SAND2019-6208C

Sandia National Laboratories

Stress relaxation in springs

PRESENTED BY

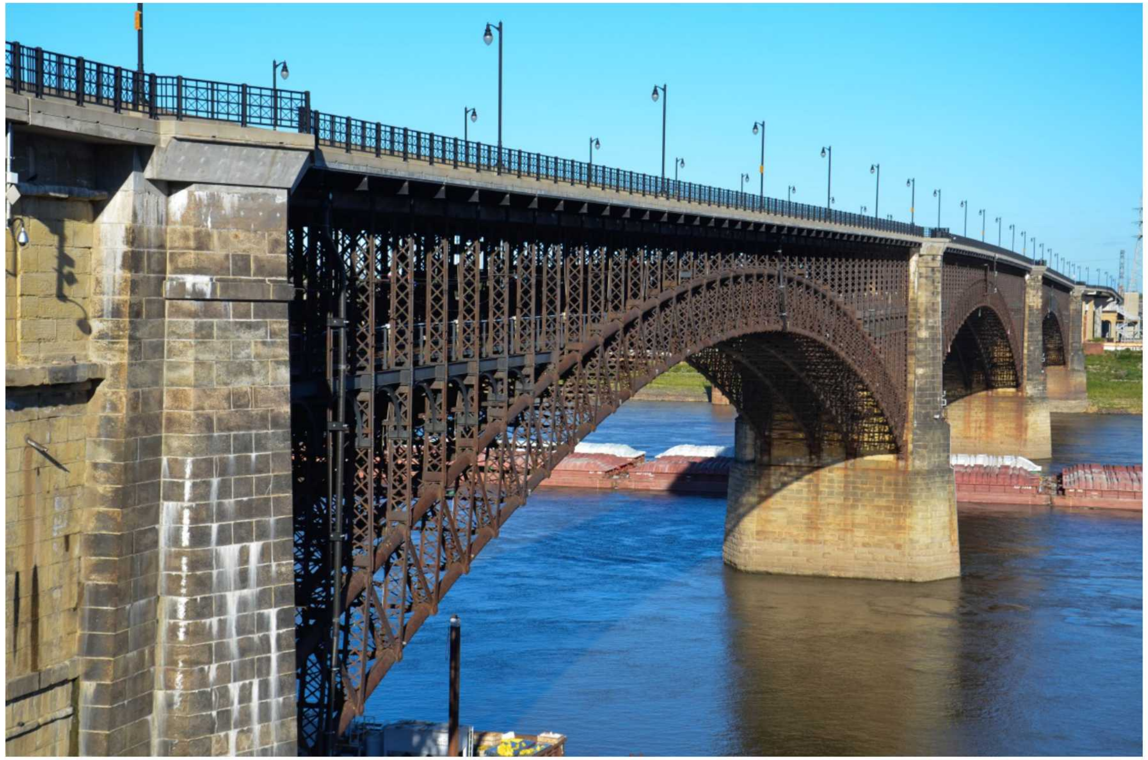
Lisa Deibler, John Laing, Chris Finfrock, Aron Robbins

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Is stress relaxation/creep at room temperature really a problem?

Over 144 years, creep of chrome steel to failure at ambient St. Louis temperature has not been an issue.

Eads bridge, St. Louis ca. 1874



Eads bridge, St. Louis 2012

Evidence of room temperature time dependent deformation

Spring set/spring relaxation

Silver braze joints which exhibited delayed failure [Kassner]

Stress relaxation in concrete bridge reinforcement [Krapf]

- From 14% YS to 64% YS and from 11% UTS to 51% UTS (in service)

Creep at moderate temperature in 4320 steel [Neu]

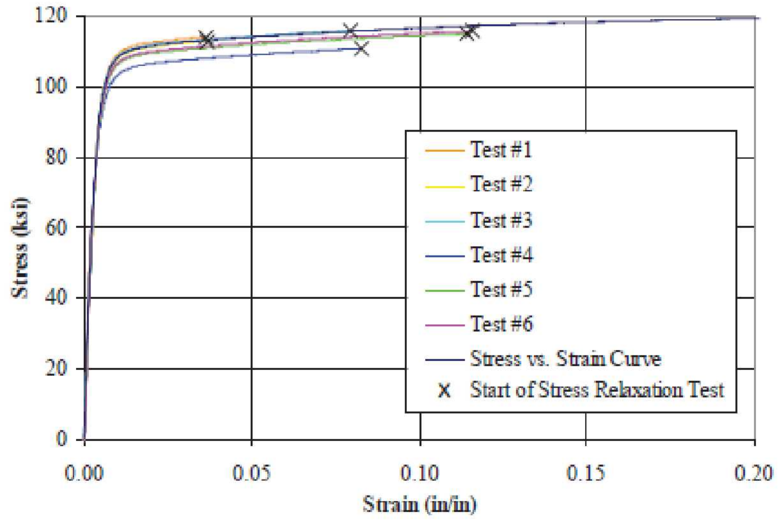
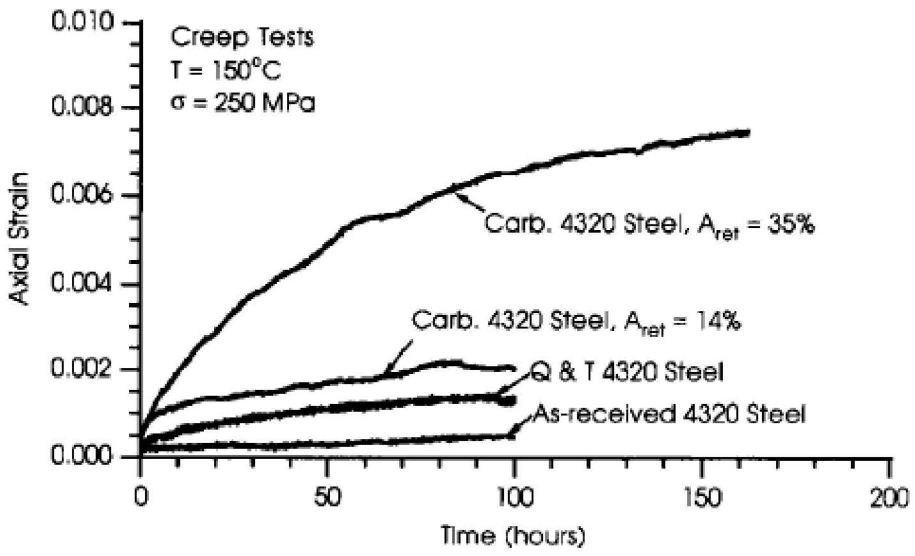


Figure 4.3: Stress *vs* Strain Curves Prior to Relaxation Tests



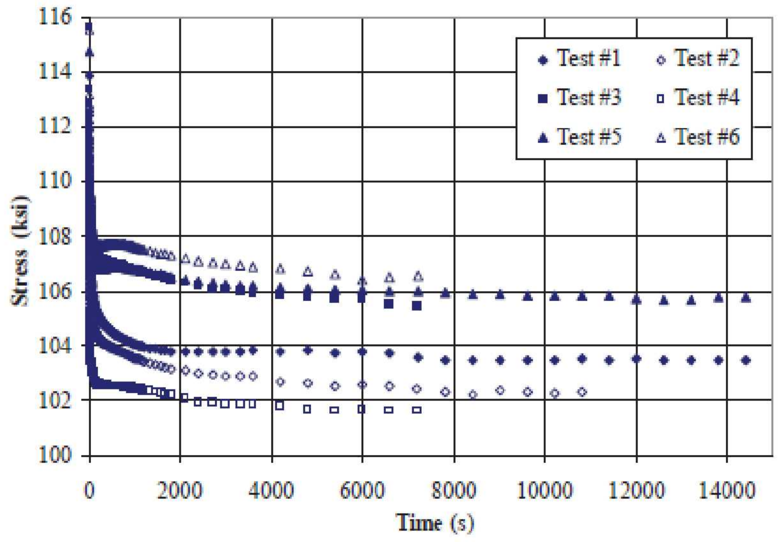
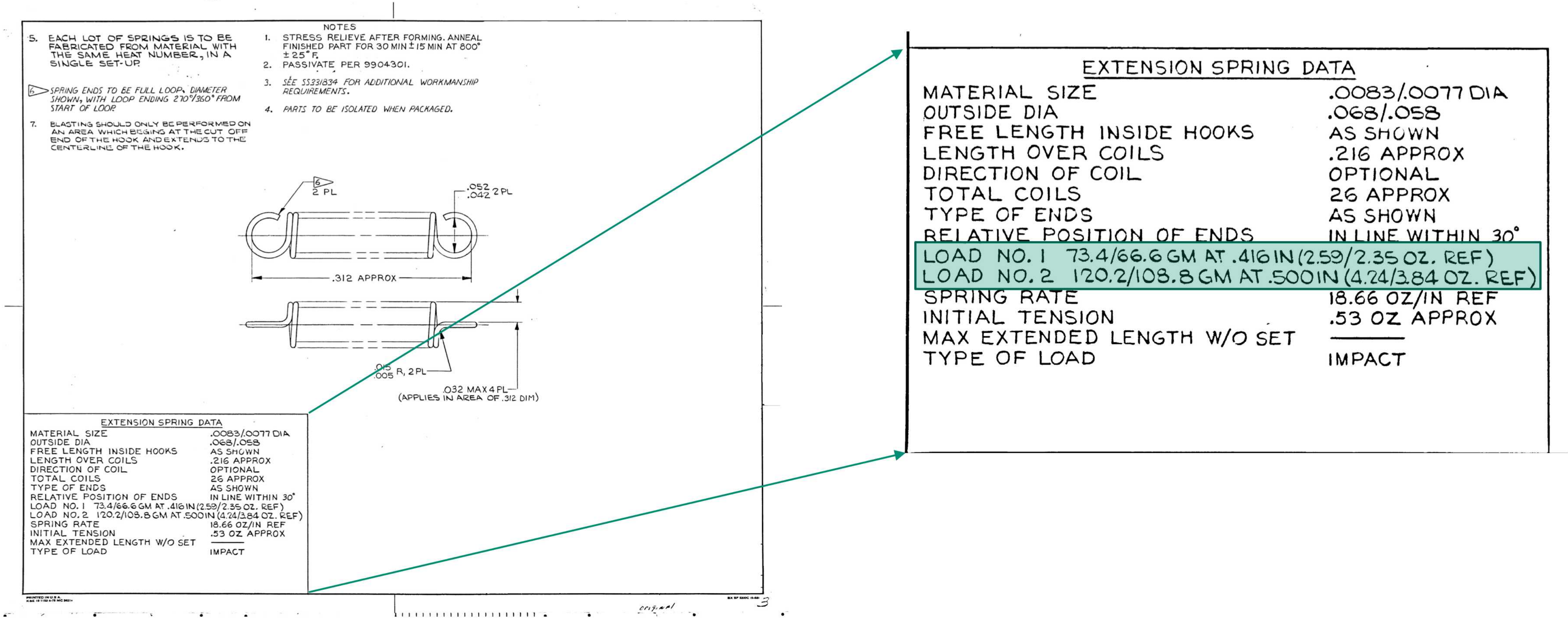


Figure 4.4: Stress Relaxation Results

Spring design

Springs typically sit at one position in the mechanism, then move to a second position to provide force during actuation.



