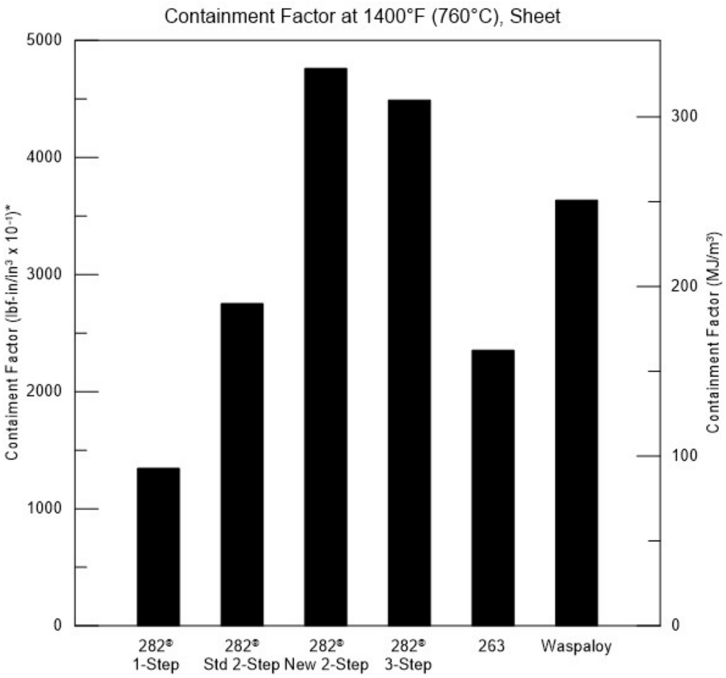
HAYNES International

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



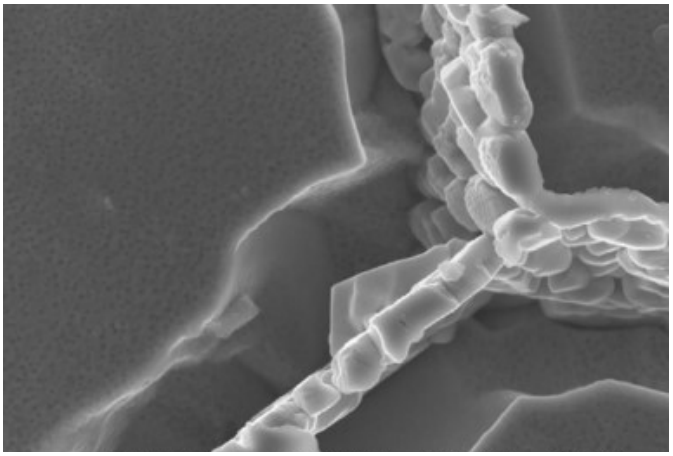
* 1 lbf-in/in^3 x 10^{-1} = 1 ksi-%

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	-	-	120.7	-	-	12.9	-	-	1300	-	-
	(605)	-	-	(832)	-	-				(92.7)	-	-
Standard 2-Step[2]	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[3]	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[4]	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)

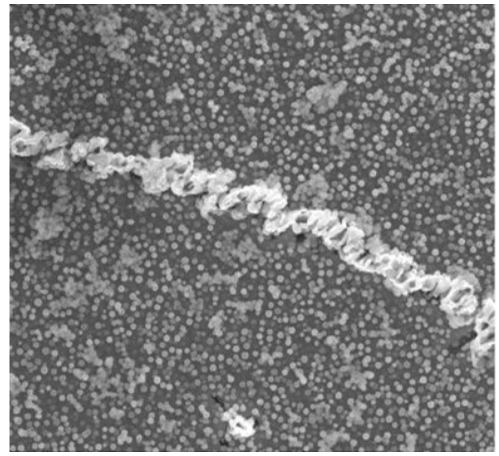
*Containment Factor (CF) = ½(YS + UTS) x ELONG
[1] 1475°F (802°C)/8h/AC
[2] 1850°F(1010°C)/2h/AC + 1450°F(788°C)/8h/AC
[3] 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC
[4] 1850°F(1010°C)/2h/AC + 1650°F(899°C)/4h/AC + 1450°F(788°C)/8h/AC

