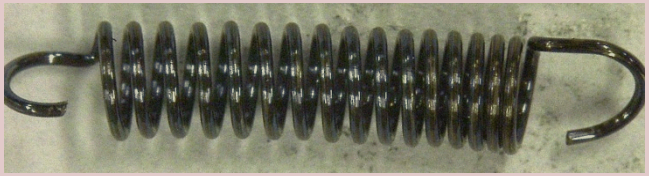
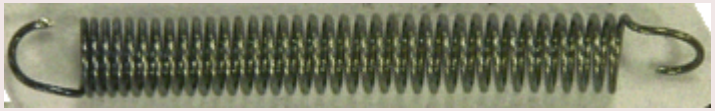
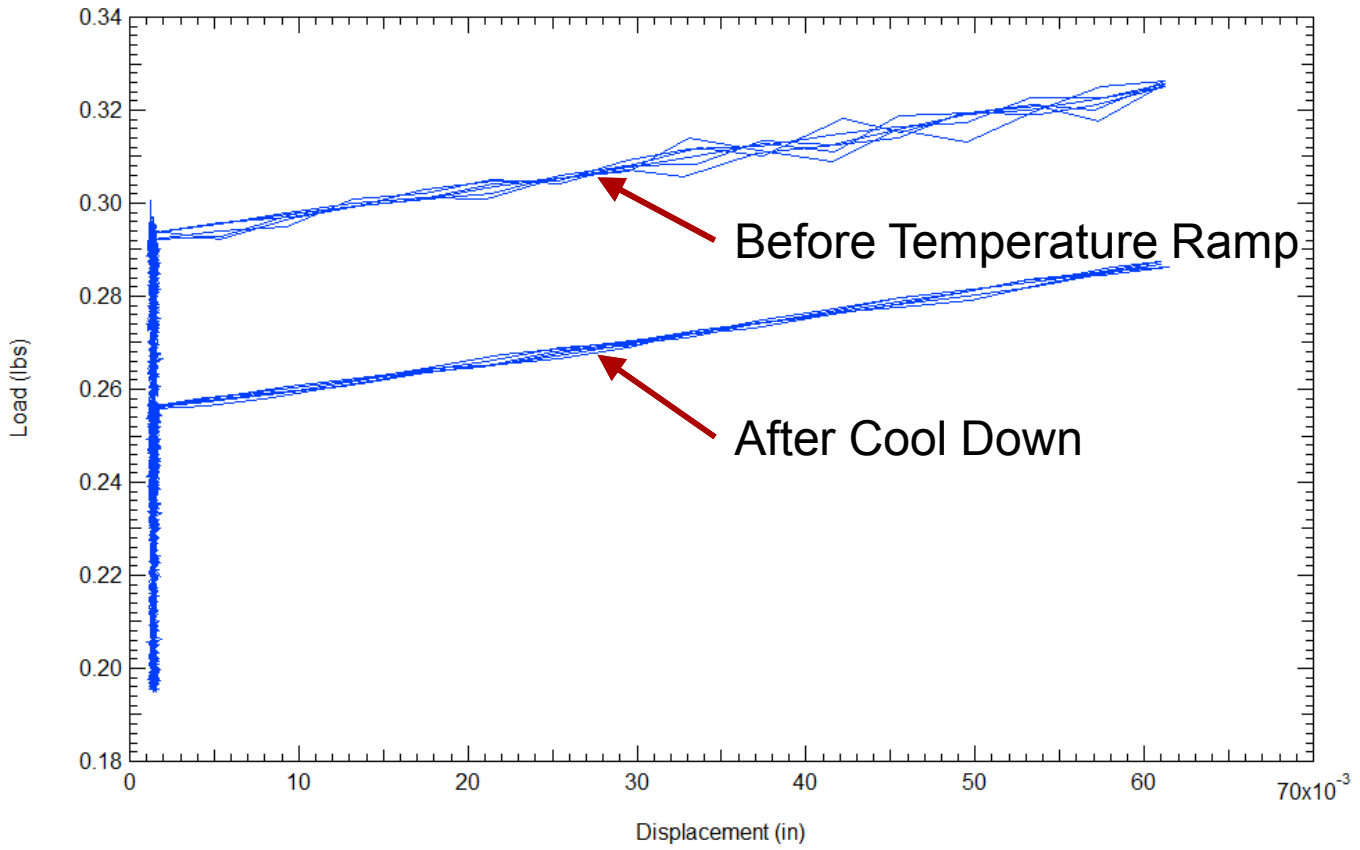
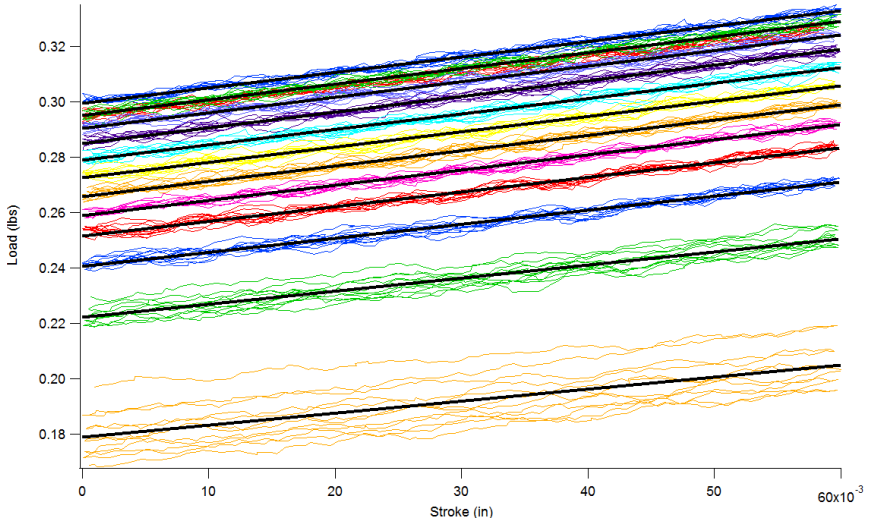
	Elgiloy	304 Stainless Steel
New		
500°C		
600°C		
700°C		