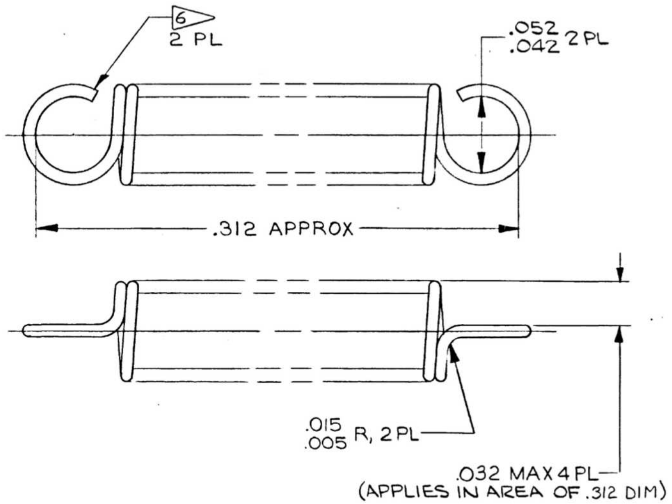
Spring design can be susceptible to room temperature creep

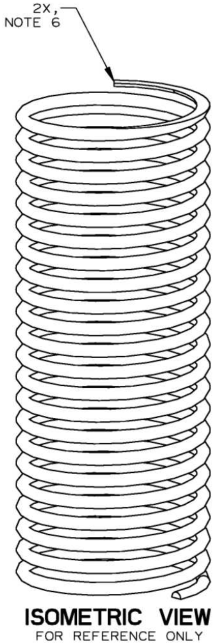
High fraction of yield

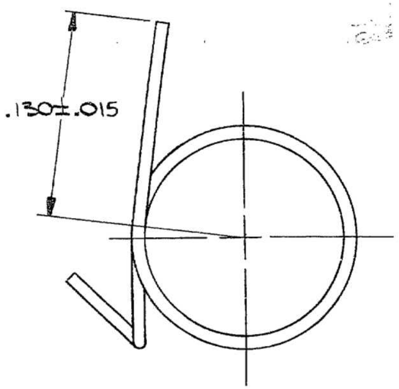
Small changes in spring dimensions can have large effect on force.

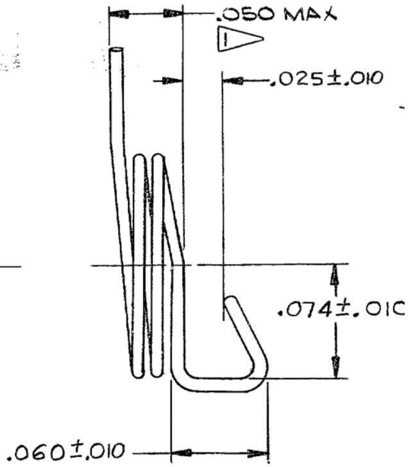
Springs are known to “take a set”.

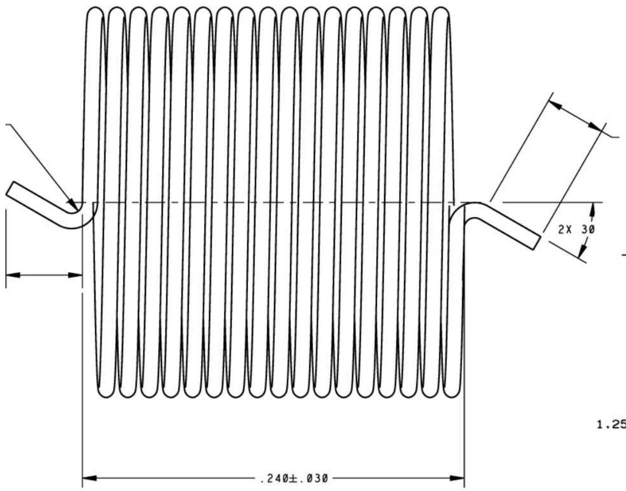
Stress state is complicated – generally torsion, some mixed.

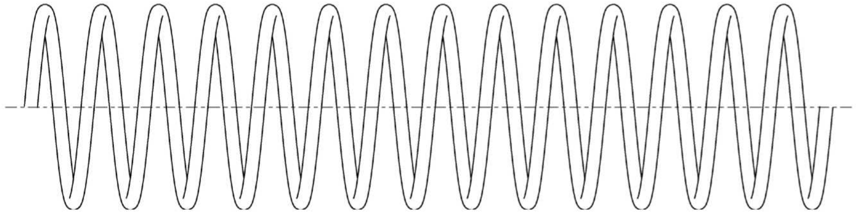


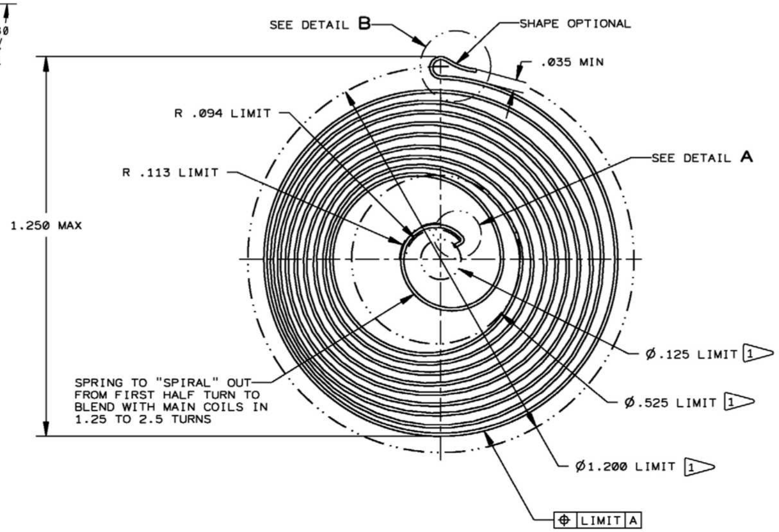












Mechanisms of creep and stress relaxation

Diffusion based
- Nabarro-Herring – through grains
- Coble – along grain boundaries

Definitely high temperature mechanisms

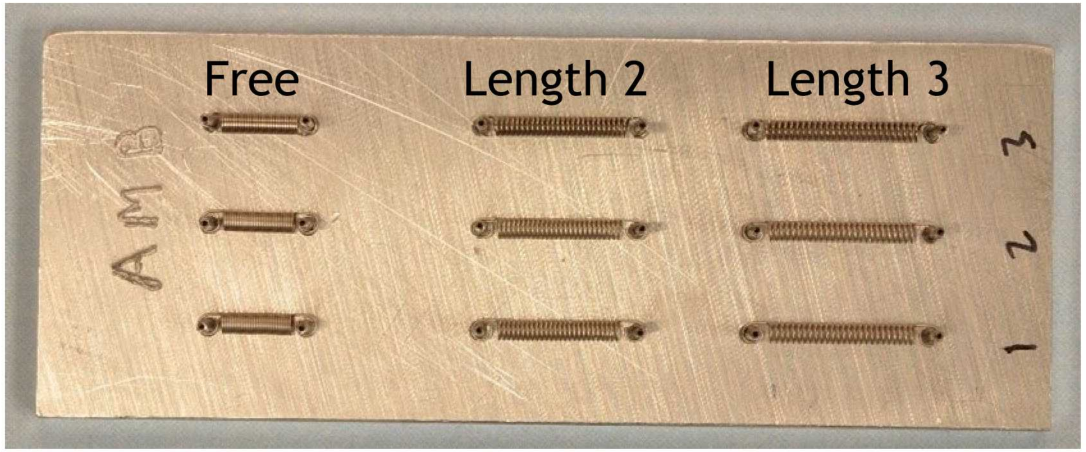
Dislocation creep – at high stresses
- Dislocation Climb
- Harper-Dorn

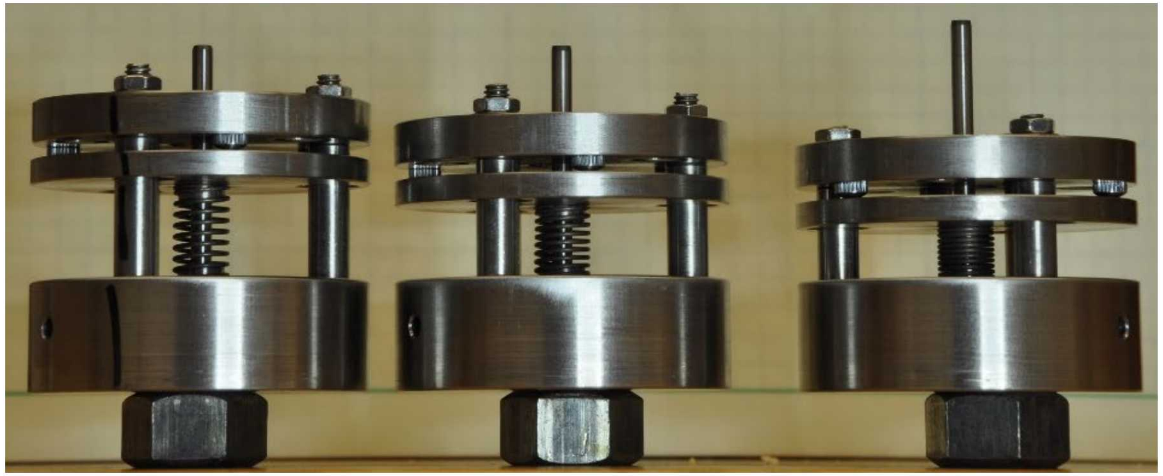
Solute drag – dislocation and diffusional flow

High temperature mechanisms, but maybe low too?

