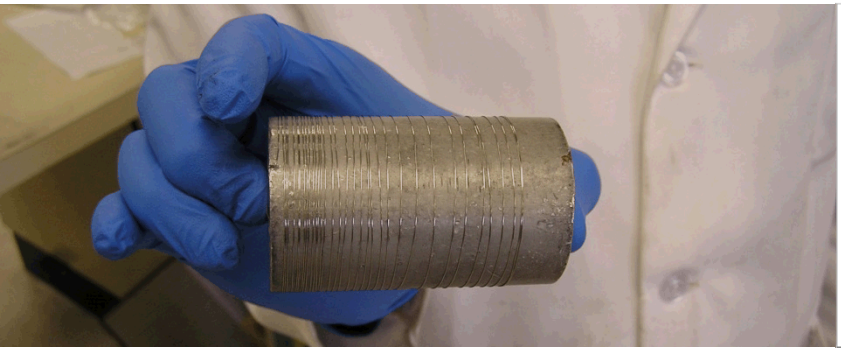
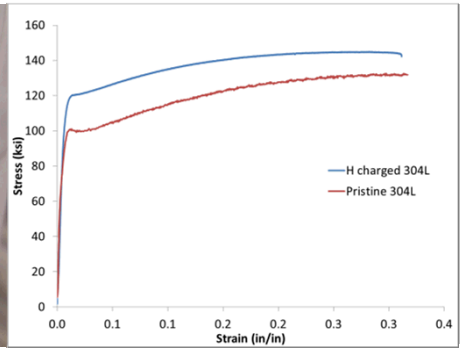
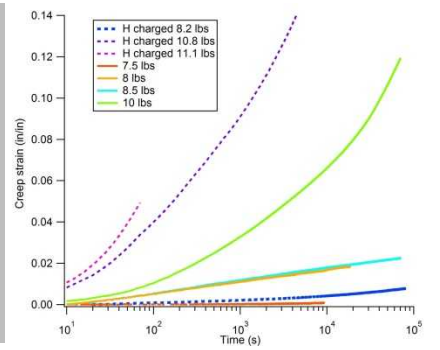
SAND2014-18504PE

Exceptional service in the national interest

Sandia National Laboratories







The effect of hydrogen on room temperature creep of 304L stainless steel wire

Lisa A. Deibler

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

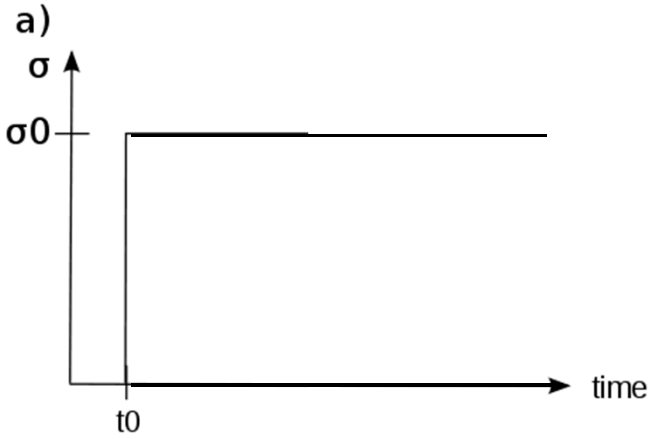
Acknowledgements

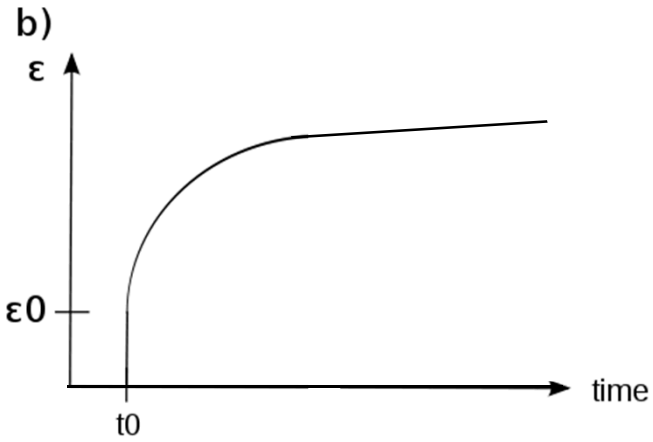
- Brian Somerday
- Jeff Campbell – H charging
- Tom Crenshaw – Creep setup

What is creep?

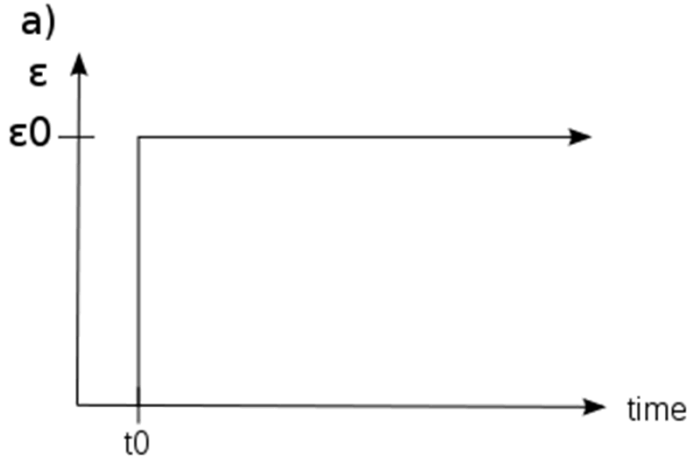
At temperatures above 0.5 melting temperature:

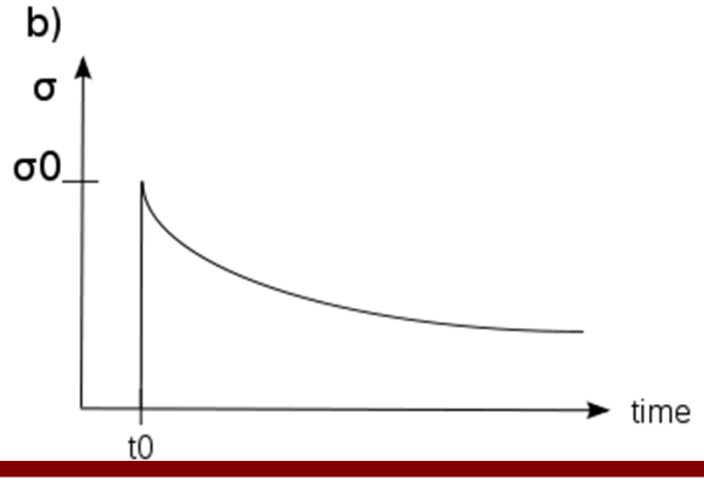
Creep





Stress relaxation





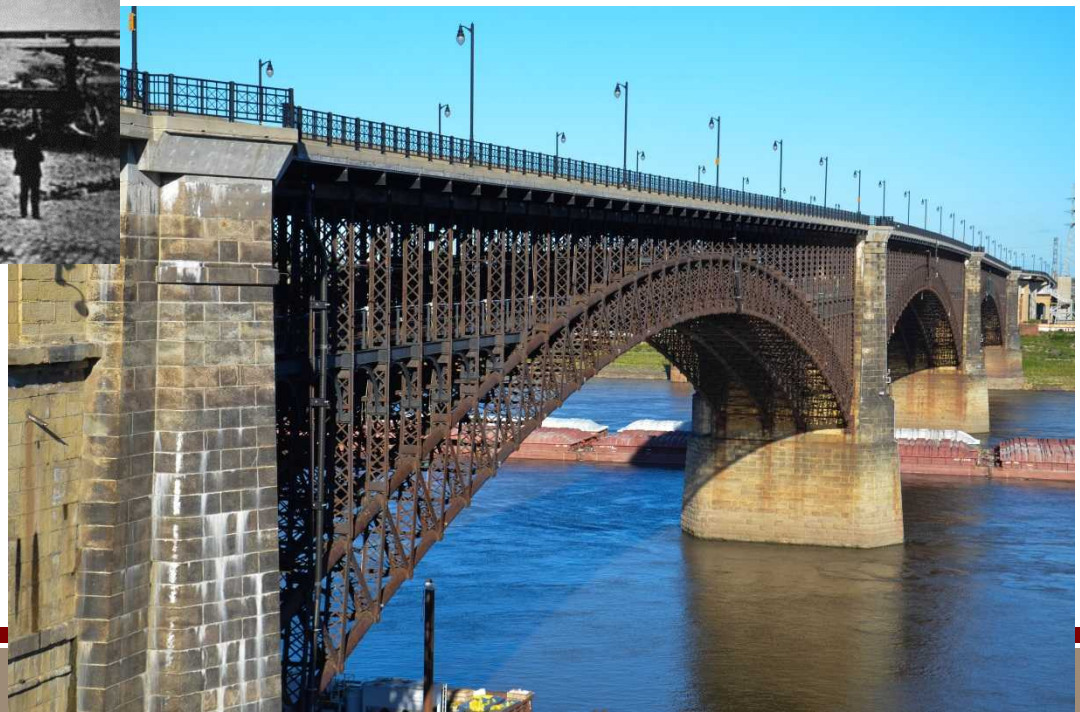
Why do we need to worry about it at room temperature?

Sandia National Laboratories

Eads bridge, St. Louis ca. 1874

It's been 140 years, creep of chrome steel to failure at ambient St. Louis temperature has not been an issue.

Eads bridge, St. Louis 2012



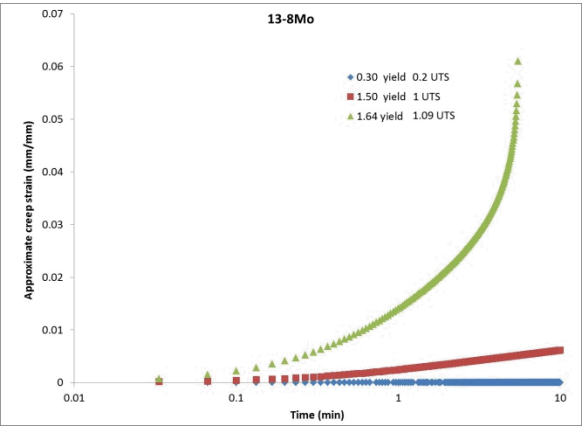
Why do I care?

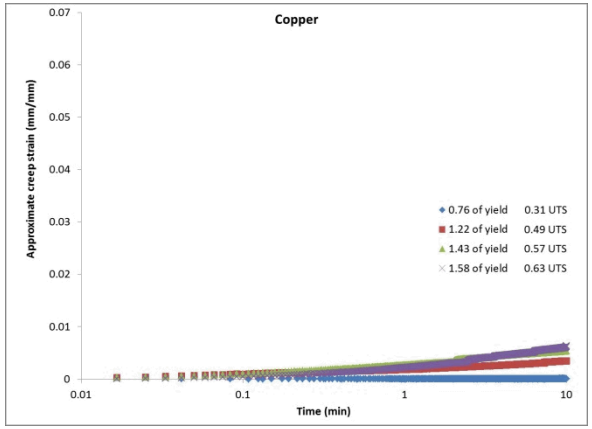
Sandia National Laboratories

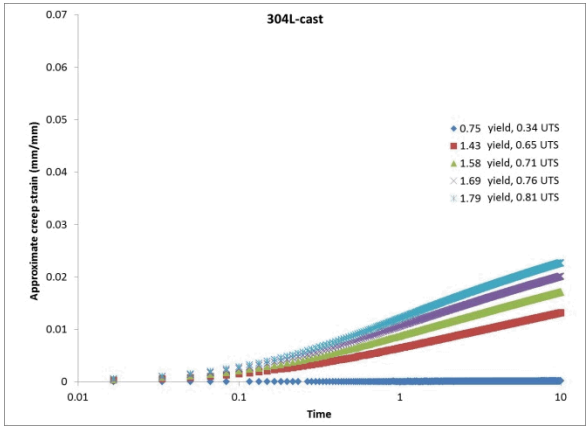
- Springs
- Glass to metal seals in electrical connectors.
- Electrical connections
- Pressure vessels
- Anywhere there's a designed residual stress

