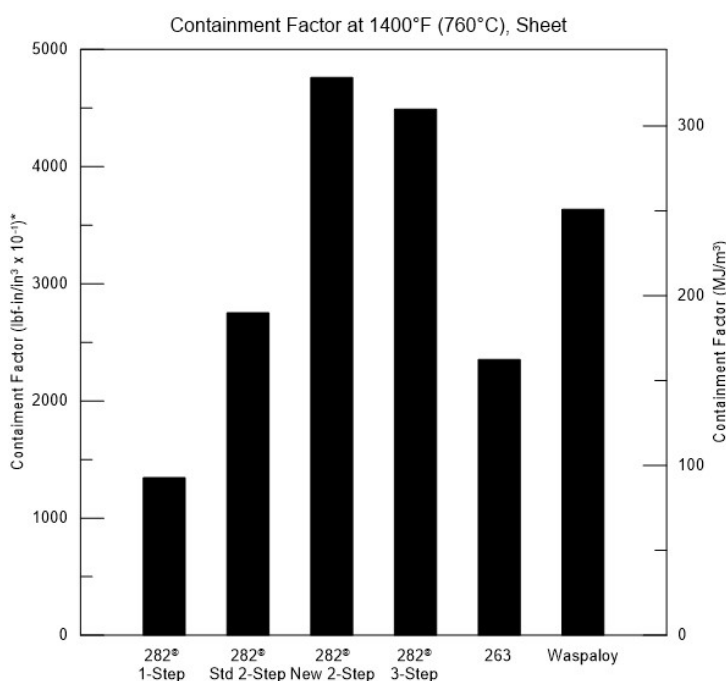


## Alternate Heat Treatments for Improved Toughness of HAYNES® 282® alloy

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/in<sup>3</sup> x 10<sup>-1</sup> = 1 ksi-%

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/in <sup>3</sup> x 10 <sup>-1</sup> (MJ/m <sup>3</sup> )		
	Sheet	Plate	Ring	Sheet	Plate	Ring	Sheet	Plate	Ring	Sheet	Plate	Ring
1-Step <sup>1</sup>	87.7	-	-	120.7	-	-	12.9	-	-	1300	-	-
	(605)	-	-	(832)	-	-				(92.7)	-	-
Standard 2-Step <sup>2</sup>	89	91.7	99.5	122.6	125.6	124.8	26.0	21.1	31.8	2750	2290	3570
	(614)	(632)	(686)	(845)	(866)	(860)				(190)	(158)	(246)
New 2-Step <sup>3</sup>	95.5	89.6	101.2	117	119.5	120.8	44.8	23.9	36.6	4760	2500	4060
	(658)	(618)	(698)	(807)	(824)	(833)				(328)	(172)	(280)
3-Step <sup>4</sup>	95.8	89.7	98	116	121.1	121.6	42.4	27.1	40.9	4490	2860	4490
	(661)	(618)	(676)	(800)	(835)	(838)				(310)	(197)	(310)

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

<sup>1</sup>1475°F (802°C)/8h/AC

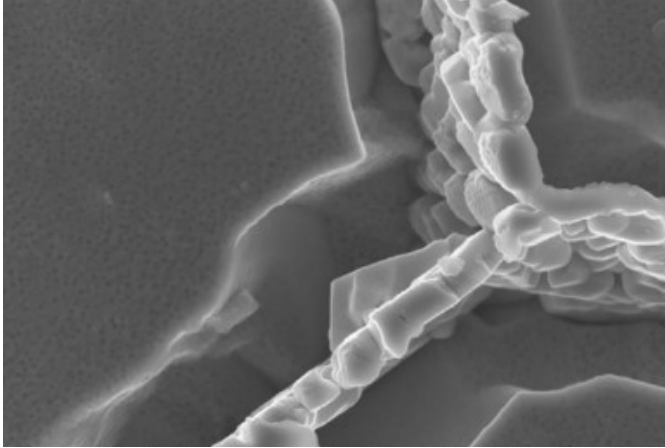
<sup>2</sup>1850°F(1010°C)/2h/AC + 1450°F(788°C)/8h/AC

