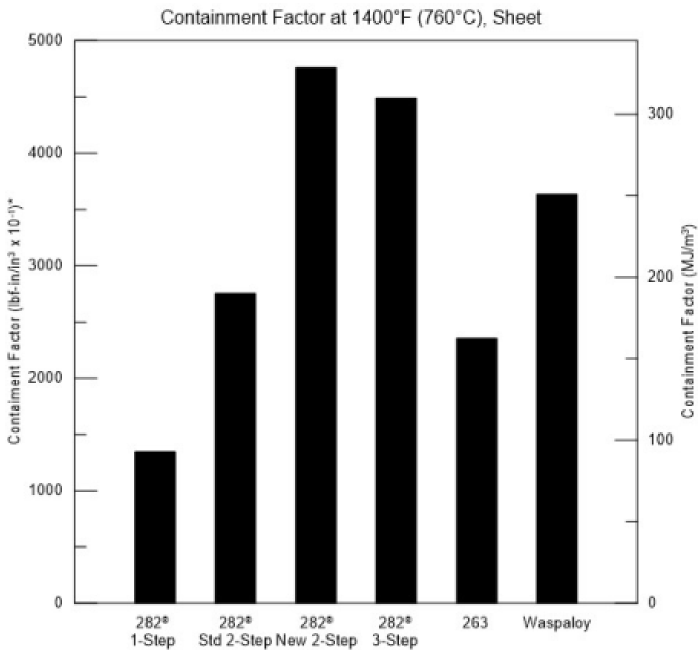
HAYNES International

HIGH-TEMPERATURE TECH BRIEF

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^3 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 or Victor Paramo 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/in^3 x 10^{-1} (MJ/m^3)		
	Sheet	Plate	Ring	Sheet	Plate	Ring	Sheet	Plate	Ring	Sheet	Plate	Ring
1-Step[1]	87.7 (605)	-	-	120.7 (832)	-	-	12.9	-	-	1300 (92.7)	-	-
Standard 2-Step[2]	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[3]	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[4]	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

[1] 1475°F (802°C)/8h/AC

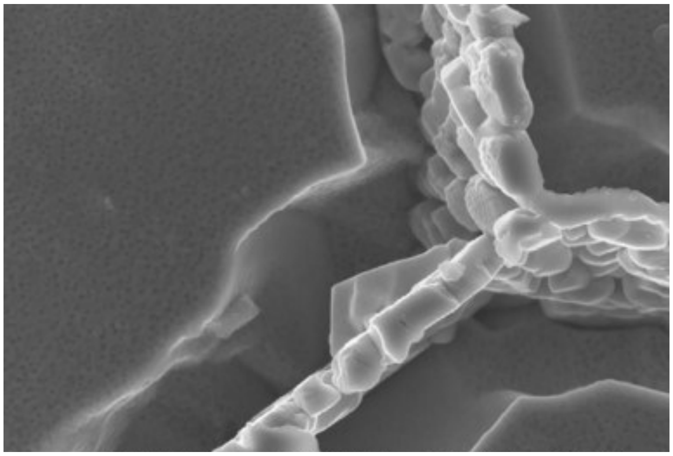
[2] 1850°F(1010°C)/2h/AC + 1450°F(788°C)/8h/AC

[3] 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

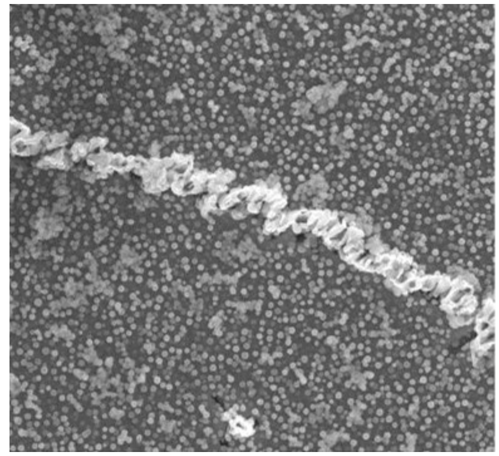
[4] 1850°F(1010°C)/2h/AC + 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

