NICKEL MAGAZINE

THE MAGAZINE DEVOTED TO NICKEL AND ITS APPLICATIONS

NICKEL, VOL. 39, Nº 2, 2024

The right amount of nickel

Nickel in low-alloy steels

Nickel on Mars SpaceX launches mega rocket

Q & A with Topsoe's Maria Jose Landeira Oestergaard

Stalatube's products used for this project include:

Type 316L (UNS S31603) (EN 1.4404) hollow sections 100 x 60 x 5.0 mm and 100 x 100 x 5.0 mm in size

Type 316Ti (UNS S31635) (EN 1.4571) hollow section 80 x 60 x 5.0 mm

Type 316 (UNS S31600) (EN 1.4401) 120 x 80 x 5 x 6000 mm welded hollow sections with two longitudinal welds

CASE STUDY 31
ROYAL CARIBBEAN ICON OF THE SEAS

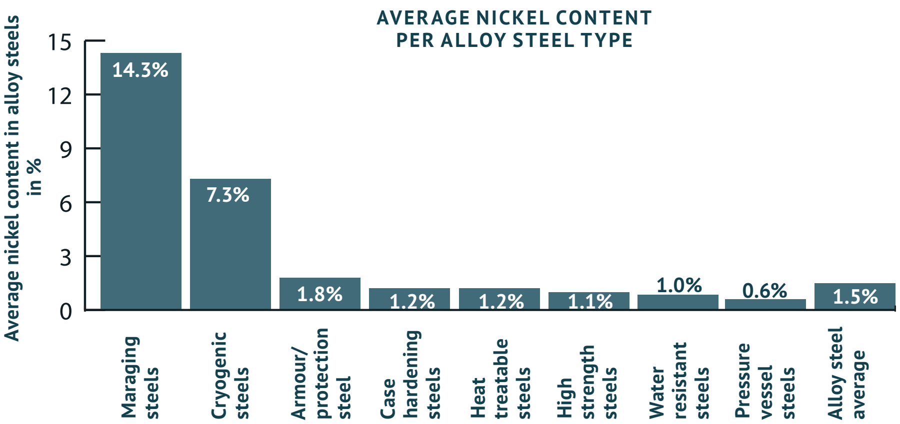
Icon of the Seas is a cruise ship built for Royal Caribbean International. It entered service on 27 January 2024 from the port of Miami and at 365 metres in length, 50 metres wide and 248,663 gross tonnage, is the largest cruise ship in the world. The ship has a crew of 2,350, and a capacity of 5,610 passengers at double occupancy, or 7,600 passengers at maximum capacity.

Nickel-containing stainless steel was chosen for specific items to withstand the most severe weather conditions.

Stalatube, a manufacturer of stainless steel products collaborated with its long-term partner, Tuteka, a supplier to the maritime industry. Stalatube provided stainless steel beams and profiles for Tuteka, which were used to build railings for staircase runs and glass-walled windbreaks for the ship's upper deck water park areas. The windbreaks are designed to withstand extreme weather conditions, such as 270 kph (170 mph) winds. Additionally, the windbreaks' glass panels are heavy, requiring the columns to be not only rigid but also corrosion resistant to the marine environment. Stainless steel structural products were also used to build the ship's cone-shaped ventilation pipes that are integrated into the ship's visual design. The partners are preparing for two new state-of-the-art cruise ships to be built at the Turku shipyard in Finland in the coming years.

EDITORIAL:
JUST THE RIGHT AMOUNT

Developing new alloys is a complicated business. Determining the combination of alloying elements to produce the best alloy steel for a given application is an art as well as a science. Finding that 'just right' amount of nickel for a given application, is the challenge for metallurgists and engineers. The goal is to arrive at the optimum nickel content which will provide the properties required, at the best value for money. And as the table below shows, often it's just a small amount of nickel that makes the difference – adding the right amount of toughness, strength, temperature resistance and weldability to an alloy. In this edition of Nickel *we feature the search for the best alloys to withstand the demands of ever higher offshore wind turbines.*

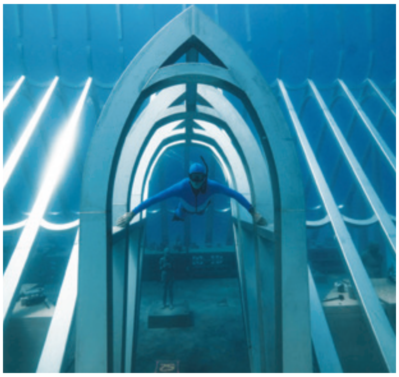


Arguably, the brutal conditions of space travel are even more demanding than the corrosive offshore environment. Turn to the article on page 8 to find out how Elon Musk is relying on nickel-containing stainless steel to take his Starship further – to Mars and back.