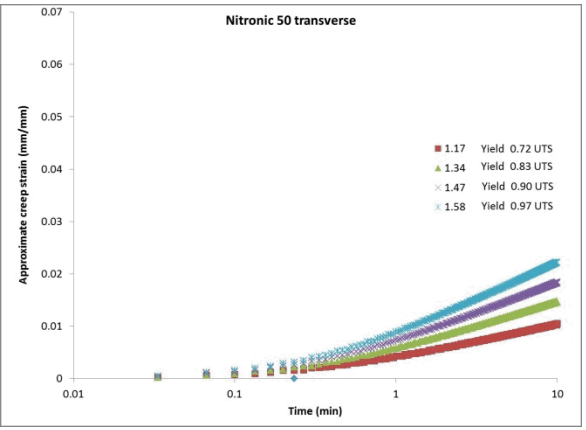
Conventional wisdom is that metals do not age (except for corrosion). Time dependent deformation is aging.

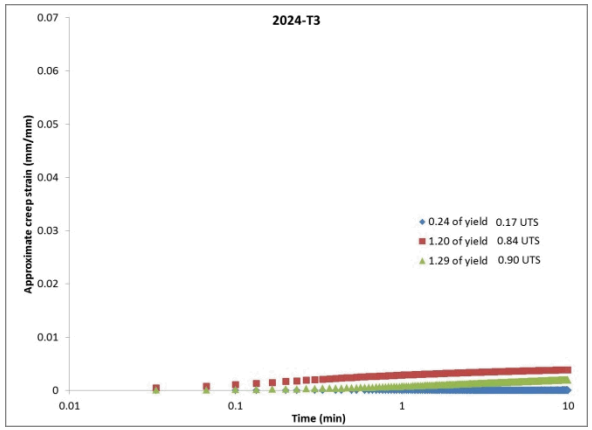
Creep happens at RT in many alloys

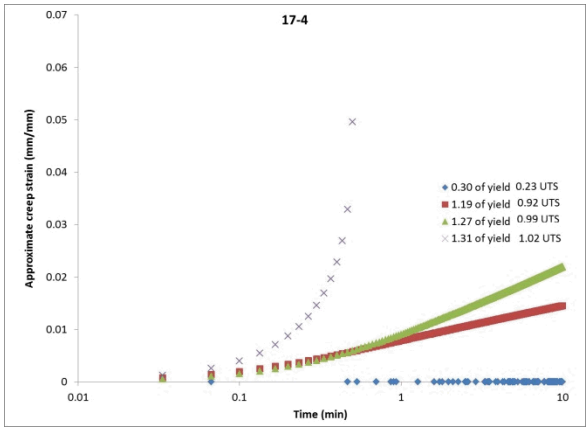


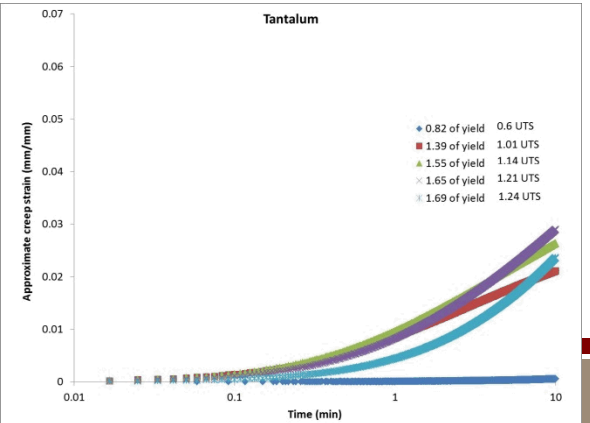


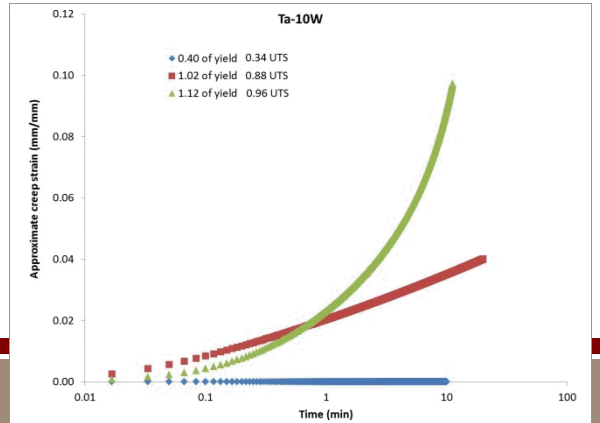




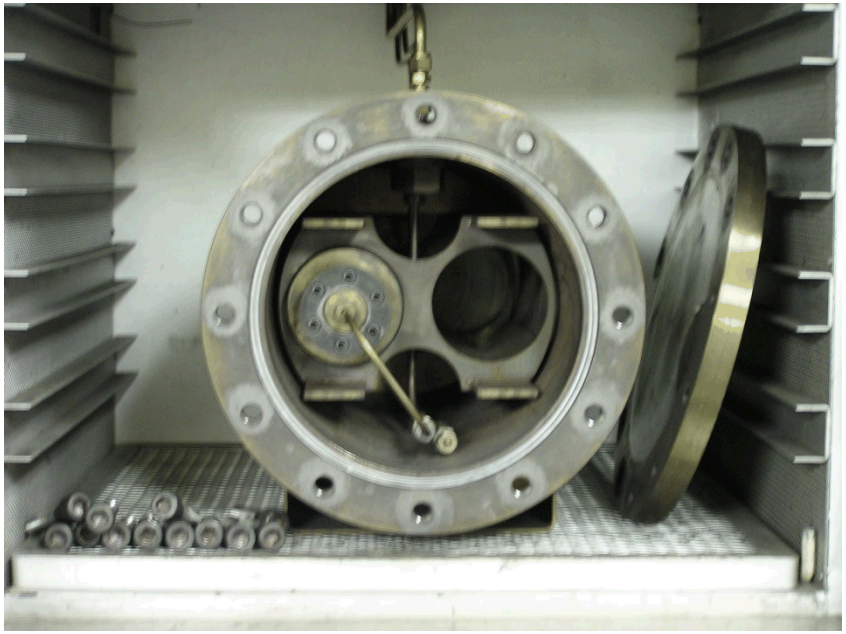








Hydrogen charging wire



