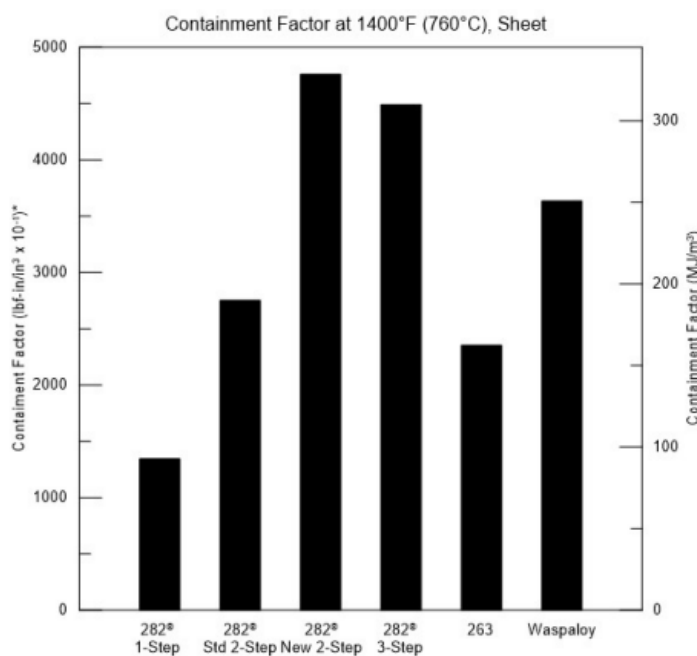


## Alternate Heat Treatments for Improved Toughness of HAYNES® 282® alloy

HAYNES® 282® alloy is a gamma-prime strengthened superalloy. The standard 2-step age-hardening treatment\* traditionally used for 282® alloy was developed to maximize creep strength at the upper end of the temperature usage range, near 1600°F (871°C) or above. Since toughness or containment capability at intermediate temperatures, around 1400°F (760°C), is a limiting factor in some applications, alternate heat treatments have been developed for 282® alloy which significantly increase the toughness at intermediate temperatures near 1400°F (760°C).

### Containment Factor



\* 1 lbf-in/in³ x 10⁻¹ = 1 ksi-%

*\*This heat treatment process is covered by claims of U.S. Patent No. 11,453,939 B2 and corresponding foreign patents. The purchase of our 282® alloy includes a license under these patents to use the method for 282® alloy and products made of 282® alloy. For additional information, please contact Brandon Furr [BFurr@haynesintl.com](mailto:BFurr@haynesintl.com) or Victor Paramo [VParamo@haynesintl.com](mailto:VParamo@haynesintl.com).*

Heat Treatment	Yield Strength at 1400°F (760°C), ksi (MPa)			Ultimate Tensile Strength at 1400°F (760°C), ksi (MPa)			Elongation at 1400°F (760°C), %			CF* at 1400°F (760°C), lbf-in/in³ x 10⁻¹ (MJ/m³)		
	Sheet	Plate	Ring	Sheet	Plate	Ring	Sheet	Plate	Ring	Sheet	Plate	Ring
1-Step <sup>1</sup>	87.7 (605)	-	-	120.7 (832)	-	-	12.9	-	-	1300 (92.7)	-	-
Standard 2-Step <sup>2</sup>	89 (614)	91.7 (632)	99.5 (686)	122.6 (845)	125.6 (866)	124.8 (860)	26.0	21.1	31.8	2750 (190)	2290 (158)	3570 (246)
New 2-Step <sup>3</sup>	95.5 (658)	89.6 (618)	101.2 (698)	117 (807)	119.5 (824)	120.8 (833)	44.8	23.9	36.6	4760 (328)	2500 (172)	4060 (280)
3-Step <sup>4</sup>	95.8 (661)	89.7 (618)	98 (676)	116 (800)	121.1 (835)	121.6 (838)	42.4	27.1	40.9	4490 (310)	2860 (197)	4490 (310)

