MICROSTRUCTURE AND PROPERTIES OF Ni-Fe BASE Ta-718

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Abstract

The Nb was replaced by Ta on a one to one atom basis in alloy 718. Structural studies show that on solidification the MC, Laves, δ, and γ'' phases which formed are similar to the corresponding phases in cast alloy 718. However, less Laves and δ phases form on solidification and homogenization occurs at a lower temperature in a shorter time than in cast alloy 718.

The γ'' phase in TA 718 is stable up to temperatures of 1850°F which is higher than in alloy 718. The γ'' to δ transition has not been observed in the normal heat treatments used in this study.

Cast TA 718 possesses tensile and stress-rupture properties as good as cast alloy 718. However, the heat treatments used in the test program are not necessarily optimum for this alloy.

Superalloys 1988
Edited by S. Reichman, D.N. Duhl,
G. Maurer, S. Antolovich and C. Lund
The Metallurgical Society, 1988

INTRODUCTION

Cast alloy 718 has been used in many gas turbine applications because of its good castability, good weldability, and low cost. However, due to the high Nb content, as-cast components of alloy 718 become highly segregated during solidification requiring long homogenization cycles which affect weldability. Highly segregated areas tend to show excessive porosity which must be closed by HIP treatments. Current trends for greater Nb contents for higher strength means greater segregation will form and homogenization may not be achieved. Chemical segregation in alloy 718 produces variation in the precipitation of δ, γ'' and γ' phases which leads to differential overaging during engine exposure.

Recent studies of the effects of Ta in Ni base superalloys have shown that Ta stabilizes phases such as MC and γ' more than Nb. Little is known of the role of Ta as compared to Nb in 718 type alloys. To study the role of Ta on segregation and phase stability in 718 type alloys, Ta was substituted for Nb on an atom for atom basis. (Table 1) This alloy is called TA 718. While Ta and Nb are crystallographically similar and would be expected to form the same phases, it is believed that Ta might not produce the same amount of segregation as Nb. A lower tendency for segregation would then allow shorter homogenization cycles, produce high mechanical properties at higher operating temperatures and improve weldability.

MATERIALS AND PROCEDURE

The material for this study was conventionally cast into 1/4 inch thick plates. A number of the plates were cut into samples for a time-temperature study to determine the solvus behavior of the cast structures. Select samples were then given a 1600°F 1 hour heat treatment to determine residual segregation remaining after the various solution temperatures.

Other plates of the TA 718 were used for tensile and stress-rupture testing after being HIPped at 2050°F/14.7Ksi/3 hrs. Based on alloy 718 data, two post HIP heat treatments were given to the test bars: Heat treatment A was 1925°F/1 hr. + 1350°F/8 hrs. + 1150°F/8 hrs. while heat treatment B consisted of 2000°F/1 hr. + 1500°F/1 hr. + 1400°F/2 hrs.

Microstructural characterization was carried out using optical and scanning electron microscopy. Chemical analyses were carried out using EDAX type X-ray analyses on many structural features. Phase extractions were completed using a 15% HCl and 85% Methanol solution. A 5 volt potential was applied for 1 and 3/4 hours. Phase identification was then completed using X-ray diffraction patterns from the extracted residues.

Standard room temperature, 1200°F, and 1300°F tensile tests were run while stress-rupture tests were carried out at 1200°F and 1300°F at 90 Ksi.

RESULTS

Structural Study

Examination of the as-cast material reveals a prominent dendritic solidification pattern containing many carbides in the interdendritic regions as well as Laves and δ phases, Figure 1. Higher magnifications show the presence of γ'' and γ' in the interdendritic regions, Figure 2. Chemical analyses show the interdendritic regions to be high in Ta and Ti but have reduced levels of Fe, Cr, and Ni relative to the dendrites.