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

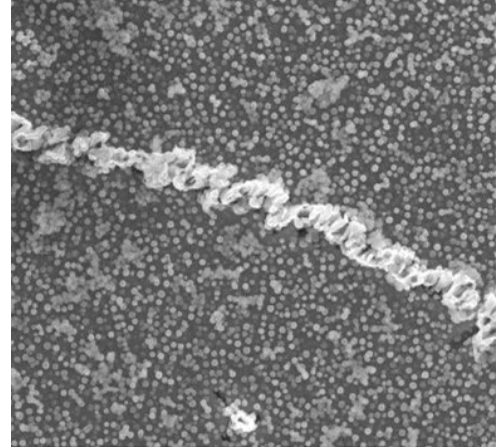
<sup>4</sup>1850°F(1010°C)/2h/AC + 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

## Effect of Heat Treatment Steps on Microstructure

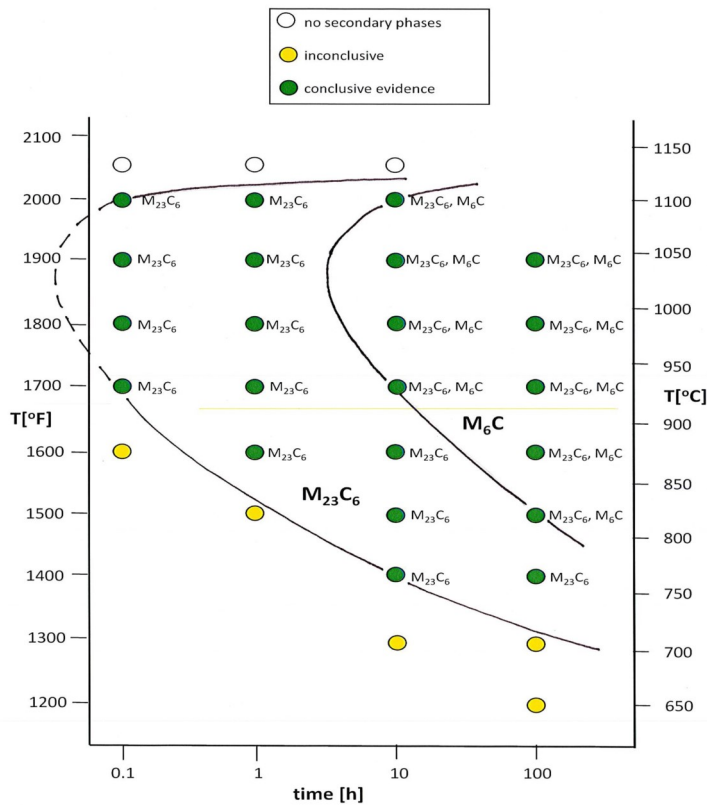
- **1850°F (1010°C)/2h** – This temperature is below the  $M_{23}C_6$  solvus and above the  $\gamma'$  solvus. This step produces the “stone wall” carbide structure at the grain boundaries.
- **1650°F (899°C)/4h** – This step results in the formation of a grain boundary layer consisting of both gamma-prime 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-prime providing the alloy with high strength.