How to accelerate spring aging?

Increase the stress



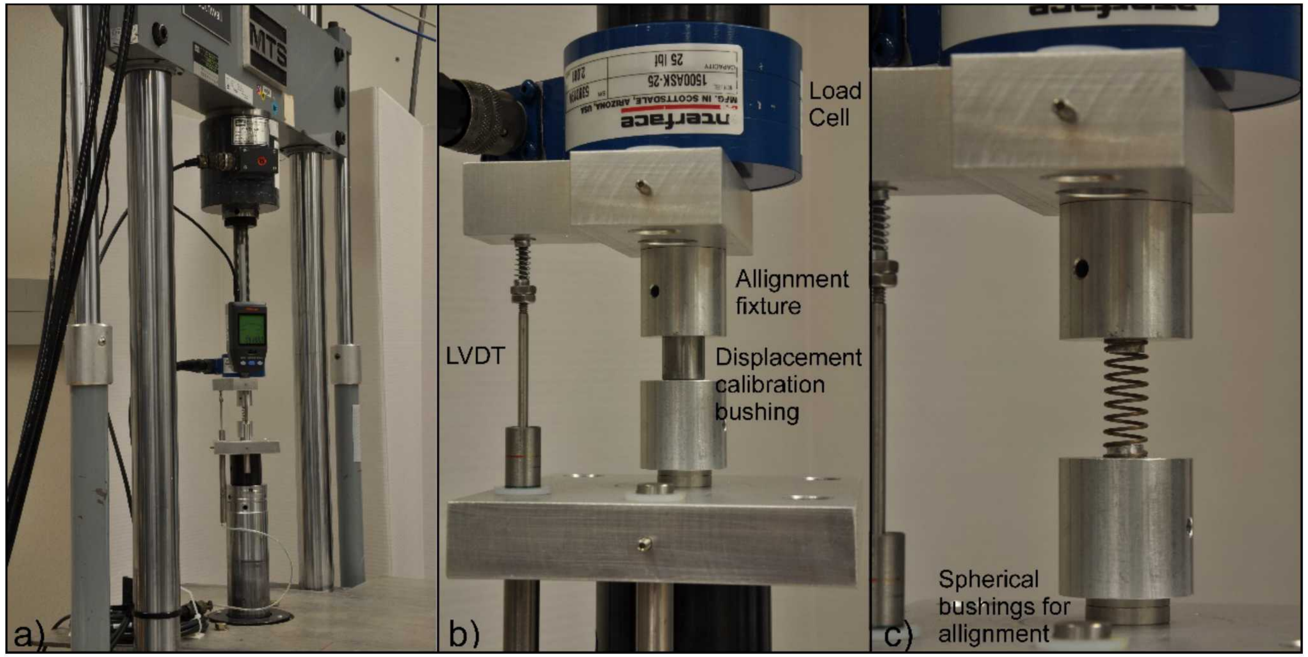


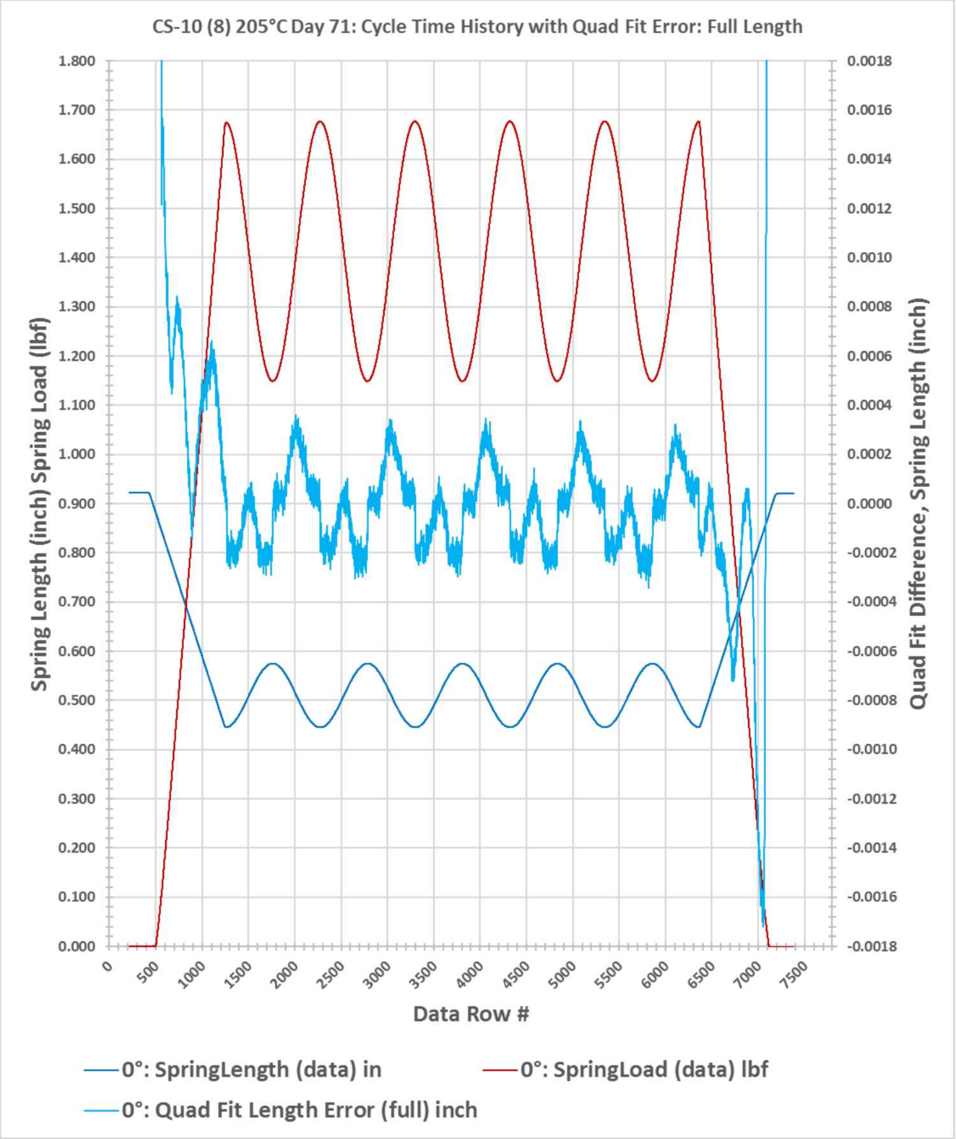
Increase the temperature < 0.4 melt temperature (Homologous temperature)

Temperature (˚C)	Homologous temperature	
	17-7 PH	303
Room temperature	0.18	0.18
70˚C	0.21	0.21
100˚C	0.22	0.22
170˚C	0.26	0.26
205˚C	0.29	0.29