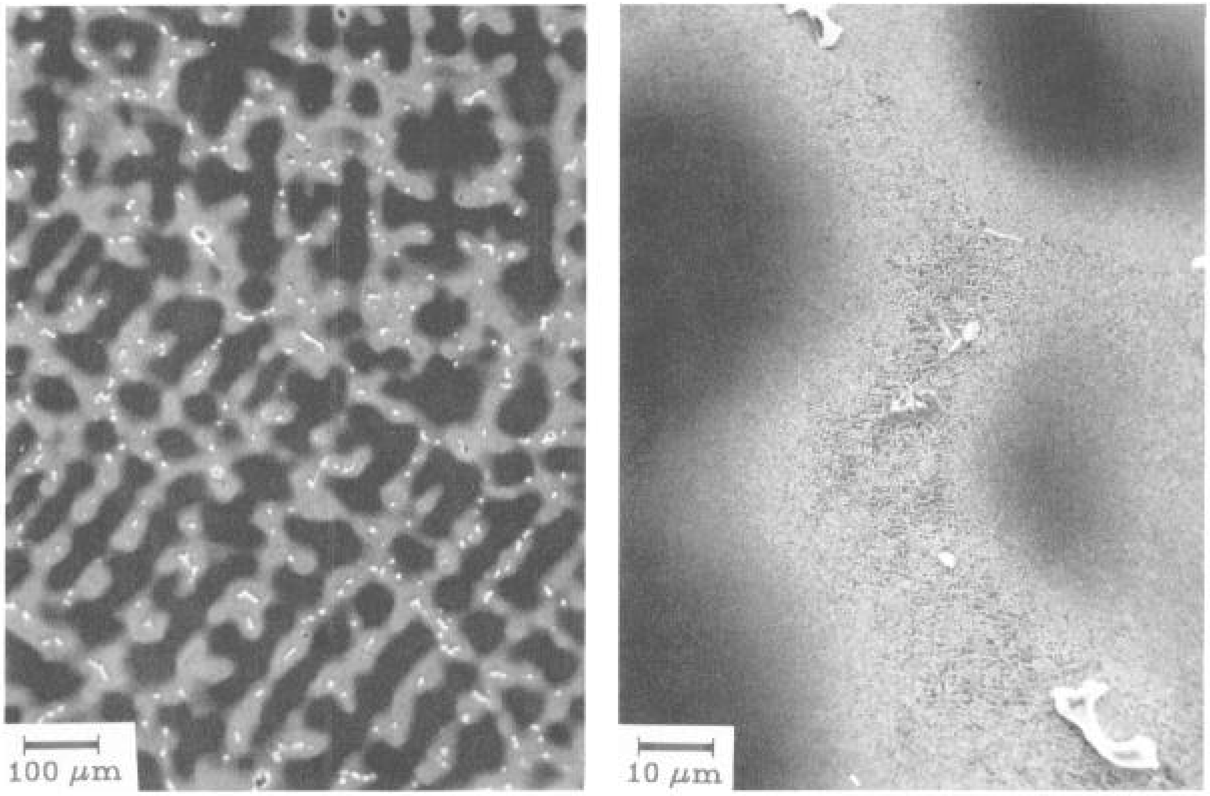
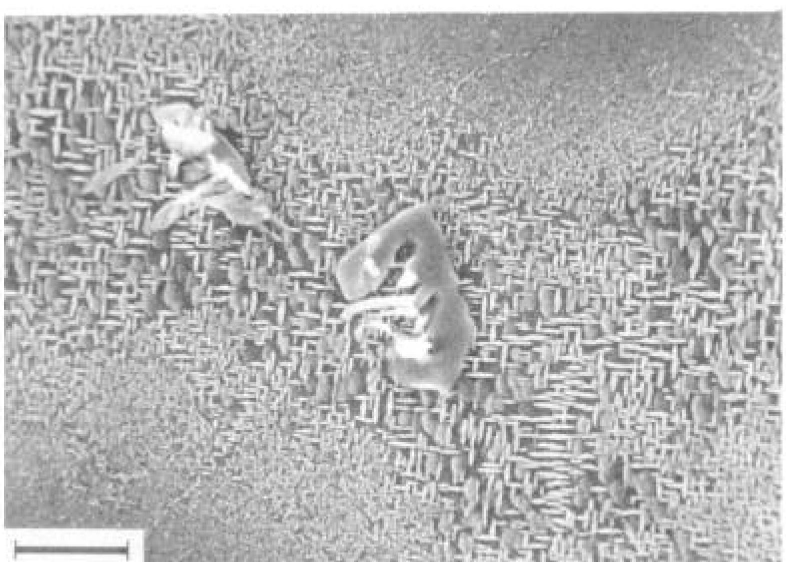


Fig. 1. TA-718 As Cast.