Pressurized to 18,750 psi with 99.9999% pure hydrogen gas for 39 days.

Stored in freezer at -70ºC until ready for testing

Normal hydrogen damage effects

- Strengthening
- Embrittlement

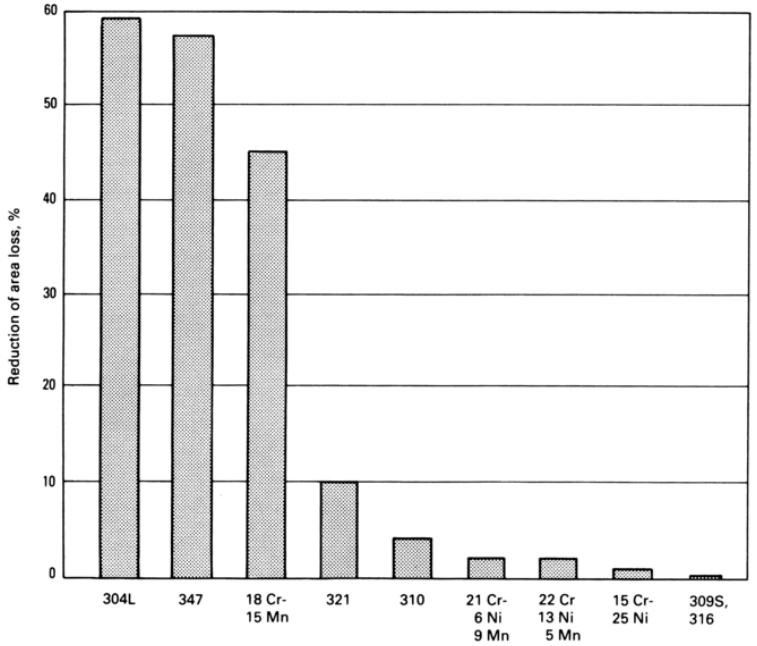
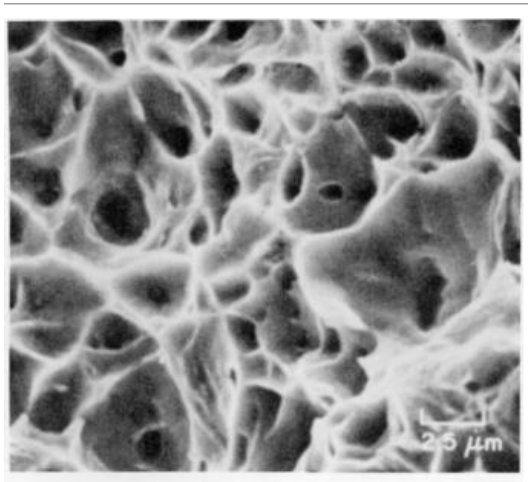
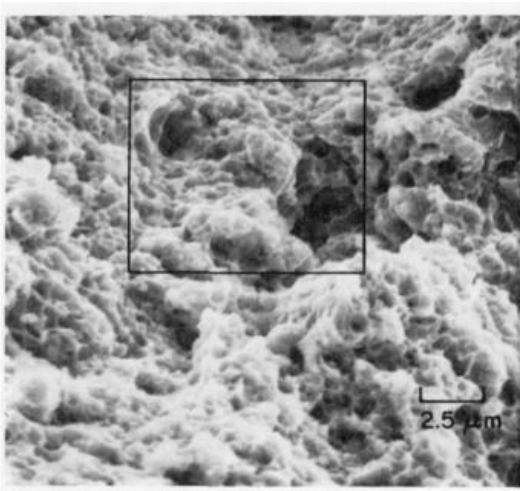


Fig. 9 Ductility loss for several austenitic stainless steels in high-pressure hydrogen. Source: Ref 21