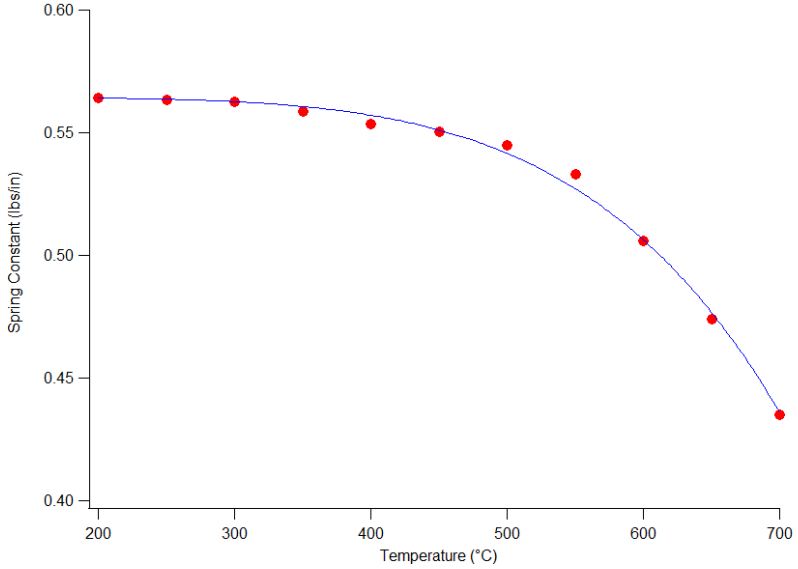
Spring Constant



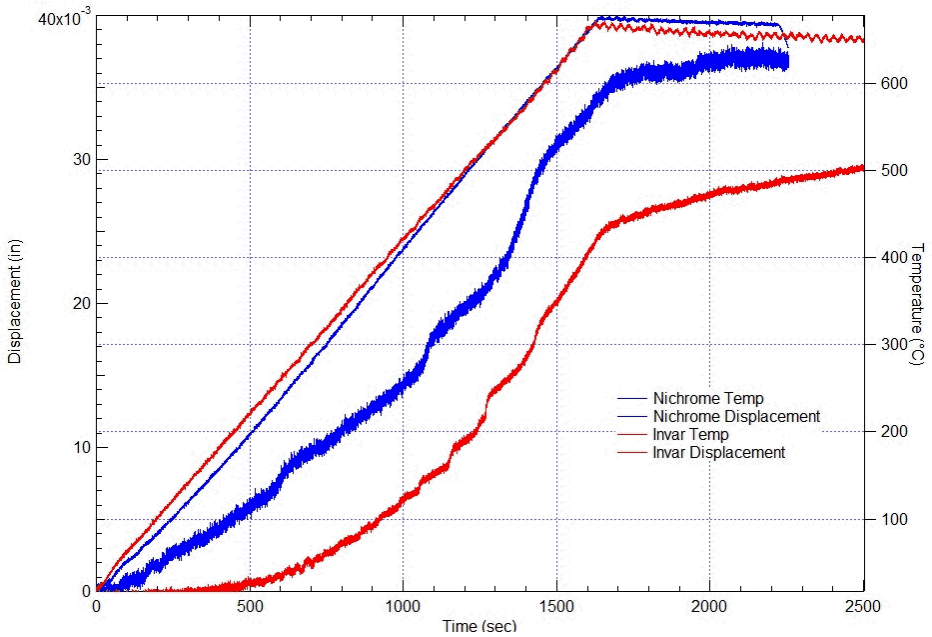
- Temperature cycle produces no lasting effect on spring constant

Temperature Dependence of Spring Constant





Fixture Improvement



- Nichrome wire is used for the hanger material for all tests shown
- 0.03” diameter wire held at 1 lbf as temperature ramped at 25° C/min
- Invar wire has much smaller CTE
- Both creep at high temperature
- PTFE coated quartz thread to be investigated

Summary

- Elgiloy is much more stable than 304 stainless steel at high temperature
- Work needs to be done to remove creep from fixture itself
  - Quartz thread
  - Ceramic support
  - Thicker wire to reduce stress
- Electromechanical frame is preferable to servo-hydraulic
- Isolating modes of deformation can be challenging