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

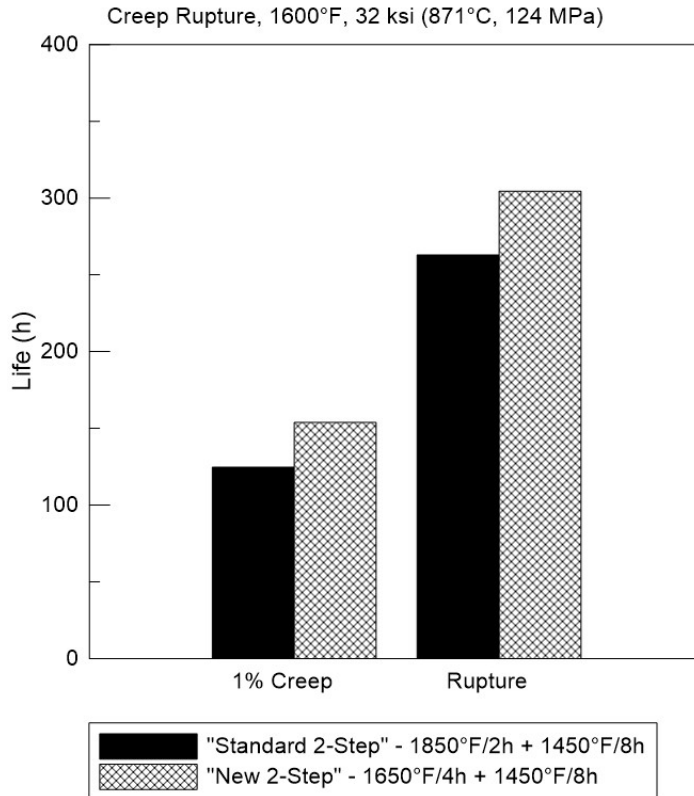
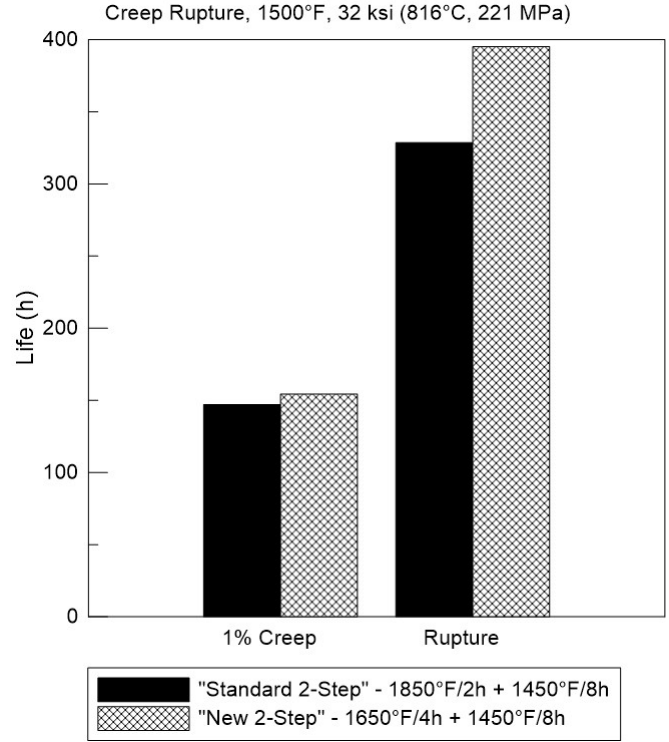
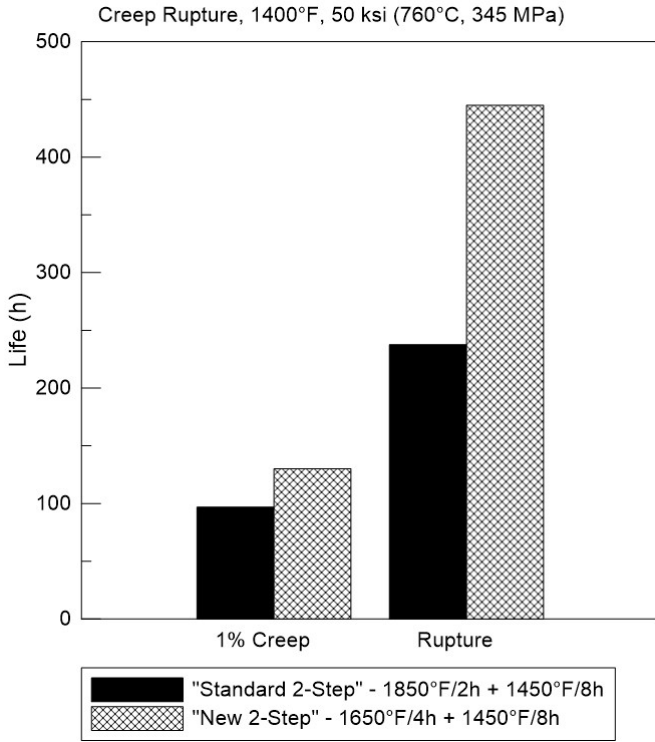


