

Materials**Nickel****Introduction**

Nickel is a silver-white metal that occurs in nature mainly in the form of sulphide, oxide and arsenic ores. It is extracted by roasting to NiO and then reducing using carbon. Pure nickel is manufactured by the Mond process whereby impure nickel is reacted with carbon monoxide (CO) to produce Ni(CO)₄, which is then decomposed at 200°C to yield 99.99% Ni. Nickel has an abundance of 80 ppm in the earth's crust. It is an extremely useful element that possesses many beneficial properties.

Properties of Nickel

Factors that make nickel and its alloys commercially valuable commodities include strength, corrosion resistance, high ductility, good thermal and electrical conductivity, magnetic characteristics (below 340°C) and catalytic properties. Stainless steels are particularly valued for their hygienic properties in hospitals and kitchens. Nickel is not tarnished by air and is resistant to fluorine (F₂) but is attacked by acids (except concentrated HNO₃). In some applications, such as jet engines, nickel alloys are essential and cannot be substituted by other materials.

Property	Value and Units
Atomic No	28
Atomic mass	58.6934 amu
Melting Point	1,455°C
Boiling Point	2,913°C
Density	8900 kg m ⁻³
Poisson's ratio	0.31
Electrical resistivity	6.84 x 10 ⁻⁸ Ω m
Linear coefficient of expansion	13.4 x10 ⁻⁶ K ⁻¹

Known annual world production capacity of primary nickel products in the early 1990s was approximately 1,240 kilotonnes, 485kt of which were in former Soviet and Eastern Bloc countries. In recent years, annual world production has averaged in excess of 900kt. Primary nickel products fall broadly into two categories – Class I and Class II. Class I products contain at least 99.8% nickel whilst all other primary nickel products are Class II. Unlike Class I products, Class II products range widely in nickel content.

Uses of Nickel

More than 80% of primary nickel is consumed in some 3,000 different alloys, grouped generally as stainless steels, alloy steels and non-ferrous alloys with approximately 60% of primary nickel used in stainless steels alone. Nickel-bearing, "austenitic" stainless steels contain between 5 and 25% nickel. Commercial uses include chemical and food processing equipment, transportation equipment, structural claddings and other architectural applications, durable consumer goods such as cookware, and hospital and medical applications.

Electroplating accounts for roughly 10% of primary nickel consumption, with the balance consumed by foundries and a host of other uses including chemicals, catalysts, batteries, welding rods, coinage, pigments for enamels/glasses/ceramics, electronics and printing inks.

Primary nickel metal powder is used in many applications including battery manufacture, coin production, welding products, fuel filters, brake linings, catalysts, cutting tools, paints, plastics, electronics, implants and surface treatments by plasma spraying.

Nickel Alloys

Nickel alloys can be hot or cold worked. Other processes include annealing, drawing, forging, spinning, and joining by soldering, brazing, gas welding, and resistance welding. Machining of most nickel alloys requires high-speed tools and flooding with cutting compounds. Some of the more common nickel alloys are listed below.

Alloy	Constituents
Monel metals	Combinations of nickel and copper
Inconel metals	Nickel alloys containing chromium and iron
Hastelloy metals	Combinations of chromium, molybdenum and iron
Illium nickels	Nickel alloys with chromium, molybdenum and copper

Nickel alloy steels are used in heavy machinery manufacturing, armoured plate, tools, and high-temperature equipment including gas turbines and environmental devices used to control emissions, such as scrubbers. Non-ferrous alloys include nickel-copper alloys, typically containing about 65% nickel, and copper-nickel alloys, typically containing about 10% nickel, used extensively in desalination plants for converting seawater into fresh water. Ni-Cu/Cu-Ni alloys are also employed in marine equipment and inorganic acid and alkali handling equipment. Nickel-chromium alloys, containing approximately 40-70% nickel, are used in corrosive chemical environments and high temperature applications such as heating elements and gas turbine aero-engine components. Nickel-copper-zinc alloys, including nickel silver with less than 18% nickel, are used for decorative purposes, including jewellery.

Alloy Type and Typical Applications

- Corrosion-resistant alloys: nickel, monel, hastelloy, illium, nirolium for use in chemical and process plant, plating coinage, food processing and water treatment.
- High temperature alloys: inconel, incoloy, nimonic, nimocast used for furnace components, boiler components, heat-treatment equipment, power generation, heat exchangers and gas turbines.
- Electrical Alloys: nickel, brightray, nichrome, constantan for use in ferry electronics, heating elements, industrial furnace elements, resistors, thermocouples and spark plugs.
- Magnetic Alloys: nickel, permalloy, mumetal used in magnetostrictive devices, magnetic shields, HF transformation, loading cells, transformer and rotor laminations, temperature compensators.
- Controlled-expansion and constant modulus alloys: invar, nile, ni-Span, elinvar, bimetals, thermostats, glass-sealing and weighing machines.
- Miscellaneous alloys: nitinol, hy-stor employed in shape-memory devices, hydrogen storage and brazing alloys.

Internet Resources

Goodfellow Cambridge Limited provide general information on nickel.

<http://www.goodfellow.com/static/A/NI00.HTML>

Electroplated nickel laboratory and medicinal equipment <http://www.nickel-electro.co.uk/>

British Electroless Nickel Society for surface plating. <http://www.sea.org.uk/BensIntro.htm>

The Health, Environment and Work website provides details upon the chemistry of nickel and its carcinogenic effects. <http://www.agius.com/hew/resource/nickel.htm>

NHS Scotland provides health and safety information concerning the use of nickel.

<http://www.trace-elements.org.uk/Nickel.htm>

The Copper Development Association presents the properties and applications of copper-nickel alloys. <http://www.cda.org.uk/megab2/corrs/tn30/default.htm>