A GLANCE AT MAIN FIRST-USE INDUSTRY FOR NICKEL IN STAINLESS STEEL

- by Vaishnavi Naik

Nickel (Ni) was first isolated as a distinct element discovered by AF Cronstedt in 1751, but at that time it had no apparent use. However, today it is much in demand. It is of a primary importance in the manufacture of steel alloys, and has had a major role in the development of the chemical and aerospace industries. It is a hard, malleable, ductile silver-white metal, somewhat ferromagnetic, and a fair conductor of heat and electricity. It has a melting point, of 1453oC, which is nearly as high as that for iron.

Properties of Commercially Pure Nickel

Compared to nickel alloys, commercially pure nickel has high electrical conductivity, a high Curie temperature and good magnetostrictive properties. Nickel is used for electronic lead wires, battery components, thyratrons and sparking electrodes. Nickel also has good thermal conductivity. This means it can be used for heat exchangers in corrosive environments.

Brief summary of the Isolation of Nickel.

It is not normally necessary to make nickel in the laboratory as it is available readily commercially. Small amounts of pure nickel can be isolated in the laboratory through the purification of crude nickel with carbon monoxide. The intermediate in this process is the highly toxic nickel tetra carbonyl, $Ni(CO)_4$. The carbonyl decomposes on heating to about 250°C to form pure nickel powder.

$Ni + 4CO\ (50°C) \rightarrow Ni(CO)_4\ (230°C) \rightarrow Ni + 4CO$

The $Ni(CO)_4$ is a volatile complex which is easily flushed from the reaction vessel as a gas leaving the impurities behind. Industrially, the Mond process uses the same chemistry. Nickel oxides are reacted with "water gas", a mixture of $CO + H_2$). Reduction of the oxide with the hydrogen results in impure nickel. This reacts with the CO component of the water gas to make $Ni(CO)_4$ as above. Thermal decomposition leaves pure nickel metal.

Recycling of Nickel Containing Products

Yes. Nickel is one of the most recycled materials in today's global economy. In the EU, almost all process scrap and over 80% of end of life nickel-containing products are collected and reused by the industry. It is collected and recycled, mostly in the form of alloys. For example, about half of the nickel content of a stainless steel cooking pan in the shop today will have come from recycled sources.

Industry experts estimate that nickel bearing scrap totaling 4.4-4.6 million tonnes per year is collected and recycled. This scrap is estimated to contain almost 350,000t of nickel (or one-quarter of the total demand) annually which is mainly used by the stainless steel industry. The nickel scrap processing industry consists of four or five major companies operating on an international level to ensure that nickel bearing scrap is collected from every corner of the globe. Most of the scrap is stainless steel scrap, resulting from the demolition of obsolete factories, machinery and equipment and consumer goods.

Applications

Commercially pure or low alloy nickel finds its main application in chemical processing and electronics. Because of its corrosion resistance, particularly to various reducing chemicals and especially to caustic alkalis, nickel is used to maintain product quality in many chemical reactions, particularly the processing of foods and synthetic fibre

Properties of Nickel 200		Unit
Annealed Tensile Strength at 20°C		450MPa
Annealed 0.2% Proof Stress at 20°C		150MPa
Elongation (%)		47
Density		8.89g/cm3
Melting Range		1435-1446°C
Specific Heat		456 J/kg. °C
Curie Temperature		360°C
Relative Permeability	Initial	110
	Maximum	600
Co-Efficient if Expansion (20-100°C)		13.3x10-6m/m.°C
Thermal Conductivity		70W/m.°C
Electrical Resistivity		0.096x10-6ohm.m

Table 1. Properties of Nickel 200, the commercially pure grade (99.6% Ni)

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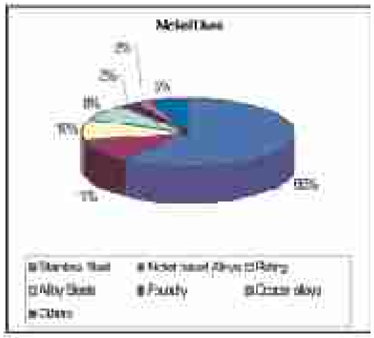

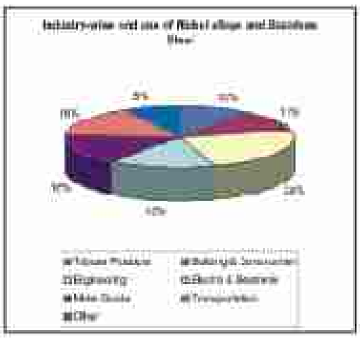

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Nickel is also frequently used as an undercoat in decorative chromium plating. The raw product, such as a brass or zinc casting or a sheet steel pressing is first plated with a layer of nickel approximately 20µm thick. This gives it its corrosion resistance. The final coat is a very thin 'flash' (1-2µm) of chromium to give it a colour and tarnish resistance that is generally regarded as more desirable in plated ware. Chromium alone would have unacceptable corrosion resistance because of the generally porous nature of chromium electroplate. Annealed nickel has a low hardness and good ductility. Nickel, like gold, silver and copper, has a relatively low work hardening rate, i.e. it does not tend to become as hard and brittle when it is bent or otherwise deformed as do most other metals. These attributes, combined with good weldability, make the metal easy to fabricate into finished items.