Effect of Heat Treatment Steps on Microstructure

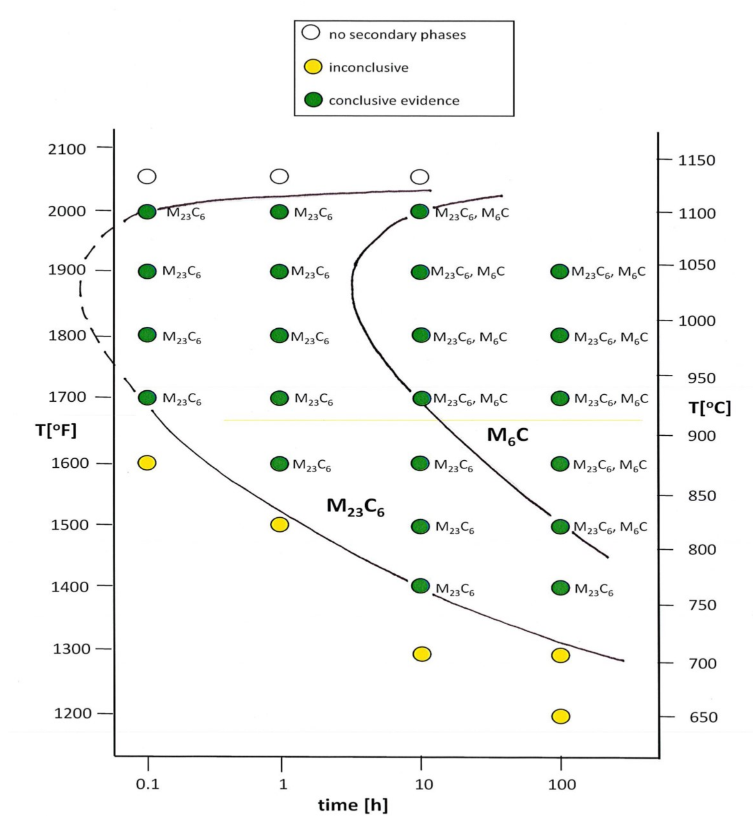
- **1850°F (1010°C)/2h** – This temperature is below the $M_{23}C_6$ solvus and above the γ' solvus. This step produces the "stone wall" carbide structure at the grain boundaries.
- **1650°F (899°C)/4h** – This step results in the formation of a grain boundary layer consisting of both gamma-prime and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



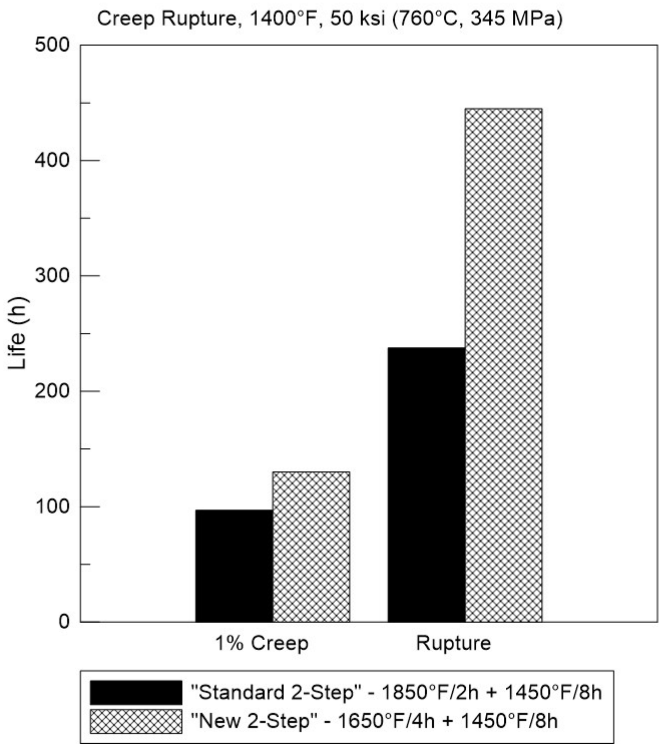
Microstructure after 1650°F (899°C)/4h + 1450°F (788°C)/8h, showing the complex gamma-prime and $M_{23}C_6$ carbide structure at grain boundaries