Effect of Heat Treatment Steps on Microstructure

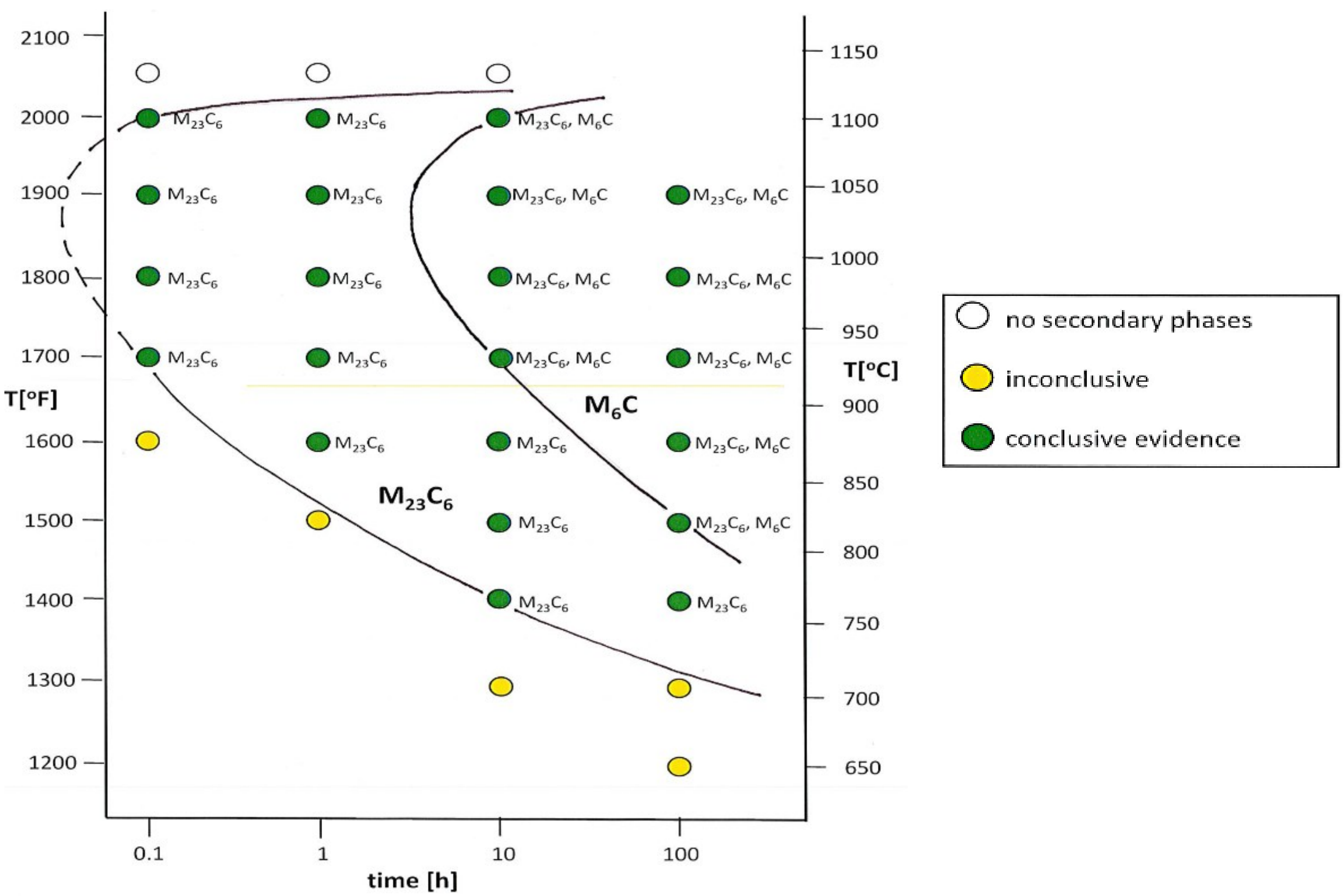
- **1850°F (1010°C)/2h** – This temperature is below the $M_{23}C_6$ solvus and above the gamma-prime (γ') solvus. This step produces the "stone wall" carbide structure at the grain boundaries.
- **1650°F (899°C)/4h** – This step results in the formation of a grain boundary layer consisting of both γ'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



