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INFLUENCE OF COBALT, TANTALUM, AND TUNGSTEN ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF SUPERALLOY SINGLE CRYSTALS

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The purpose of this study was to investigate the influence of Co, Ta, and W on the microstructure and mechanical properties of nickel-base superalloy single crystals. A matrix of alloys was based on Mar-M 247 stripped of C, B, Zr, and Hf. The microstructures of the alloys were examined using optical and electron microscopy, phase extraction, X-ray diffraction, and differential thermal analysis. Tensile and creep-rupture tests were performed at 1000° C. An increase in tensile and creep strength resulted when Co was removed from alloys containing high refractory metal contents, but Co effects were negligible for alloys with lower refractory metal levels. In the composition range studied, W was more effective than Ta in increasing the creep resistance. The mechanical properties will be discussed in relation to the microstructures of the alloys.

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- COSAM
- TENSILE AND CREEP-RUPTURE TESTS AT 1000° C
- MICROSTRUCTURAL FEATURES: γ' VOLUME FRACTION
  γ' COARSENING RATE
  γ,γ' COMPOSITION
  γ-γ' MISMATCH
  TCP FORMATION

SINGLE CRYSTAL ALLOY MATRIX

ALLOY	COMPOSITION			TCP FORMATION*	NOTES
	Co	Ta	W		
A	0	0	10	NONE	
B	0	3	10	1 TO 2%	NASAIR 100 2 CASTINGS
C	0	0	13	<1%	
D	5	0	10	NONE	
E	5	3	10	NONE	~ALLOY 3 (-Hf)
F	10	0	10	NONE	
G	10	3	10	NONE	"STRIPPED" Mar-M247
H	10	0	13	NONE	

*SOLUTION TREATED PLUS 1000 hr AT 1000° C

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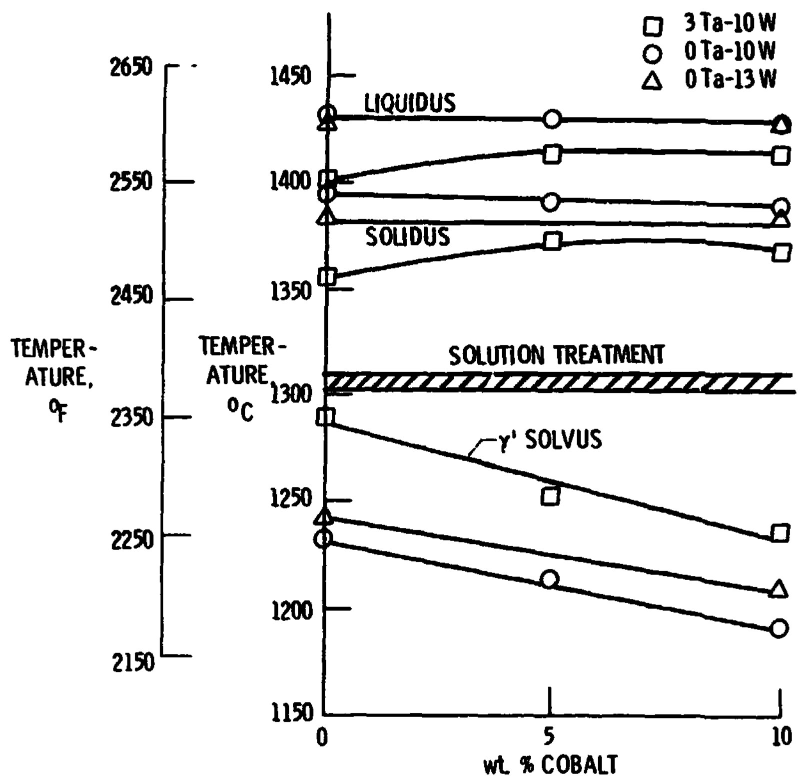
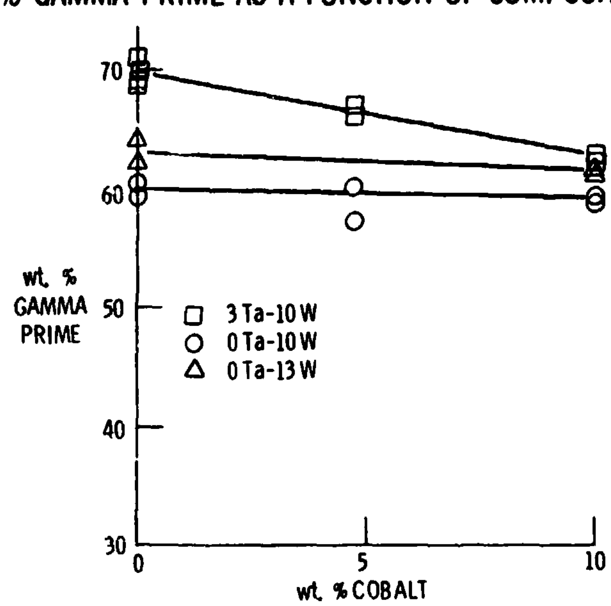
TRANSFORMATION TEMPERATURES AS A FUNCTION OF COMPOSITION