Contrast this with another brilliant use of nickel in stainless steel in challenging conditions. British sculptor Jason deCaires Taylor's underwater art structure in Australia, featured on the back cover, is providing sanctuary for vulnerable species. Take a look at his ocean greenhouse for 'coral gardening', 12 metres deep.

Just some examples of how just the right amount of nickel can assist in going higher, further and deeper.

Clare Richardson
Editor, *Nickel*



Coral Greenhouse
Nickel-containing stainless steel provides a stable framework for the underwater greenhouse, supporting the growth of coral and marine life on John Brewer Reef, Great Barrier Reef, Australia.

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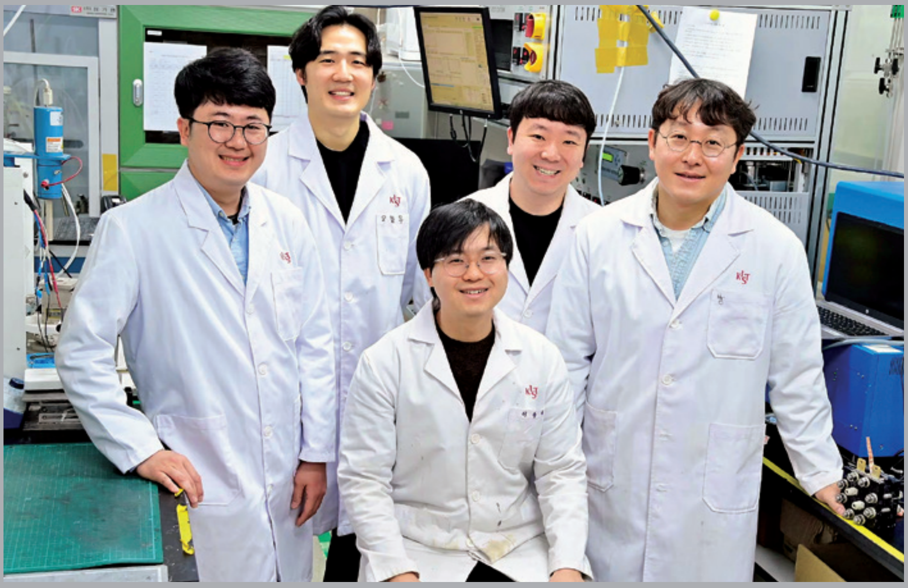


KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY (KIST)

Bettering bifunctional catalysts

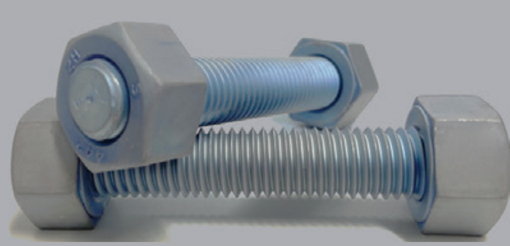
A group of Korean researchers have devised an innovative methodology using bifunctional platinum-nickel alloy catalysts to improve the reversibility and durability of electrodes. The team from POSTECH and Yonsei University together with the Clean Energy Research Center at the Korea Institute of Science and Technology (KIST,) substituted separate catalysts with the bifunctional platinum-nickel catalysts. These newly created alloy catalysts possess an octahedral structure that exhibits both oxygen reduction and generation reactions. This work provides a new direction for the development of bifunctional catalysts, an important technology for electrochemical energy conversion. It will also contribute to the commercialisation and carbon neutrality of electrochemical systems such as Unitized Renewable Fuel Cells (URFC) in the future.

Sustainability guiding principles

Awareness of the strategic importance of nickel as a critical material in the energy transition and sustainable mobility is increasing. Nickel production is on the up globally, including in regions where there is less knowledge of nickel and its responsible use. The Nickel Institute has accumulated knowledge and expertise over more than 40 years which has informed the development of the *Sustainability Guiding Principles*. The principles aim to provide nickel-specific guidance to companies on their journey to achieve high Environment, Social & Governance (ESG) standards and inspire action throughout the nickel sector and the value chain. The new publication is available at www.nickelinstitute.org and contains useful resources and references.

A sea-worthy new coat

Working together, US companies Sigma Fasteners, Dipsol, and Integran have developed a Nanostructured Zinc Nickel coating system for the offshore oil and gas industries, where challenging conditions require innovative solutions. Trademarked as ZNnGard™, this engineered coating is designed to replace conventional cadmium, thus eliminating environmental and worker safety issues while significantly improving performance and reducing life-cycle costs. Using proprietary technology, the coating is produced via pulse electrodeposition using an alkaline Zn-Ni bath chemistry. Benefits include improved hardness, corrosion resistance, excellent coating adhesion, high dimensional consistency, no hydrogen embrittlement, and superior surface finish. Steve Cabral, Sigma Fasteners, says "We are excited to bring this technology to market, solving long-standing issues and meeting demands."