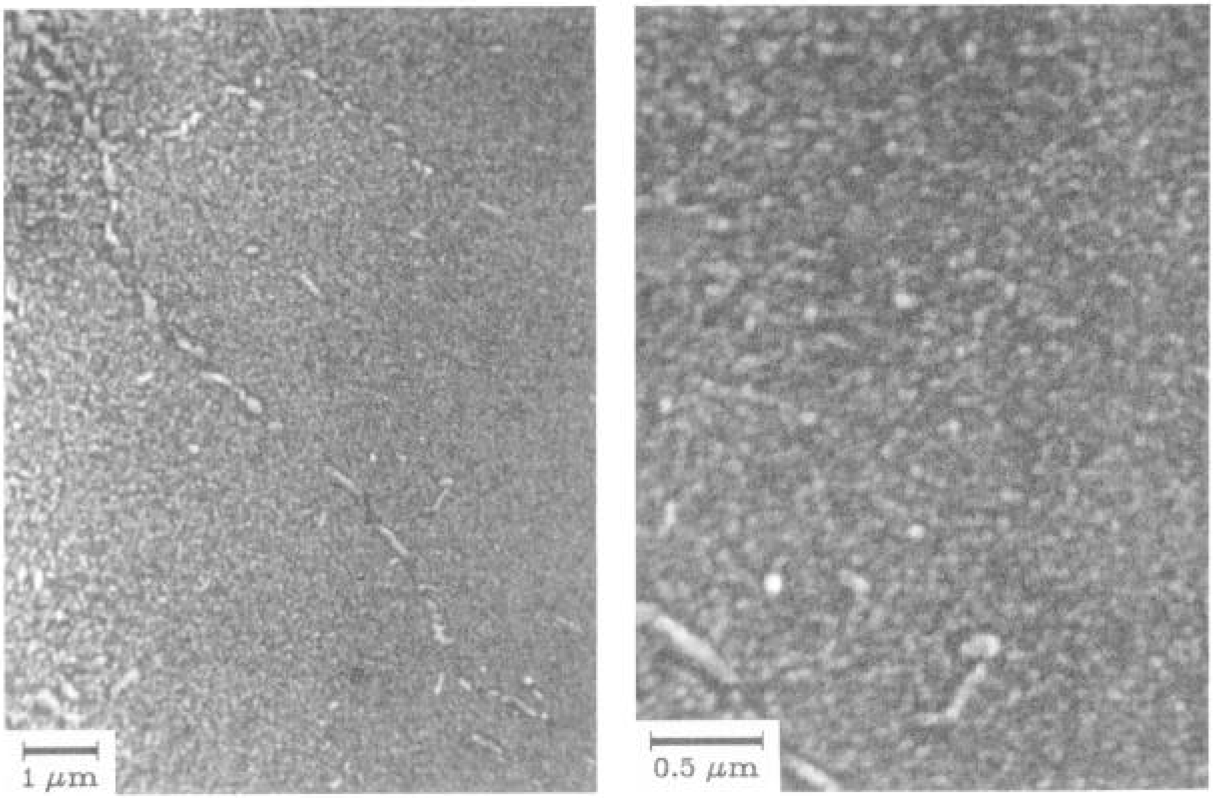


Fig. 2. TA-718 As Cast.