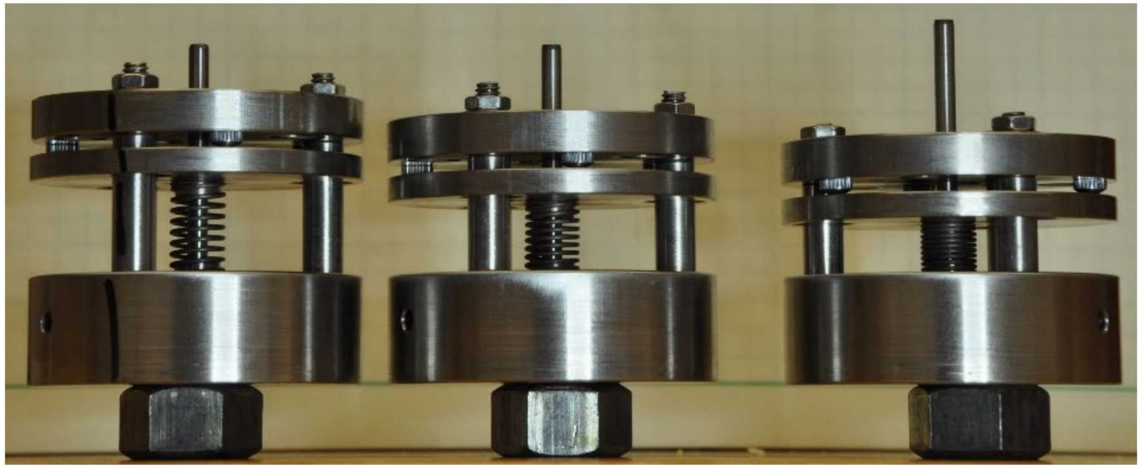
How to measure tiny displacements

Minimize experimental variation





Particular springs tested and motivation

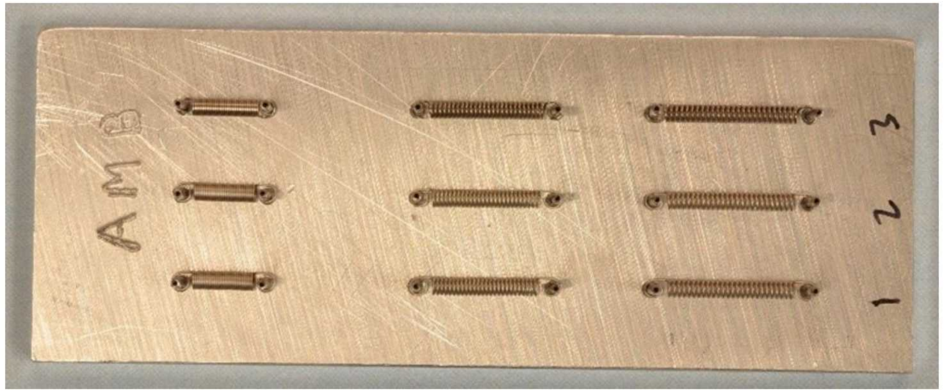


Piston springs

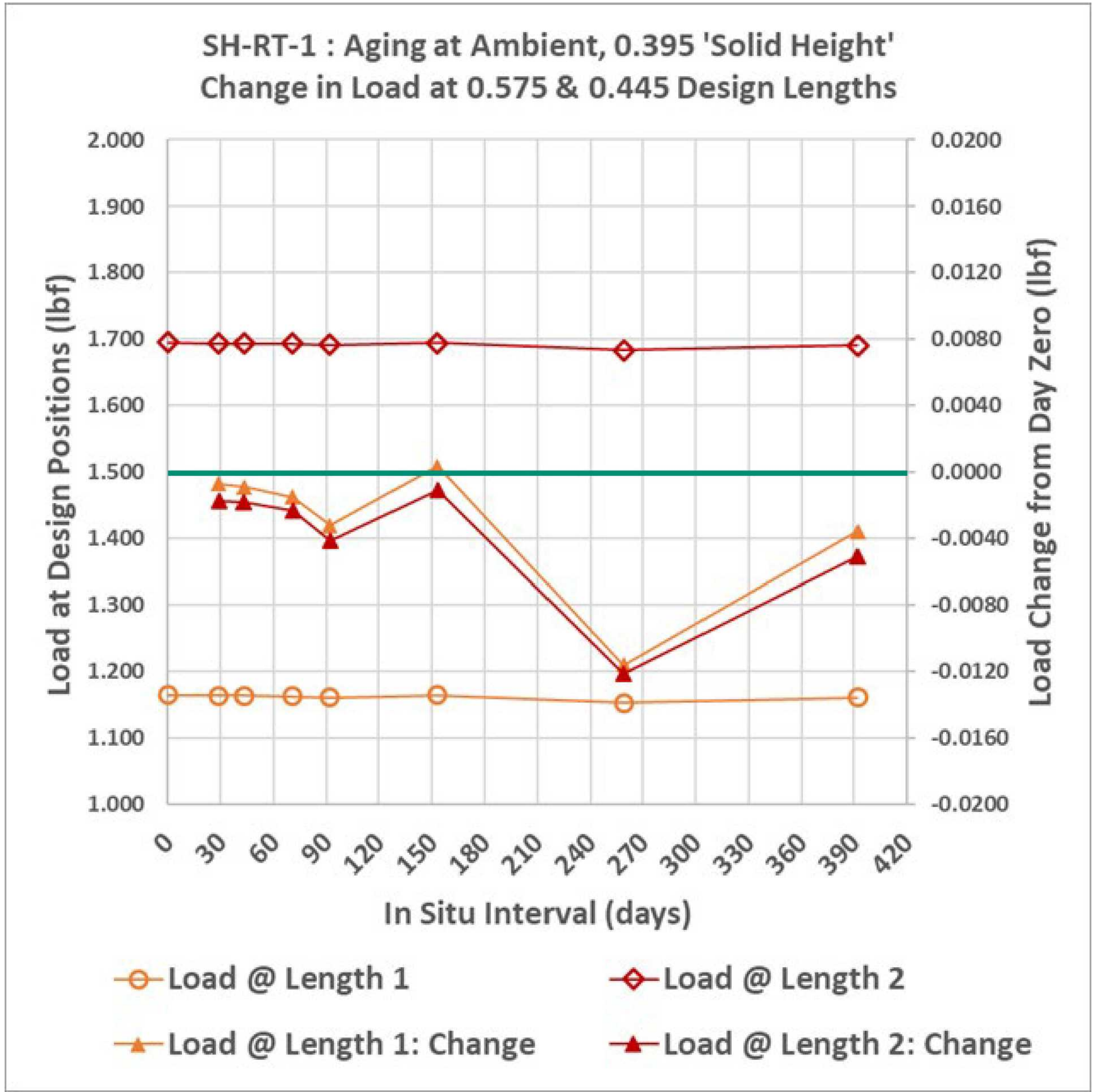
- Potential spring performance degradation concern
- 17-7 PH compression spring

Timing springs

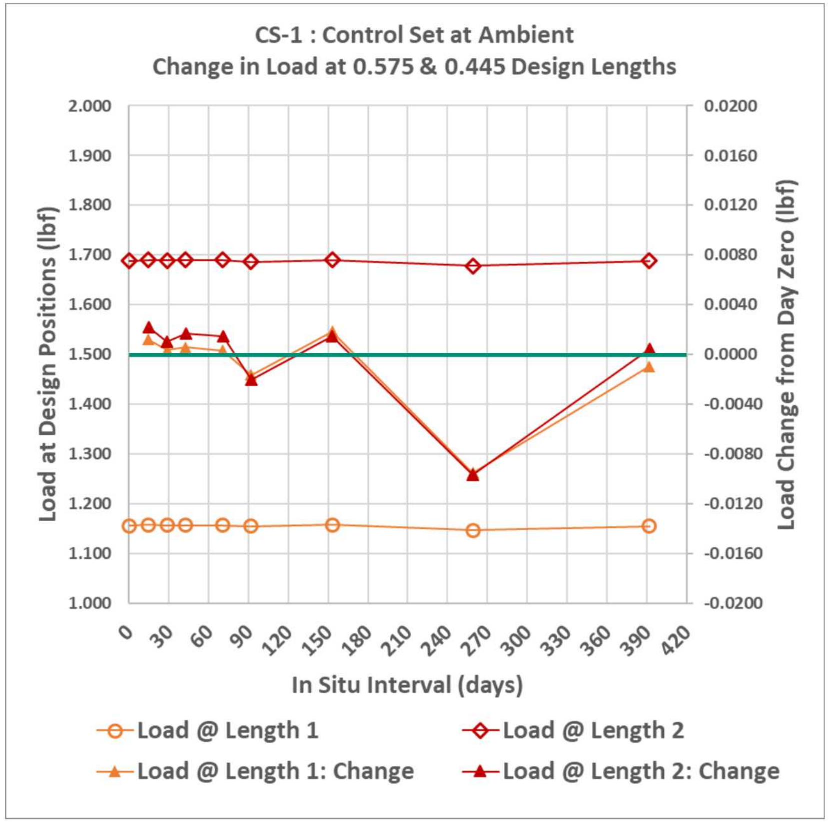
- In many systems, and potential for spring performance degradation
- 303 stainless steel tension spring



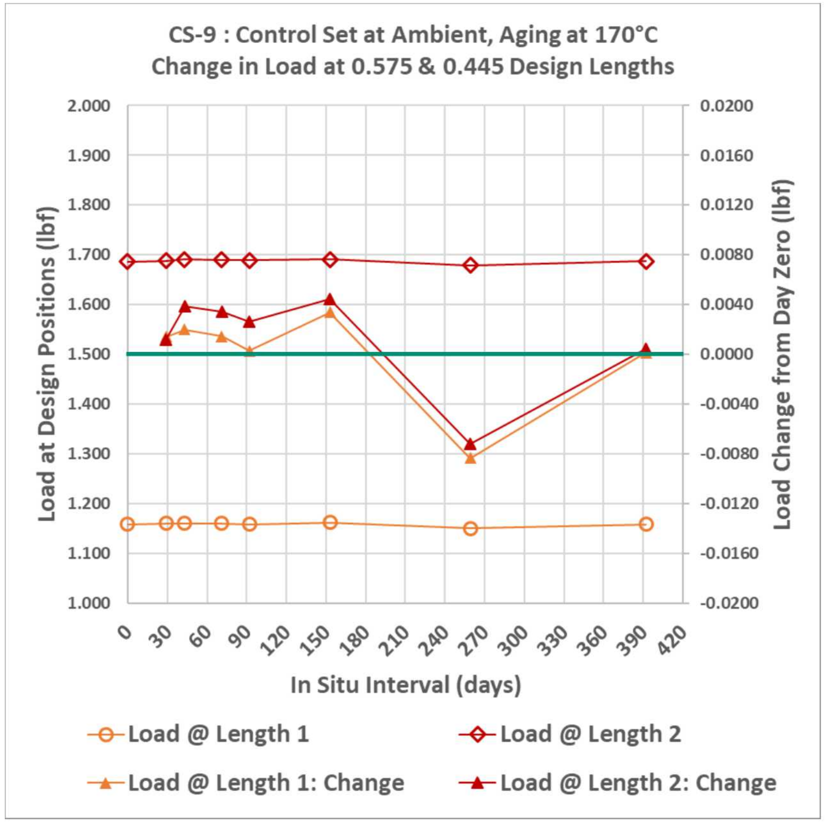
Example of data – 17-7 compression spring at ambient temperature, solid height, 390 days



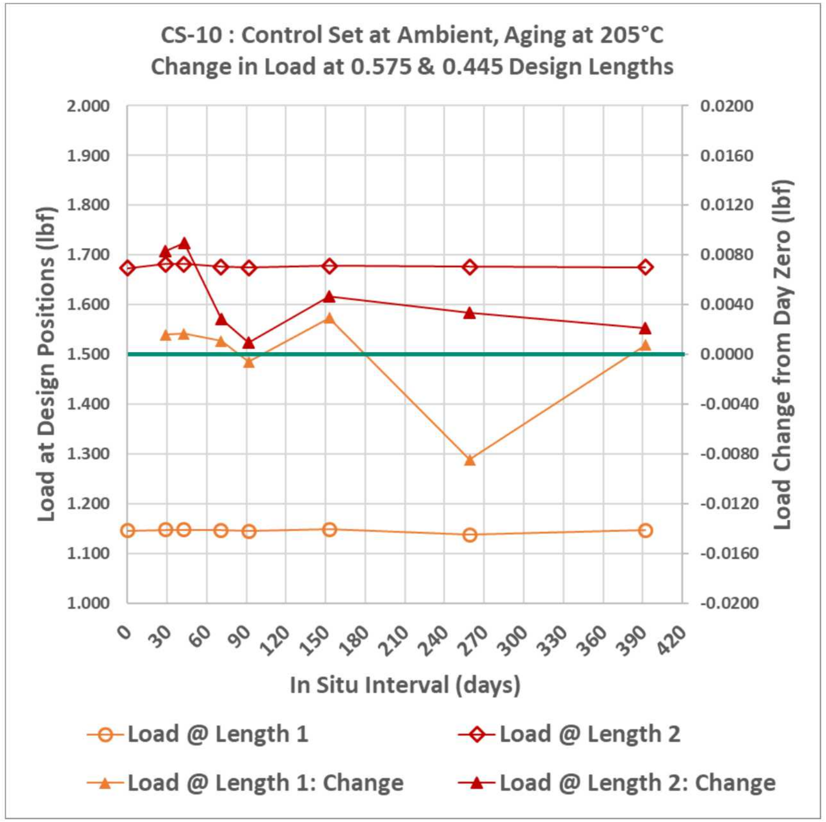
Results from 17-7 PH compression springs – free length at various temperatures