SIGMA FASTENERS, INTEGRAN TECHNOLOGIES © 2023

A first for India

Standing at 62 metres tall, India's first stainless steel diagrid frame building is a testament to innovation, as well as being earthquake-resistant and energy-efficient. Located in Chennai, United India Insurance Company's new HQ has a distinctive curvature profile made with approximately 1000 tonnes of 316L (S31603) grade high-quality stainless steel. Redefining conventional construction, there are no columns in this structure. The stainless steel frames serve as the main load-bearing structure in the building. Jindal Stainless' Mr. Abhyuday Jindal, said, "It's an architectural marvel in glass and stainless steel, and most certainly a feast for the eyes."

CONSTRUCTION CATALYSERS PVT. LTD.

NICKEL INDUSTRY PART 2
PROCESSING NICKEL LATERITES SMELTING

In Part 2 of this series we dig deeper into the specifics of laterites, one of the two main nickel ore types and look at smelting, the most common processing technique.

Laterites make up over 70 % of both nickel production and known terrestrial resources today and have been the fastest growing source of nickel for some time.

Laterite orebodies

Laterite orebodies are formed from weathering of bedrock by the passage of water, creating layers over the original rock. Other variations of these orebodies can contain aluminium (bauxite) or gold, with their composition determined by the parent bedrock and degree of weathering. Nickel laterites come from high-magnesium bedrocks with low nickel content in silicate rocks. During weathering, elements are dissolved and mobilised, then re-crystallised. These processes can create laterite deposits in under a million years, though some exposed deposits in temperate and boreal zones are not fully altered after over a billion years.

The two main processing methods for laterite ores are smelting and High-Pressure Acid Leaching (HPAL). Smelting is used primarily on saprolite ores to obtain an iron-nickel alloy (ferronickel – FeNi, Nickel Pig Iron – NPI) while HPAL is used primarily to process limonite or for higher-purity end products.

Laterite smelting

The industry is now dominated by the Rotary Kiln Electric Furnace approach (RKEF). Blast furnaces are now used less frequently. The RKEF route consists of three main steps: dry, reduce, and smelt. Saprolite ore is the normal feed, but limonite ores can also be smelted. Most facilities follow the process outlined below, but there are exceptions.

RKEF route

The prepared ore (crushed and blended as necessary) is dried in a rotary dryer, which is generally run with coal or gas firing to provide the necessary heat to remove some of the free moisture in the ore by heating it over 100 °C. The goal is to produce a material that is neither sticky nor dusty for the next processing steps.

After drying, the ore is passed to a rotary kiln for further drying and the start of the chemical processing. In the rotary kiln, more heat is added through combustion of fossil fuels to raise the temperature to around 900 °C. A high-carbon product like anthracite coal is also added as a chemical reductant – to remove the oxygen from the iron oxide and nickel oxide minerals so they can be produced as metals.

Limestone may also be added to adjust the chemistry for smelting. Both sets of hot tumbling equipment generate dust, which must be captured from the vent gases and the solids recycled, which adds complexity in both dust capture and blending dust with fresh feed.

The hot, partially-reduced ore is then passed to the electric furnace, where the chemical reduction is completed. The ore is melted at a temperature of around 1500 °C by the addition of electricity and the continued reaction of the carbon added in the kiln, as well as reaction of the carbon electrodes which are slowly consumed. The end result is a liquid 'metallised' iron-nickel product that sinks to the bottom of the furnace, from where it is removed, while the lighter slag materials float on top. The molten iron-nickel alloy is refined to remove materials detrimental to the later steel-making processes, and then either converted to solid forms for transport or, in some recent integrated operations, transported hot into the steel-making.

The large rotary equipment has to run continuously, at high temperature, on well-maintained roller systems. Electric furnaces require a very large continuous power supply, with some facilities requiring up to 40 MWh/t Ni produced. Most furnaces require sophisticated cooling systems to ensure long life of the furnace lining.

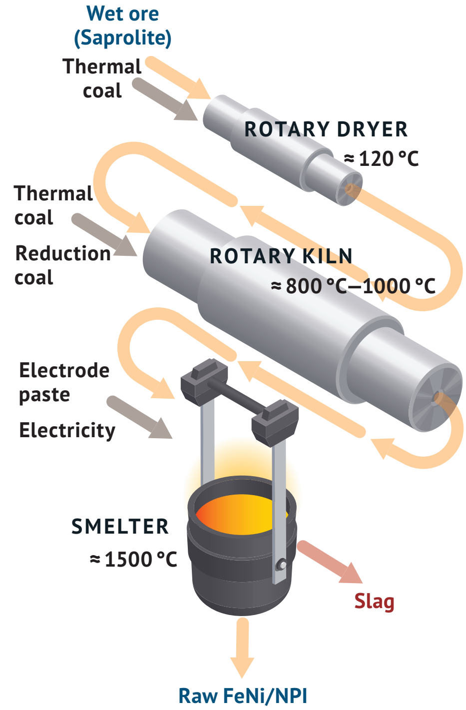
Smelting is very energy-intensive, using fossil fuels for thermal energy and chemical reduction, as well as electrical power generation. Air pollution from coal combustion is similar to power plants, as long as metal-bearing dusts are well-controlled. The slag produced is reasonably stable and often usable as a construction material.