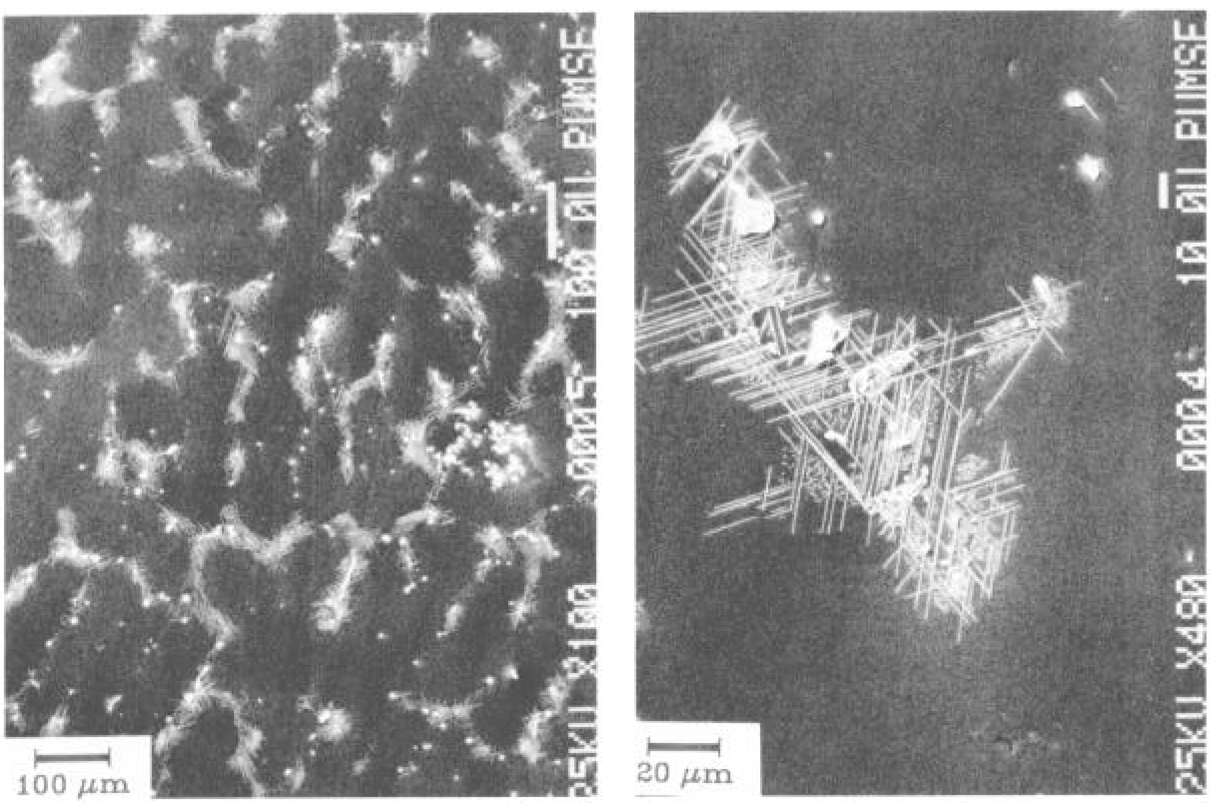


Fig. 3. Delta Phase 1900 °F/10 hrs.

X-ray diffraction patterns of residue extracted from the as-cast material confirm the presence of an MC phase, Laves phase, and γ'' phase. Lattice parameter measurements and EDAX analyses of the extracted residue show the MC phase to contain predominately Ta with lesser amounts of Ti. Ta, Ti, Fe, Cr, and Ni were detected by EDAX in the Laves phase while Ta, Ti, and Ni were detected in the γ'' residue. The γ'' phase was extracted using the 15% HCl and 85% Methanol solution.

Time-Temperature Study

When exposed 10 hours at 1900°F, plates of δ phase form as seen in Figure 3. Within the plate areas a fine disk shaped structure is present. After 2000°F for 1 hour, the MC and Laves distribution have undergone little change, but the amount of δ decreases and the disk shaped phase disappears, Figure 4.

The MC and Laves phases are increasingly solutioned by the application of higher temperatures and/or longer times. Figure 5 shows the amount of MC present after 2050°F for 1, 3, and 20 hours of heat treatment. As samples are heat treated at higher temperatures, a reduction is observed in MC carbies in both size and quantity.

