



# Special Metals Corp: Nickel-Base Alloys for High Performance Fasteners

# Special Metals Corporation

## PCC Energy Group of Companies



World leader in the design, development and production of nickel-base and other high performance alloys.

Most comprehensive range of alloys and product forms available from any one manufacturer worldwide.



# Corporate Structure

- Precision Castparts Corp.
  - PCC Forged Products
    - PCC Energy Group
      - Special Metals Corp.
        - Huntington Alloys

# Mill Product Forms

- Ingot
- Billet for forging
- Bar
- Sheet/Strip
- Plate
- Wire Rod
- Seamless Tubing
- Extruded Shapes



# Melting / Refining / Remelting

- VIM (Vacuum Induction Melting)
- AIM (Air Induction Melting)
- EAF (Electric Arc Furnace)
- AOD (Argon Oxygen Decarburization)
- ESR (Electro-Slag Remelting)
- VAR (Vacuum Arc Remelting)



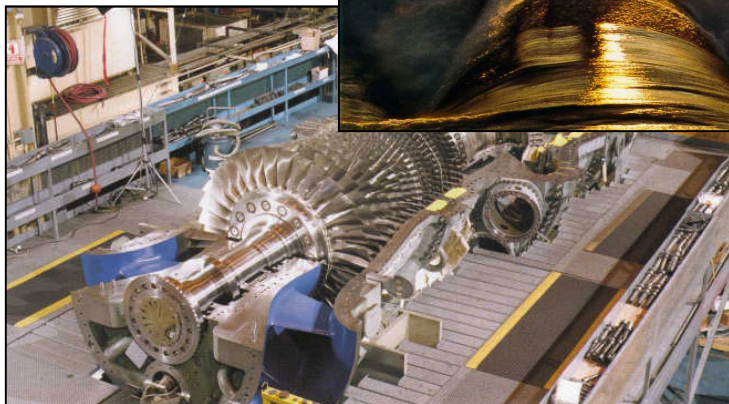
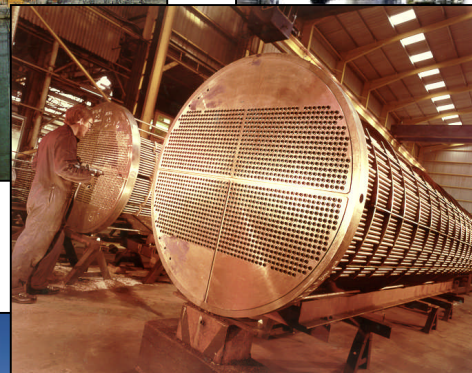
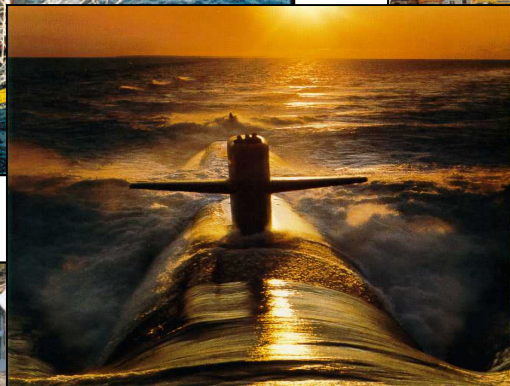


# Processing

- Forging
- Hot Rolling
- Cold Rolling
- Cold Drawing
- Extrusion
- Cutting & Shearing