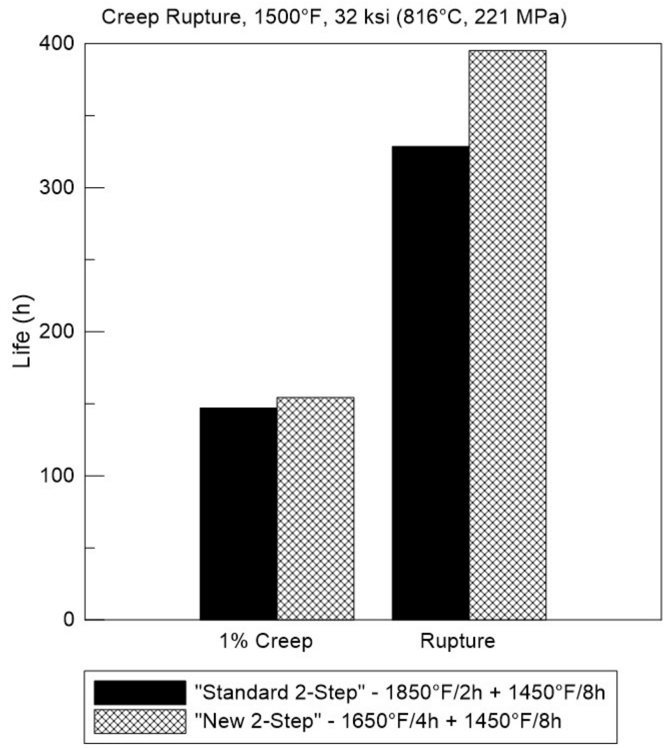


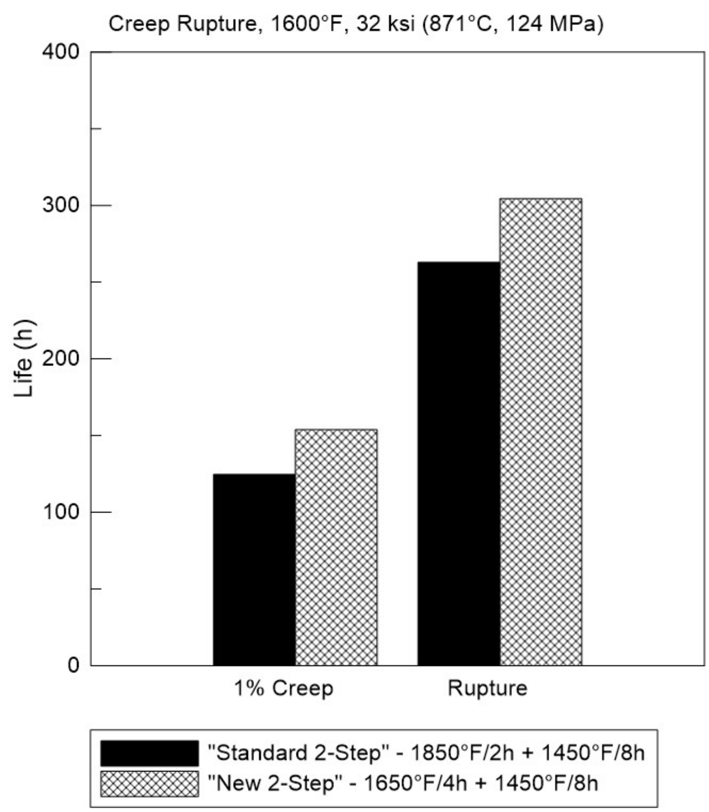
All the heat treatments are designed to precipitate $M_{23}C_6$ and to precipitate and/or grow gamma prime.

However, the morphology and location of the phases can vary considerably.

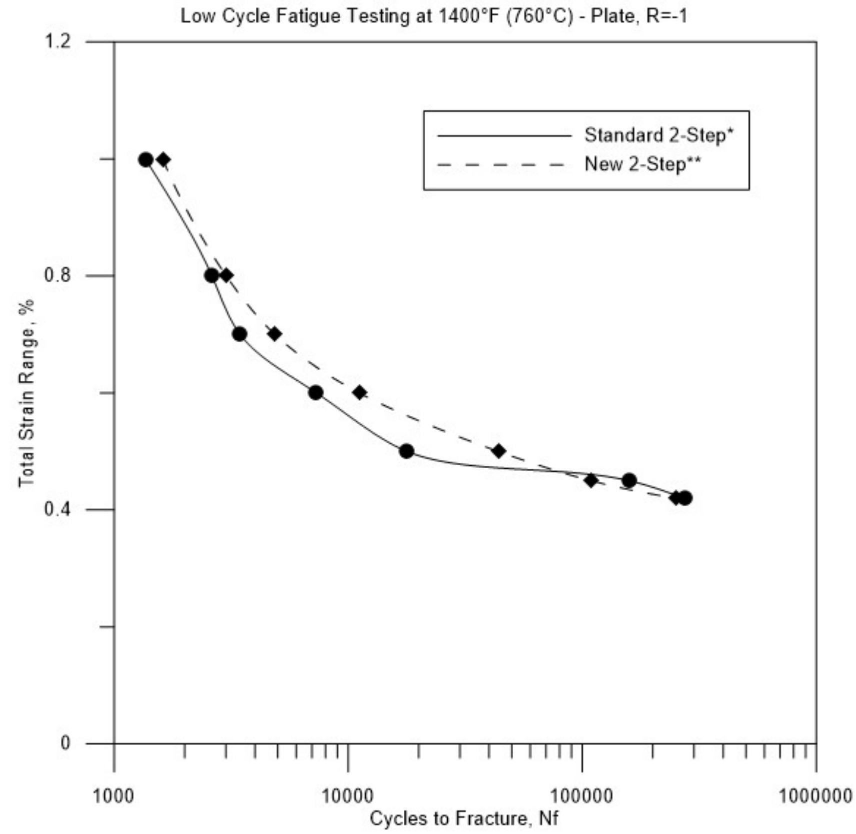
Creep Rupture







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 γ' + $M_{23}C_6$ 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.