More than 80% of the world's nickel production is used in alloys. When alloyed with other elements nickel imparts toughness, strength, resistance to corrosion, and various other electrical, magnetic and heat resistant properties. At least 3000 nickel alloys have been identified. About 60% of world nickel output is used in the manufacture of stainless steel. When nickel is added to stainless steels (a group of iron-based alloys that contain chromium, carbon and other elements) their corrosion resistance and strength is considerably increased. Stainless steels containing nickel are therefore widely used in the chemical industry, consumer products (e.g. sinks, cooking utensils and cutlery), motor vehicles and construction.

A large number of other steels also contain nickel, particularly structural alloy steels used in pipelines, aircraft, vehicles and building. Many alloys, usually containing more than 50% nickel, have been developed for high temperature strength in aircraft gas turbines and jet engines. Nickel is also an important constituent of non-ferrous alloys used in corrosion-resistant fastenings, water pumps and shafts, and pipelines to carry seawater. Nickel has been widely used in coinage since 1860, when Belgium started minting coins comprising 75% copper and 25% nickel. Nickel is also used for electroplating, catalyzing the addition of hydrogen to natural oils, (converting the oils into solids that can be used in soap and margarine) and in nickel-cadmium and nickel-iron storage batteries.

Global Stainless Steel Scenario

The main first-use industry for nickel is stainless steel. Nickel-containing stainless steels (there are other kinds) commonly contain between 8 and 14% nickel, and account for approximately 60 percent of primary nickel use The modern refining processes used to produce stainless steel allow a wide range of raw materials to be used economically, of which scrap from stainless steel products is only one.

Sophisticated "blending" processes are used by specialist suppliers in order to provide quality-assured feed to stainless steel mills. These blending processes can utilise nickel-containing products from a very wide range of fabricating or end-of-life sources - including low-nickel steels; high nickel alloys; mixed turnings; end-of-life engineering assemblies; reject products from primary nickel producers; and re-melted ingot from processing nickel-containing slags, dusts, batteries, and spent plating fluids. This "omnivorous" character of the stainless steel industry means the stainless steel industry puts a higher value on many of these products than does the industry which originally generates the products. Hence, many products become feed for the "stainless steel loop" rather than feed for the industry sector that originally produced the products. Any attempt to model the recycling of nickel has to include all aspects of the stainless steel loop. The high price of nickel also encourages commercial users to use nickel very efficiently in the first use. This can result in the nickel content of a fabricated product being too small at end-of-life to commercially motivate the collection and sorting of the product primarily for its nickel content.

About 60% of nickel is used to manufacture stainless steel. Around 20% is used in other steel and non-ferrous alloys, often for specialized industrial, aerospace and military applications. About 10% is used in plating, while 6% in used in other applications, including coins and a variety of nickel chemicals. Stainless steel has been witnessing an average growth rate exceeding 5% per year worldwide during the last three decades. Production of stainless steel in different regions, especially in Asia is showing impressive growth in recent years.

As the emerging middle class in countries such as China and other Asian nations demand more stainless steel products from sinks to door handles, nickel consumption is on the rise. Stainless steel currently accounts for about two-thirds of nickel consumption up from one-third in the past three decades. While nickel demand in Europe and the Americas decreased in the period from 1997-2002, this demand increased in Asia and the former East Bloc countries. During the past decade, consumption of stainless steel in China and India has grown at an average rate exceeding 20% and 10% respectively. However per capita consumption in these countries is 4.1Kg and 1.1 Kg which is relatively very low indicating huge scope for growth. Chinese nickel consumption increased by 15.4% in 2005, slightly less than the 19.1% growth reported in 2004.

Chinese consumption during this decade has actually been the single largest factor impacting the nickel market, with supply struggling to keep pace with this rising demand due to a physical shortage of the metal. In fact, China recently announced a cut-back in stainless steel production because they are unable to source enough nickel. This rising demand and limited supply is pushing up prices. As of July 2006, nickel was trading at over $12.00US per pound in contrast to historical prices of less than $5.00US over the previous 15 years. Experts predict that this continued high demand – based not only on China's continuing economic boom but also on the West\'s demand for hygiene, will continue for the foreseeable future.