# SMC Alloy Markets





# Aerospace Manufacturers supplied by Special Metals

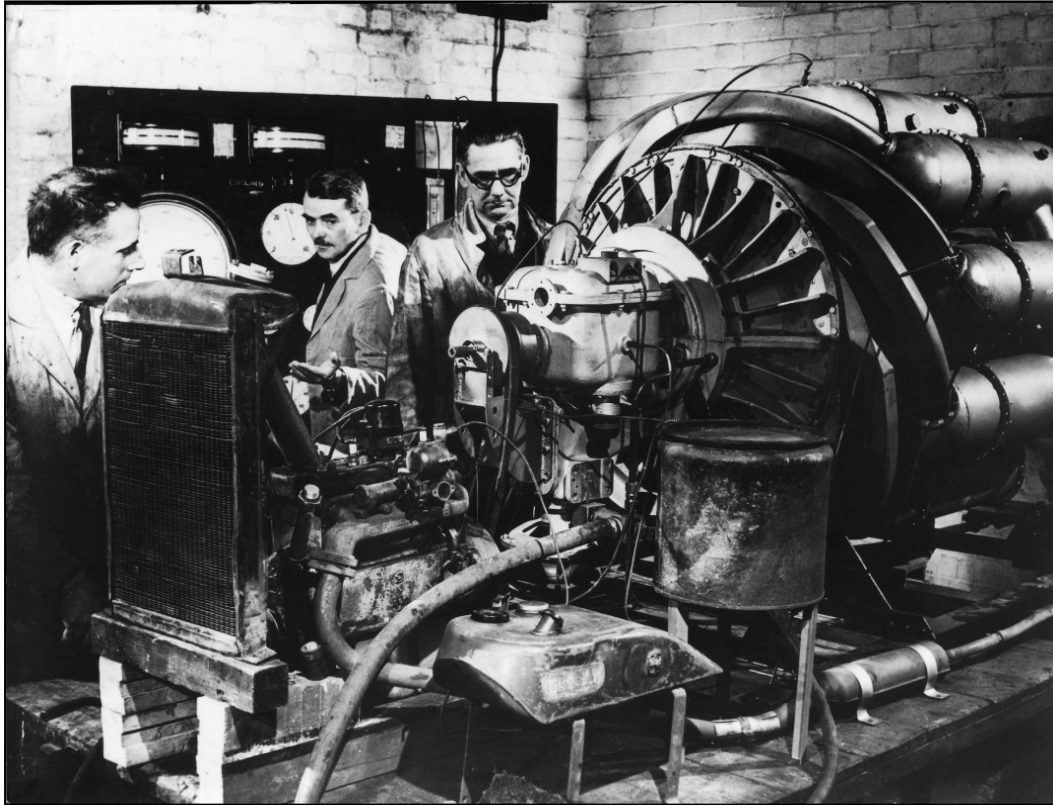
- General Electric
- Pratt & Whitney
- Rolls-Royce
- Snecma
- Turbomeca
- Boeing
- Airbus
- Honeywell
- MTU



# SMC Aerospace History



- 80% of aerospace nickel alloys were developed the current Special Metals group of companies
- Vacuum melting of nickel alloys was pioneered by Special Metals.



**Development of the jet engine by Sir Frank Whittle in the United Kingdom was greatly assisted by the simultaneous development of NIMONIC superalloys at Henry Wiggin & Co., Ltd. (now Special Metals Wiggin, Ltd.) in Hereford.**



**Perhaps the first aerospace use of a nickel alloy was the Monel Metal (now MONEL alloy 400) radiator jacket used to cool the 90 horsepower gasoline engine of the Curtiss JN4-D “Jenny” WWI U.S. Military Aircraft.**