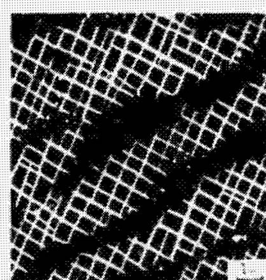


wt. % GAMMA PRIME AS A FUNCTION OF COMPOSITION

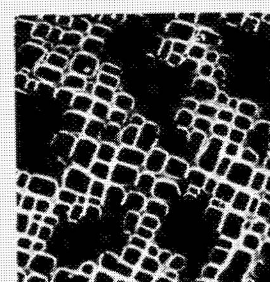


MICROSTRUCTURES OF SELECTED ALLOYS

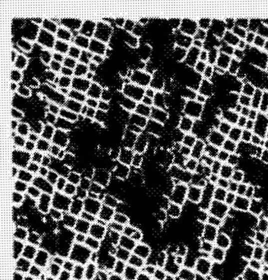
Solution treated plus 100 hrs. at 1000°C



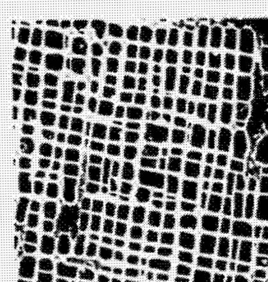
0Co 3Ta 10W



0Co 0Ta 10W

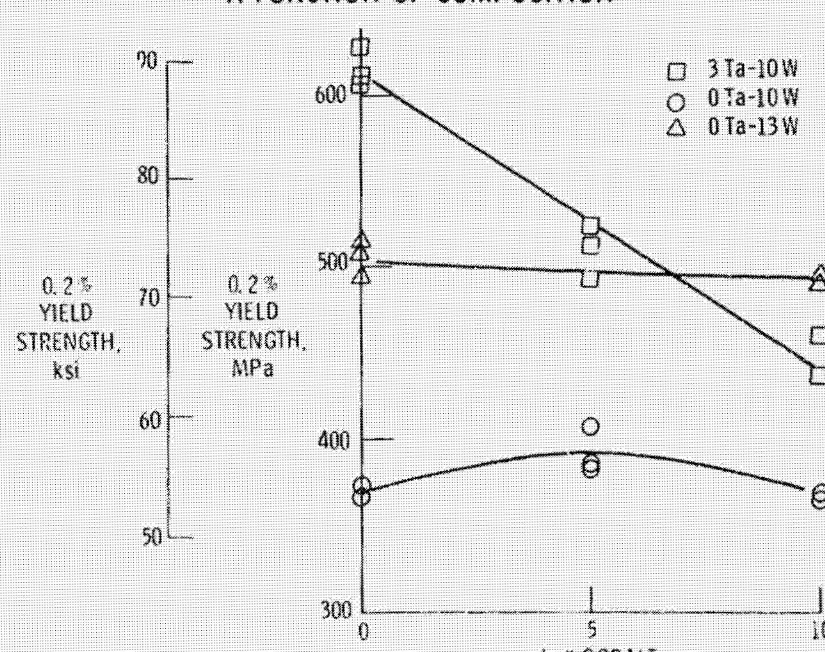