\*Containment Factor (CF) = ½(YS + UTS) x ELONG

<sup>1</sup> 1475°F (802°C)/8h/AC

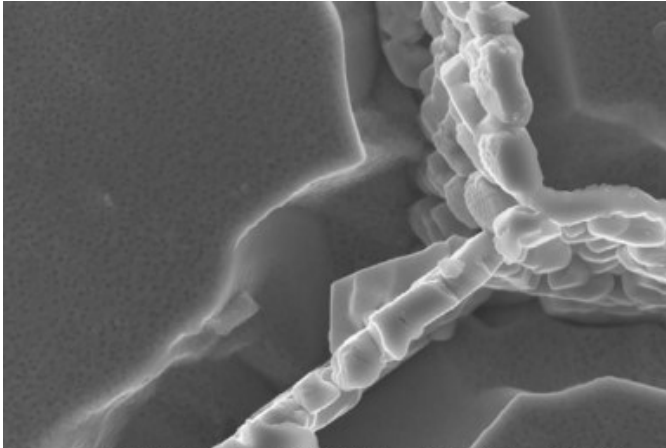
<sup>2</sup> 1850°F(1010°C)/2h/AC + 1450°F(788°C)/8h/AC

<sup>3</sup> 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

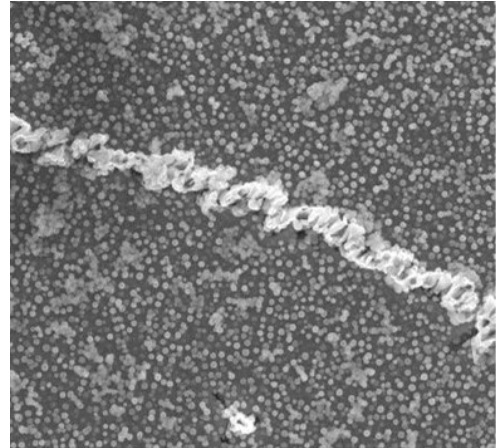
<sup>4</sup> 1850°F(1010°C)/2h/AC + 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