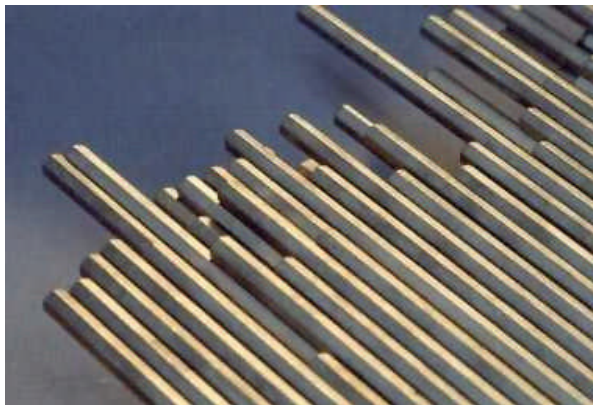




**SMC has always been heavily involved in the US space program.**



# Bar & Wire Rod



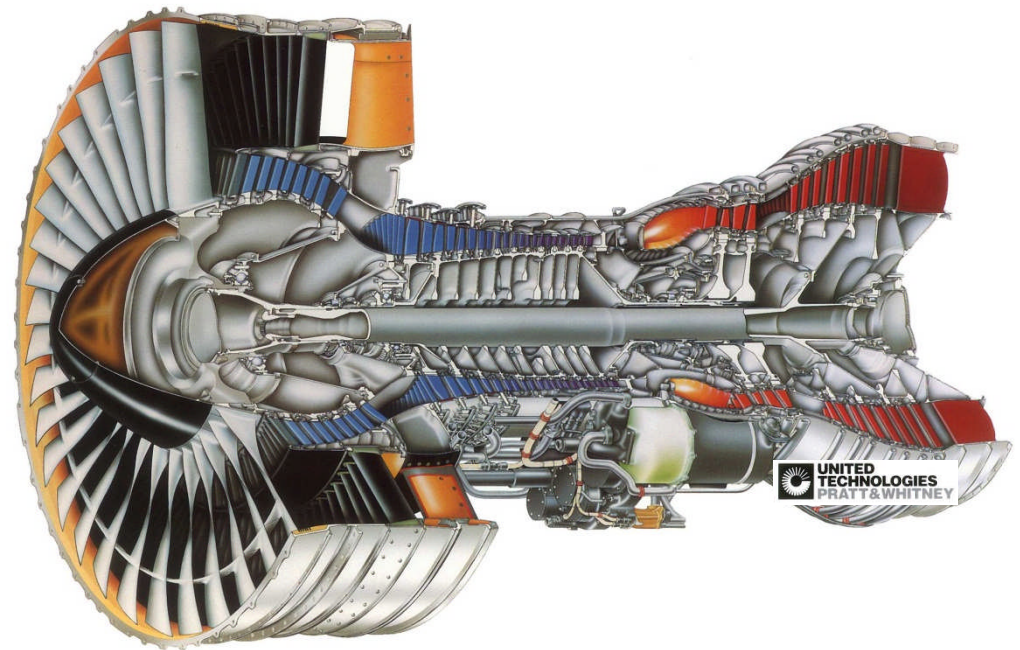
# Bar & Rod for Fasteners



**Nuts, bolts, and other forms of fasteners for service in corrosive environments are manufactured from SMC products including INCONEL 625, 686, 718 & 725 & MONEL 400, R-405 & K-500.**

# Aerospace Engine Applications

- Discs & Shafts
- Blades & Vanes
- Cases
- Rings & Seals
- Combustors
- Fasteners