Residual Segregation Study

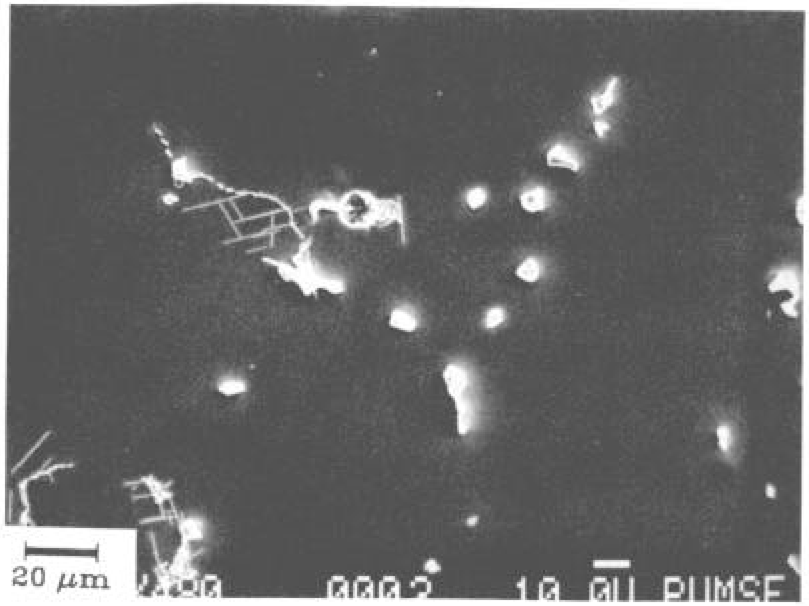
The samples given the 4 hour heat treatments at 2000 , 2050 , and 2150°F were given a 1600°F/1 hour tag heat treatment to precipitate γ'' in areas of high Ta and Ti content. Figure 6 shows the effects of the 4 hour heat treatments on homogenization. Even after the 2150°F F/4 hour heat treatment, the original solidification pattern is visible indicating that residual segregation remains after this heat treatment.

Mechanical Property Results

The results of the mechanical properties are given in Table 2. Room temperature tensile values of over 155 Ksi show that the strength of TA 718 is as good as alloy 718 and far above the GE specification for tensile properties. Heat treatment B produces a smaller drop in YS than Heat Treatment A and an ultimate tensile strength of 130 Ksi at 1300°F and 1200°F indicates that TA 718 retains its strength at higher temperatures than that of alloy 718.

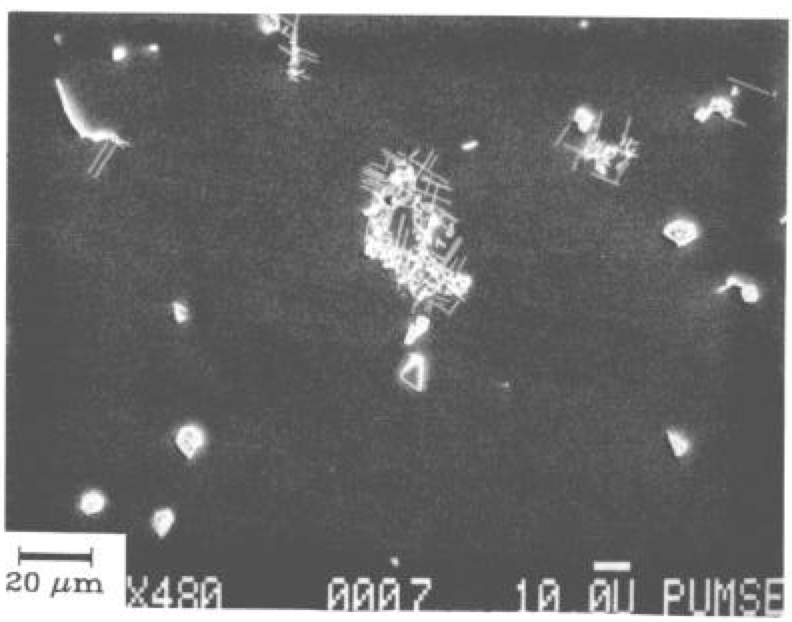
The stress-rupture life at 1300°F is only a few hours for both heat treatments, but the 1200°F life of TA 718 ranged from 30 to 140 hours which easily meets the GE specification for cast alloy 718. Such wide scatter is common in alloys like 718 and is expected in TA 718.

Structural studies were carried out on the broken test bars in order to understand the structural response of the TA 718 to post HIP heat treatments. Figure 8 shows the structures produced by A and B heat treatments. It is apparent that different thermal treatments can produce different responses in TA 718 and the heat treatments selected for the mechanical test program are not necessarily optimum for TA 718. Additional thermal treatments on solutioned TA 718 samples show that the γ'' phase precipitates as the major phase at a temperature of 1850°F without δ plate phase precipitation.