25°C



170°C



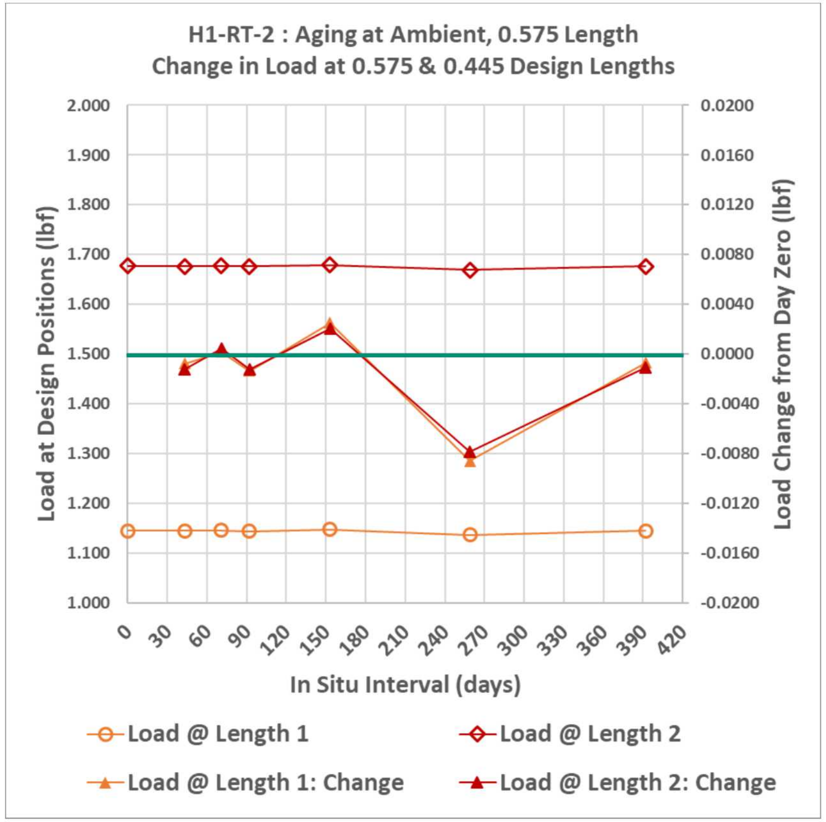
205°C

Shows variation of measurement – some deviation at the 260 day measurement

Essentially no change

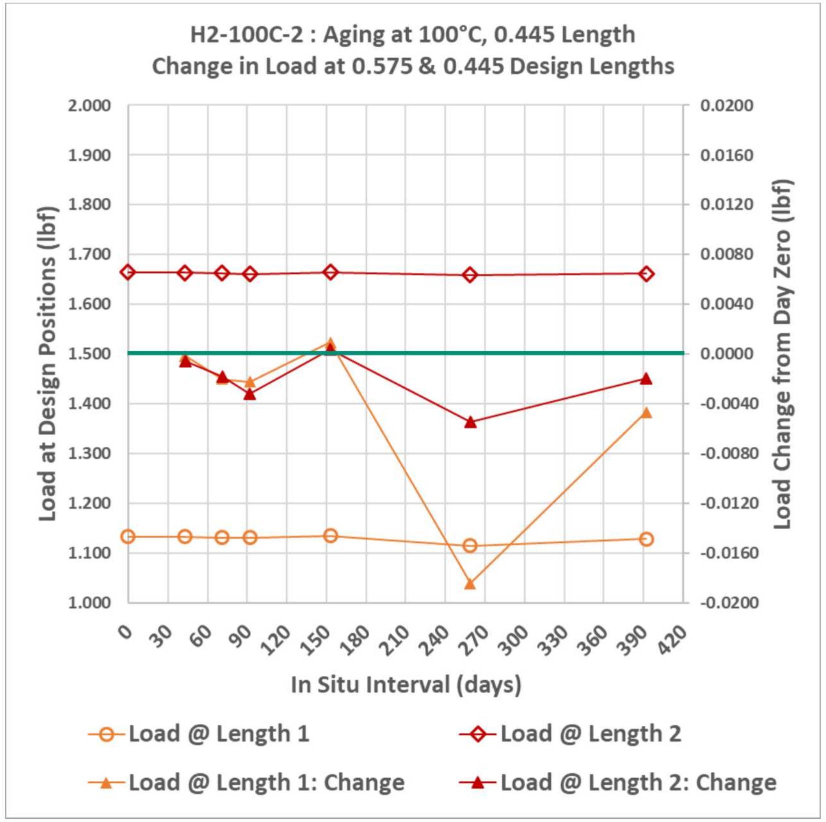
The springs got longer?!

Results from 17-7 PH compression springs – Height 2 at various temperatures



25°C

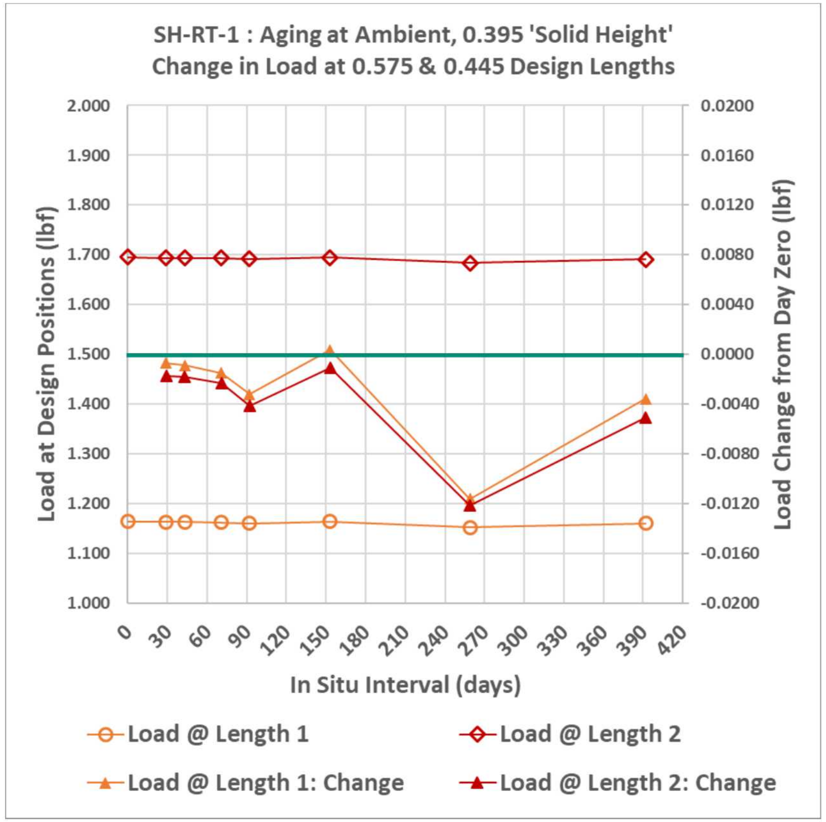
Essentially no change



100°C

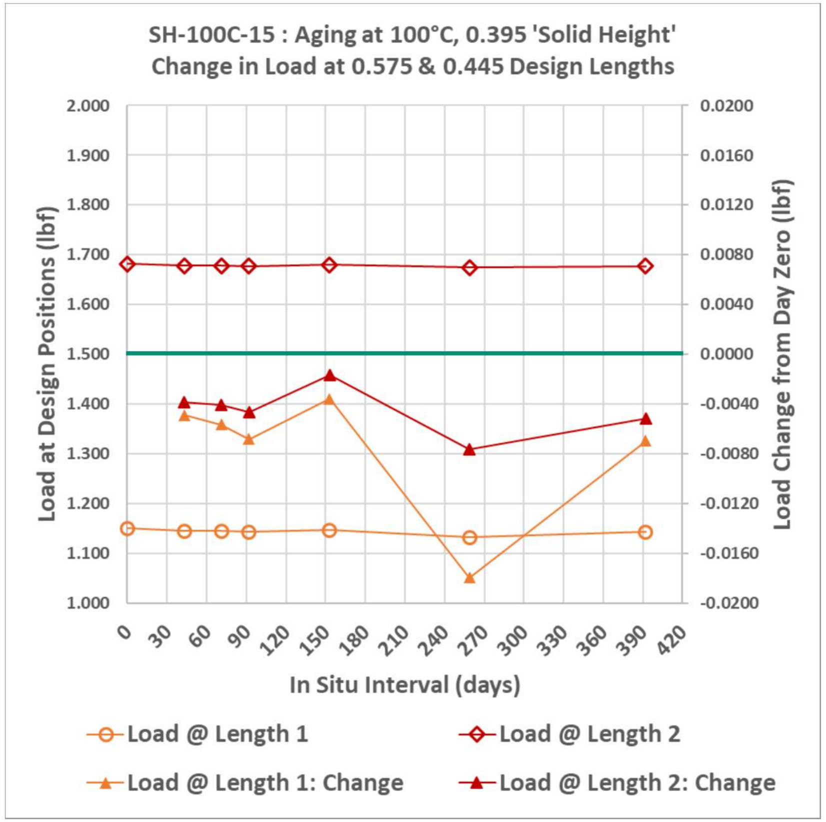
Essentially no change, not sure what happened to load at length 1 – think it is not real.