10Co 3Ta 10W

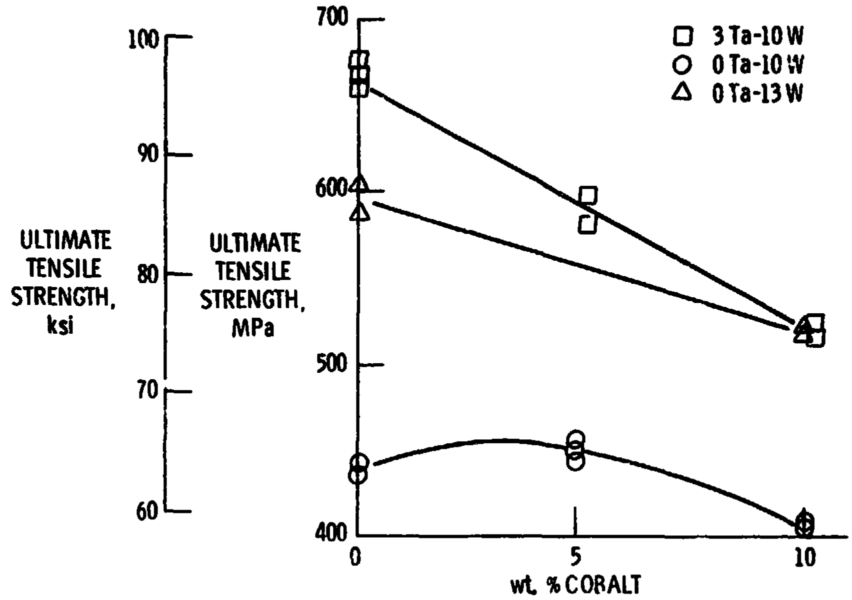


0Co 0Ta .3W

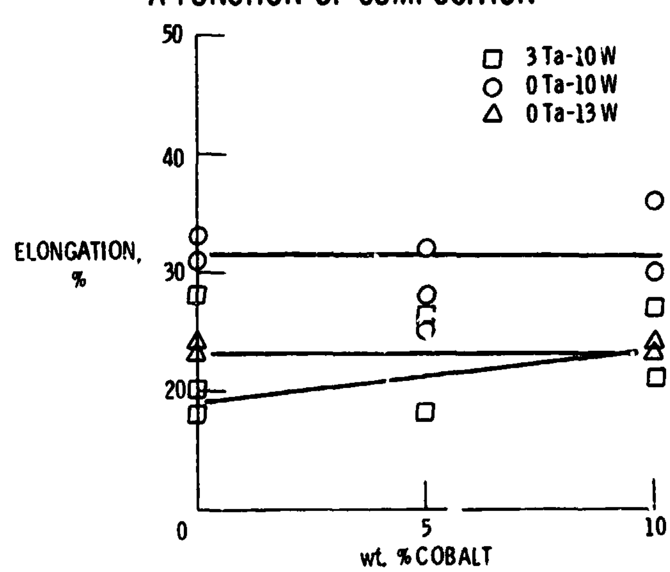
1000° C YIELD STRENGTH OF [100] ORIENTED SINGLE CRYSTALS AS A FUNCTION OF COMPOSITION



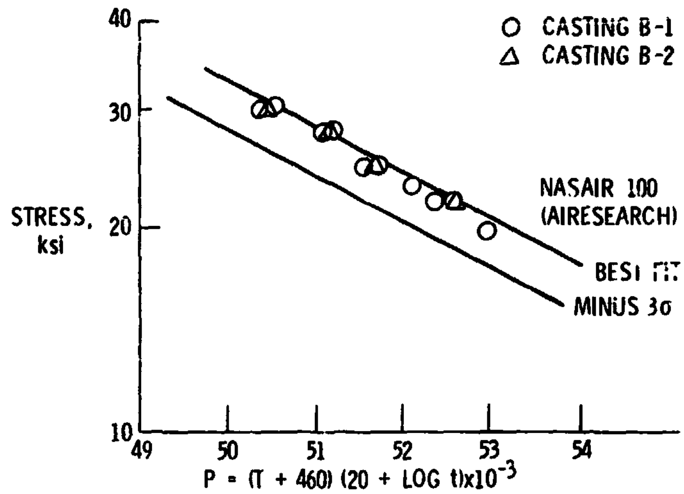
1000° C ULTIMATE TENSILE STRENGTH OF [100] ORIENTED SINGLE CRYSTALS AS A FUNCTION OF COMPOSITION