## Effect of Heat Treatment Steps on Microstructure

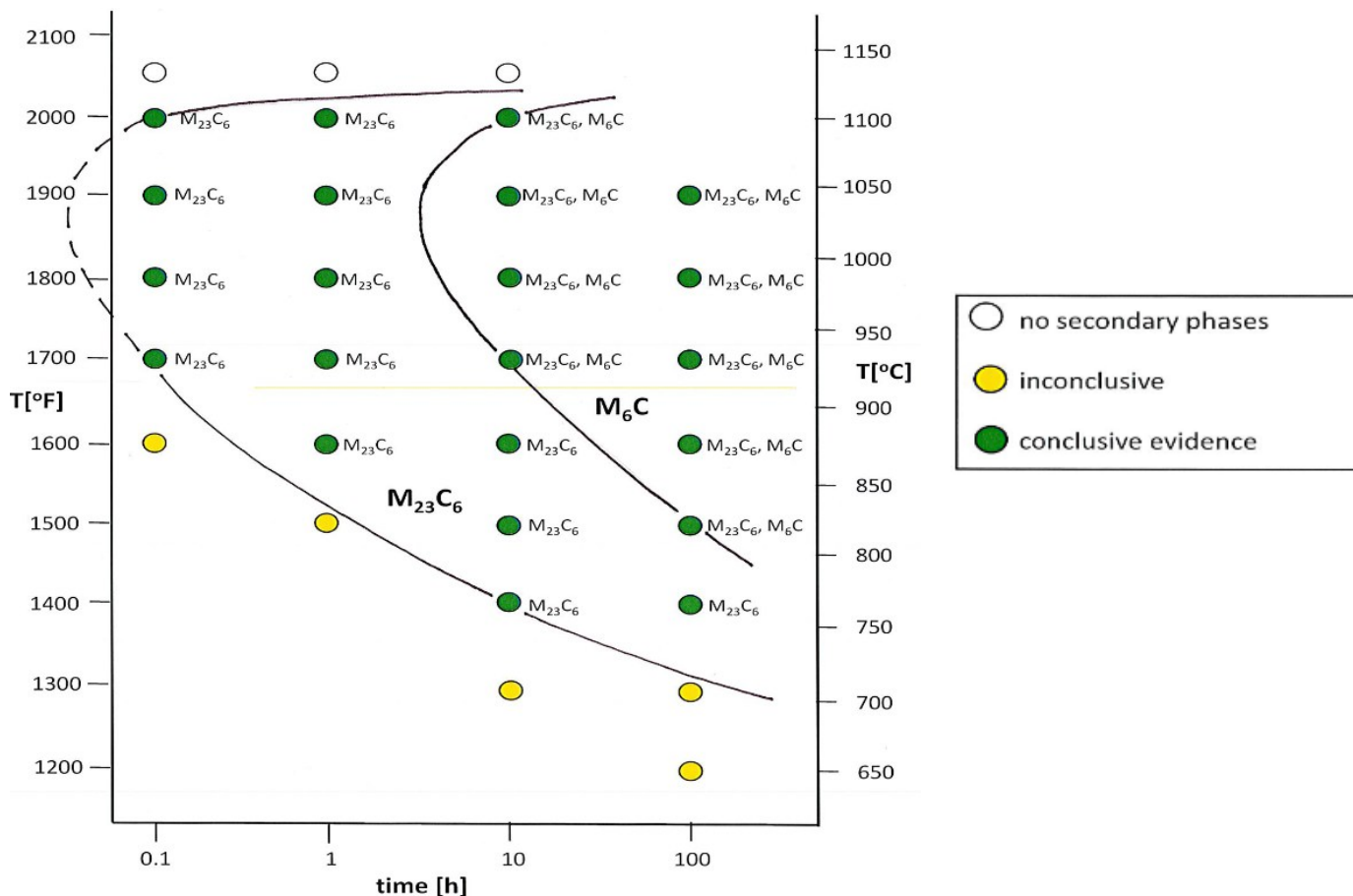
- **1850°F (1010°C)/2h** – This temperature is below the  $M_{23}C_6$  solvus and above the gamma-prime ( $\gamma'$ ) solvus. This step produces the “stone wall” carbide structure at the grain boundaries.
- **1650°F (899°C)/4h** – This step results in the formation of a grain boundary layer consisting of both  $\gamma'$  and  $M_{23}C_6$  at the grain boundary. This layer is believed to be responsible for the improved ductility at temperatures around 1400°F (760°C).
- **1450°F (788°C)/8h** – This step completes the precipitation of  $\gamma'$  providing the alloy with high strength.



Stone wall carbide structure at grain boundaries which forms at 1850°F (1010°C)/2h.