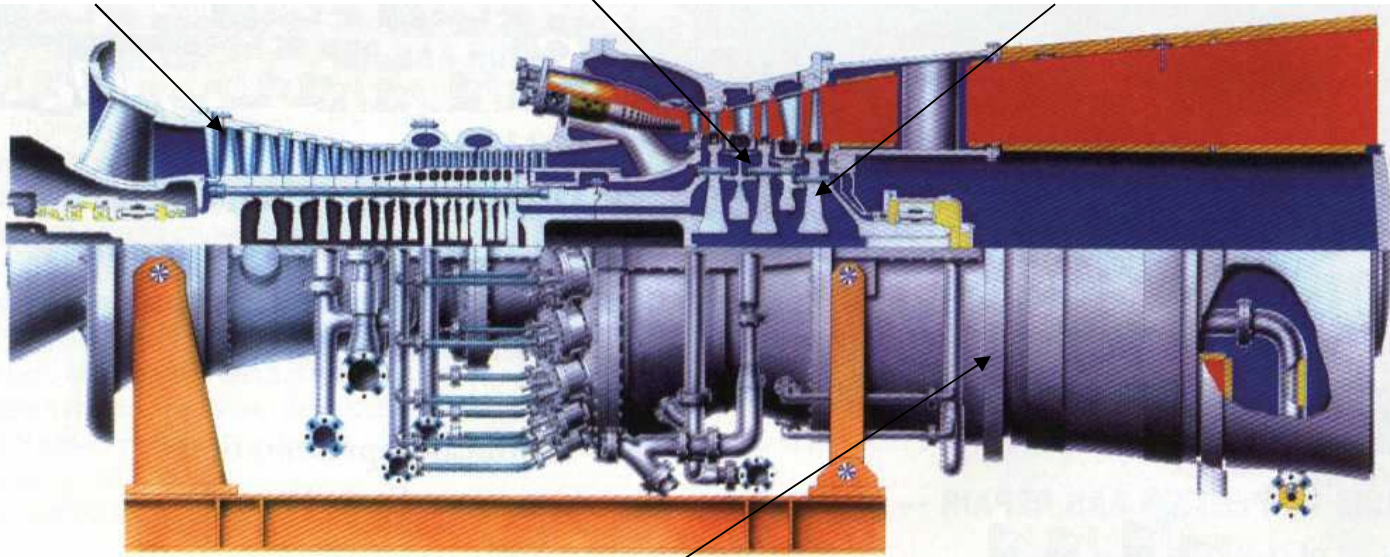


# SMC Alloys in Land Base Gas Turbines

Wheels, Spacers, Shafts – INCONEL alloy 706 & 718 Bar & Forgings

Blades – NIMONIC alloy 90,  
105, 115 & PE16 Blade Bar

Superalloy Fasteners – INCONEL alloys 718,  
X-750, & 783 & NIMONIC alloys 80A & 90 Bar