Full life-cycle approach

For highly-recycled metals such as nickel, the environmental impact associated with initial production can be amortised over time, depending on how often the nickel is recovered at the end of one product cycle (e.g. nickel batteries or nickel-containing stainless steel) and re-used in another. The full 'life-cycle' of nickel is usually much longer than that of the products in which it has been incorporated.

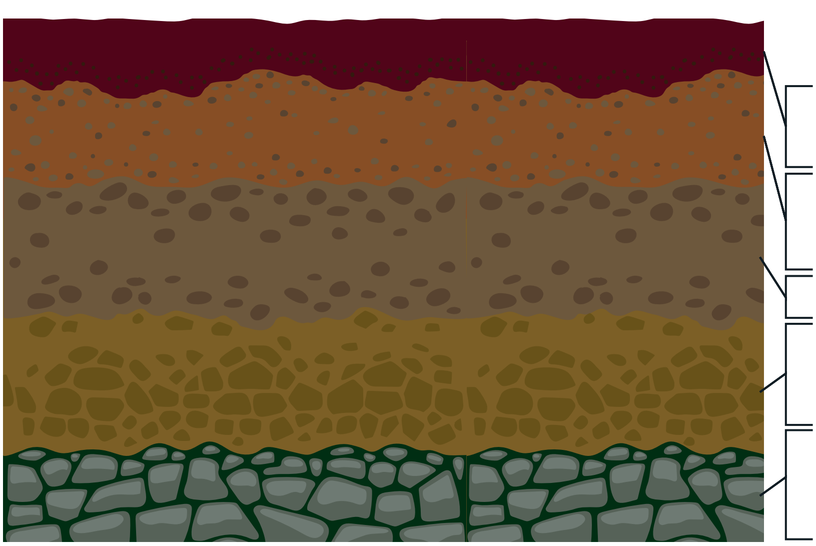
In the next edition of *Nickel* we will take a look at HPAL, which is ramping up in capacity to supply battery markets with intermediate nickel products. Ni

Simplified RKEF process



Rotary dryers are typically 3–5 m in diameter by 30–50 m long, while rotary kilns can be well over 100 m long.

Typical composition of nickel laterite deposit



Mineral type	Typical grades		
	Fe	MgO	Ni
Ferricrete (overburden)	>50%	<0.5%	<0.5%
Limonite (HPAL feed)	40–50%	0.5–5%	0.8–1.5%
Transition	25–40%	5–15%	1–2%
Saprolite (smelter feed)	10–25%	15–35%	1.5–3%
Bedrock	5%	35–45%	0.30%

LIFT-OFF WITH NICKEL
SPACEX LAUNCHES MEGA ROCKET

NASA is counting on Starship's success to return humans to the moon. The most recent crewed lunar mission was Apollo 17 in 1972. SpaceX's objective is not only to return humans to the moon but also to go beyond and reach Mars.

As SpaceX continues to fine-tune its Starship, the fourth test flight of its two-stage mega-rocket took place in June 2024, and nickel was onboard. Nickel was pivotal in providing optimal strength and resilience while offering economies of scale.

The test flights serve as a platform for learning and advancing the successful elements of the program. The fourth launch marks a significant milestone as it is the largest and most powerful rocket ever flown.

The Starship has two stages: the Super Heavy booster and the Starship spacecraft. Their main structure is made from 300 series nickel-containing stainless steel. Earlier prototypes were constructed of 304L (UNS S30403), which still may be the case, though SpaceX has hinted that a 300 series variant with optimised properties may be the final material.

Both stages are equipped with Raptor engines, which utilise nickel-base alloy 718 (N07718) in the combustion chamber due to its exceptional strength and heat resistance.

Originally, the plan was to construct the rocket using carbon fibre, chosen for its high-tensile strength and low density. However,

Could this be what life on Mars will look like?

SPACEX

SPACEX

in December 2018, the structural material was switched to 300 series stainless steel. Elon Musk cited several reasons for this change, including lower cost, ease of manufacture, increased strength of stainless steel at cryogenic temperatures, and its ability to withstand high heat.

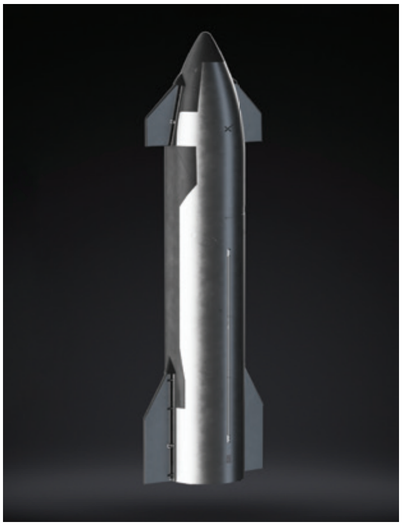
According to Musk, carbon fibre is incredibly pricey, costing some $135/kg (or 2.2 lbs), with as much as 35% of the material wasted just through the cutting and shaping process. Stainless steel costs less than $3/kg with very little waste.