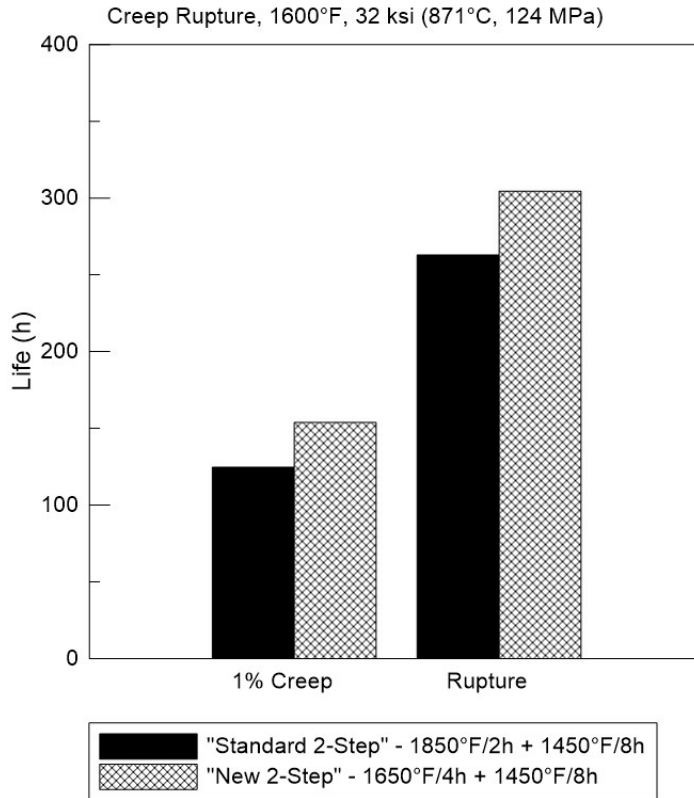
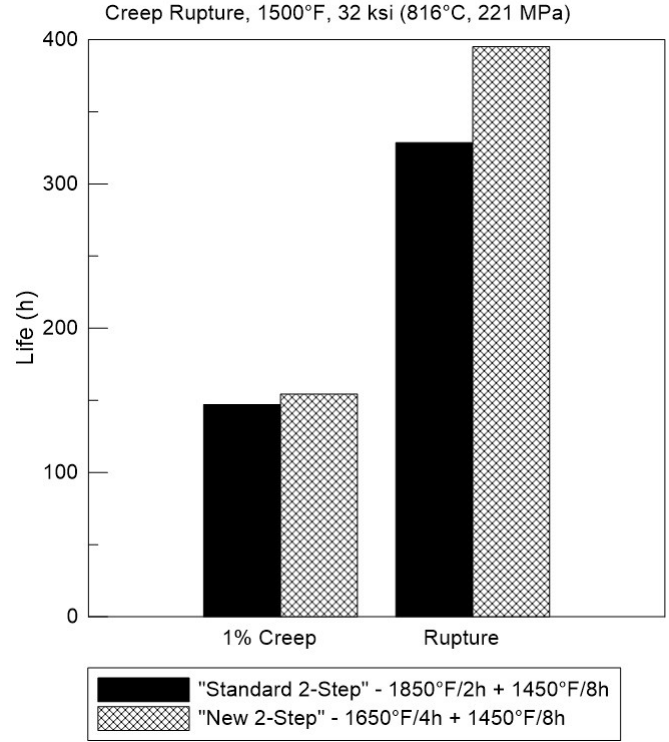
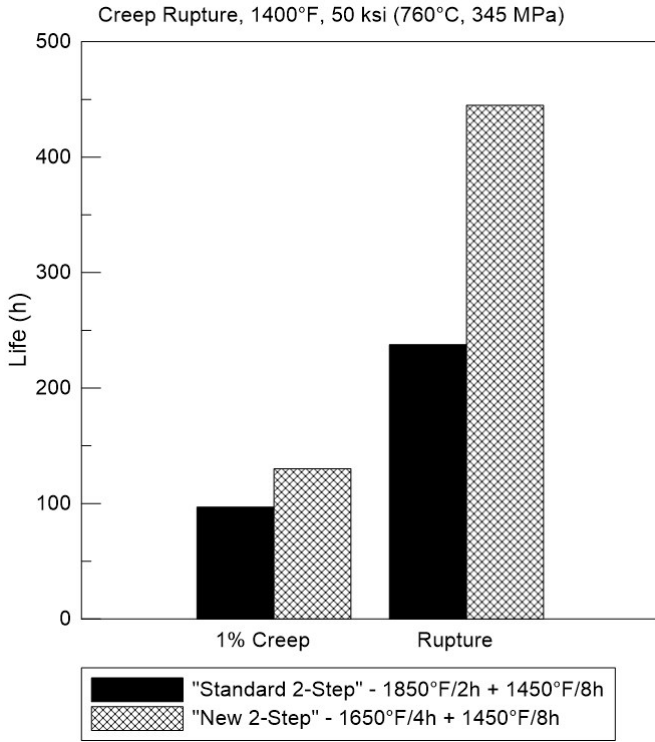