Hot Gas Path Components, Combustors

INCONEL alloy HX, 617 & N06230 & UDIMET alloy 188 Plate



# SMC Aerospace Alloys

## ➤ INCONEL®

➤ 600, 617, HX, 625, 625LCF, 718, X-750, 783

## ➤ NIMONIC®

➤ 75, 80A, 90, 105, 115, 263

## ➤ INCOLOY®

➤ 903, 907, 909, A-286

## ➤ UDIMET®

➤ 720, 720LI, R41, L-605, 188

# SMC Aerospace Alloys

- Precipitation Hardened
- Solid Solution Strengthened

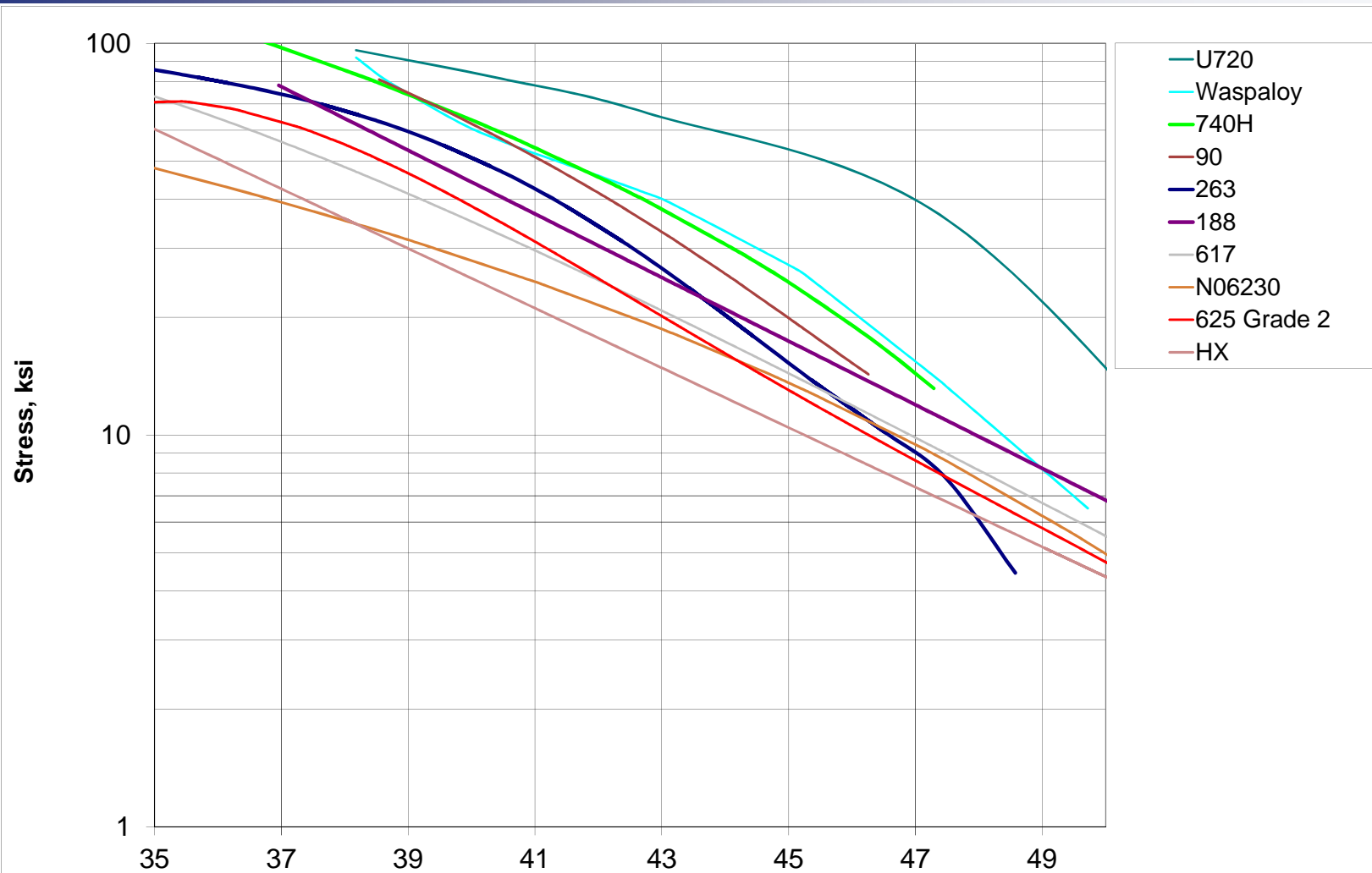
# Precipitation Hardened Alloys

- Hardened by precipitation reaction induced by heat treatment.
- Nickel alloys – gamma prime ( $\text{Ni}_3\text{Al}$ , Ti, Nb) strengthened.
- Greater strength possible by the combination of cold work & age hardening heat treatment.
- Applications limited to precipitation hardening heat treatment range. Overaging results in loss of strength.

# Chemical Composition Nickel-Base Superalloys

Alloy	Ni	Co	Fe	Cr	Mo	W	Nb	Al	Ti
INCOLOY A-286	26	-	Bal	15	1	-	-	-	2
INCONEL X-750	Bal	-	7	16	-	-	1	0.5	2.5
INCONEL 718	54	-	Bal	18	3	-	5	0.5	1
Waspaloy	Bal	14	-	20	4	-	-	1.5	3
UDIMET 720	Bal	15	-	16	3	1	-	2.5	5
NIMONIC 90	Bal	18	-	20	-	-	-	1.5	2.5
NIMONIC 105	Bal	20	-	15	5	-	-	4.5	1.5
INCONEL 783	28	Bal	26	3	-	-	3	5.5	-





**Larson Miller Stress Rupture Plot of Nickel Alloys**

# INCOLOY alloy A-286

- Age Hardenable FeNiCrTi “Stainless Steel”
- 25% Nickel = Economy
- “Poor man’s 718”
- Automotive fasteners for elevated temperature service
- Aerospace & turbine applications
- Corrosion & heat resistance

# INCONEL alloy X-750

- Age hardenable INCONEL alloy 600
- High nickel content – 72%
- Resistance to stress cracking
- Nuclear steam & water service ('HTH')
- Connecting & reinforcing rod
- Steam turbine applications

# INCONEL alloy 718

- Age Hardenable NiCrMoNbTi Superalloy
- Aerospace & Oilfield / Marine grades
  - Aerospace – 150 ksi min YS
  - Oilfield – 120 ksi min YS + toughness
- Specifications
  - Aerospace – AMS 5662, 5663, 5664
  - Oilfield – NACE MR0175, API 6A718

# Aerospace alloy 718

- Maximum strength & rupture strength
- Long term heat treatment (18 hours)
- Precipitation of gamma prime & delta phase
- Limited toughness
- Elevated temperature service
- SAE AMS 5662, 5663, 5664