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

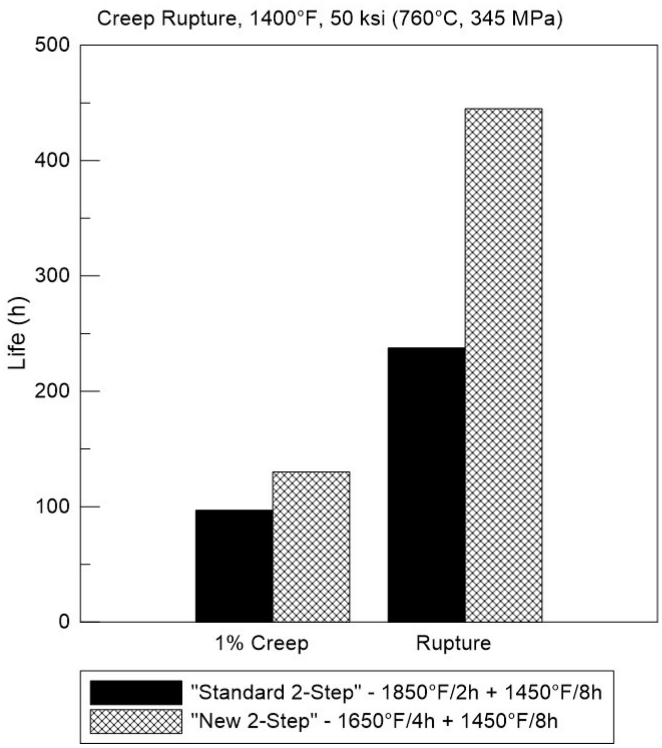


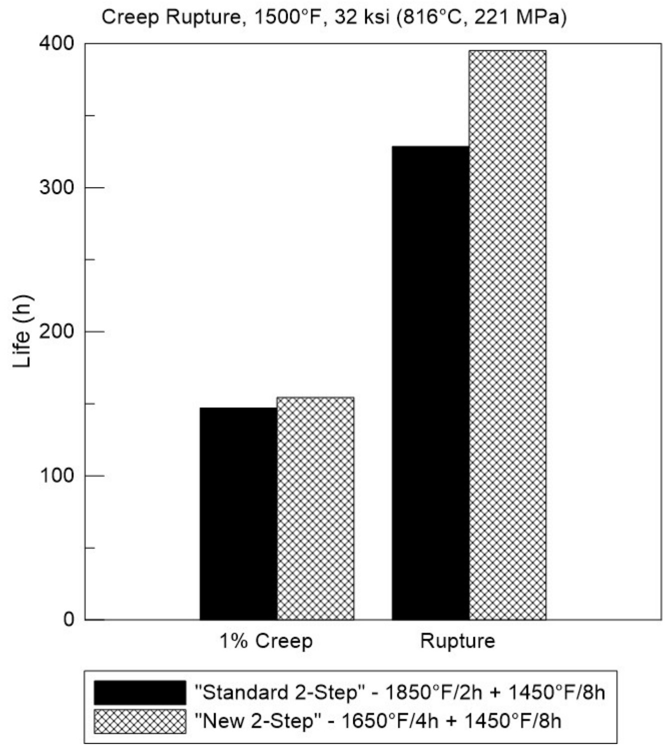
Microstructure after 1650°F (899°C)/4h + 1450°F (788°C)/8h, showing the complex γ' and $M_{23}C_6$ carbide structure at grain boundaries