Microstructure after 1650°F (899°C)/4h + 1450°F (788°C)/8h, showing the complex  $\gamma'$  and  $M_{23}C_6$  carbide structure at grain boundaries

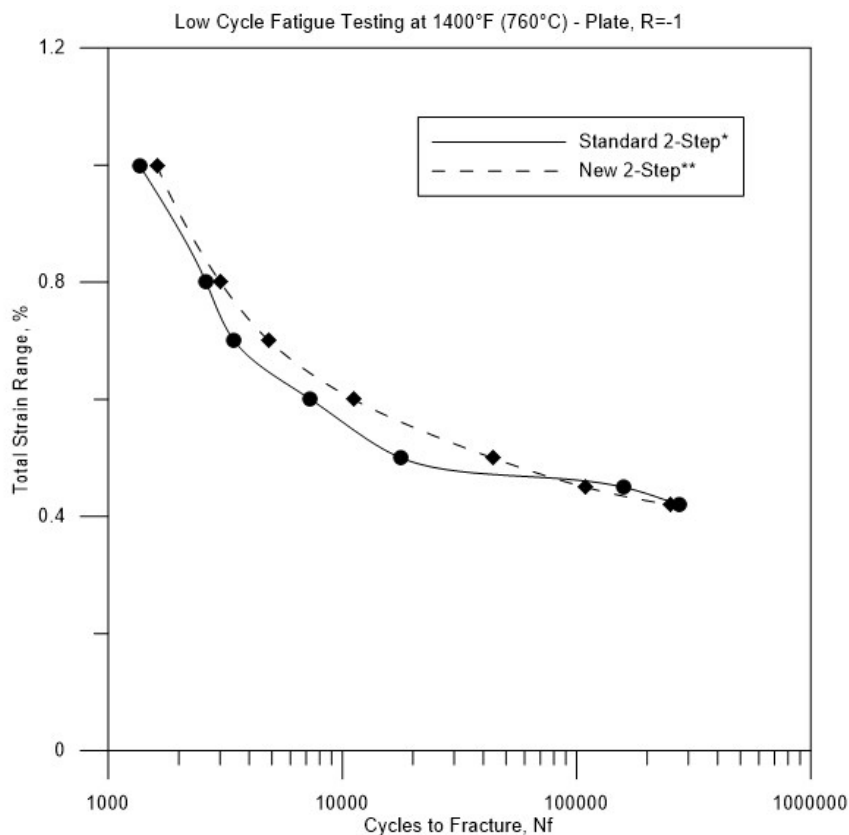


All the heat treatments are designed to precipitate  $M_{23}C_6$  and to precipitate and/or grow  $\gamma'$ . However, the morphology and location of the phases can vary considerably.

# Creep Rupture



## Low Cycle Fatigue



\*1850°F(1010°C)/2h/AC + 1450°F(788°C)/8h/AC  
\*\*1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

## Summary

- New heat treatments for HAYNES<sup>®</sup> 282<sup>®</sup> alloy provide substantial improvements to 1400°F (760°C) ductility and containment factors compared to previously established heat treatments.
- The new heat treatments improve properties in sheet, plate, and ring forms.
- The improved properties are attributed the formation of favorable  $\gamma' + M_{23}C_6$  structure at the grain boundaries.
- Not only were other properties, such as creep and LCF, not adversely affected, but may also provide slight improvements with the new heat treatments..

**The new heat treatments should be strongly considered for all hot section applications which require high containment: cases, rings, etc.**

For more information, please contact a metallurgist at <https://haynesintl.com/contact/technical-support>.

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