# NICKEL AND ITS ALLOYS

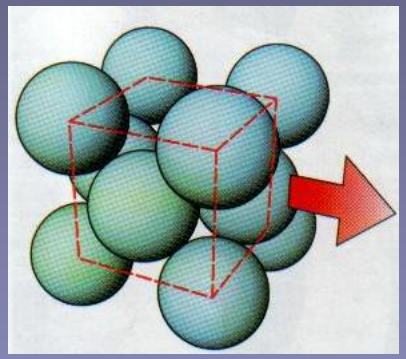
Used for their outstanding corrosion and high temperature resistance. Many are related to the austenitic stainless steels but are much more highly alloyed, particularly with nickel, chromium and molybdenum in order to enhance their corrosion resistance. These alloys are resist extremely corrosive conditions in the energy, power, chemical and petrochemical industries

The atomic weight is 58.71 and **density is 8.9 g/cm$^3$**.

Useful properties of the element are the modulus of elasticity and its magnetic and magnetostrictive properties, and high thermal and electrical conductivity.

Hydrogen is readily adsorbed on the surface of nickel. Nickel will also adsorb other gases such as carbon monoxide, carbon dioxide, and ethylene. It is this capability of surface adsorption of certain gases without forming stable compounds that makes nickel an important catalyst.

| Nichel Proprietà | |
|---|---|
| Proprietà fisiche | |
| Numero Atomico | 28 |
| Massa atomica | 58,6943 kg/kmol |
| Densità a 20°C | 8,90 kg/dm$^3$ |
| Temperatura di fusione | 1453 °C |
| Coeff.di dilataz.lineare | 13,1 $10^{-6}$ 1/K |
| Resistività elettrica a 20°C | 6,4 $10^{-8}$ ohm m |