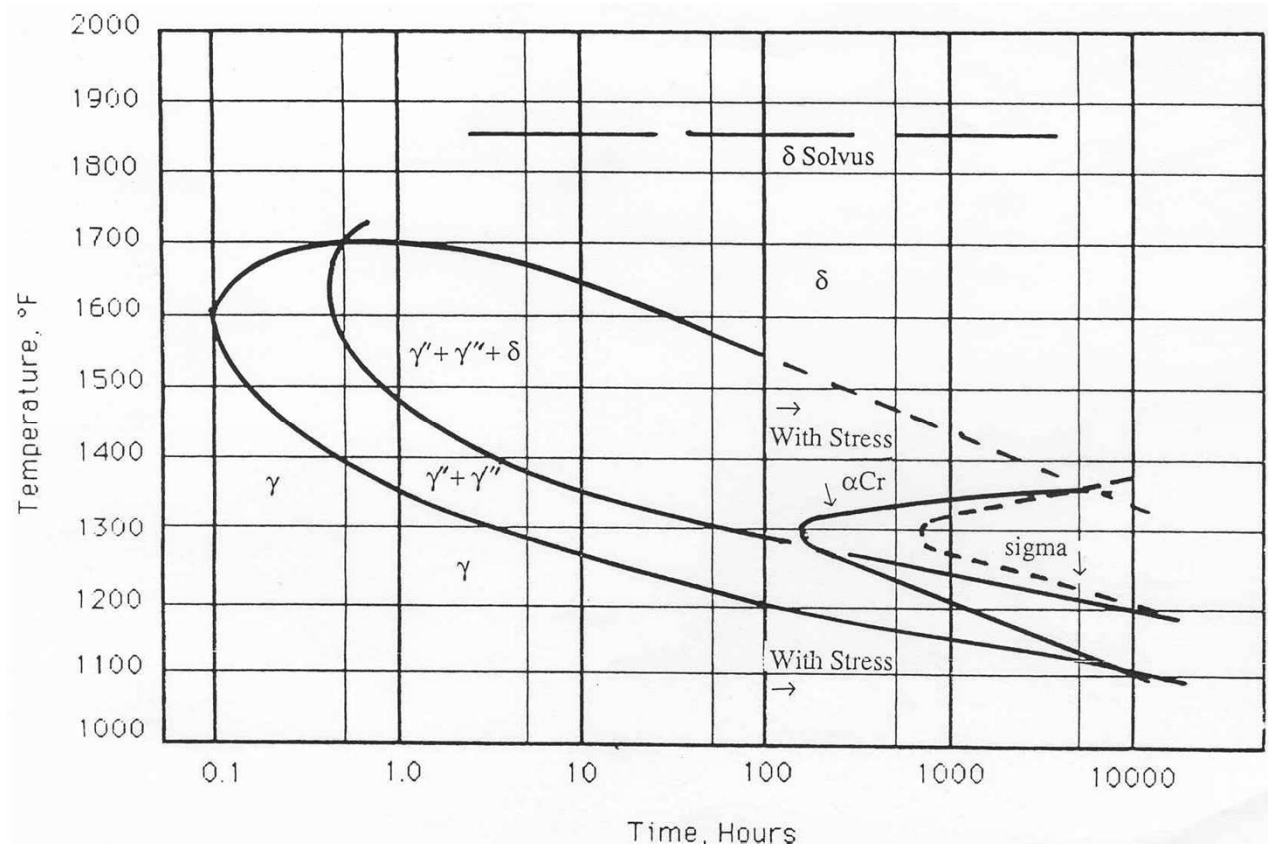


# Oilfield / Marine alloy 718

- Reduced strength for increased ductility, toughness & impact
- Short term heat treatment (6 to 8 hours)
- Corrosion resistance
- Free of delta phase
- Resistant to hydrogen embrittlement
- Low temperature applications

# INCONEL alloy 718

## Time-Temperature-Transformation



# Waspaloy

- Old, well-established aerospace alloy
- NiCoCrMoTi age hardenable superalloy
- Introduced in 1960's ... still widely used
- Excellent high temperature properties
- Especially useful at 1200 to 1600°F
- blades, seals, rings, shafts, turbine disks ... and fasteners

# UDIMET alloy 720

- Precipitation hardened by gamma prime
- Solid solution strengthened by tungsten and molybdenum
- Good metallurgical stability – ductility and toughness after high temp exposure

# NIMONIC alloy 90

- Age hardenable NiCrCoTiAl superalloy
- Creep & rupture properties to 1700°F
- Oxidation resistance
- Land base gas turbine fasteners



# INCONEL alloy 783

- CoNiFeAlNbCr superalloy
- Low coefficient of thermal expansion
- Cr + Al for oxidation resistance
- Age hardenable for high strength
- Unique combination of properties
- Aerospace, gas & steam turbines

# Solid Solution Strengthened Alloys

- Strength controlled by composition
- Additional strength from cold work
- Serviceable at high temperatures
- Metallurgical stability
- Conventional fabrication

# Chemical Composition

## Solid Solution Strengthened Alloys

Alloy	Ni	Cr	Co	Mo	Fe	W	Al
INCONEL HX	48	22	1	9	18	1	---
INCONEL 617	52	22	12.5	9	1.5	---	1.2
INCONEL 686	58	21	---	16	1	4	---