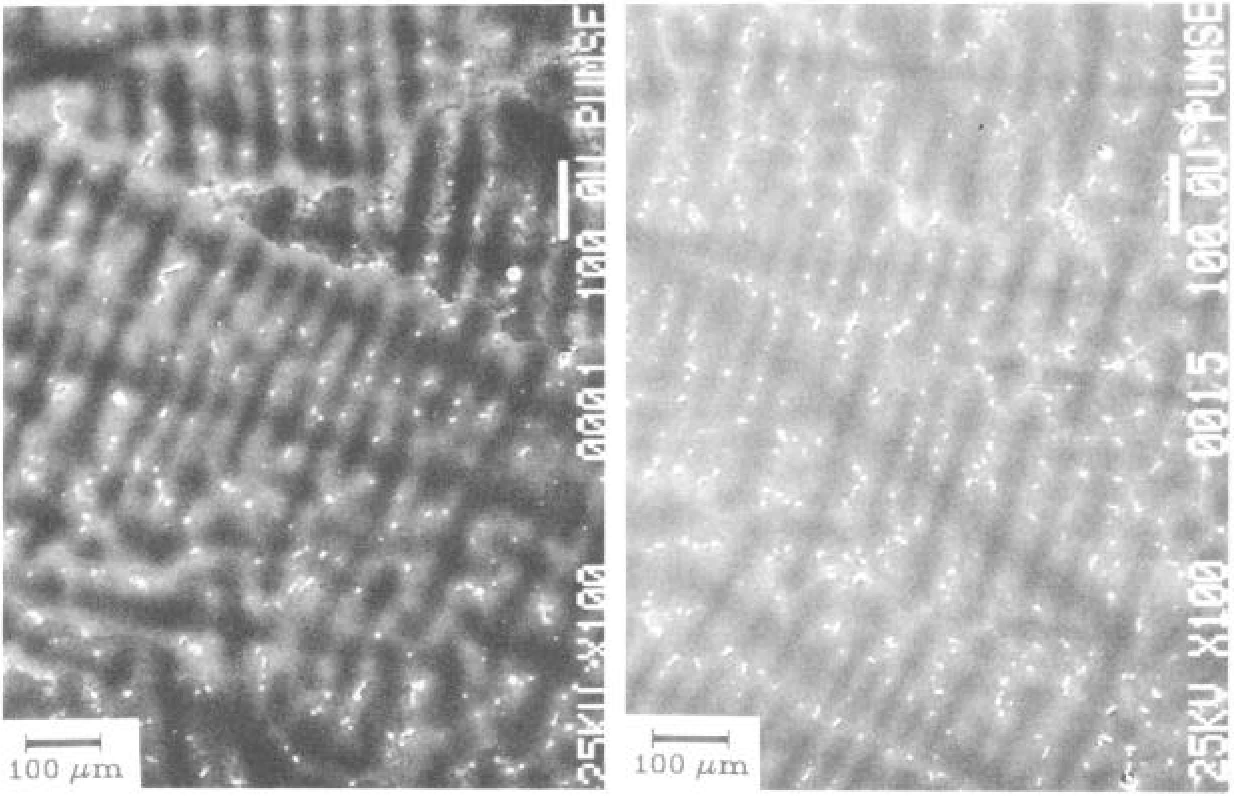


1 Hour

Fig. 4. Phase Stability @ 2000°F.