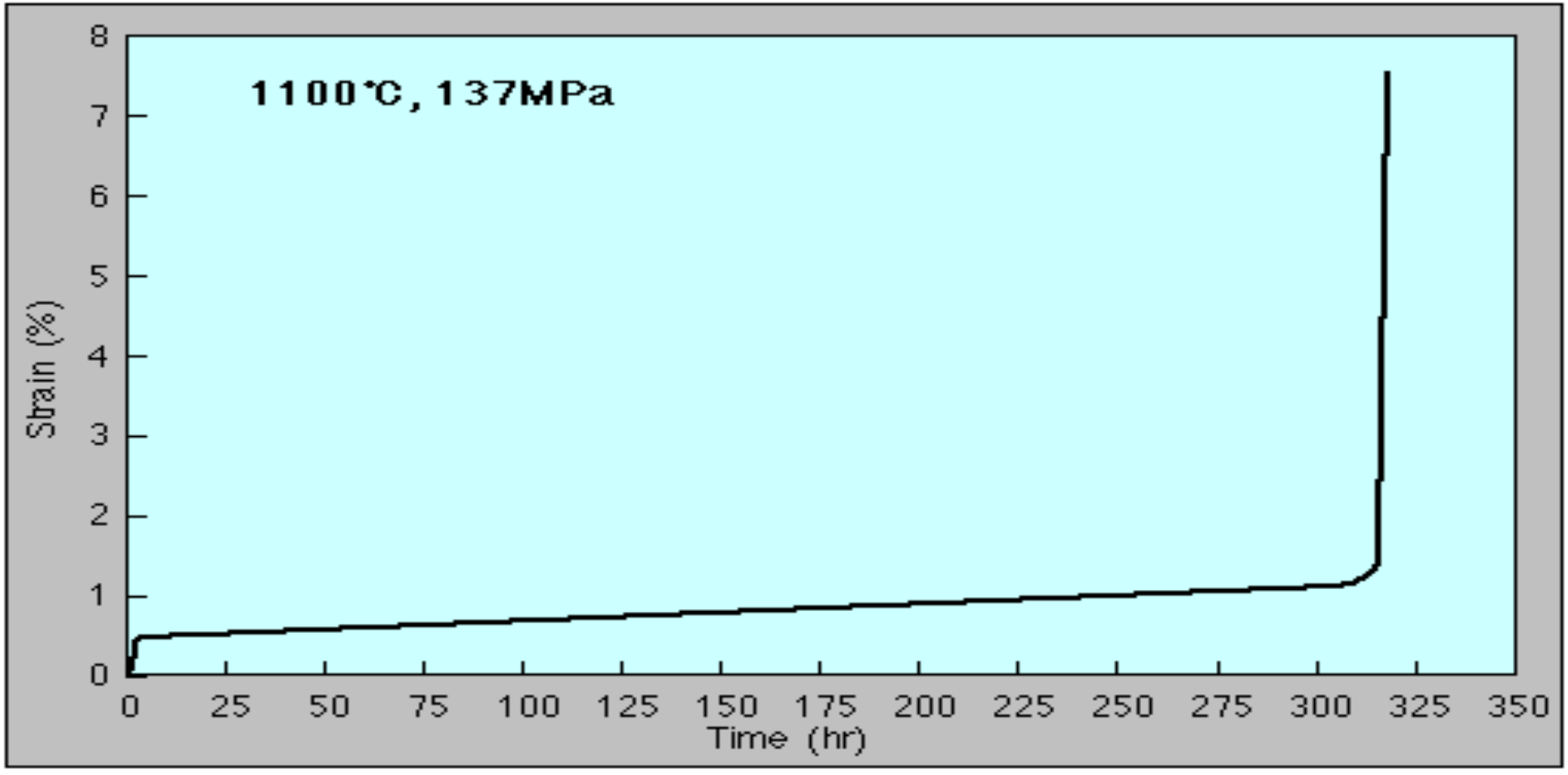


**C.F.C.**

(CUBICO A FACCE CENTRATE)

242.000 t nei Paesi ex sovietici, 193.000 t in Canada, 125.000 t nella Nuova Caledonia e 88.000 t in Indonesia; è stato scoperto nel Labrador nordorientale, a Voisey-Bay, il più esteso giacimento di nichel del mondo, entrato in attività nel 2006.

Acciaio Inossidabile (e altre leghe resistenti alla corrosione);
Acciaio al Nichel (impieghi a bassa temperatura);
Alnico (lega usata nei magneti);
Mumetal (schermatura campi magnetici);
Nitinol (e altre leghe a memoria di forma, usate nella robotica e nell'endodonzia);




*Tipica curva di creep per una superlega monocristallina base nichel*

# Forms of Attack

Hydrogen attack is omitted because nickel alloys are highly resistant.

**Oxidation**. Oxidation, the most common form of corrosion at elevated temperatures, is characterized by the formation of metal oxide corrosion products. So called scales are usually quite dense and tenacious and thus able to retard further attack. However. in severely hostile environments oxide scales can be penetrated or spall off.

**Chromium** is by far the most important element for conferring oxidation resistance. As with stainless steels small additions of **aluminum silicon and rare earth elements** further enhance oxide stability and tenacity especially under thermal cycling conditions. Stable oxide scales not only retard further oxidation but also act as an effective barrier against other forms of attack.

## Sulfidalion

Sulfidation produces scales rich in metal sulfides that offer little if any protection against further attack. ***Reducing-sulfidizing environments are usually more aggressive than oxidizing-sulfidizing atmospheres. Nickel alloys as a class are more susceptible to sulfidation than stainless steels largely because of the formation of low melting point nickel sulfide***. **As with oxidation alloying with chromium progressively improves resistance**

## Chloridation

High-temperature exposure to Cl and its compounds rapidly corrodes stainless steels. Because iron chlorides and oxychlorides are quite volatile, severe chloridation may proceed without appreciable scaling. ***Nickel-base alloys are far more resistant than iron-base alloys making them the materials-of-choice for environments containing chlorine or chlorides.***

## Carburization

In high carbon activity atmosphere, carbon tends to diffuse into the metal matrix and form metal carbides. This form of attack, called carburization can cause severe impainnent of mechanical properties notably duclility and impact strength. **Nickel alloys exhibit good carburization resistance because nickel unlike iron is not a strong carbide former.**

## Nitridation

Nitridation often called nitriding refers to nitrogen diffusion into the metal lattice to form metal nitrides. In the chemical industry it is encountered primarily in high-temperature ammonia rich atmospheres. As in carburization damage manifests not as metal loss but as embrittlement. ***Nickel does not form nitrides which accounts for the excellent nitridation resistance of nickel-rich alloys***

# Internal attack

**Carburizalion and nitridation are by no means the only high-temperature degradation modes characterized by intemal damage**. Virtually all high temperature corrosion is diffusion driven and characterized by substantial subsurface attack predominanlly along grain boundaries. That applies to oxidation, sulfidation and especially to halogenation.

In many instances. internal attack penetrales deeper into the metal than surface metal loss

Evaluation of high temperature corrosion should therefore be based not solely on thickness or weight loss but additionally on metallographic examination

## Pure nickel

Pure nickel (Alloy 200) has very good resistance to a wide range of reducing acids and salts **but is not a suitabte choice for strongly oxidizing environments such as nitric acid**. The most significant attribute of pure nickel is unexcelled resistance to caustic alkalis, even when molten. Though outstanding in its resistance to dry halogen environments, nickel is not adequately resistant below the water dewpoint. For applications than 600°F. a low·carbon variant, designated Nickel 201 (UNS N02201), is the preferred choice.