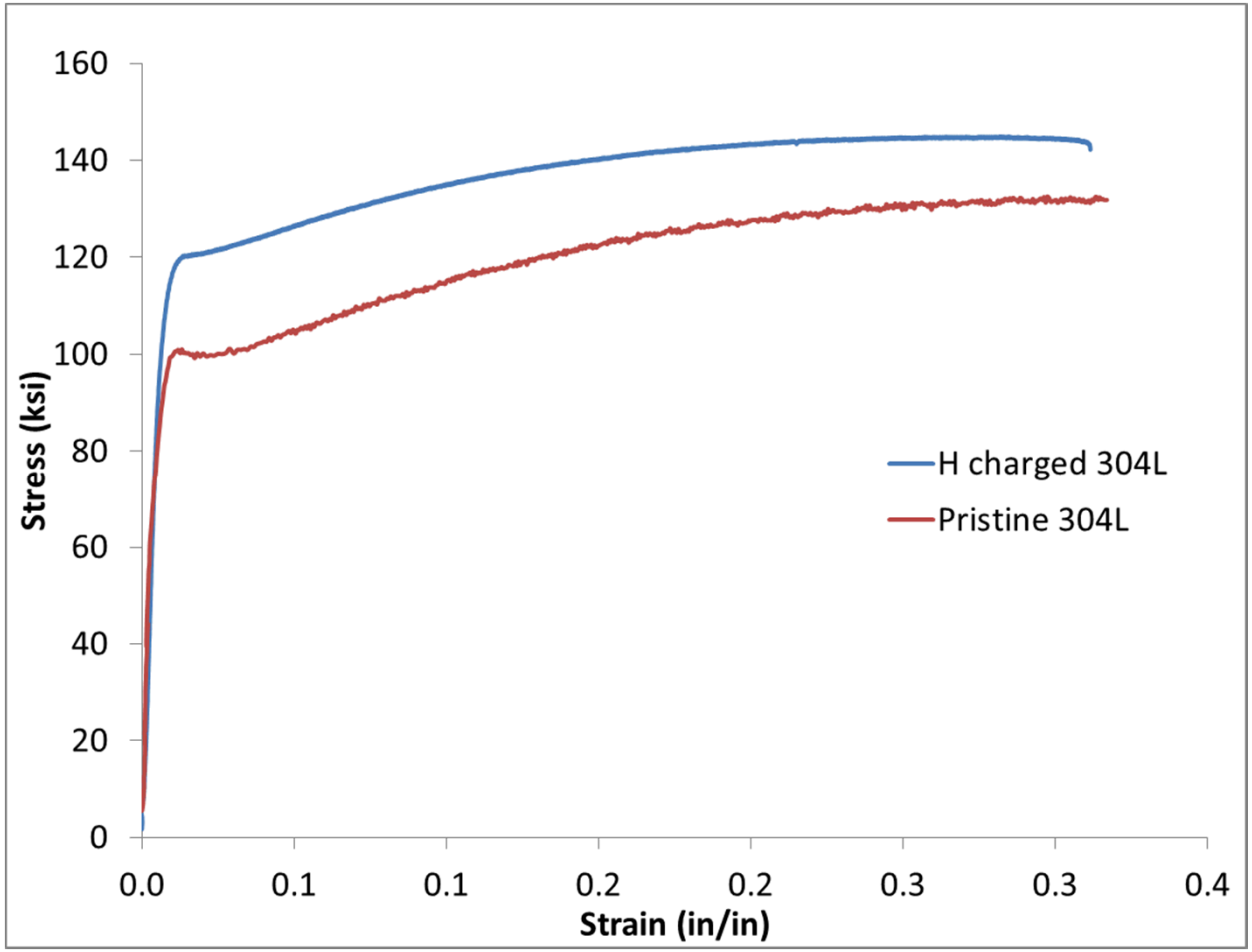


13-8 PH

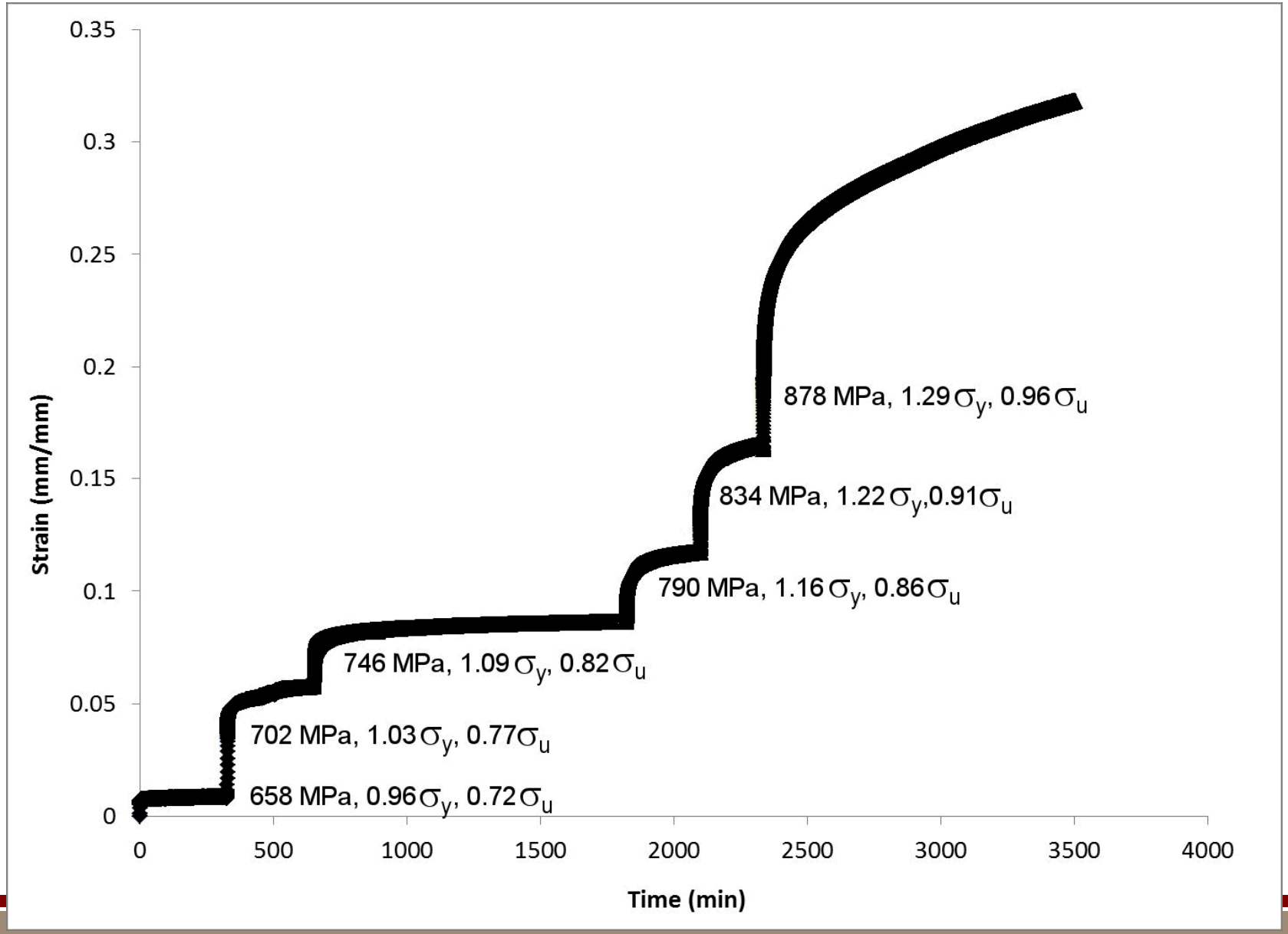


13-8 PH exposed to hydrogen

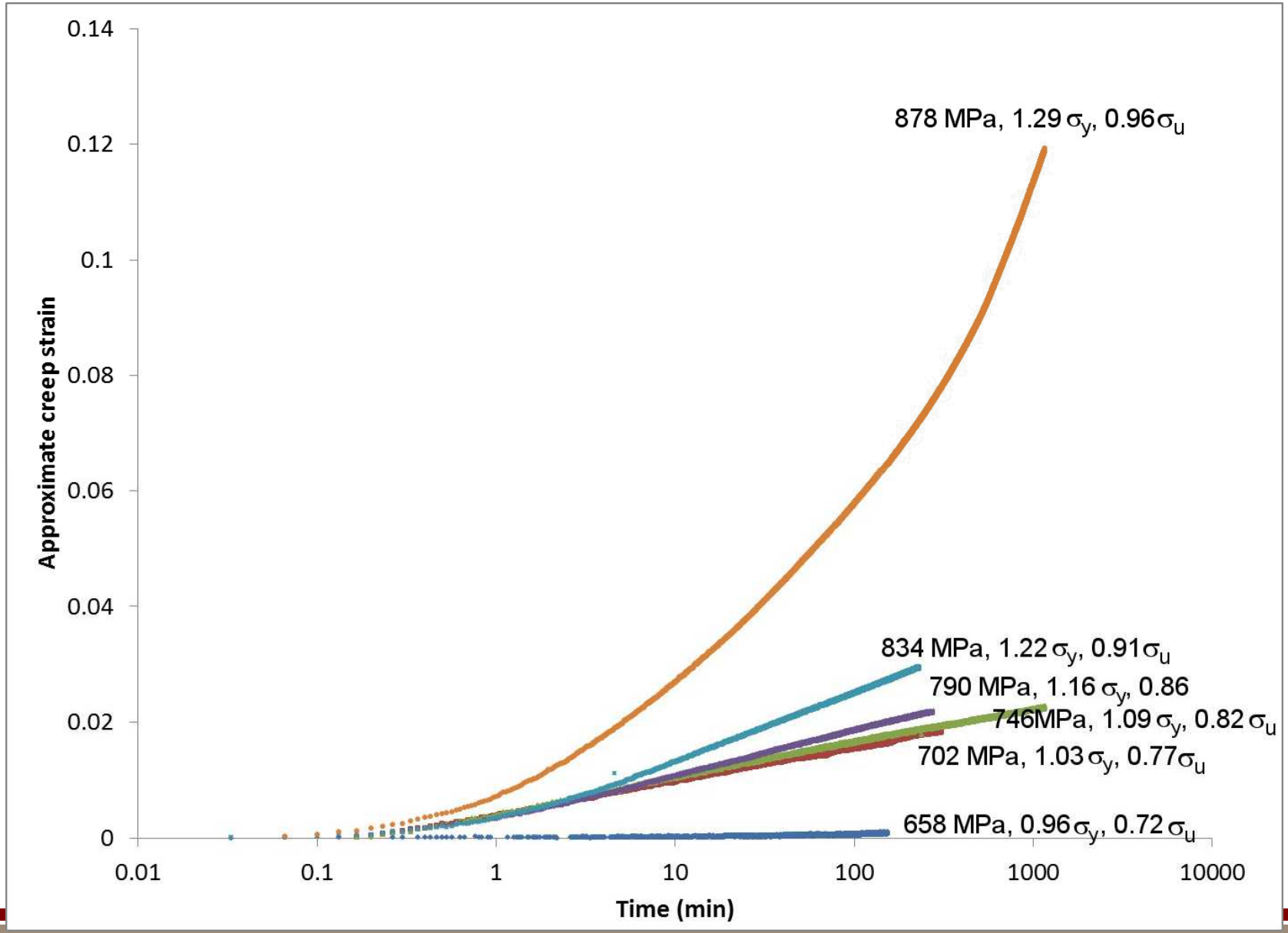
Hydrogen effects on 304L wire



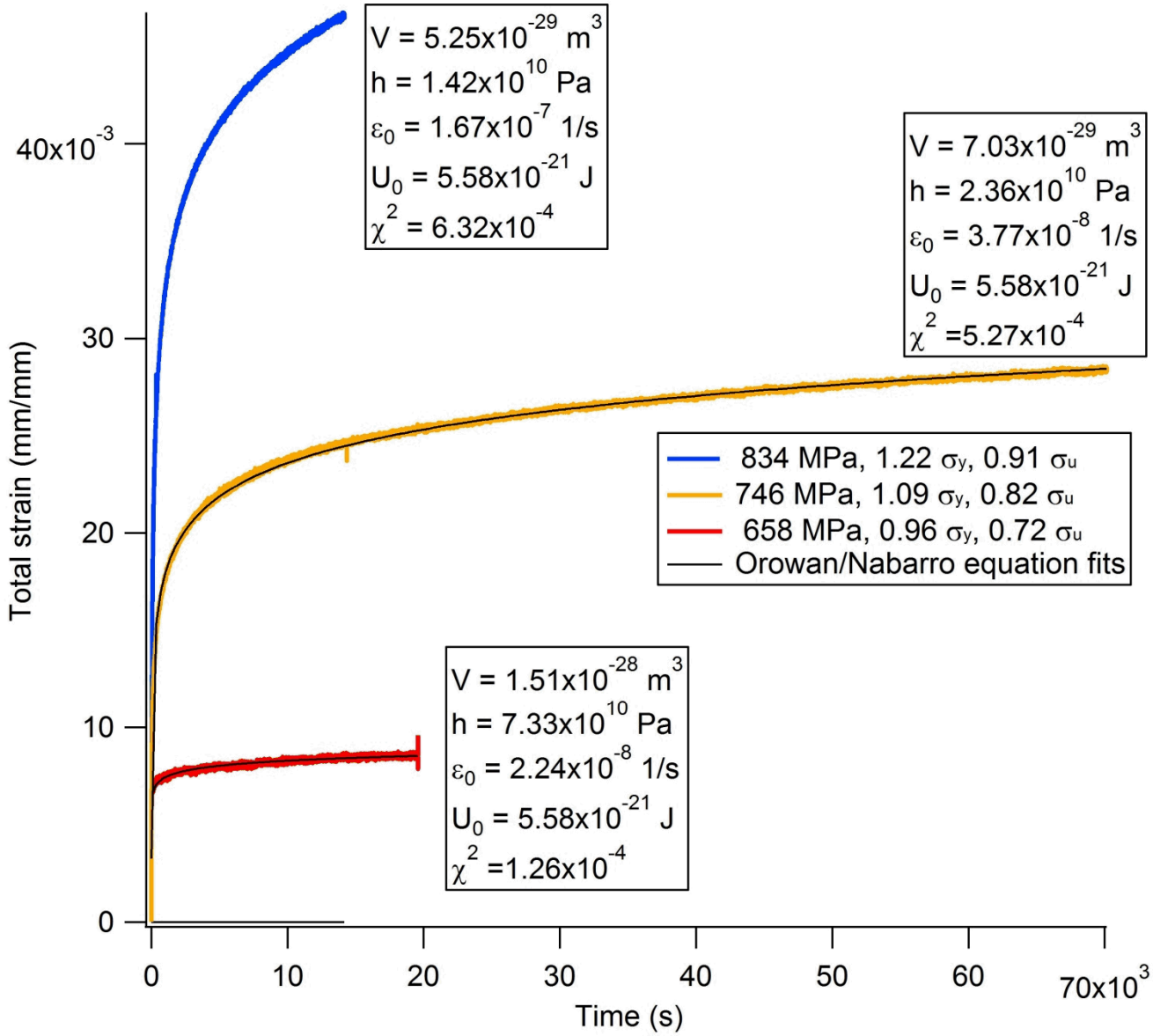