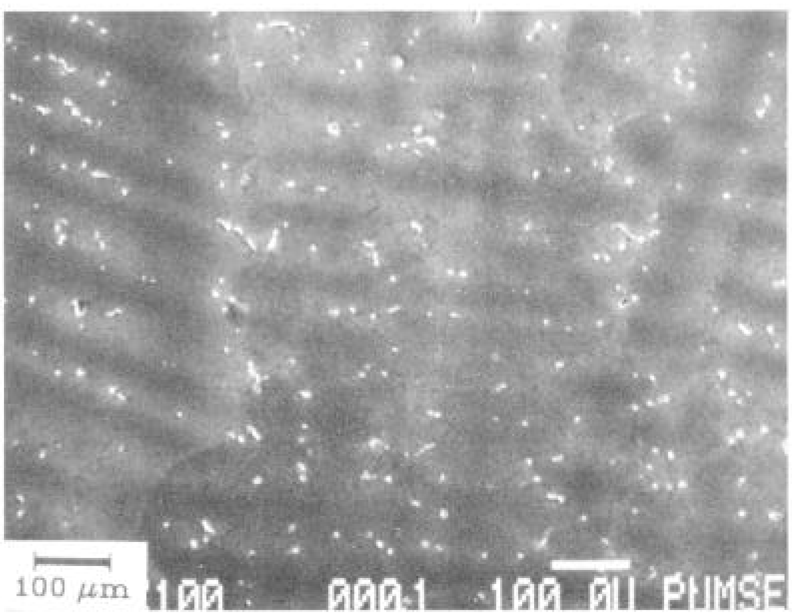
4 Hours



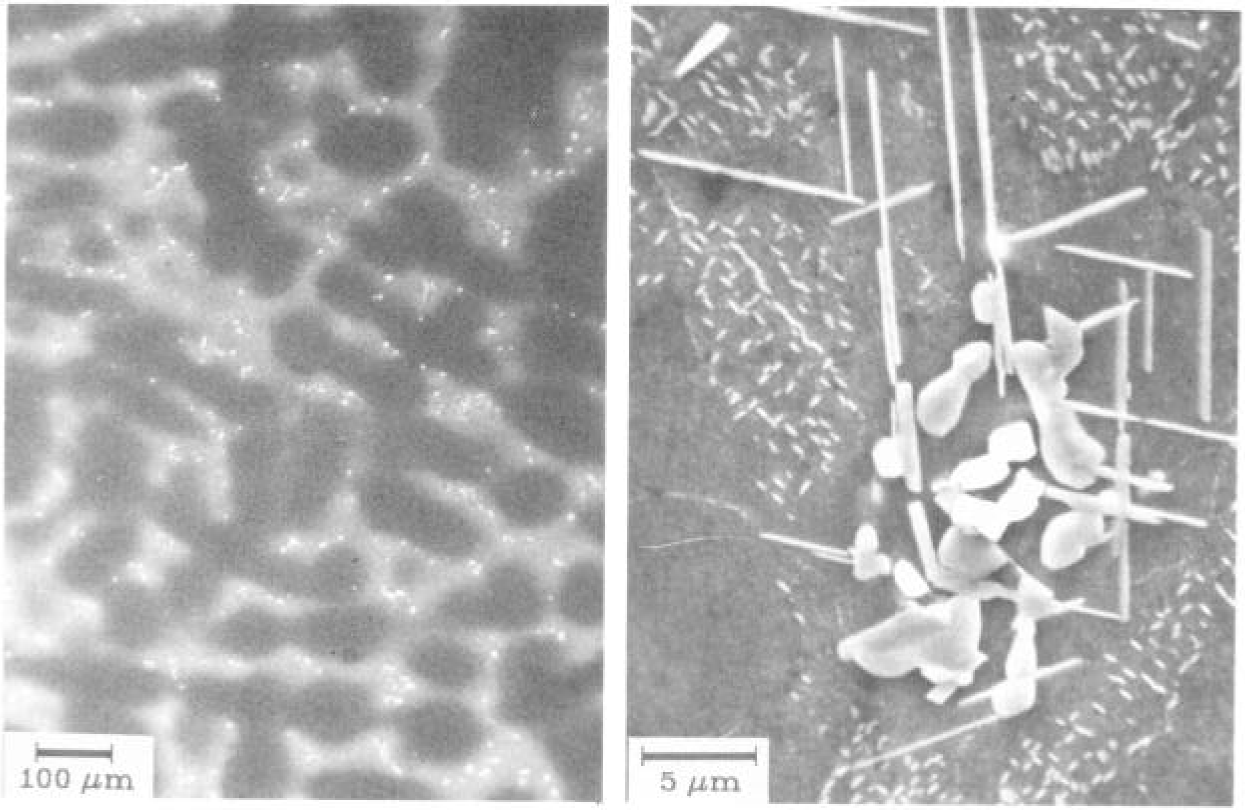
2000°F/4h+1600°F/1h

2050°F/4h+1600°F/1h

Fig. 5. Segregation Pattern after Heat Treatment.