Stainless steel also benefits from a high melting point, enabling it to resist the high temperatures encountered during re-entry and reducing the need for heat protection insulation.

In addition, the fabrication is much easier and faster. It is manufactured by stacking and welding stainless steel cylinders, which is no more difficult than the welding used to construct stainless steel tanks, which is routinely done. Since the rocket is intended to be reusable, repairs are possible and easy to perform.

Overall, nickel-containing stainless steel is helping Starship achieve its primary objectives: controlling launch costs, enabling the reuse of both rocket stages, increasing payload mass to orbit, facilitating launch frequency, and creating a mass-manufacturing pipeline, all of which can be adapted to a wide range of space missions.

Considered a success, the latest launch advances SpaceX's lofty mission to establish human settlements on the moon and Mars. Ni



SPACEX

Starship spacecraft
Super Heavy booster
Raptor engine

INTERVIEW WITH **DR. MARIA JOSE LANDEIRA OESTERGAARD** SENIOR MANAGER OPERATIONS EXCELLENCE, TOPSOE

COLLIN RICHIE PHOTOGRAPHY

Maria Jose Landeira Oestergaard Senior Manager Operations Excellence, Topsoe

Danish technology company Topsoe is renowned for its expertise in catalysis and advanced technologies for the chemical and refining industries. We spoke to materials specialist Dr. Maria Jose Landeira Oestergard, Senior Manager, Operational Excellence about nickel's role in Topsoe's processes and her curiosity about materials.

Q: Tell us about yourself and how you got interested in materials.

The decision to follow the science and technology path was calculated; chemistry seemed to open the most job opportunities. At university, I specialised in electrochemistry. I was fascinated by the fact that such small particles as electrons ruled all reactions. Electrochemistry brought me to corrosion after reading *8 forms of corrosion* by Fontana & Greene. My PhD in corrosion in desulphurisation plants led to my first job with cement producer FLSmidth.

Q: When did you start at Topsoe?

In 2001, I was the first Materials and Corrosion engineer to see if it was beneficial for the company to have such knowledge in-house. I quickly realised there was a huge need for training non-materials engineers so we could understand each other. So, I built the internal Materials and Corrosion training which is conducted in Denmark, India and other Topsoe locations as needed, on average every 1.5 years.

Q: Tell us more about the company and the role of nickel in the technologies Topsoe is pioneering.

Topsoe's commitment to sustainability is evident in its R&D focus on creating technologies that lower greenhouse gas emissions and promote the use of renewable resources. Our innovative solutions address climate change and resource scarcity. Topsoe plays a crucial role in supporting the transition to a more sustainable and environmentally friendly industrial landscape by improving energy efficiency and developing clean energy alternatives.

An early company success came in 1948 with the development of the first nickel catalyst.

Today, Topsoe delivers a wide range of nickel-based catalysts and process technology essential for producing clean fuels from crude oil and waste, removing harmful emissions from power plants, and raising the efficiency of industrial processes.

Q: For example?

Based on decades of scientific research and innovation, some of the key areas we are working on include: green hydrogen; processes to convert renewable electricity into green fuels and chemicals; carbon capture and utilisation: electrochemical processes to produce chemicals and fuels more sustainably; and biomass conversion.

Q: What nickel-containing materials are used extensively in Topsoe processes and why?

Nickel-containing materials are integral to many of Topsoe's processes, primarily due to their catalytic properties and durability under extreme conditions.
For instance:

Hydroprocessing Catalysts: Nickel is a crucial component in most hydroprocessing catalysts in the refining industry. It promotes the removal of sulphur, nitrogen, and other impurities from crude oil, and its excellent catalytic properties enhance the hydrogenation reactions essential for producing cleaner fuels like low-sulphur diesel, gasoline, and jet fuel.

Reforming Catalysts: Nickel-based catalysts are widely used in Steam Methane Reforming (SMR) for hydrogen production. Nickel effectively facilitates the conversion of methane and steam into hydrogen and carbon monoxide, a process fundamental to producing hydrogen for various industrial applications.

Q: What are the other uses of stainless steel and nickel alloys by Topsoe?

We select the alloys for all equipment and piping based on the potential degradation mechanisms in the given environment and the mechanical properties needed at room and high temperatures. The alloys must also withstand start-ups, shutdowns, as well as temperature and pressure spikes.

Nickel alloys are especially important for wet environments with high chloride concentrations in hydroprocessing environments or for dry environments at very high temperatures, such as some burner components in syngas technologies.