# NICHEL PURO O BASSO LEGATO

- ✓Nichel A → Placcature e manufatti chimici
- ✓Nichel D → Resistenza attacco solforati (fino a 540°C)
- ✓Nichel L → Consente grandi deformazioni
- ✓Nichel Z → Resistenza alla corrosione e proprietà meccaniche eccellenti (costruzione di aste ed alberi)
- ✓Permanickel → Conducibilità elettrica e proprietà magnetiche elevate

# LEGHE DI NICHEL

**Leghe nichel-rame**

*Impieghi*: ambienti acidi fortemente corrosivi

*Nomenclatura* : Monel K, Monel R, Costantana

Deaeratore impianto chimico

Monel 400

Leghe Cu-Ni, i Monel, possono essere indurite per aggiunta di Al e Ti; la precipitazione di fasi coerenti Ni3Al e Ni3Ti conferisce ulteriore aumento della resistenza a seguito di invecchiamento e resistono fino a 400 C

## Ni·Cu Alloy 400 (Ni=66.5%, Cu=31.5, C=0.15, Fe=1.25, Mn=1)

The corrosion behavior of nickel-copper Alloy 400 is like that of nickel. **It is best under reducing conditions** and can be compromised by aeration and oxidizing chemicals. Alloy 400 possesses very good resistance to halogen acids and compounds. Particularly hydrofluoric acid and hot gases rich in fluorine or hydrogen fluoride.

The alloy is used widely for handling sulfuric acid solutions, sea water and brines. For applications requiring higher strength such as that demanded for valve and pump components, use is made of Alloy K-500 (N05500), a precipitation-hardenable variant of Alloy 400

# LEGHE DI NICHEL

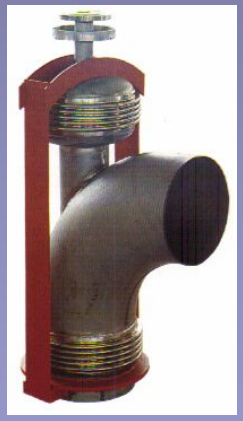
**Leghe nichel-molibdeno**

*Impieghi*: elementi soggetti a corrosione e a temperature di esercizio elevate

*Nomenclatura* : Hastelloy B, Hastelloy C, Hastelloy N

Valvola di sicurezza impianto chimico

Hastelloy C



molto versatile poiché abbina un ottima resistenza alla corrosione ad una buona stabilità termica conferita da una scarsa propensione alla precipitazione a bordo grano nella zona termicamente alterata.
Utilizzabile per una vasta gamma di applicazioni nel campo degli impianti chimici laddove vi sia necessità di costruzioni saldate.

## Ni-Mo "B" alloys.

Hastelloy B  Mo=28%, Cu=31.5, Co=2,5, Fe=5, Ni resto)

Alloy B-2 has exceptional resistance sulfuric, phosphoric and hydrochloric acids under reducing conditions. It is particularly suited for equipment handling hydrochloric acid at all concentrations and temperatures up to the boiling point.

Oxidizing chemicals adversely affect its corrosion resistance. notably such strong oxidizers as ferric and cupric salts that may be present as contaminants

# LEGHE DI NICHEL

**Leghe nichel-silicio**

*Impieghi*: elementi sottoposti ad acido solforico a tutte le concentrazioni fino alla temperatura di ebollizione

*Nomenclatura* : Hastelloy D

Reattore produzione acidi

Hastelloy D

Da usare in ambienti super ossidanti perche' il silicio forma ossidi molto protettivi

# LEGHE DI NICHEL

**Leghe nichel-cromo**

*Impieghi*: resistenza alle alte temperature e al ciclaggio termico (turbine,diffusori razzi, tubi di scappamento)

*Nomenclatura* : Inconel 600,Inconel X-750

Diffusori motore NASA

Scarichi motore Ferrari F1

Inconel X750


il loro utilizzo si è esteso ad impieghi che oscillano tra temperature criogeniche e temperature di 1100° C

## Ni-Cr Alloy 690

Alloy 690 has the highest chromium content among nickel alloys suitable for fabrication of pressure equipment which confers exceptional resistance to oxidizing media. It is effec tively used for **hot concentrated sulfuric acid, nitric acid and nitric/hydrofluoric acid mixtures**, as well as for oxidizing salts. The high chromium content also improves resistance in hot sulfidizing environments