# INCONEL alloy HX

- Solid solution strengthened
- Well established NiCrMo alloys for service at elevated temperature
- Well known in the aerospace community
- Strength + Heat Resistance
- Applications to 2200°F

# INCONEL alloy 617

- NiCrCoMo solid solution strengthened alloy
- Chromium + Aluminum for enhanced heat resistance, especially at very high temperatures
- Cobalt + molybdenum for high strength
- Excellent weldability and a good welding product, especially for dissimilar welding

# INCONEL alloy 686

- Cold worked to 85, 125 & 150 ksi YS
- Excellent resistance to corrosion in seawater
- Qualified by US Navy for ship construction
- MIL-DTL-1222 USN fastener specification
- Currently in service on US Navy ships & submarines





# What's New ???



# INCOLOY alloy 945

- FeNiCrMo corrosion-resistant alloy
- Precipitation hardenable
- Minimum yield strength of 140 ksi
- Qualified per NACE MR0175 Level VII at 400°F and Level VI for 450°F.
- Resistant in elemental sulfur tests to 350°F

# INCOLOY alloy 945X

- Higher strength grade of alloy 945
- Minimum yield strength of 140 ksi
- Minimum yield strength of 160 ksi for some products
- Cold worked / aged minimum yield strength of 210 ksi with 12% minimum elongation

# INCONEL alloy 740H

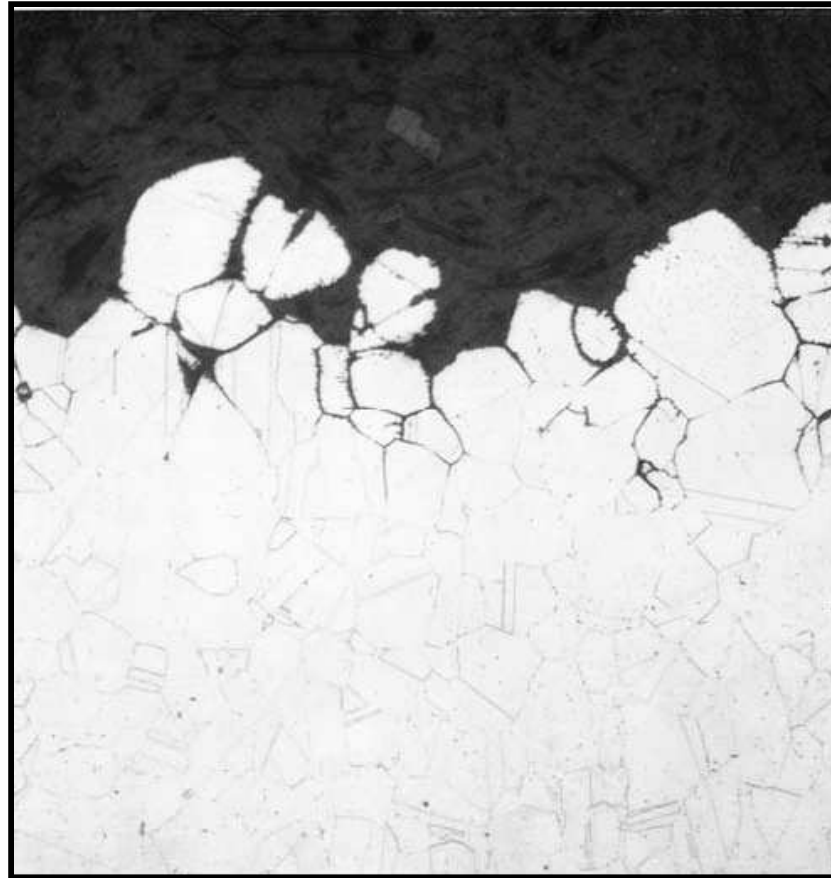
- Ni - 20Co - 25Cr - 2Nb - 2Ti - 1Al
- Developed for Advanced Ultra-Supercritical (A-USC) Boiler Service
- Age Hardened + Stability + Heat Resistance
- Service to 800°C
- Weldable in heavy sections after age hardening
- Candidate for High Temperature Fasteners