Q: What is the most interesting part of your work? What excites you for the future?

In my previous roles as a materials specialist and manager, the most exciting part was selecting the most appropriate alloys for aggressive environments, conducting failure analyses, and building knowledge about materials and their degradation mechanisms in Topsoe technologies. My goal was to make myself redundant by creating a team of experts in materials and corrosion in existing and new Topsoe technologies.

Building a department of experts with metallurgists, welding engineers, and Finite Element specialists has been really rewarding, especially the team spirit despite the team being in three different locations.

In my current role on the Operations Excellence team, I enjoy planning and facilitating projects within Value Engineering and FMECA (Failure Mode, Effects, and Criticality Analyses) for Topsoe's proprietary equipment. Motivating the team to contribute positively to design improvements without jeopardising quality and reliability, creating valuable results, and presenting them to the relevant stakeholders is hugely exciting.

In the future my wish is that the teams of Facilitators for Root Cause Analyses, Value Engineering, and FMECA grow. Ni

Maria's advice for young people looking for a career involving materials

1. *Never stop being curious. Be open to new ideas and challenge the status quo.*
2. *Think before you act. When we face a challenge, we often feel better by doing something about it, but there is a risk of not selecting the smartest way to solve the issue to accomplish the task.*
3. *To females in this field, it's important to not be afraid of expressing your thoughts and opinions and demonstrating your value. The 'science is only for males' stereotypes still exist. Female scientists are not accepted in several countries and, in others, are only taken seriously once we have demonstrated our knowledge and capabilities.*
4. *Choose an activity/hobby/passion. Often learnings outside the workplace are directly applicable to work situations and contribute to making the material specialist a whole person.*

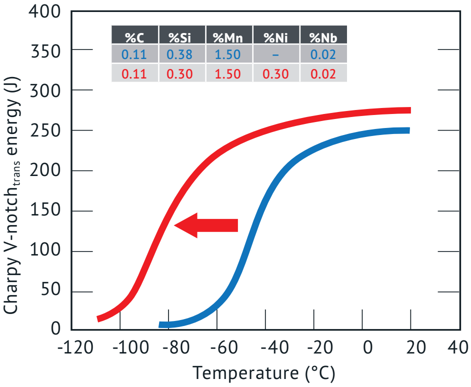
I believe we should follow Dr. Topsoe's own vision of leaving the world in better shape than when we got it, and I do my best every day—both at work and outside work—to contribute to achieving that vision.

JUST THE RIGHT AMOUNT
NICKEL IN LOW-ALLOY STEELS

Many are surprised to hear that alloy development work is actively occurring on low-alloy steels. But haven't we figured out all there is to know about steels, which have been produced and used for thousands of years? While we certainly know an incredible amount, there are always new applications where steels with properties pushing the existing limits are needed.

Take offshore wind turbine towers for example, which have to cope with extreme conditions. They must withstand a great amount of cyclical stress from wind and wave action and tolerate frigid temperatures as well as hot. They need some corrosion resistance, and most importantly, must maintain these properties after welding. Supporting larger and larger nacelles, the wall thickness of the towers can be as much as 150 mm with heights up to 140 m or more.

It is well known that nickel provides exceptional properties to steel, one of the most important being improved toughness (lack of brittleness) especially at lower temperatures. Nickel also increases the strength of an alloy. And nickel is the only alloying element that improves these two properties simultaneously without having a significantly negative effect on weldability. Nickel improves the fatigue properties in both the base metal and Heat Affected Zone (HAZ) of a weld.



The graph at right shows that only a very small amount of nickel (0.30%) dramatically improves the low temperature toughness of plain carbon steels.

The role of nickel in low-alloy steels is complex however, especially when combined with other alloying elements. Determining the sweet spot with the optimum nickel content, that maximises the cost benefit, is the challenge. And the Nickel Institute and two major steel plate producers are rising to it.

They are partnering on a major three-year research project to study the effect of nickel on the HAZ and fatigue properties of thick steel plate including weldments, based on the alloy currently being used in wind turbine towers. Salzgitter Mannsmann Forschung is performing the research, with useful results after the first year. Additional partners are being sought. The goal is to develop an alloy that falls within the existing specification with enhanced properties resulting in a lower as fabricated cost with 'just the right amount' of nickel. Ni

NITINOL
THE METAL THAT REMEMBERS

Nitinol (UNS N01555) is a metal alloy of nickel and titanium, where the two elements are present in roughly equal atomic percentages (55 to 56% weight percent nickel). Nitinol exhibits the unique properties of Shape Memory (SM) and Super-Elasticity (SE). Its shape memory property allows it to be bent out of shape but revert to its original structure upon heating above its 'transformation temperature.'

These properties are due to a phase transformation (a change in crystal structure). Below the transformation temperature the microstructure is known as martensite, while above this temperature it is known as austenite.

