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 by 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 Curtis JN4-D “Jenny” WWI U.S. Military Aircraft.
SMC has always been heavily involved in the US space program.
Bar & Wire Rod
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 (Ni₃Al, 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

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Ni</th>
<th>Co</th>
<th>Fe</th>
<th>Cr</th>
<th>Mo</th>
<th>W</th>
<th>Nb</th>
<th>Al</th>
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<td>3</td>
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<tr>
<td>UDIMET 720</td>
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</tbody>
</table>
Larson Miller Stress Rupture Plot of Nickel Alloys

Stress, ksi

LMP = [(T+460)*(20+log(rl)]*0.001

T in °F, rl in hours
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

- CoNiFeAlINbCr 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

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Ni</th>
<th>Cr</th>
<th>Co</th>
<th>Mo</th>
<th>Fe</th>
<th>W</th>
<th>Al</th>
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</tbody>
</table>
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 !!!