**INCONEL alloy 740H**  
**15" OD x 3" wall**  
**14K lbs. x 34 ft.**

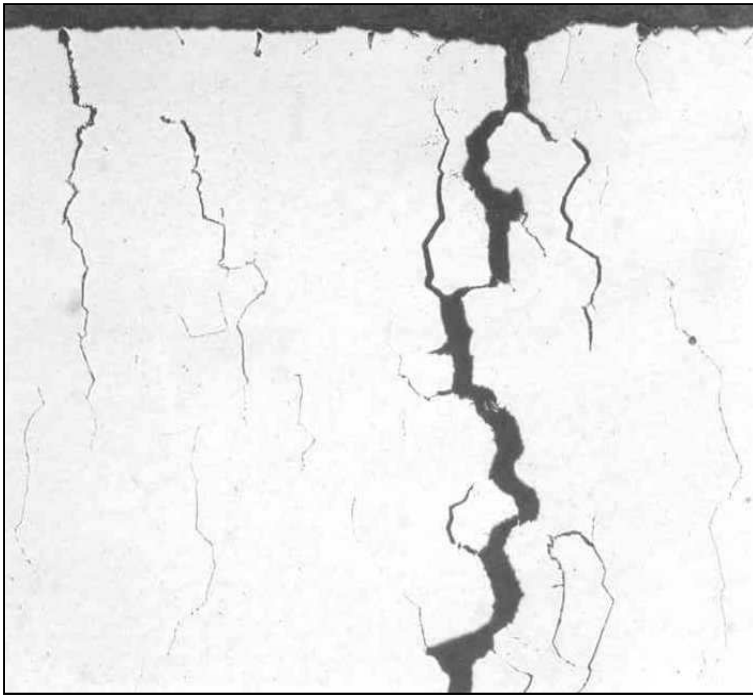


# Nickel Alloy Metallurgy 101





# How Metals React to Stress



Distortion

Relaxation

Creep

Relaxation Cracking

# Distortion during Aging

- Most nickel-base alloy contract slightly during the precipitation heat treatment ... up to about 0.07%. Thus, either:
  - Machine in the aged condition.
  - Machine oversize, precipitation heat treat, and machine or grind to final dimensions.

# Galling

Nickel-base alloys are very subject to galling. Threshold galling stress < 2 ksi.  
To improve resistance:

- Dissimilar metal coupling
- Oxide-on
- Lubricants & coatings

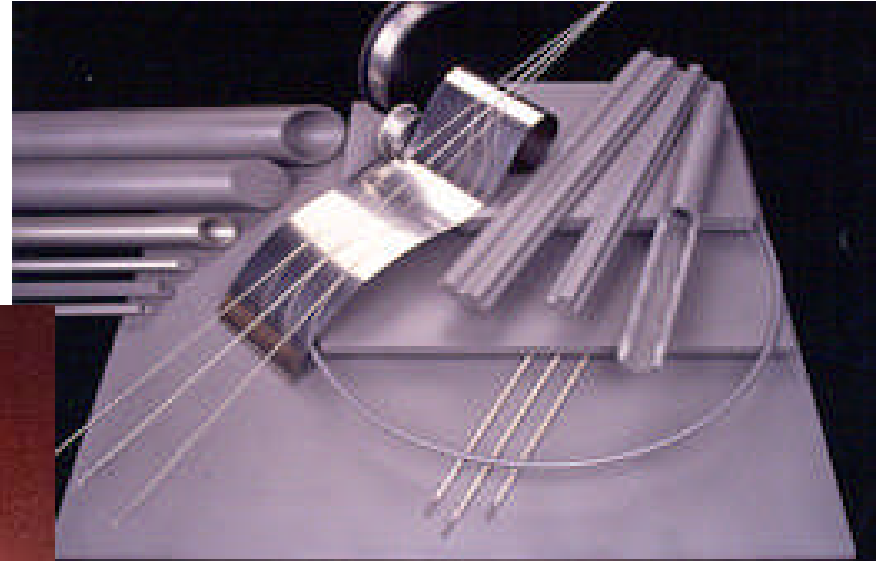
# Age Hardened Alloys at High Temperatures

- Use limited by aging temperature range
- Alloys overage (gamma prime coarsening) when used in the aging range.
- Creep & relaxation
- Torque monitoring & tightening required



## **Special Metals Corporation**

### **“Technology in Action”**



**A World Leader in  
High Performance Alloys**





# Thanks !!!