Microstructure after 1650°F (899°C)/4h + 1450°F (788°C)/8h, showing the complex gamma-prime and  $M_{23}C_6$  carbide structure at grain boundaries

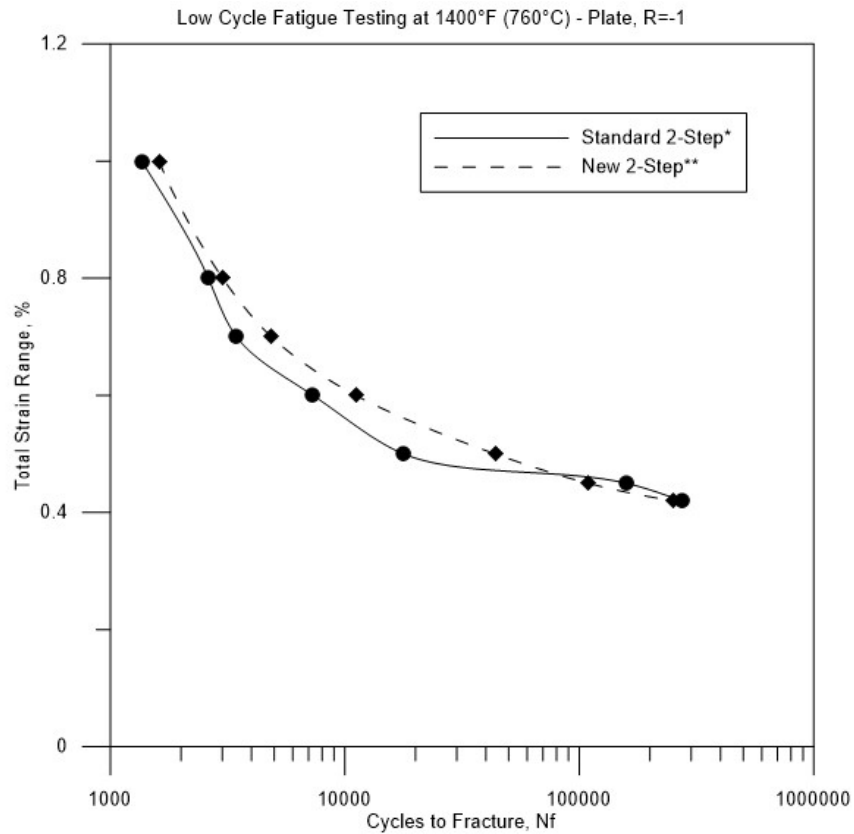


All the heat treatments are designed to precipitate  $M_{23}C_6$  and to precipitate and/or grow gamma prime. However, the morphology and location of the phases can vary considerably.

# 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 patented heat treatments have been discovered for HAYNES® 282® alloy which provide substantial improvements to 1400°F (760°C) ductility and containment factors vs. previously established heat treatments.
- The new heat treatments have been shown to improve properties in sheet, plate, and ring forms.
- The improved properties are believed to be a result of the formation of a favorable  $\gamma' + M_{23}C_6$  layer at the grain boundaries.
- Other properties, such as creep and LCF, may also slightly improve 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.**

Additional data are available. For more information, please contact Victor Paramo at (765) 456-6226 or [vparamo@haynesintl.com](mailto:vparamo@haynesintl.com).

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