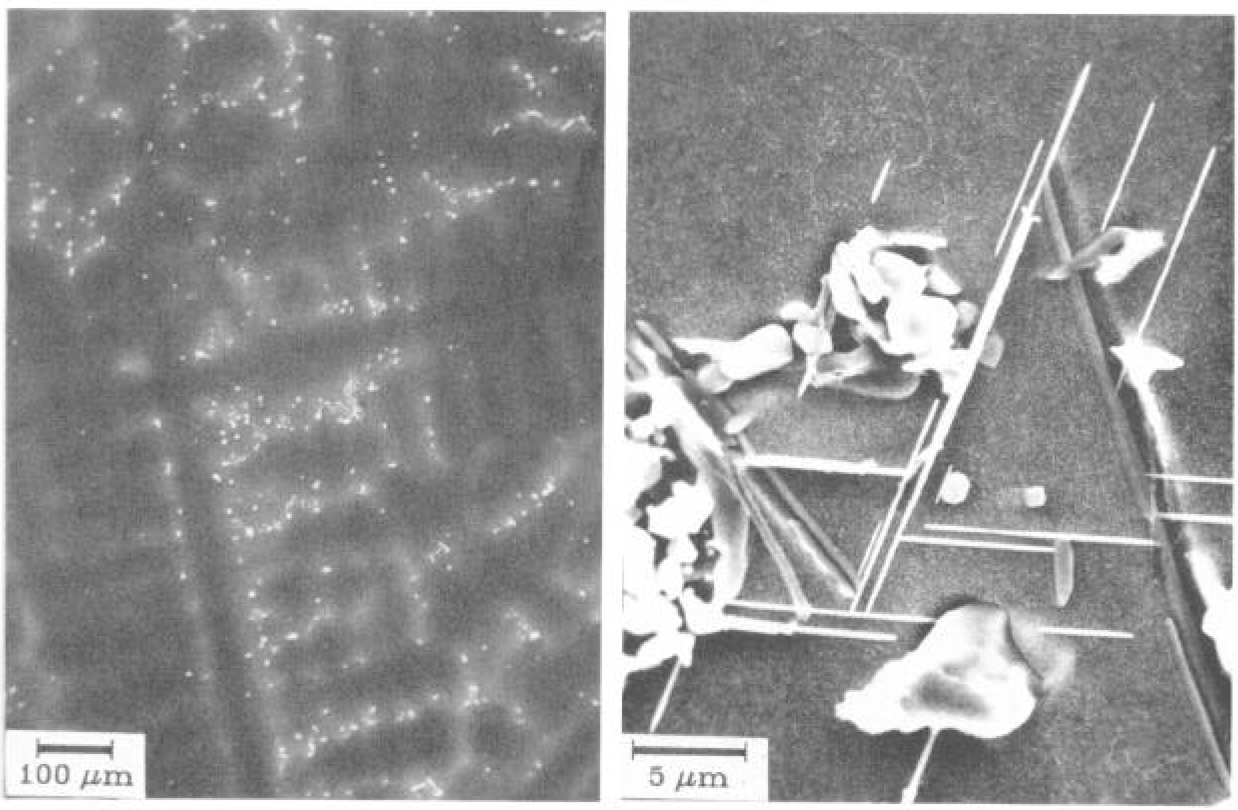


2150°F/4h +1600°F/1h



Heat Treatment A.

Fig. 6.



Heat Treatment B

TABLE I. TA 718 Composition.

TA-718 wt%	TA-718 at%		Typical IN-718 wt%	Typical IN-718 at%
48.0		Ni	52.5	
19.2		Cr	18.5	
18.0		Fe	18.5	
0.02		Nb	5.1	3.2
9.1	3.1	Ta	---	
3.0		Mo	3.0	
1.04		Ti	0.9	
0.47		Al	0.5	
0.0043		B	---	
0.044		C	0.04	
0.02		Si	0.02	
0.0018		S	---	
0.0036		O	---	

TABLE II. Mechanical Test

TENSILE TEST

I.D. #	TEMP (°F)	ULT STRENGTH	.2% YIELD
A-1a	Room	155.2Ksi	114.9Ksi
A-1b	Room	155.4	121.2
B-1a	Room	154.5	131.3
B-1b	Room	160.7	136.7
Inconel 718*	70	149	122
A-3a	1200	122.4	105.2
B-3a	1200	129.5	113.6
Inconel 718*	1200	128	104
A-2a	1300	122.2	109.1
B-2a	1300	132.2	119.4
Inconel 718*	1300		

STRESS RUPTURE (90Ksi)

I.D. #	TEMP. (°F)	LIFE (Hrs)
A-5	1200	88.1
A-6	1200	66.2
B-5	1200	30.0
B-6	1200	141.0
Inconel 718§	1200	20
A-4	1300	1.2
B-4	1300	2.8

* Reference 2
§ Reference 1