Results from 17-7 PH compression springs – Solid height at various temperatures



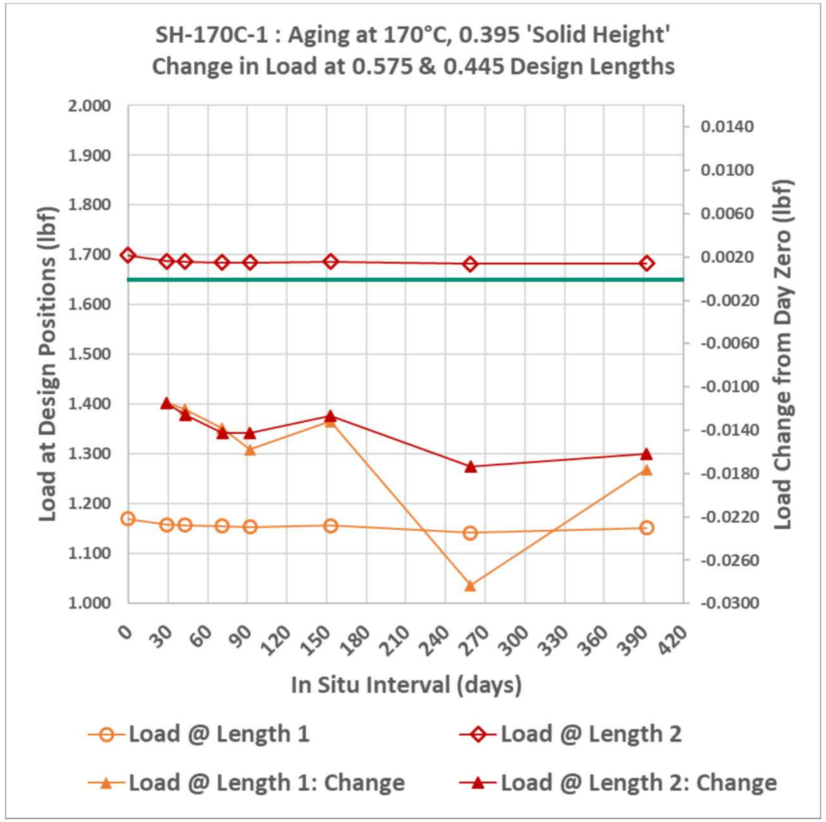
25°C

Springs got shorter



100°C

Springs got shorter



170°C

Springs got shorter

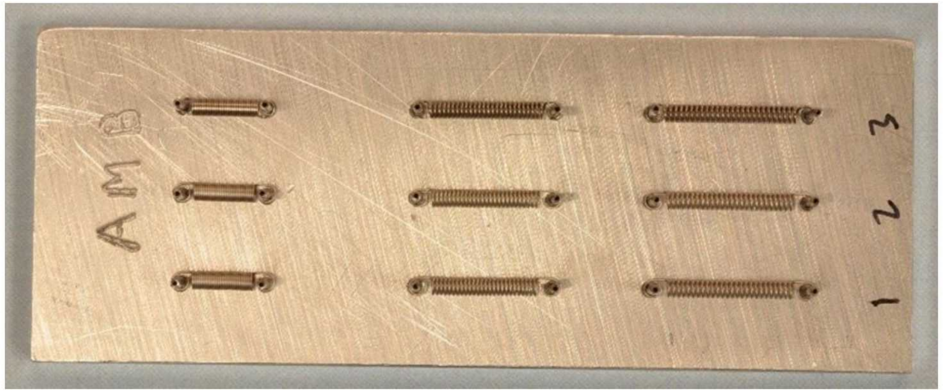
17-7 compression springs results summary

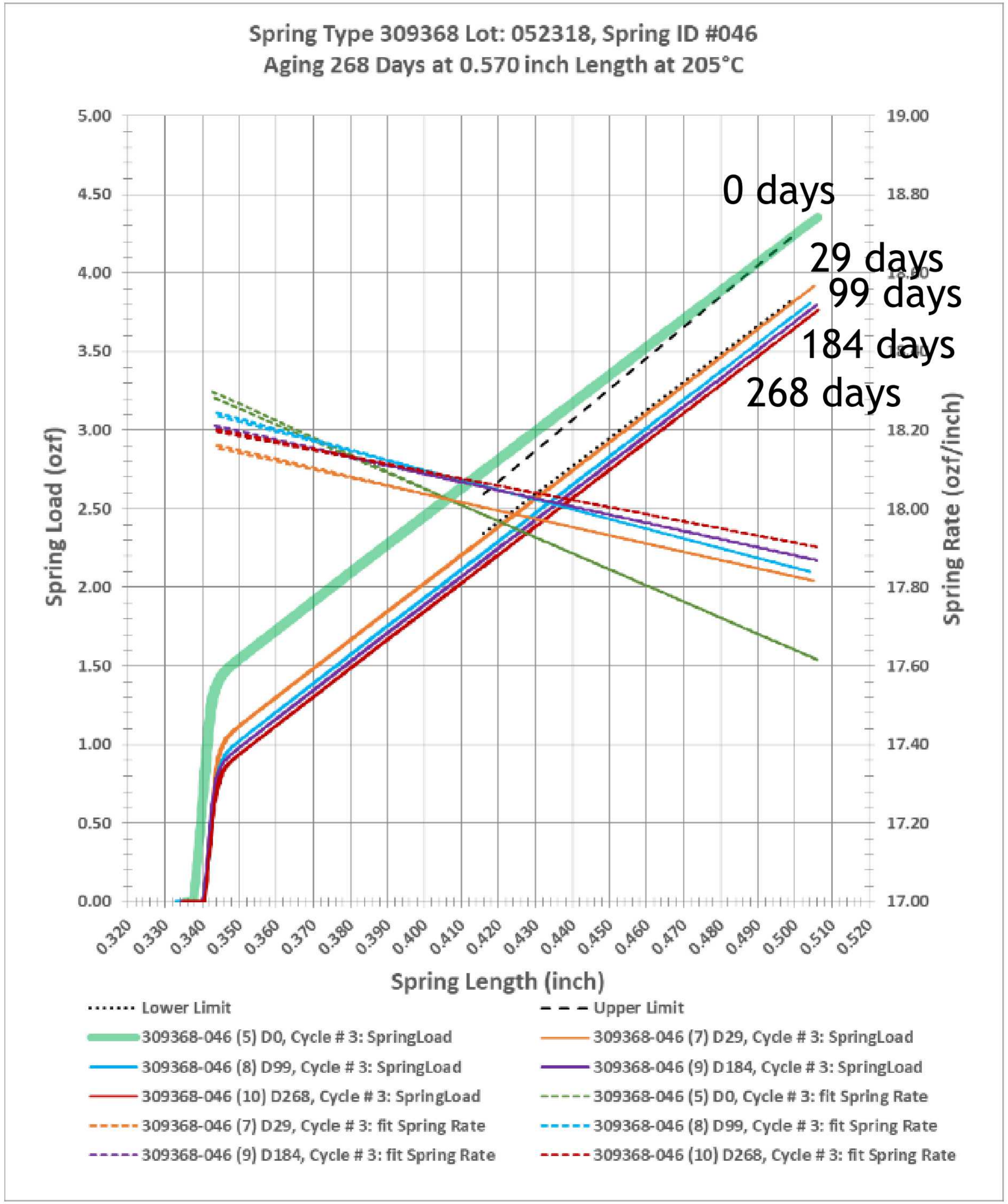
Springs at elevated temperatures of 170°C and 205°C do change shape – at 205°C they get longer if unconstrained – evidence of residual stress relaxation.

Springs at 100°C and room temperature only change shape if they're held at solid height.

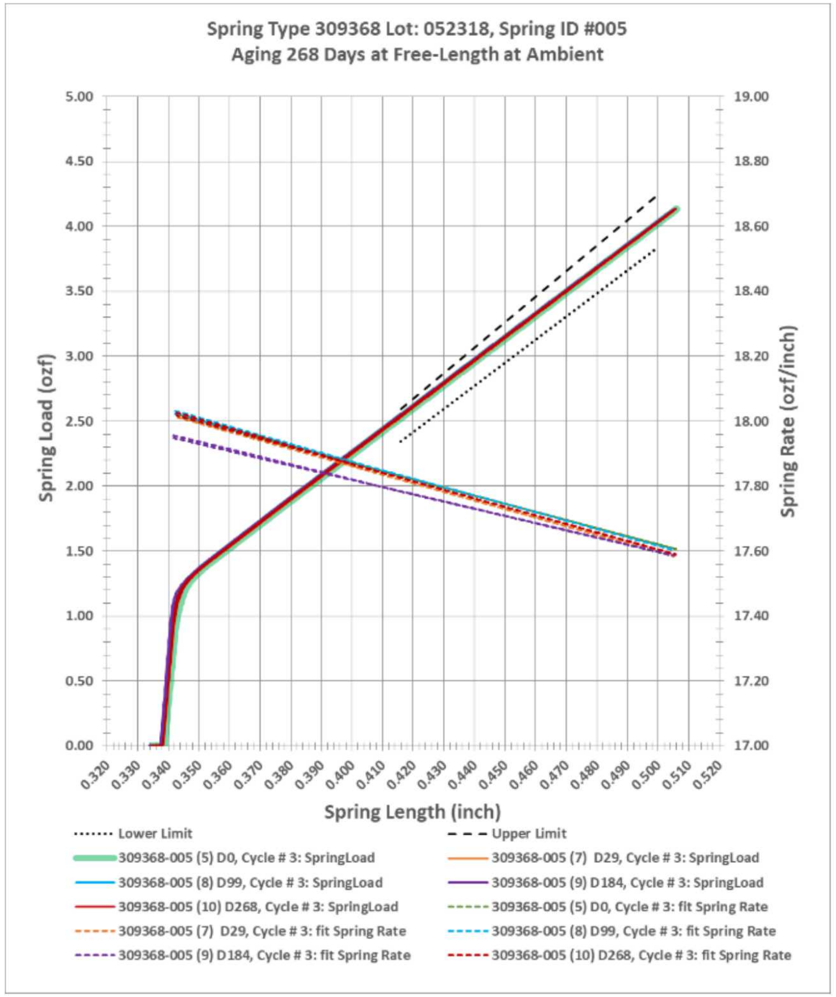
Conclusion: It is not expected that the compression springs will experience any significant stress relaxation over a period of 30 years if kept below 100ºC and in either height 1 or height 2 position.