Only about 1.3 million tons of new or primary nickel is produced and consumed annually, compared with over 15 million tons of copper and nearly 800 million tons of steel. The growing world economy through the mid-nineties triggered an expansionary drive in nickel capacity by existing manufacturers resulting in a production increase of 30%, in the five year period from 1993-1998. European expansion in both Finland and the United Kingdom accounted for most of the 48% (60,000 ton) increase in production, while expanded production in Australia and New Caledonia accounted for all of the 39% (35,000 ton) increase in Oceania. Japan accounted for most of the 22% increase in production in Asia during that same period. The rising demand for nickel production, with its associated

Global Stainless Steel Production

Region	2005	2006	2007
Asia	12,498	15,074	16,850
America	2,688	2,951	2,850
W.Europe & Africa	8,795	9,971	9,700
Central & Eastern Europe	310	363	400
World Total	24,292	28,358	29,800

Source: ISSF

Annual Increment %

Period	1980-1995	1995-2000	2000-2006
Stainless Steel Production	4.1	5.5	6.2
Nickel use in Stainless Steel (Primary+ Scrap)	3.9	4.8	5.2

Source:INSG

Primary Nickel Usage ('000 tonnes)	1998	1999	2000	2001	2002	2003	2004	2005(r)	2006(p)
Africa	31,2	33,2	32,2	31,2	35,9	45,5	45,5	32,0	42,0
America	183,2	193,4	193,3	170,7	159,7	159,0	164,6	174,1	180,4
Asia	377,0	430,4	465,0	441,5	501,2	550,4	579,6	590,8	681,8
Europe	415,7	422,5	430,1	458,4	476,0	461,0	454,3	447,2	489,0
Oceania	2,1	2,1	2,0	2,0	2,0	2,7	2,0	2,8	2,9
World Total	1009,2	1081,6	1122,6	1103,8	1174,8	1218,6	1245,9	1246,9	1399,1

(r) - revised; (p) - preliminary, Tables' revision date: 10/OCT/2007
Source:INSG

high commodity prices, has spawned new approaches to nickel production.

Historically, most sulfide nickel ore bodies are mined underground at relatively low production rates and with mining costs that can approach $20 per ton, or even more. The current lack of high grade nickel sulfide exploration targets has more recently shifted attention to laterite nickel deposits, which can be mined at low cost using modern mining and process methods that recover ore at grades well below those that had traditionally been exploited. These new methods are changing the way large mining companies and knowledgeable investors are looking at mineral properties.

Nickel Production

Strong world economic growth through the last five years has continued to support rising nickel production. In 2006 world primary production stood 14% higher than in 2002. In Europe, expansion in production was registered in Russia and Norway. In Oceania, Australia and New Caledonia experienced a decline in primary nickel production while Japanese primary nickel production also declined in both 2005 and 2006. Although world nickel production looks likely to recede in 2007 compared with 2006, further expansions by existing producers mainly in China, Canada and Russia indicate that a nickel production increase looks likely for 2008.

Acquisitions and mergers have completely changed the structure of the global nickel industry since 2004. The two largest nickel producers in Canada were taken over by even larger foreign mining companies' intent on diversification. Regulatory authorities in Canada, the European Union, and the United States approved both takeovers after extensive antitrust investigations. Shortly afterwards, the largest nickel producer in the world—a Russian company—moved to acquire an Ohio-based company with important downstream nickel processing facilities. Some nickel consumers were concerned that global demand for the metal would outstrip supply before key, new mining projects could be completed. The larger of the two Canadian takeover targets has been constructing a laterite mining complex at Goro near the southeastern tip of New Caledonia. The New Caledonian nickel was to be recovered onsite using advanced pressure acid leach (PAL) technology.

Australia's leading nickel producer was also developing a large laterite deposit near Ravensthorpe, Western Australia. Nickel and cobalt were to be leached from the ore and converted onsite to an intermediate hydroxide, which was to be shipped to Yabulu in Queensland for refining. Several other companies were considering employing some form of acid leach technology to recover nickel at greenfield sites in Cuba, Guatemala, Indonesia, Kazakhstan, and the Philippines. A new type of heap-leaching process was being used to recover nickel in Turkey. At least five automobile manufacturers planned to use nickel-metal hydride (NiMH) batteries to power their gasoline-electric hybrid vehicles for the 2008 and 2009 model years. Demand for gasoline electric hybrid vehicles has been gradually building in the United States since their introduction in late 1999, and has accelerated dramatically with the sharp increases in gasoline prices in 2005-06. One leading manufacturer was expanding operations so that it could produce more than 1 million hybrid vehicles annually by 2010.

Substitutes

With few exceptions, substitutes for nickel would result in increased cost or a tradeoff in performance of the product. Aluminum, coated steels, plain chromium steels, and plastics can replace stainless steel to a limited extent in many construction and transportation applications. Nickel-free specialty steels are sometimes used in place of stainless steel within the power generating, petrochemical, and petroleum industries. Titanium alloys or specialty plastics can substitute for nickel metal or nickel-base alloys in highly corrosive chemical environments. Recent cost savings in manufacturing lithium ion batteries allow them to compete against NiMH in certain applications