1000° C TENSILE DUCTILITY OF [100] ORIENTED SINGLE CRYSTALS AS A FUNCTION OF COMPOSITION

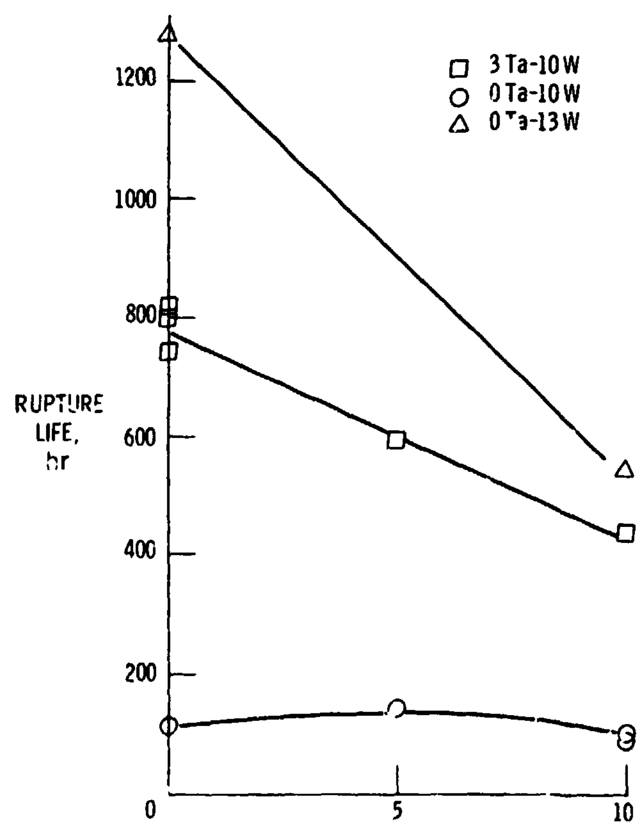


STRESS RUPTURE LIFE OF ALLOY B (0 Co-3 Ta-10 W)



RUPTURE LIFE OF [100] ORIENTED SINGLE CRYSTALS AS A FUNCTION OF COMPOSITION

1000° C, 148 MPa (21.5 ksi)