303 stainless steel tension spring

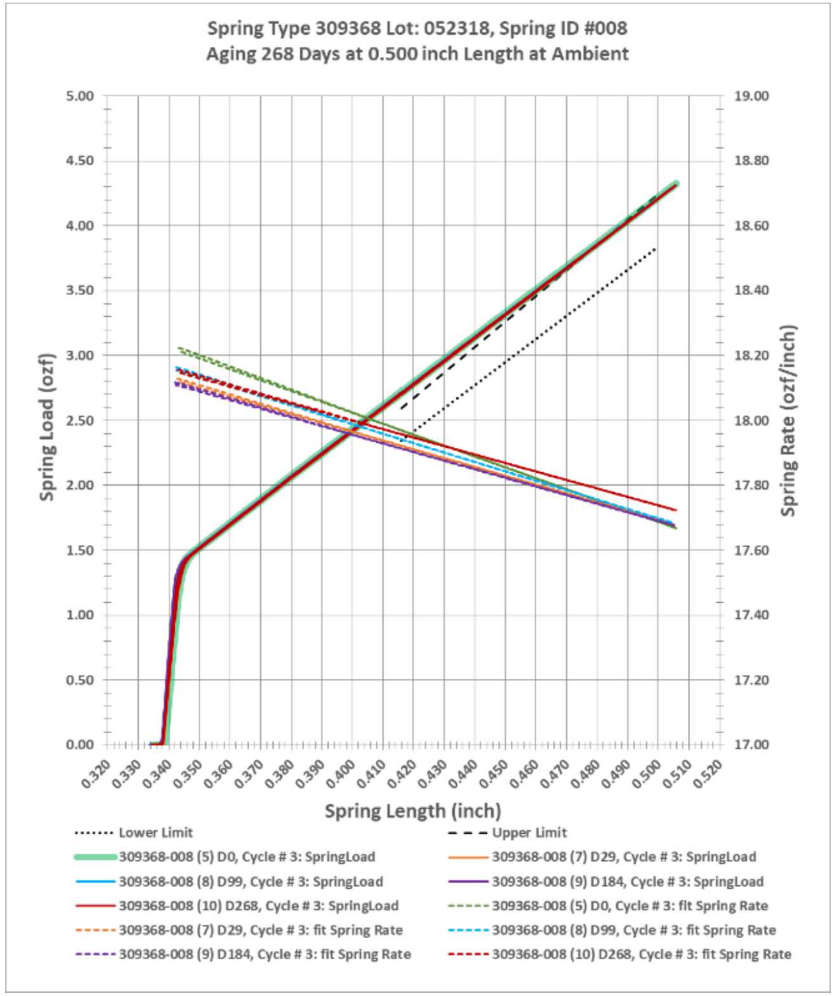




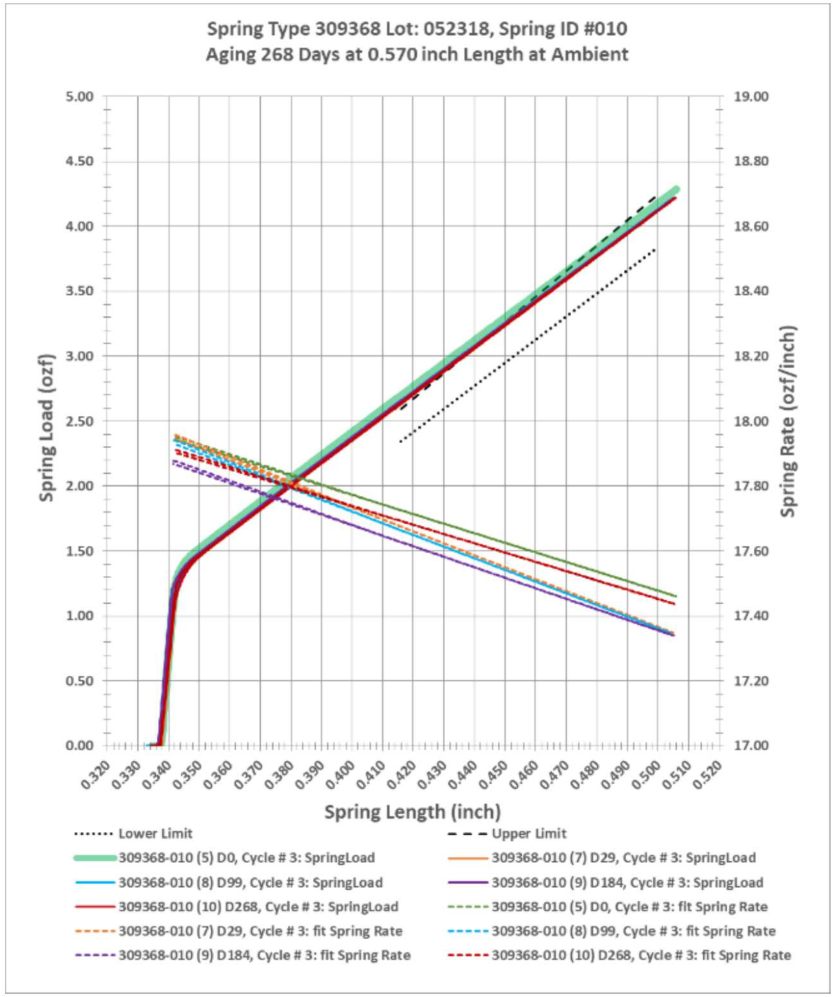
303 stainless steel 268 days aging results – ambient temperature