Nitinol displays SE above its transformation temperature, due to martensite forming in areas that are stressed. When the stress is removed, this martensite returns to the undeformed austenite state. While most metals can tolerate only a small fraction of a percent of strain without permanent deformation, nitinol can take up to an eight percent strain and return to its original shape.

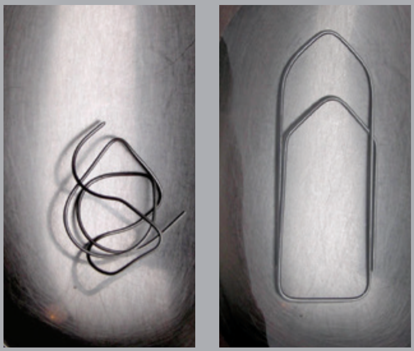
Similarly, SM enables nitinol to revert to its original structure after deformation. To fix the original 'parent shape,' the alloy must be held in position and heated to about 500 °C (930 °F). This process is called shape setting. Nitinol will revert to its original shape when deformed below its transformation temperature. Simply heating the nitinol causes the martensite to transform back to the undeformed austenite.

Making small changes in the composition can change the transition temperature of the alloy significantly. Transformation temperatures in nitinol can be controlled within a range from about −20 to +110 °C (−4 to 230 °F).

Healthcare and medical device applications are increasingly making use of nitinol's properties including ear implants, eyeglass frames and stents. A medical stent needs to be severely compressed so that it can be inserted into an artery, but when the compression is removed it springs out to support and hold open the artery. Ni

WWW.THINOPTICS.COM/FLEXIBLE-READING-GLASSES

Eyeglass bridge made from nitinol



WIKIMEDIA COMMONS

A deformed paper clip returns to shape after immersion in hot water.

Nitinol stents can be fabricated at one temperature, folded smaller at another temperature, then inserted into an artery where the body heats the material above its transformation temperature and it returns to its original size.

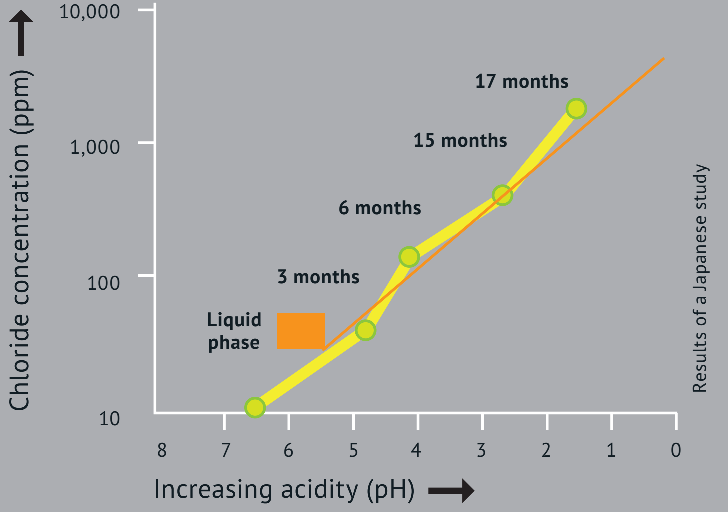
ASK AN EXPERT FAQ FROM THE NICKEL INSTITUTE TECHNICAL ADVICE LINE

Geir Moe P.Eng. is the Technical Inquiry Service Coordinator at the Nickel Institute. Along with other material specialists situated around the world, Geir helps end-users and specifiers of nickel-containing materials seeking technical support. The team is on hand to provide technical advice free of charge on a wide range of applications such as stainless steel, nickel alloys and nickel plating to enable nickel to be used with confidence.
https://inquiries.nickelinstitute.org/

Q: Is Type 316L stainless steel suitable for a hot water tank in potable water with 20 mg/l (ppm) chloride?

A: Chloride is a problem for all grades of stainless steel due to the potential for pitting corrosion, but each grade of stainless steel has a different level of resistance based primarily on its composition. Increasing chromium and molybdenum contents are beneficial. However, there are many other factors, such as pH, oxygen content, surface finish, other contaminants in a fluid and temperature that can influence the potential for pitting. In the case of water at room temperature 316L is generally considered resistant to up to 1000 mg/l (ppm) of chloride. However, a hot water tank is generally a closed system with a vapour space in the top of the tank. Evaporation will carry chloride up into the vapour space where it will be deposited on the surface and will concentrate over time. If the surface in that vapour space is not periodically rinsed by either spraying water on the surface or allowing the water in the tank to rinse the surface, chloride could eventually concentrate to a level where pitting corrosion could occur. Also, above 60 °C (140 °F) there is the additional possibility of chloride stress corrosion cracking. If steps are taken to prevent chloride concentration, 316L would be a suitable material. Ni

Buildup of chlorides and increase in acidity on a tank wall in the vapour space



Nickel can be found in many forms from nanowires to stainless steel alloys. But what are the properties of nickel that make it an essential element in everyday objects?