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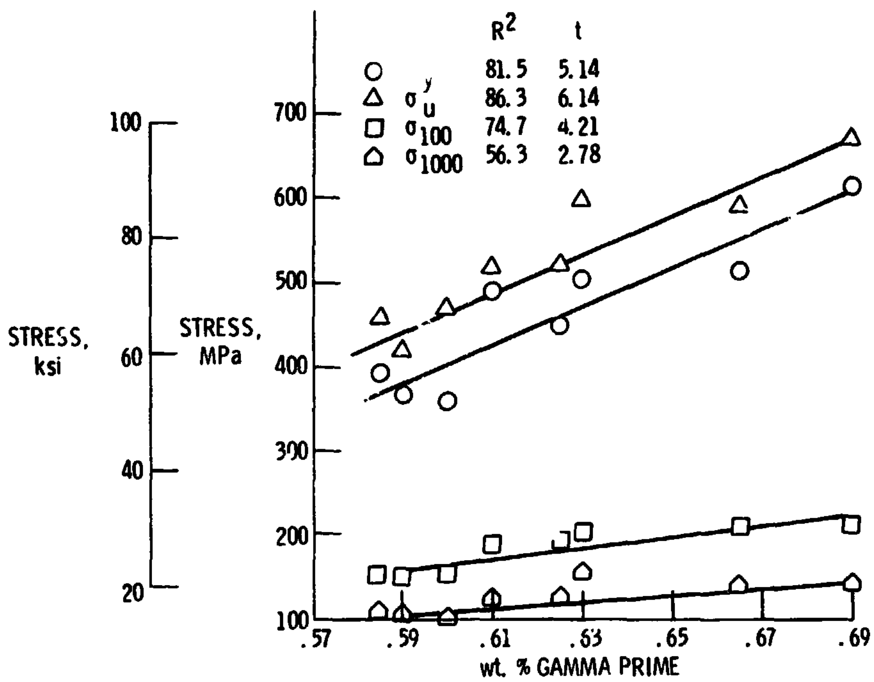
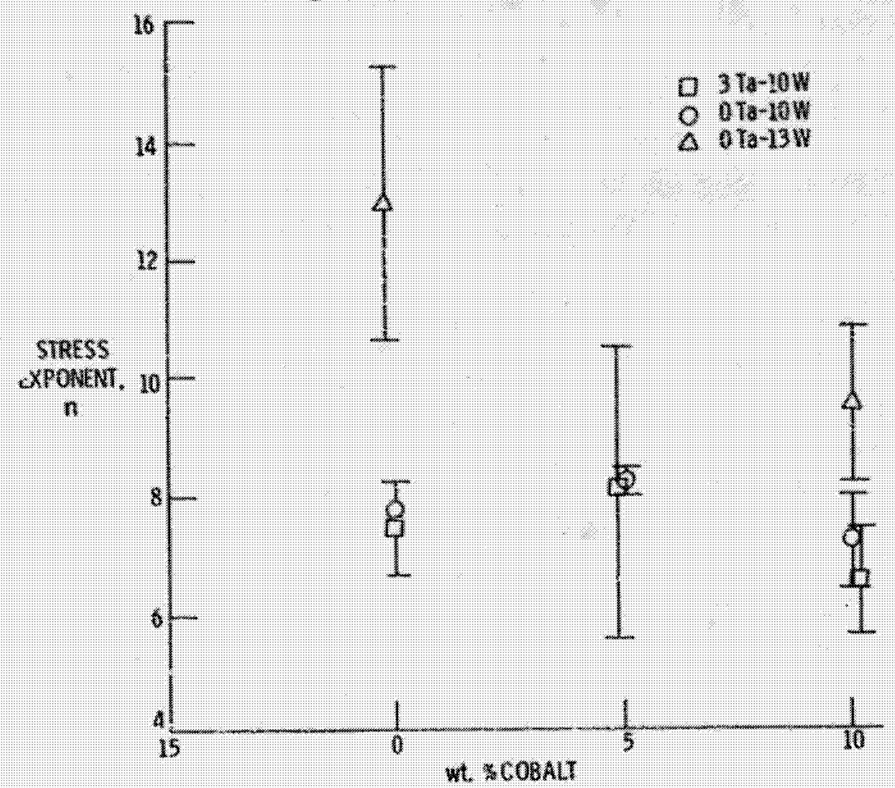
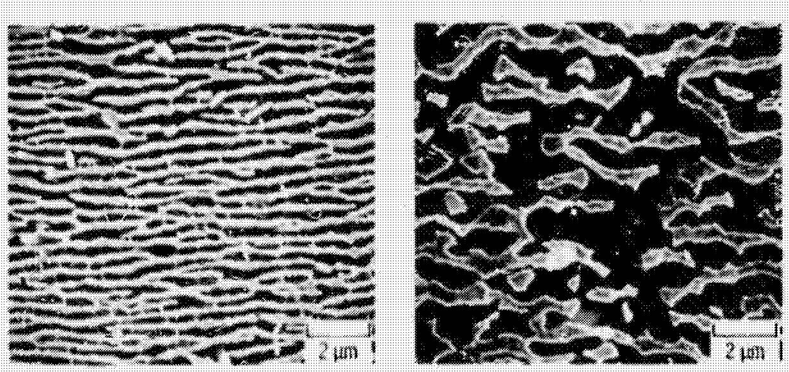
1000° C STRESS CAPABILITY OF [100] ORIENTED SINGLE CRYSTALS AS A FUNCTION OF wt. % GAMMA PRIME