Creep testing pristine wire



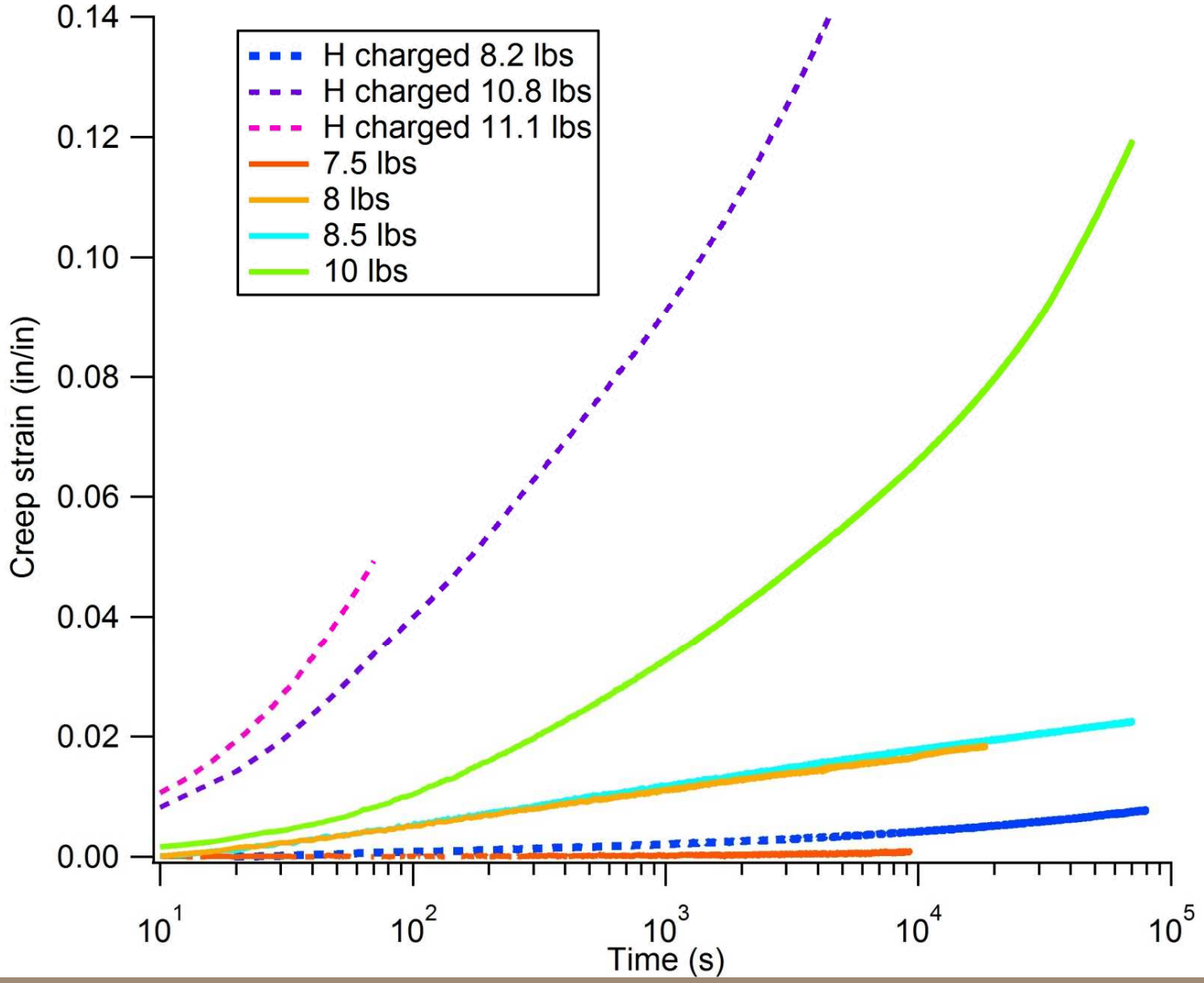
Pristine 304L creep behavior



Fitting equation to creep behavior

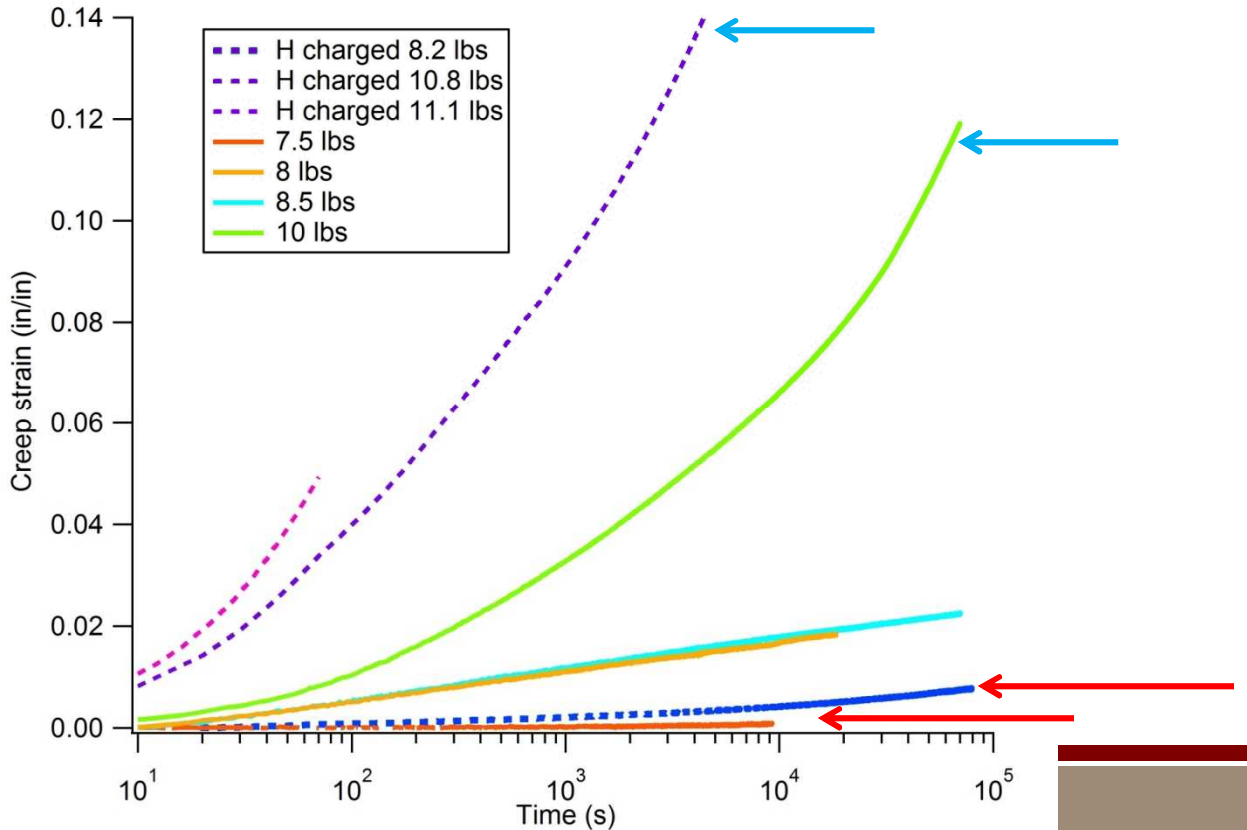


H charged data compared with uncharged data



Normalized comparison of stresses

Sample	Load (lbs.)	Stress (ksi)	Applied stress/yield	Applied stress/ultimate
Pristine	7.5	95.5	0.96	0.72
Pristine	8	101.9	1.03	0.77
Pristine	8.5	108.2	1.09	0.82
Pristine	10	127.3	1.29	0.96
H-charged	8.2	104.4	0.87	0.72
H-charged	10.8	137.5	1.15	0.95
H-charged	11.1	141.3	1.18	0.97



Conclusions

- Hydrogen exposure causes strengthening in 304L wire.
- Hydrogen increases creep rates at similar normalized stresses.

Future work

- Can the Orowan/Nabarro equations be fit to hydrogen creep?