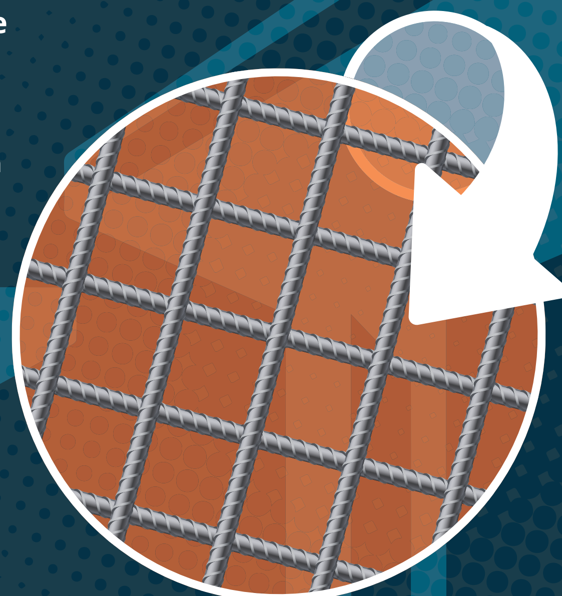
Why nickel?

NICKEL IN YOUR HIGHWAY BRIDGES

Rebar (reinforcing bar) is used in most concrete structures to make them stronger.

Why? Concrete is strong when compressed but weak when stretched. It can also crack easily. Steel, however, is strong in both ways and doesn't break easily in normal temperatures.

In a highway bridge, both kinds of strength are needed, so rebar is laid down before the concrete is poured. This makes the bridge strong enough to handle a lot of traffic.



Salt is bad for steel. Road salt or sea salt can go through concrete and start corroding the steel. Corrosion makes the concrete crack and fall apart, causing traffic jams when repairs are needed.

We can stop corrosion by using stainless steel rebar with nickel. Nickel helps make the rebar strong and resistant to salt, lasting over 100 years.

With nickel in the rebar, you can get to where you're going, faster and safer.

UNS DETAILS

Chemical compositions (% by weight) of the alloys and stainless steels mentioned in this issue of *Nickel*.

UNS	C	Co	Cr	Cu	Fe	Mn	Mo	N	Nb	Ni	P	S	Si	Ti
N01555 pg 13	0.07 max	0.05 max	0.01 max	0.01 max	0.05 max	–	–	–	0.05 max	54.0–57.0	–	–	–	bal
S30403 pg 8	0.030 max	–	18.0–20.0	–	bal	2.00 max	–	–	–	8.0–12.0	0.045 max	0.030 max	1.00 max	–
S31600 pg 2,16	0.08 max	–	16.0–18.0	–	bal	2.00 max	2.00–3.00	–	–	10.0–14.0	0.045 max	0.030 max	1.00 max	–
S31603 pg 2,5	0.030 max	–	16.0–18.0	–	bal	2.00 max	2.00–3.00	–	–	10.0–14.0	0.045 max	0.030 max	1.00 max	–
S31635 pg 2	0.08 max	–	16.0–18.0	–	bal	2.00 max	2.00–3.00	0.10 max	–	10.0–14.0	0.045 max	0.030 max	1.00 max	5x(C+N) min–0.70 max

CAT VINTON

Coral is propagated on a collection of sculptures modelled on local children.

Commissioned by: Townsville, Australia and funded by state and federal governments funds

Materials: Nickel-containing stainless steel, zinc, pH neutral cement, basalt and aggregates

Location: John Brewer Reef, Australia, Pacific Ocean

Depth: 12 m

Installation date: 2019

THE CORAL GREENHOUSE

Australia's first and only underwater museum, created by British sculptor Jason deCaires Taylor, holds the Guinness World Record for the largest underwater art structure.

The Coral Greenhouse weighs in at 165 tons and is constructed with corrosion-resistant Type 316 (S31600) stainless steel and pH-neutral substances. Resting on the bottom of John Brewer Reef, the greenhouse is fully submerged under 16 m of seawater and stands 12 m tall. The artist explains that the biomorphic frame is modelled after nature's patterns, "bringing into focus the diverse fields of study including marine science, coral gardening, underwater and environmental art and architecture. It provides a starting point and new perspective for understanding the Great Barrier Reef and its ecology." For protection during adverse weather conditions, it has a large cement base and integrated cyclone tethers, while its triangular cross sections are engineered to have a very low centre of gravity for stability. In addition, the elevated beam sections provide minimal resistance to wave energy while creating an ideal elevated substrate for filter-feeding organisms and schooling fish to congregate. Located about 80 km from Townsville, Australia, this magnificent sanctuary has intricate matrices for small fish looking to escape predation and glass enclaves for octopuses and sea urchins looking for shelter in the day. Ni