Free length

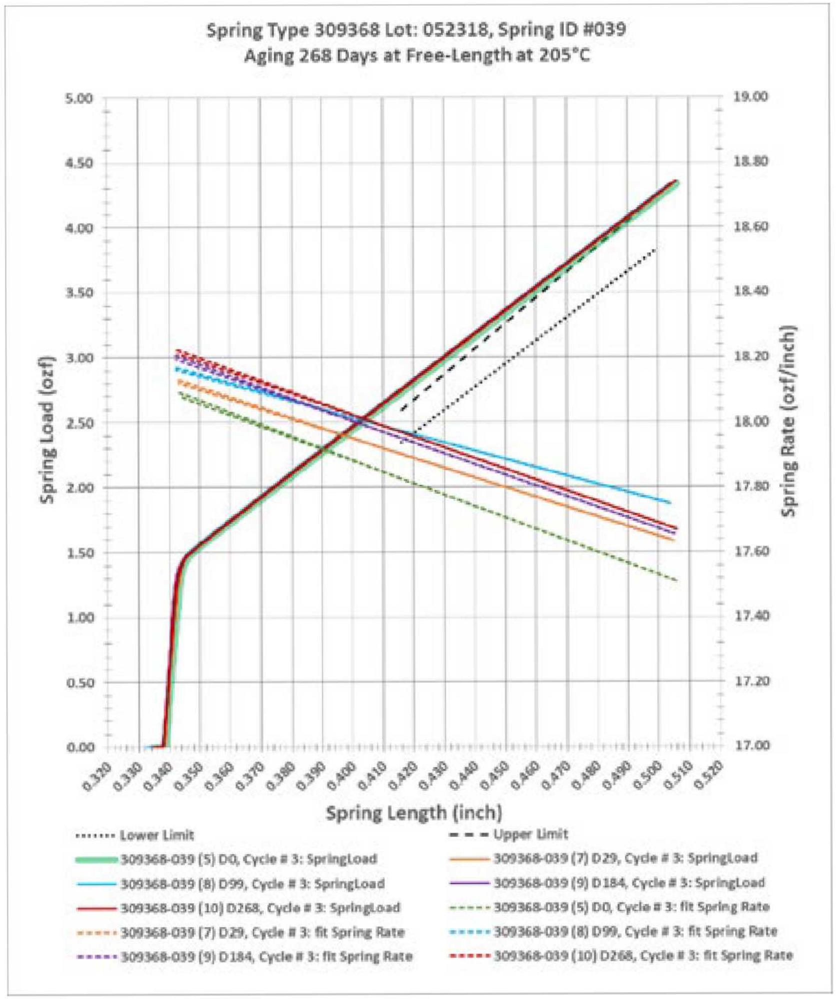


Length 2

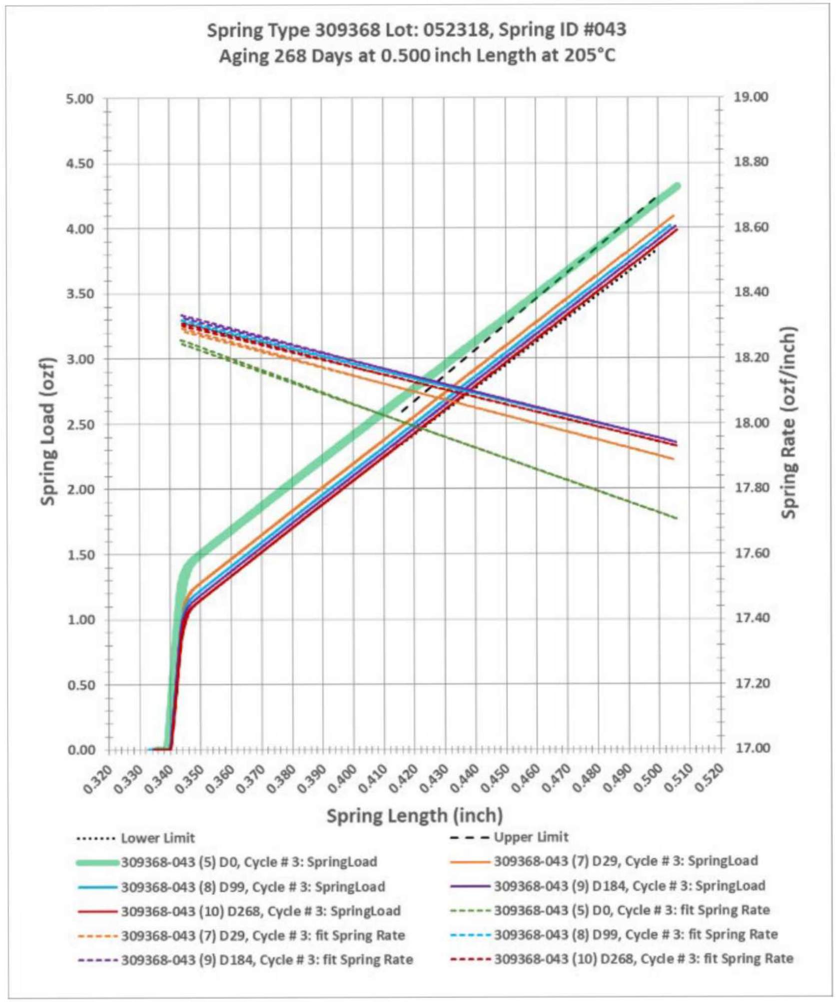


Length 3

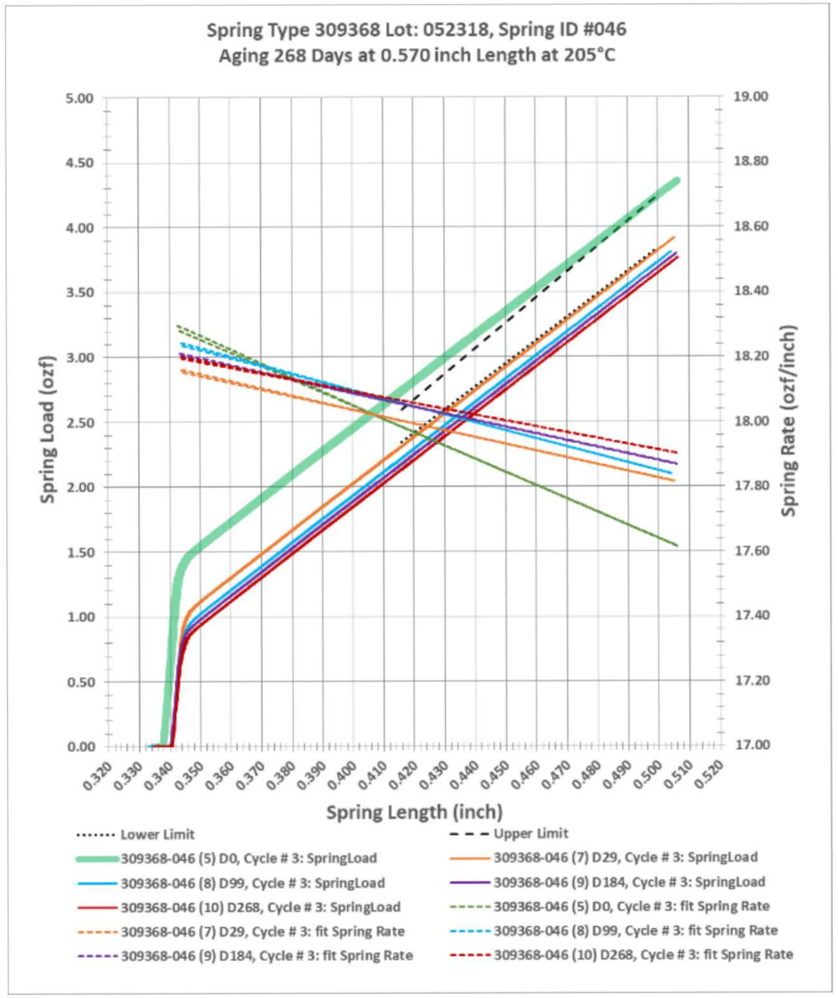
303 stainless steel 268 days aging results – 205°C



Free length

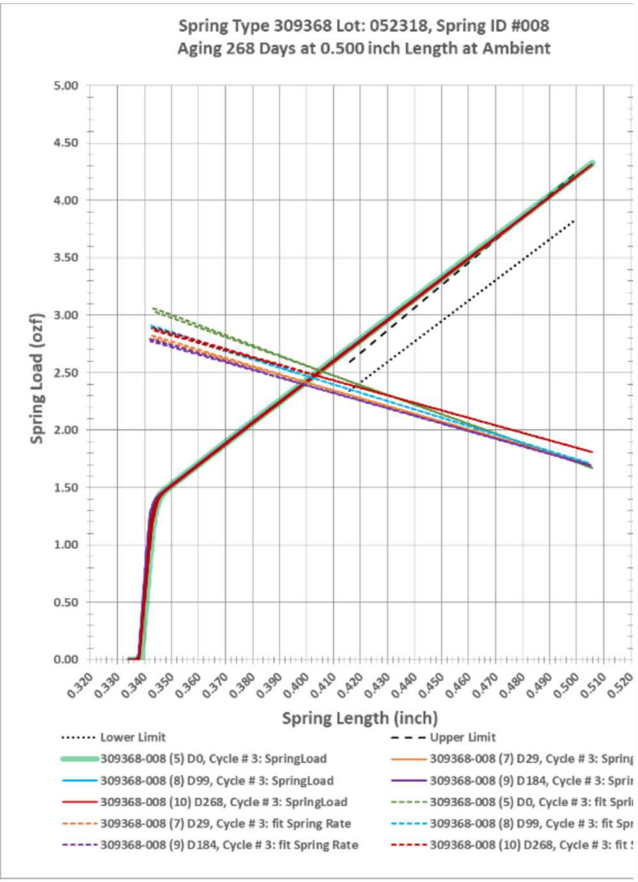


Length 2

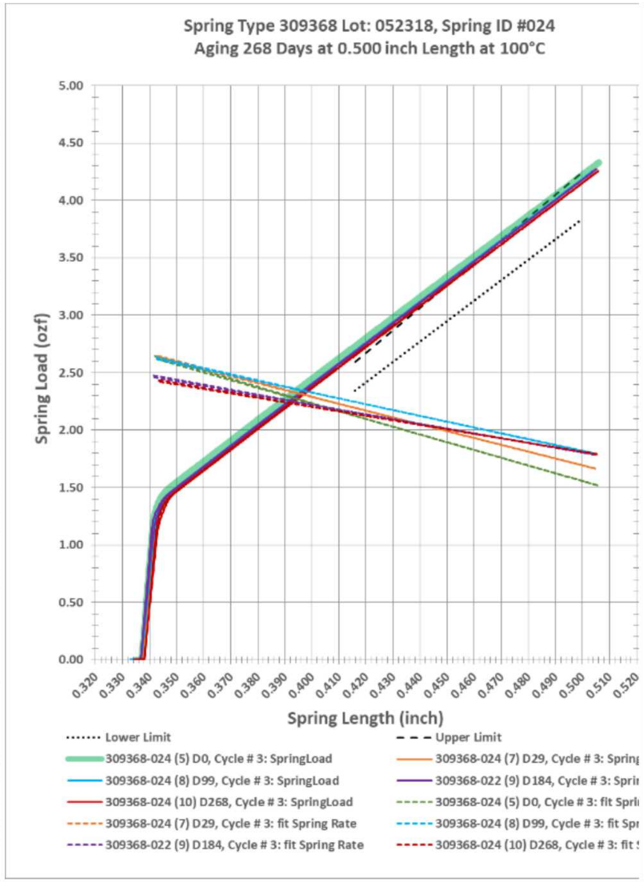


Length 3

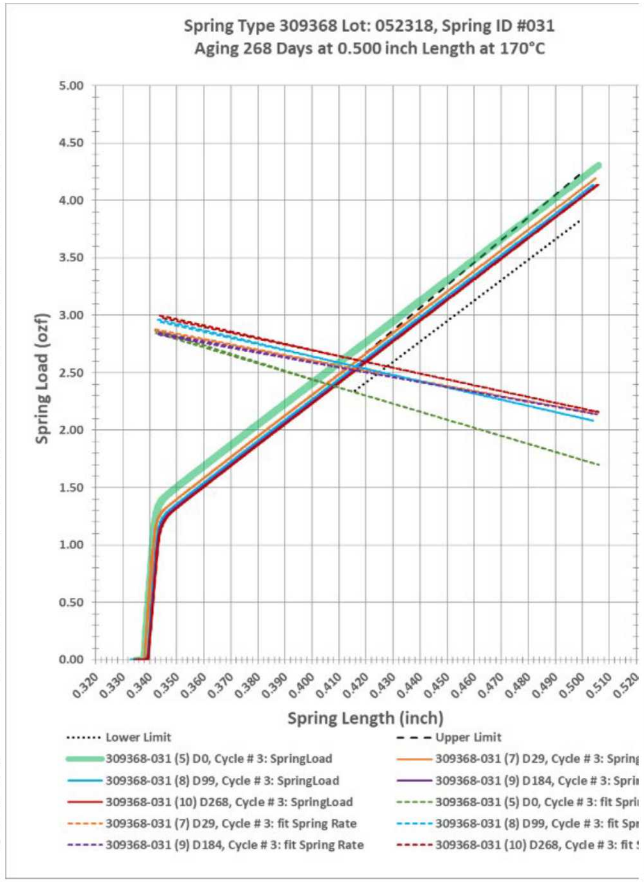
303 stainless steel 268 days aging results – Position 2



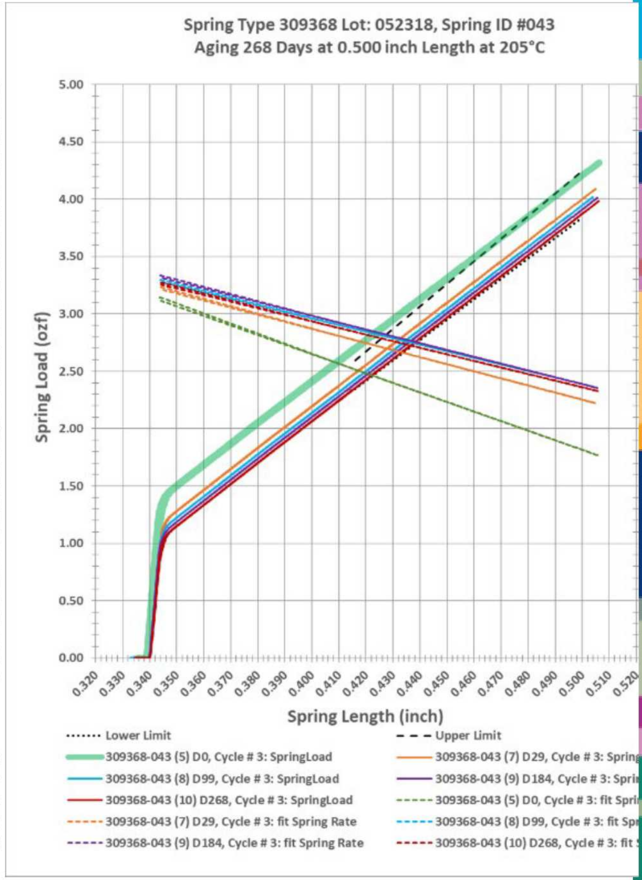
Ambient



100ºC



170ºC



205ºC

303 results summary

Springs under stress appear to change spring constant at room temperature, even at Length 2.

Springs at high temperature appear to change spring constant even at free length.

Initial tension does not change in springs at free length at any temperature.

Initial tension changes some at 0.57 inches at ambient and at 100ºC and 0.5 inch.

Overall summary

We have determined stress and temperature boundaries for onset of low temperature creep in 303 and 17-7 springs.