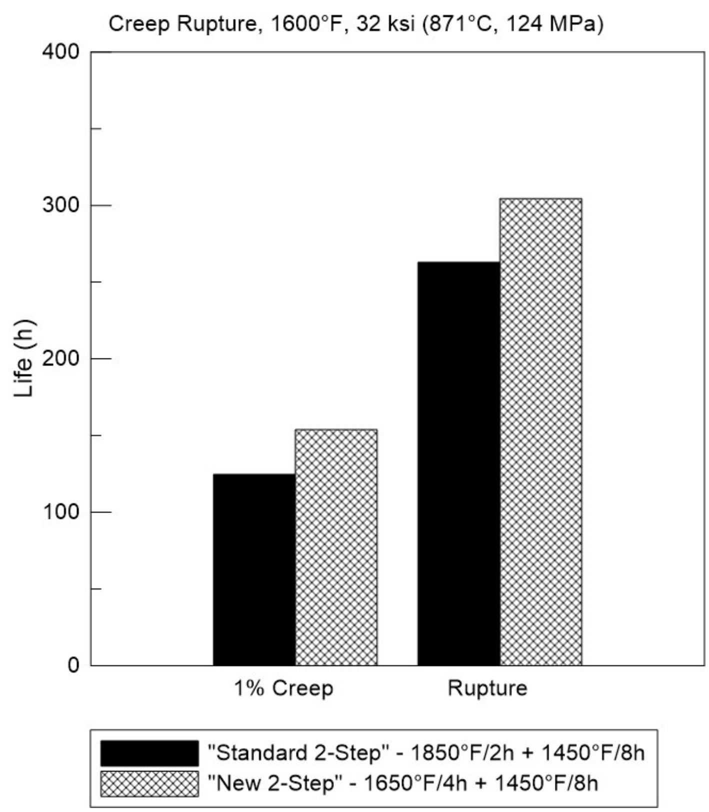


All the heat treatments are designed to precipitate $M_{23}C_6$ and to precipitate and/or grow γ'.
However, the morphology and location of the phases can vary considerably.

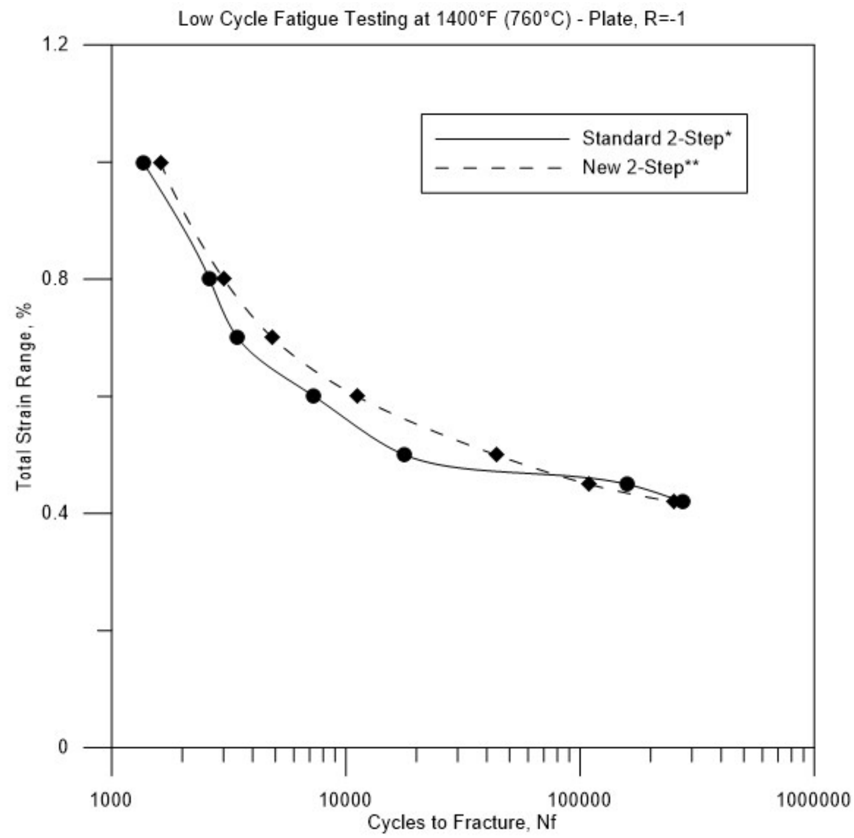
Creep Rupture







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® 282® 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 γ' + $M_{23}C_6$ 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.