# LEGHE DI NICHEL

**Leghe nichel-cromo-molibdeno**

*Impieghi*: dispositivi metallici a contatto con acido solforico e nitrico (pompe e valvole impianti)

*Nomenclatura* : Illium B,Illium 98, Illium G

Pompa impianto acido solforico

Illium 98

**Ni-Cr·Mo "C" alloys** C 276 (57%Ni - 16%Cr - 16%Mo - 4%W)

**Alloy C-276 is considered the preeminent alloy employed in the chemical industry for exceptionally corrosive environments that are beyond the capability of stainless steels.** It has outstanding resistance to acids acid salts and a wide spectrum of other aggressive substances encountered in chemical processing.

Alloy C·276 is particularly effective in such punishing environments as wet chlorine and hypochlorites. Owing to its molybdenum content, Alloy C-276 is highly resislant to chloride-induced pitting and crevice corrosion.

The quest for materials possessing better metallurgical propenies and corrosion resistance than Alloy C-276 has spurred the development and commercialization of several proprietary alloys.

All have roughly comparable molybdenum content but significantly higher chromium content than Alloy C-276. Some grades also contain tungsten and copper.

# LEGHE DI NICHEL

**Leghe nichel-cromo-ferro**

*Impieghi*: resistenza alla corrosione ad elevate temperature (forni e resistenze)

*Nomenclatura* : Incoloy 800, Incoloy 825,Incoloy T

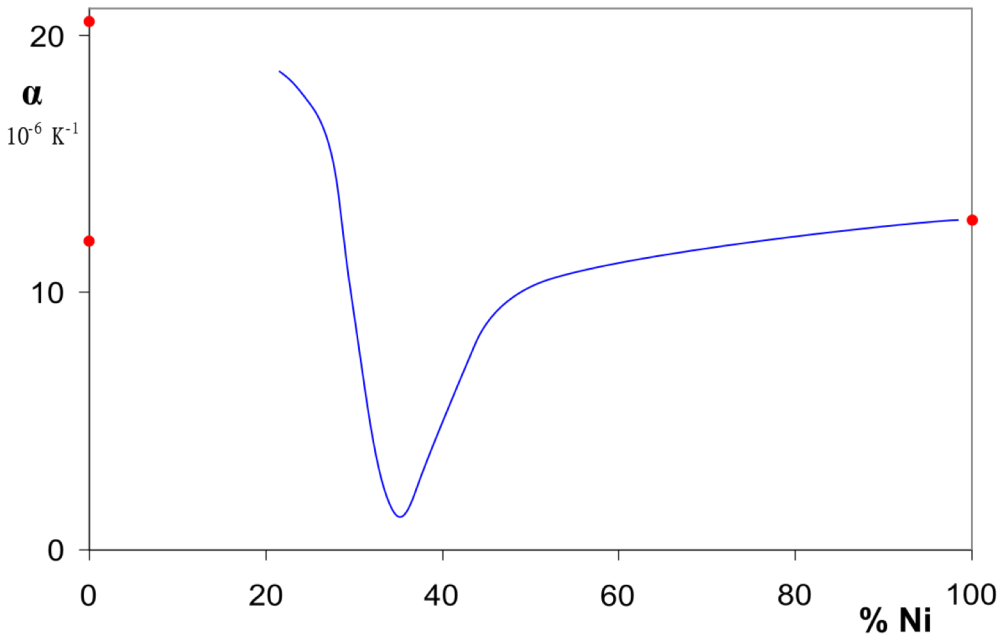
Resistenze piastra

Incoloy 800

## Ni·Cr·Fe Alloy 825

Because of its near 30% iron content Alloy 825 is sometimes included in the family of super-austenitic stainless steels. The alloy excels in sulfuric and phosphoric applicalions that as with Alloy 20, were major development targets. Though reasonably resistant to hydrochloric acid, Alloy 825 is subject to chloride pitting and crevice corrosion particularly in stagnant unaerated solutions. Its high iron content makes Alloy 825 less resistant than higher nickel containing alloys to alkalis and halogens.

Leghe Ni-Fe con il 36% di Ni (Invar) possiedono coefficiente di espansione termica quasi nullo ($10^{-6}$ /K, con conseguente ottima stabilità dimensionale.




Leghe Ni-Ti con circa 50 % di Ti (Nitinol) presentano effetto di memoria di forma sfruttato in diverse applicazioni in campo biomedico, meccanico, aerospaziale