1000° C STRESS EXPONENTS OF [100] ORIENTED SINGLE CRYSTALS AS A FUNCTION OF COMPOSITION



ORIENTED COARSENING OF GAMMA PRIME DURING CREEP DEFORMATION AT 1000° C AND 148 MPa



TEST INTERRUPTED AT t = 20
ε = 0.005, t/t_f = 0.025

FAILED SPECIMEN,
ε_f = 0.15, t_f = 790 hr

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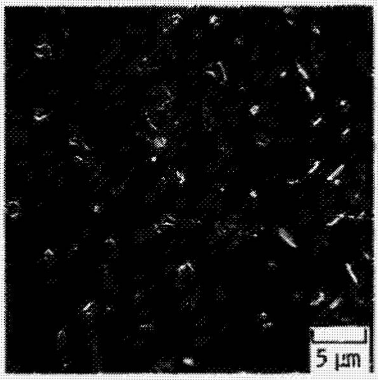
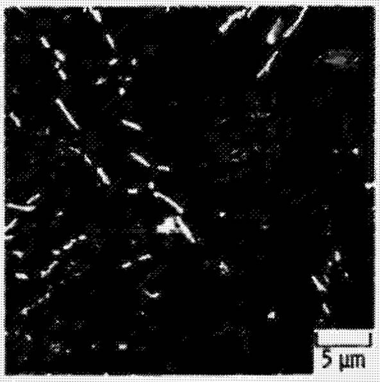
ALPHA-TUNGSTEN AND MU PHASES FOUND IN ALLOY B (0 Co-3 Ta-10 W)



SOLUTION TREATED



FAILED RUPTURE SPECIMEN,
1000° C, 207 MPa, t_f = 790 hr

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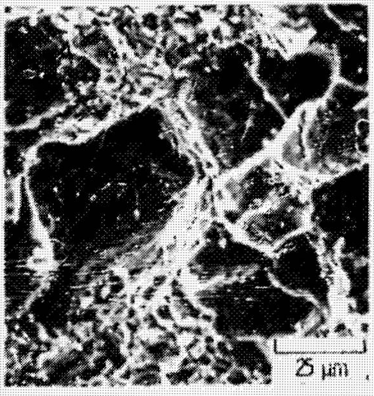
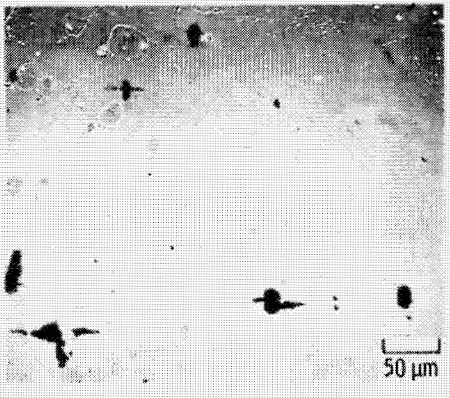
MICROSTRUCTURE OF
FAILED CREEP-RUPTURE SPECIMEN, ALLOY B (0 Co-3 Ta-10 W)

1000° C, 207 MPa (30 ksi), t_f = 110 hr



FRACTURE SURFACE



LONGITUDINAL SECTION

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SUMMARY

MICROSTRUCTURE OF SINGLE CRYSTAL ALLOYS

1. DECREASE Co: INCREASE IN γ' SOLVUS
   : INCREASE IN wt. % γ' (3 Ta-10 W)
   : INCREASE IN TCP PHASE FORMATION
2. SUBSTITUTE Ni FOR Ta: STRONG DECREASE IN γ' SOLVUS
   : STRONG DECREASE IN wt. % γ'
3. SUBSTITUTE W FOR Ta: SMALL DECREASE IN γ' SOLVUS
   : SMALL DECREASE IN wt. % γ'

MECHANICAL PROPERTIES OF SINGLE CRYSTAL ALLOYS

1. DECREASE Co: INCREASE IN CREEP RESISTANCE AND TENSILE STRENGTH FOR THE HIGH (Ta + W) LEVELS
   : VERY SMALL EFFECT FOR THE LOW (Ta + W) LEVELS
2. ALL ALLOYS HAD TENSILE ELONGATIONS GREATER THAN 18 %. LOWER STRENGTH ALLOYS HAD HIGHER DUCTILITY
3. TUNGSTEN IS MORE EFFECTIVE THAN Ta FOR CREEP RESISTANCE
4. 1000^0 C STRESS CAPABILITY IS STRONGLY CORRELATED WITH wt. % γ'
5. CASTING POROSITY APPEARS TO BE A MORE SERIOUS DEFECT THAN THE PRESENCE OF TCP PHASES